Capnography: The New Smoke in EMS

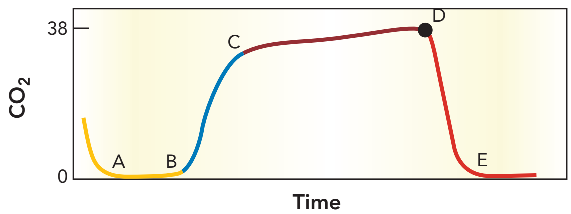
By S. CHRISTOPHER SUPRUN JR.

Fire conferences fill their classroom sessions with important topics such as fireground safety, unit operations, and the art of reading smoke. It is time for those of us assigned to the EMS side of the house to learn to read smoke, too, but a different smoke—the smoke represented on the capnogram.

Capnography is the visual representation of exhaled carbon dioxide, and although we have been considering carbon dioxide medically for years, the capnograph has amazing new possibilities for the care of our patients.

A capnogram, shown in Figure 1, starts with exhalation. We begin expiration by blowing out the air that fills our physiologic dead space. This gas does not contain the products of cellular metabolism—carbon dioxide included—so it is represented on a capnogram with a flat line at zero (the line from A to B). As the exhalation occurs and the subject begins to exhale CO_2, an ascending limb occurs on the graph (the B to C segment).

Figure 1
The Normal Capnogram:



As CO_2 is exhaled, there comes a plateau (from C to D) when the body is no longer creating CO_2. This plateau will help measure whether the respiratory system is acting normally, has some other issue, or if there is a cardiac or metabolic output problem with the patient.

As your subject inspires air, the carbon dioxide level will rapidly decrease (seen from D to E) as oxygen fills the lung and brings the amount of CO_2 to a level near zero. In some cases where the patient re-breathes carbon dioxide, such as hyperventilation, the flat line may never reach zero.

Capnography usually measures gases in an endotracheal tube but sometimes measures air exhaled from the mouth with the monitor coming off a nasal cannula. Chemically, we know that we inhale zero carbon dioxide and exhale 35 to 45 mm Hg per breath. This is important because carbon dioxide does not otherwise occur naturally. Stomach acid, soda, and ambient air cannot produce carbon dioxide on their own. Because of this, the first use for capnography is airway confirmation.

Several studies have questioned paramedics' ability to intubate patients correctly. Many suggest that the real problem is that tubes can become dislodged before they can be confirmed by receiving caregivers such as a physician, respiratory therapist, or nurse. Whether or not that's true, it is vital that medic crews be able to guarantee correct tube placement throughout transport. Capnography provides a risk management tool that is second to none in this regard. If the only thing that gives the Figure 1's signature curve is the presence of carbon dioxide, and that curve is missing, it clearly indicates a missed ET placement.

That simple consideration is very important, especially in rapid sequence intubation attempts where a provider team takes away patients' ability to breathe on their own. Missing the tube after inducing respiratory arrest is a recipe for significant time in the courtroom. Capnography may not keep you from missing the tube, but at least you will know what's going on and be able to take corrective action.

For an intubated patient, a capnogram is a better indicator of a patent airway than other indicators such as heart rate or pulse oximetry. Heart rate can be altered by multiple drug combinations, some of which you may be administering to the patient. Similarly, we know that oxygen will stay bound to hemoglobin for several minutes before it is used, thereby creating a false sense of security. A capnogram, on the other hand, is direct evidence of respiration.

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Respiratory Assessment and Treatment

One issue for many paramedics, both experienced and new to the street, is lung sound auscultation and definition. Is that high-pitched sound wheezing, rales, something else? In one previous set of protocols, our respiratory treatment algorithm divided in part based on lung sounds. If the patients had wheezes, they received albuterol and epinephrine. If it was rales, they received nitroglycerin, lasix, and morphine.

