I. Introduction

Capnography monitors the concentration of CO2 in the respiratory gases, which is a rapid and reliable method to detect life-threatening conditions, such as malposition of endotracheal tubes, unsuspected ventilatory or circulatory failure, and defective breathing circuits. Capnography is the most comprehensive way to monitor the patient’s ventilation, making the difference between life and death. In 1998, the American Society of Anesthesiologists made capnography mandatory for "every patient receiving general anesthesia."

The VetSpecs® Capno-1 Veterinary Capnograph, also called CO2 monitor, is an effective Anesthesia Disaster Early Warning System, which monitors not only your patient’s ventilation but also the anesthesia system. Employing the state-of-the-art VetSpecs® proprietary Micro-flow™ side-stream capnography, the Capno-1 works effectively in cats, dogs, and a wide variety of other animals, and provides:

- Real-time CO2 waveforms (capnogram)
- End-tidal CO2 reading (ETCO2)
- Respiratory rate (RR)
- Audible and visual apnea alarms
II. Set up the monitor

The Capno-1 comes with a moisture trap, an airway adapter, two sample lines, and an AC power adapter.

1. Install the moisture wrap

Take out the moisture trap from the package. Hold the moisture trap straight up as shown below, and then attach it onto the moisture trap holder on the right side of the monitor.

The two airway tips need to be inserted into the two holes on the moisture trap holder, and the two holding clips on the moisture trap need to click into the position as shown below.
To detach the moisture trap, push inward the two holding clips and then pull the moisture trap away from the monitor.

2. Connect the sample line

Screw one end of the sampling line securely on the gas inlet of the moisture trap, and the other end of the sampling line securely on the airway adapter. The registered readings may be inaccurate if there is a leakage at the connections.
3. Place the monitor

It is suggested to hang the monitor securely on the anesthesia machine or a proper object nearby with the string on the monitor. Place the monitor at a secure location to prevent the monitor from being knocked around which could cause damages to the monitor.

For monitoring in dentistry, place the monitor away from the patient mouth area to prevent it from getting wet.

Store the monitor at a secure and dry place when it is not in use. Avoid direct sunshine, heat, and corrosive materials.

4. Connect the power

Connect the AC adapter to the power port located at the left side of the monitor, and then plug to a power outlet.

Only use the AC adapter which came with the monitor. Do not apply any other AC adapter which is not provided by VetSpecs for use exclusively with the Capno-1.
III. Clinical Instructions

1. Capnography

Capnography is measurement and waveform display of CO2 concentration at the patient’s airway. It monitors various components of patient and anesthesia equipment as well as the critical connection between the two. Capnography provides information about CO2 production, pulmonary perfusion, alveolar ventilation, respiratory patterns, and elimination of CO2 from the anesthesia circuit and ventilator, and therefore, is very effective for early detection of adverse respiratory events.

A capnogram is the graphical waveform depicting CO2 concentration throughout respiration. In a single breath, air sampled during inspiration should contain virtually no carbon dioxide. As exhalation begins, the air passing the instrument initially represents dead space that has not been in contact with alveolar air, therefore containing virtually no carbon dioxide. As exhalation continues, alveolar air mixes with the dead space, with a resultant gradual increase in the amount
of carbon dioxide measured by the instrument (upstroke of the capnogram curve). Eventually, the air passing the sampling port is alveolar air, and the partial pressure of CO2 reaches a plateau, which is reported by the instrument as the end-tidal CO2.

The diagram below shows the shape of a normal capnogram.

Phase I: A near zero baseline — Exhalation of CO2-free gas contained in dead space.
Phase II: Rapid, sharp rise — Exhalation of mixed dead space and alveolar gas.
Phase III: Alveolar plateau — Exhalation of mostly alveolar gas. At the end of exhalation, CO2 concentration reaches the peak - end-tidal CO2 value.
Phase 0: Rapid, sharp down-stroke — Inhalation.
The end-tidal CO2 (ETCO2), which can be expressed as mmHg or percentage, refers to the measurement of CO2 concentration at the end of exhalation.

ETCO2 is a product of three major determinants: the rate of CO2 production by the tissues, the rate of exchange of CO2 from the blood to the alveoli, and the rate of CO2 removal by alveolar ventilation. Because CO2 is a highly soluble gas, diffusing from air to liquid and back again occurs very quickly. Because of this solubility, the relationship between CO2 and minute ventilation is a straight line, the higher the ventilation, the lower the CO2. Conversely, hypoventilation leads to high CO2 levels as the gas is retained. Therefore, ETCO2 provides a close clinical estimate of the alveolar and thus the arteriolar CO2.

