Capnography, which is the measurement of carbon dioxide in a patient's breath, provides a good picture of the respiratory process, comprising metabolism, circulation, and ventilation. It can pick up changes in metabolism that result from factors such as fluctuation in a patient's temperature that causes an increase or decrease in CO2 excretion.

The American Society of Anesthesiologists (ASA) considers monitoring CO2 a standard of basic anesthetic protocol. The association's guidelines include ensuring adequate ventilation to patients receiving general anesthesia, providing continuous evaluation of ventilation, and verifying correct positioning of an endotracheal (ET) tube by measuring CO2 in the expired gas. In a closed claim study, anesthesiologists who reviewed 1,175 anesthetic-related closed malpractice claims found capnography and pulse oximetry could have potentially prevented 93 percent of avoidable anesthetic mishaps. Some of those reported cases included death or injury from intubation error.

Capnography reflects changes in circulation resulting from poor cardiac output, variations in ventilation frequency and rate, or restrictive disease. Equipment-related anesthetic problems can be promptly detected and corrected when using capnography. For some of these problems, both physiologic and equipment-related, there is no other parameter that will alert you of trouble before the patient is adversely affected. For instance, just as the anesthesiologists found in their study, monitoring CO2 in a patient's breath instantly confirms whether tracheal intubation was successful.

Equipment mistakes and malfunctions
Capnography can detect a multitude of equipment problems and malfunctions. Eliminating accidental esophageal intubation is one, but monitoring CO2 can alert staff to several other complications that occur at the endotracheal site. A CO2 reading can signal a leaking or deflated cuff, kinked or obstructed tube, bronchial intubation, accidental endotracheal extubation, or inadvertent disconnection of the breathing circuit from the endotracheal tube. Within a couple of breaths, alterations in the shape of a previously normal waveform appear. It also picks up faults with the anesthesia machine in real time. Malfunctioning unidirectional valves, exhausted or faulty CO2 absorbent/channeling, and excessive dead space can all be seen with capnography.

Unidirectional valves
How do unidirectional valves work? Circle anesthesia machines have a light, thin disk that is seated at the top of the exhalation and inhalation valves. This component, which is commonly referred to as the flutter disk, should lay completely flat, closing off the exhalation valve during inhalation and only opening to allow expired gas to move through to the absorber canister or vent out to the adjustable pressure limiting (APL) valve during expiration. If the exhalation valve is incompetent—which means the flutter disk on the exhalation valve is open during inhalation—the patient is able to rebreathe CO2 from the expiratory limb of the breathing circuit. Rebreathing could also occur if the inhalation valve is not functioning as intended. A misaligned, warped, or cracked flutter disk also increases the risk of rebreathing of CO2. Without the use of capnography, signs of a defective unidirectional valve could easily go unnoticed.
Exhausted carbon dioxide absorber
Expired CO₂ absorbent is an often-overlooked explanation for anesthetic complications and cause for rebreathing carbon dioxide. Typically, CO₂ absorbent should be replaced after every eight to 10 hours of use. You may need to change it more frequently based on your anesthetic caseload, length of your procedures, size of the patients you treat, and the fresh gas flow rate. Relying on color change alone is unreliable. Most traditional CO₂ absorbents do not have a temperature change. This only occurs during the actual chemical reaction with CO₂. The absorber will revert close to its original color after some time. Once carbon dioxide absorbent has exhausted its ability to absorb CO₂, it can still appear off-white in color. Remember to tap the canister while filling with CO₂ absorbent granules to help prevent channeling. When gas takes the path of least resistance, it can overexpose those granules, and if that path is in the middle of the canister, the color change may not be obvious. Thus, when replacing the absorber based on its color change, the patient may actually be rebreathing CO₂ (InspCO₂). This problem can be spotted immediately when using capnography.

Dead space
Excessive dead space is another potential anesthetic complication that can be addressed by monitoring capnography. An area where there is no gas exchange, dead space is a component of the veterinary anesthesia machine and patient that can be ignored easily. Some dead space in a patient is normal, such as anatomical dead space, but it is when we fail to recognize the added equipment or mechanical dead space that we run into complications. With the aid of the CO₂ sensor, an increase in carbon dioxide levels will be seen and staff can react in a timely and effective manner.

Summary
To spot abnormalities, it is essential to know the appearance of a normal waveform, to understand the different characteristics of the capnogram, and to know normal ETCO₂ and InspCO₂ values for both cat and dog. Recognizing the different phases of the waveform will help identify whether the problem is occurring during expiration or inhalation. Figure 1 shows the appearance and characteristics of a normal capnogram. Figure 2 illustrates the appearance of a patient rebreathing CO₂. And Figure 3 depicts the appearance of the capnogram when the ET tube is accidentally placed in the esophagus.

Wavespace Evaluation:
A normal capnogram is the best available evidence that the ET tube is correctly positioned and that proper ventilation is occurring. When the ET tube is placed in the esophagus, either no CO₂ is sensed or only small transient waveforms are present.

REFERENCES
2. Contribution by Donald Sawyer, DVM, PhD, DACVA

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