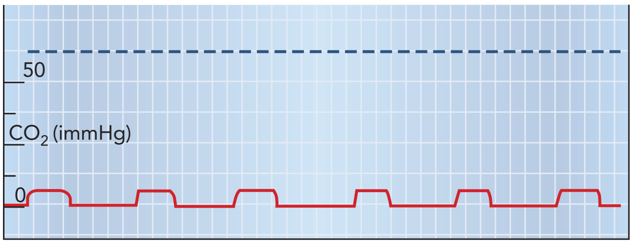
One comment heard often in the field is just to treat respiratory issues with albuterol. Although albuterol has several positives in the treatment of some respiratory diseases, it is certainly not a cure-all by any means. Its cardiac side effects should always be taken into consideration, and a patient whose respiratory condition is secondary to their cardiac problem could deteriorate from inappropriate albuterol administration.

Lung sounds and dispatch information are not enough. Thorough assessment is required in any patient, but capnography can take us another step into the realm of definitive respiratory assessment and treatment by giving us another tool to better care for our patients.

Patients who have bronchospastic disease processes such as asthma will typically show a shark-finned capnogram as seen in Figure 2. This shark fin is caused by the additional force on exhalation caused by these bronchospastic "air trapping" diseases. But capnography can not only show current disease, it has predictive value, too, particularly for asthma states.

Asthma is increasingly a killer disease across population groups. Many EMS systems have moved well beyond albuterol and epinephrine and treat aggressive asthma with more albuterol, atrovent, solumedrol, dopamine, and occasionally terbutaline and magnesium sulfate. In many asthma cases, patients will begin to breathe faster. As with any hyperventilation, this causes the carbon dioxide level to go down initially as more oxygen is inhaled. We also expect the patient to be exhibiting some level of distress. After all, we probably did not just show up at the scene by chance, but were called via 911. So in the initial stages of any acute asthma attack we would expect to find a patient in distress, with an elevated respiratory and heart rate and a capnogram that was shark-finned but with a

Figure 2

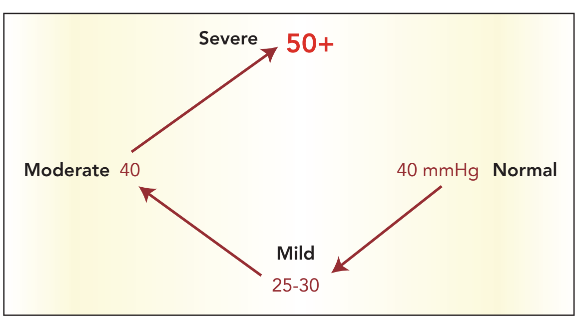


capnometry number of less than normal. For illustration purposes, let's say it is 25. (See Figure 3.)

The problem is, most patients who experience asthma do not call emergency units right away, so this isn't who we actually get to see. Most patients will self-treat with their albuterol or other prescribed medicines. When we arrive, we typically will see the next stage for the patients, where they still have elevated respiratory and heart rates. Their capnograph is shark-finned but because of the physiologic air trapping, their carbon dioxide is normal. This is a dangerous situation and should be considered carefully because while the numbers are "right," the situation is not right at all.

In cases where you can tell a patient is exhibiting signs of labored breathing that has gone on for a while, the capnograph will confirm that indeed you are treating a bronchospastic disease. The corresponding number will tell you how early into the attack you are. Again, if the CO_2 numbers are low, as if the patient is trying to catch his breath by breathing faster, then you expect to be early in the asthma attack.

Figure 3
Phases of Asthma



A warning though: if the CO_2 numbers are increasing or are at a normal level, you should expect the patient to be tiring from the labored breathing and that his condition will be deteriorating. These patients should become higher priority patients and receive more aggressive airway management and pharmacological assistance. These patients will either progress to respiratory failure or will improve. Those in respiratory failure will likely show a capnometry number closing on 50 or higher and their respiratory rate will also slow due to the intense amount of work these patients are doing to expel air. Improving patients should have visibly lower levels of distress and work of breathing.