The normal range of ETCO2 for most mammals is 30 – 43 mmHg or 4.0 – 5.6%.
Normal Values

Arterial $\text{CO}_2$ (PaCO$_2$)
Arterial Blood Gas Sample (ABG)

Normal PaCO$_2$ Values
35 - 45 mmHg
4.7 - 6.0 kPa
4.6 - 5.9%

ETCO$_2$
from Capnograph

Normal ETCO$_2$ Values
30 - 43 mmHg
4.0 - 5.7 kPa
4.0 - 5.6%

Capnography Depicts Respiration

Metabolism $\rightarrow$ Transport $\rightarrow$ Ventilation $\rightarrow$ CO$_2$

ETCO$_2$

34
15
2. Clinical implications

Normal ETCO2 readings, together with a normal capnogram, indicate normal function of the patient’s metabolism, circulation, and ventilation, and of the anesthesia machine.

Increases in ETCO2 may be due to anesthetic induced respiratory depression, increased metabolism, or the addition of CO2 to the circulatory system as a result of re-breathing CO2. Re-breathing CO2 can be due to soda lime exhaustion or incompetent expiratory valve on the anesthesia machine allowing exhaled CO2 to be re-inhaled.

Decreased or abolished ETCO2 may be due to hyperventilation, low cardiac output, respiratory arrest, or cardiac arrest.

Capnogram also provides vital information regarding the patient’s airway patency. A depressed or absent capnogram may be due to a dislodged, misplaced, or obstructed endotracheal tube or airway, a leak around endotracheal tube cuff, or disconnection of the endotracheal tube from the anesthetic machine.

The following are some examples of abnormal capnograms.
(1) **No ETCO2 recorded**

Possible causes:
- Apnea
- Accidental endotracheal tube disconnect
- Esophageal intubation
- Airway obstruction
- Cardiac arrest
- Respiratory arrest

A sudden drop of the ETCO2 to near zero followed by the absence of capnogram is potentially life-threatening, which could indicate malposition of the endotracheal tube, disruption of airway integrity, disruption of sampling lines, or a sudden cardiac arrest.
(2) **Increasing ETCO2 (hypoventilation)**

Possible causes:
- Decreased respiratory rate
- Decreased tidal volume
- Deep anesthesia
- Interference with chest expansion
- Increased metabolic rate

In anesthetized patients, ETCO2 higher than 50mmHg indicates hypoventilation.

(3) **Decreasing ETCO2**

Possible causes:
- Increased respiratory rate
- Increased tidal volume
- Reduced cardiac output
- Leaks around the tube (dilution)
- Decreased metabolic rate – e.g. hypothermia

Gradual reductions in ETCO2 often reflect decreases in PaCO₂ that occur following increases in minute ventilation or a reduction of the metabolic rate.

(4) **Baseline does not return to zero**

At the same time the ETCO2 value will also start to rise.

Possible causes:
- Incompetent or absent unidirectional dome valves
- Insufficient fresh gas in non-rebreathing circuit
- Exhausted soda-lime in rebreathing circuit
• Absorber canister bypassed
• Leak in Bain circuit inner hose
• Excessive dead space in anesthetic circuit

(5) Abnormal Upstroke (Shark Fins)

Possible causes:
• Kinked or occluded endotracheal tube.
• Upper airway obstruction
• Obstruction on expiratory side of anesthesia machine
• Bronchospasm

(6) Abnormal Down Stroke

Possible causes:
- Leak around endotracheal tube cuff
- Artificial airway is too small for the patient

(7) **Abrupt fall in ETCO2 level**

![Graph showing ETCO2 level changes](image)

Possible causes:
- Pulmonary artery compression
- Pulmonary artery embolism
- Sudden hemorrhage
- Acute cardiac tamponade
- Cardiac compression

Abrupt decreases in the ETCO2 are often associated with an altered cardiopulmonary status (embolism or hypoperfusion).
(8) **Differential emptying**

The above capnograms can result from the following:

- Positioning of the endotracheal tube at or beyond the carina, so that one side of the lung has impaired emptying. This makes the retained gas higher in CO2 and later to empty than from the normal lung. The “spike” can occur anywhere in the plateau phase.

