

The Dromedary Sign—An Unusual Capnograph Tracing

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ABNORMAL capnographs are not unusual in clinical anesthesia. These typically result from uneven ventilation in patients with lung disease. Previous reports also have noted abnormal capnograph tracings resulting from loose connections between the end-tidal carbon dioxide sample line and the gas analyzer or other leaks in the system.¹⁻⁴ The resulting biphasic waveform has been described as a long lower plateau followed by a short higher plateau rather than the usual single plateau waveform. We report a case of an abnormal triphasic capnograph tracing with a mid-plateau hump. As we eventually discovered, this was due to a longer than normal sample line combined with a cracked water trap (Apollo, Dräger Medical, Telford, PA). This case highlights the importance of prompt recognition of abnormal carbon dioxide waveforms and the resulting clinical implications. Also, we identified an equipment failure that was not detected during the Dräger Apollo anesthesia machine self-check.

Case Report

A 54-yr-old woman (American Society of Anesthesiologists physical status 2) presented for right front temporal craniotomy for superficial temporal artery to middle cerebral artery bypass graft under mild hypothermia with intraoperative electrophysiologic monitoring. Her past medical history was notable for bilateral Moyamoya disease, atrial aneurysm, uterine fibroids, obstructive sleep apnea, hypertension, and hyperlipidemia. She was 160 cm tall and weighed 90 kg.

All routine preoperative checks were performed on the Dräger Apollo anesthesia machine without incident, including the machine's automated self-test and leak test. The patient was preoxygenated and a normal appearing capnograph waveform was observed. Routine intravenous induction was performed with muscle relaxation and the trachea intubated. We confirmed bilateral breath sounds and end-tidal carbon dioxide were present. The endotracheal tube was secured at 23 cm at the lip. Subsequently, an abnormal capnograph waveform with a single hump midplateau was noted (fig. 1). At this time, end-tidal carbon dioxide = 36 mmHg, tidal volume = 513 ml, peak inspiratory pressure = 30 cm H₂O, respiratory rate = 10, and inspiratory to expiratory ratio = 1:4. There was no obvious cause for this unique waveform, but we thought that it may be related to a leak in the sampling system. Tightening the sample line connections resulted in no change. We then replaced the entire sample line with a new 10-foot sample line and observed the higher than normal plateau move from the midwave position to the right

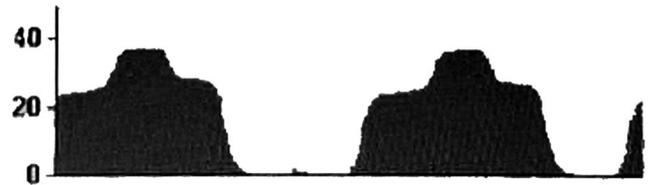


Fig. 1. A triphasic capnograph demonstrating the dromedary sign.

of the capnogram (fig. 2). Next, the water trap was inspected and cracks were seen (fig. 3). Because a new water trap was not immediately available, the cracked water trap was wrapped with a 3M Tegaderm dressing (3M Health Care, St. Paul, MN) and reinstalled. This resulted in a normal appearing waveform (fig. 4).

To investigate the cause of the midplateau hump (or dromedary sign, given its resemblance to a single humped camel), we examined the gas sample line, which consisted of normal sample-line tubing (anesthesia gas sampling line, GE Health Care, Helsinki, Finland, 3 m or 10 feet, with a dead space of 3.7 ml) to which had been added a 24-inch arterial extension tubing (volume 1.5 ml; Hospira, Lake Forest, IL). To determine if this modified sample line contributed to the leak, we placed it under water in a high-pressure system; no leak was observed. By way of confirmation and to examine the effect of further increasing the sample line's dead space, we sought to recreate the dromedary sign in this same patient. We peeled the 3M Tegaderm HP dressing off the water trap and reinstalled it. We also reinstalled the original modified sample line. The abnormal capnograph waveform reappeared (see fig. 1). We then added a second 24-inch extension tubing (total length, now 14 feet; dead-space volume, 6.7 ml) and noted that the hump moved from the midplateau position to the left of the capnograph (fig. 5). After a new sample line without extensions and a new water trap were installed, a normal waveform was again observed (fig. 4).