Cardiac Arrest

If you can recall the early weeks of your paramedic class, you will remember the infamous Krebs cycle. While it has caused many of us pain, you will remember that the Krebs cycle, along with glycolosis and the electron transport chain, is the biochemical basis for cellular respiration. With cellular respiration we gain energy and create byproducts from the breakdown of glucose or other food molecules using oxygen. The two by-products of this energy formation process are water and carbon dioxide. This is important because we know that healthy cells will normally consume oxygen and glucose and produce energy, water, and carbon dioxide. The opposite is true also, though. Cells that do not consume oxygen because they are irreversibly damaged from any number of conditions do not produce carbon dioxide.

This is important, because in cardiac arrest states there is no blood flow. Even when well-trained providers perform the best CPR possible, they achieve only an estimated one-third of the pump efficiency of the heart. The patient is not moving any oxygen around the body; because of that, the cells are not producing carbon dioxide. However, when we initiate CPR to move oxygen-bearing blood and add in appropriate ventilation with oxygen, those cells not starved, and should continue their cellular respiration. We should get a carbon dioxide reading post-intubation.

One study suggested that capnography can detect pulmonary blood flow before pulses could be felt, indicating that EMS providers may be able to use capnography to tell whether their work is succeeding. Where our defibrillator/monitors have shown us the difference between ventricular fibrillation and a normal sinus rhythm, now we will be able to see the increased cardiac output effects that coincide with our last defibrillation.

In another study, it was found that capnography could be used to make an accurate prediction more than 70 percent of the time about which patients would achieve a return of spontaneous circulation. In the study, 71 percent of patients with an initial capnography number of 15 or higher achieved a ROSC. Although this number should not be construed as a factor for termination of efforts, no-starts, or neurologic outcome, it does provide additional assessment criteria.

Additionally, because cardiac output is so dependent on good CPR compressions, capnography can be used as an additional feedback mechanism on the efficacy of compressions. Depending on the capnogram, it may be time to get a new set of hands performing CPR.

Trauma and Metabolic Cases

As in cardiac arrest, we know that sometimes we transport very seriously injured patients to our trauma centers and emergency rooms. On some trauma cases, we perform excellent assessment skills, move our patients to long backboards, and initiate oxygen, cardiac monitoring, and intravenous lines. For the very seriously injured we may add advanced airways such as intubation. Another assessment tool to add is the capnograph.

Again, go back to our understanding of cellular respiration in the normal cell: oxygen goes in, carbon dioxide comes out, providing us with our capnogram. If cells are starting to die from lack of oxygen or injury, you may see a declining capnography number which can frequently be correlated to declining cardiac output similar to that of cardiac arrest. This may be information that we would have gotten later in a normal assessment, but it might help guide an early decision to divert from a local emergency room to a trauma center.

Additionally, low capnograph numbers may indicate metabolic acidosis. We know, for instance, that normal human pH is between 7.35 and 7.45, with a lower number indicating acidosis and a high number alkalosis. We also know that normal carbon dioxide is between 35 and 46 and bicarbonate normally runs approximately 22 to 28. This system measures our two primary buffer systems. In diabetic ketoacidosis, one thing we expect is an elevated respiratory rate, but similarly we may see a decreased capnograph number.

Dr. Baruch Krauss described an incident at Boston Children's Hospital, where a diabetic patient had a capnograph number of six and was treated for DKA. While six seems nearly impossible, this patient's pH number was 6.93; because of the early assessment using capnography, the patient was quickly admitted to their intensive care unit, where definitive care occurred.

While they say where there's smoke, there is fire, it is clear to see that the new smoke of capnography assessment has the ability to catch fire and help firefighters across the country in the everyday assessment of several conditions. ●

REFERENCES

1 White R D, Asplin B R: Out of hospital quantitative monitoring of end-tidal carbondioxide pressure during CPR. *Ann Emerg Med* January 1994; 23;25-30.

2 Callaham M, Barton C: Prediction of outcome of CPR from end-tidal carbondioxide concentration. *Crit Care Med* 1990; 18:358-362.

3 Kalenda Z: Capnogram as a guide to the efficacy of cardiac massage. *Resuscitation* 1978; 6:259-63.