- Any functional blockage of a major airway, below the carina – foreign body, mucous, compressed airway, etc.
Cardiogenic oscillations are ripples superimposed on the expiratory plateau and the descending limb of the capnogram, which are caused by small gas movements inside the airway. Although cardiogenic oscillations can occur in any animal where the pulsations of the aorta and heart cause areas of lungs to be compressed and thereby emptied and filled, they are typically seen in large dogs with a slow RR. The guide to the fact that this is happening is that the oscillations are in synch with the heartbeats. The displayed respiratory rate can be much higher than the actual respiratory rate when cardiogenic oscillations occur.
IV. Operating Instructions

1. Turn on the monitor

Push the power button at the left side of the monitor.

2. Apnea alarm

If the patient has stopped breathing for more than 30 seconds, an alarm will be sounded, and the monitor flashes APNEA on the screen. The audible alarm will automatically be suspended after 60 seconds. However, the flashing APNEA will stay until the patient is breathing again.

The 30 second apnea alarm limit was preset by factory. It can not be adjusted by the user. The volume of the audible apnea alarm was also preset by the factory, and can not be adjusted by the user.

3. ETCO2

End-tidal CO2 (ETCO2), which can be expressed as mmHg or percentage, refers to the measurement of CO2 concentration at the end of exhalation.
To switch between units of mmHg and Volume % push and hold the TRENĐ button on the left side of the monitor.

4. Calibration

The monitor will automatically calibrate itself whenever necessary. Generally speaking, the monitor will go into calibration right after it is powered on, and when there is a change in the temperature of the environment or a major change in the respiratory rate or exhaled volume of the patient.

A calibration usually takes only about 3 to 4 seconds. For calibration, the monitor will suspend the measurement (the waveform goes flat line) and display CAL on the screen.

5. RS232 port

The RS232 port at the left side of the monitor is for system calibration during production and potential software update by a VetSpecs engineer only. It is not for data download or any other purposes. Do not connect anything to this port.
6. The sample lines

The Capno-1 comes with two sample lines. It is suggested to rotate the two sample lines between procedures so that the moistures inside can have enough time to dissipate.

The sample line is a disposable item. For accurate readings, after the sample line has been used for a period of time, it must be replaced due to the residuals accumulated inside.

7. Moisture Trap

The moisture trap is to filter out the moistures inside the sample line. It is normal to see liquid to accumulate inside the moisture trap, which will not affect the performance of the monitor or cause any damages to the system. However, the moisture trap must be replaced when the liquid inside reaches to a quarter of the water tank.

8. The exhaust port

In order for the monitor to perform properly, do not block the exhaust port.
V. Technical Support

For customer support or ordering accessories, call 1-800-599-2566

To return the Capno-1 for service, please ship it to VetSpecs, Inc.
111 Mountain Brook Drive, Suite 200,
Canton, GA 30115, USA
Limited Warranty

VetSpecs, Inc. ("VetSpecs") warrants the VetSpecs® Capno-1 Veterinary Capnograph (hereinafter “the Capno-1”) to be free from defects in materials and workmanship, when stored under appropriate conditions and given normal, proper and intended usage, for ONE (1) YEAR from the date of delivery of the Capno-1 to the original end user purchaser (“Buyer”). VetSpecs agrees during the applicable warranty period to repair or replace defective unit without cost to Buyer. VetSpecs shall not have any obligation under this Limited Warranty to make replacements which result, in whole or in part, from catastrophe, fault or negligence of Buyer, or anyone claiming through or on behalf of Buyer, or from improper use of the Capno-1, or use of the Capno-1 in a manner for which it was not designed, or by cause external to the Capno-1.

The AC adapter is covered by a one (1) year limited warranty. The sample lines, airway adapter, and moisture trap are disposable items and have no warranty.

Buyer shall notify VetSpecs of any product which it believes to be defective during the warranty period. Such product shall be returned by Buyer, transportation and insurance prepaid, to VetSpecs for examination and testing. VetSpecs shall repair or replace any such product found to be so defective and return such product to Buyer, transportation and insurance prepaid. The provisions of the foregoing Limited Warranty are exclusive and are expressly in lieu of any other warranty, whether express or implied, written or oral. VetSpecs’ liability arising out of the manufacture, sale or supplying of the Capno-1 shall not exceed the actual purchase price paid by Buyer for the Capno-1. In no event shall VetSpecs be liable to Buyer or any other person or entity for special, incidental or consequential damages (including, but not limited to, loss of profits, damages to properties, and injuries to the patient and/or the user) arising out of the manufacture, sale, supplying or use of the Capno-1. The foregoing Limited Warranty extends to Buyer only and shall not be applicable to any other person or entity including, without limitation, customers of Buyer.