Discussion

The measurement of end-tidal carbon dioxide is a fundamental component of patient monitoring during anesthesia. Any abnormalities must be noted, investigated, and treated accordingly. To our knowledge and subsequent review of the literature, the observed abnormal capnograph waveform (fig. 1) was unlike any previously reported. The gas analyzer in the Dräger Apollo anesthesia machine aspirates 200 ml/min (\pm 40 ml/min) of respired gases from the elbow connector at the Y piece through the sample line and water trap for the measurement of end-tidal gas partial pressures. Biphasic, dual-plateau



Fig. 2. An example of the capnogram after replacement of the original (modified) sample line (5.2-ml dead space) with a new standard length sample line (3.7-ml dead space). Note that the midcapnograph hump has moved to the right (shorter transit time) of the capnograph tracing.

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Fig. 3. Cracked water trap.

waveforms have been described⁵ and are the result of room air drawn into the sample line, often through a leak or loose connection anywhere between the elbow connector and gas analyzer. The leak allows room air to enter the sample line during expiration as the result of negative pressure produced by the sampling pump's suction. The entrainment of room air dilutes the expiratory carbon dioxide in the sample. With the onset of positive-pressure mechanical ventilation, the pressure gradient across the leak reverses; the leak is now outward, eliminating the dilution effect. The onset of inspiratory flow begins well before the gas sample arrives at the analyzer. This sample lag time is dependent on sample line dead space, sample flow rate, and ventilator pressures. The result is a late expiratory plateau prior to the normal down slope of the capnograph waveform. While we suspected a sample line leak in our originally observed capnogram, the occurrence of a midexpiratory hump was difficult to explain.



Fig. 4. Example of a normal-appearing capnogram after wrapping the water trap with a 3M Tegaderm dressing (3M Health Care, St. Paul, MN) and with a normal length sample tube.



Fig. 5. An example of the capnogram after adding an additional 24 inches (additional 1.5 ml of dead space) of arterial tubing to the original (modified) sample line (6.7-ml total dead space). Note that the original midplateau hump has moved further to the left of the capnogram (longer transit time).

We hypothesized that this triphasic capnogram was a result of increased dyssynchrony between the positive-pressure phase of mechanical ventilation and the arrival of the end-tidal gas at the gas analyzer. During expiration, negative pressure at the crack in the water trap allowed room air to enter the sample, thereby decreasing the carbon dioxide concentration by sample dilution (first plateau). At the initiation of inspiration by the mechanical ventilator, the negative pressure at the cracked water trap is reversed as the piston exerts positive pressure (peak inspiratory pressure), represented by the higher plateau (hump). The higher plateau most accurately represents end-tidal carbon dioxide as sample dilution is eliminated. We hypothesize that the third plateau was due to the increased sample line volume. This increases the dead space and therefore the time between expiration and the arrival of end-tidal carbon dioxide at the analyzer. Assuming a 200 ml/min sample flow rate, a 1.5-ml increase in sample-line dead space could be expected to result in a 0.45-s increase in transit time. Thus, the positive-pressure phase of inspiration shifts to the left (longer transit time) in the capnograph waveform. At the end of the positive-pressure phase of mechanical ventilation, the expiratory carbon dioxide in the sample line is diluted again as a result of the leak in the water trap producing the lower plateau (third plateau).

Therefore, the transit-time delay caused by the addition of dead space in the sample line combined with a cracked water trap that aspirated room air into the expiratory gas sample resulted in the appearance of a midexpiratory hump on the capnogram. This case illustrates the need to understand capnography and the importance of machine checks given that erroneous end-tidal carbon dioxide measurements should be recognized to avoid inaccurate clinical decisions. The manufacturer may consider adding a machine check for the cracked water trap or any additional leaks from the circuit in the automated machine-check algorithm.

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