Just Keep Breathin' and Breathin' and Breathin': Respiratory Monitors – Monitoring Ventilation

Brandon Wahler, DVM, MS, Practice Limited to Anesthesia

Your trusted partner in specialized veterinary care.

Goals

Identify what the difference between capnometry, capnometer, capnography, capnograph, and a capnogram is

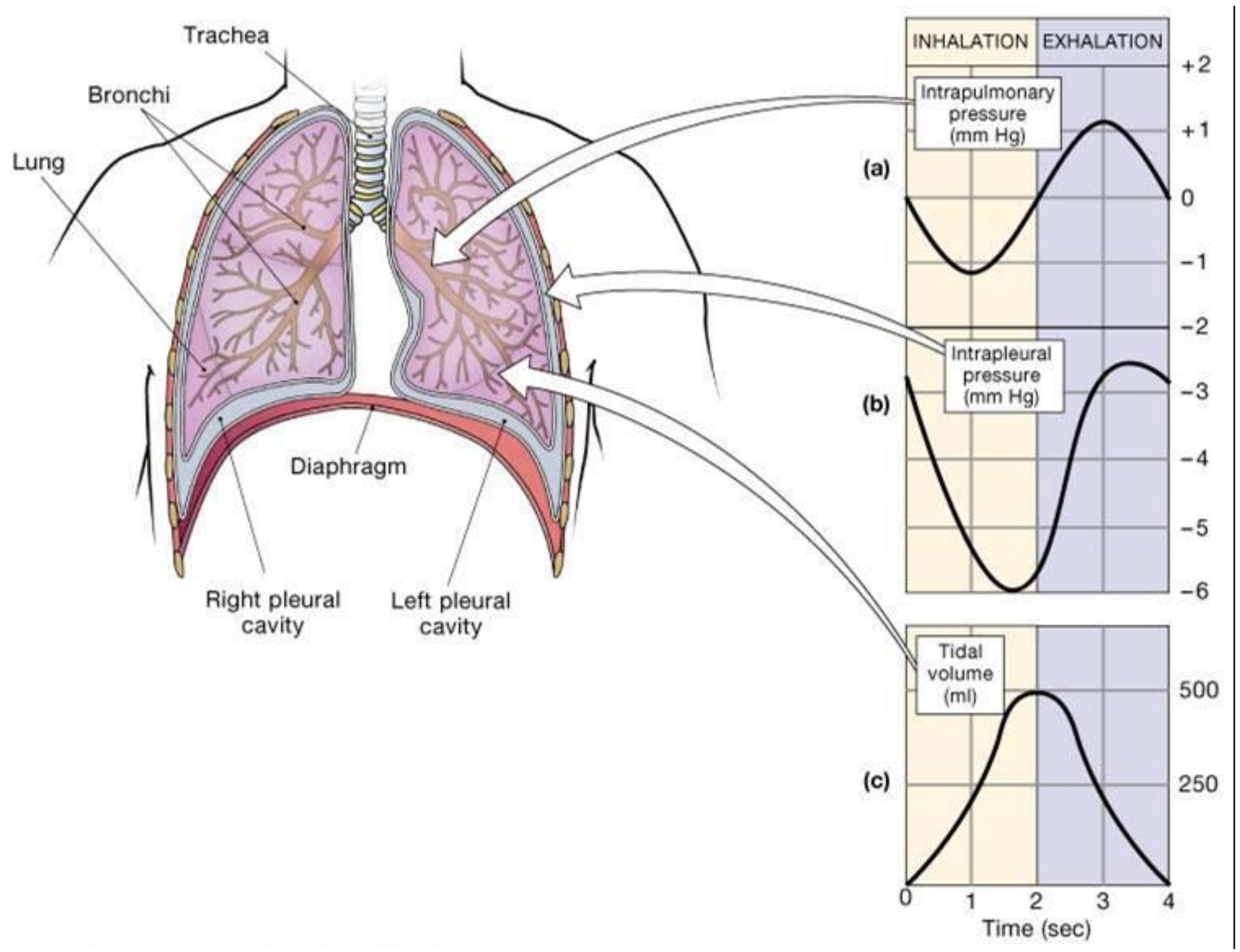
Identify and describe the different types of capnometry/capnography used in modern anesthetic practice. What is the benefit of one over the other?

Identify the different parts of the capnogram

Interpret several common capnogram waveforms and list potential differentials for them

Discuss relevant literature involving capnometry and capnography in veterinary practice

Ventilation

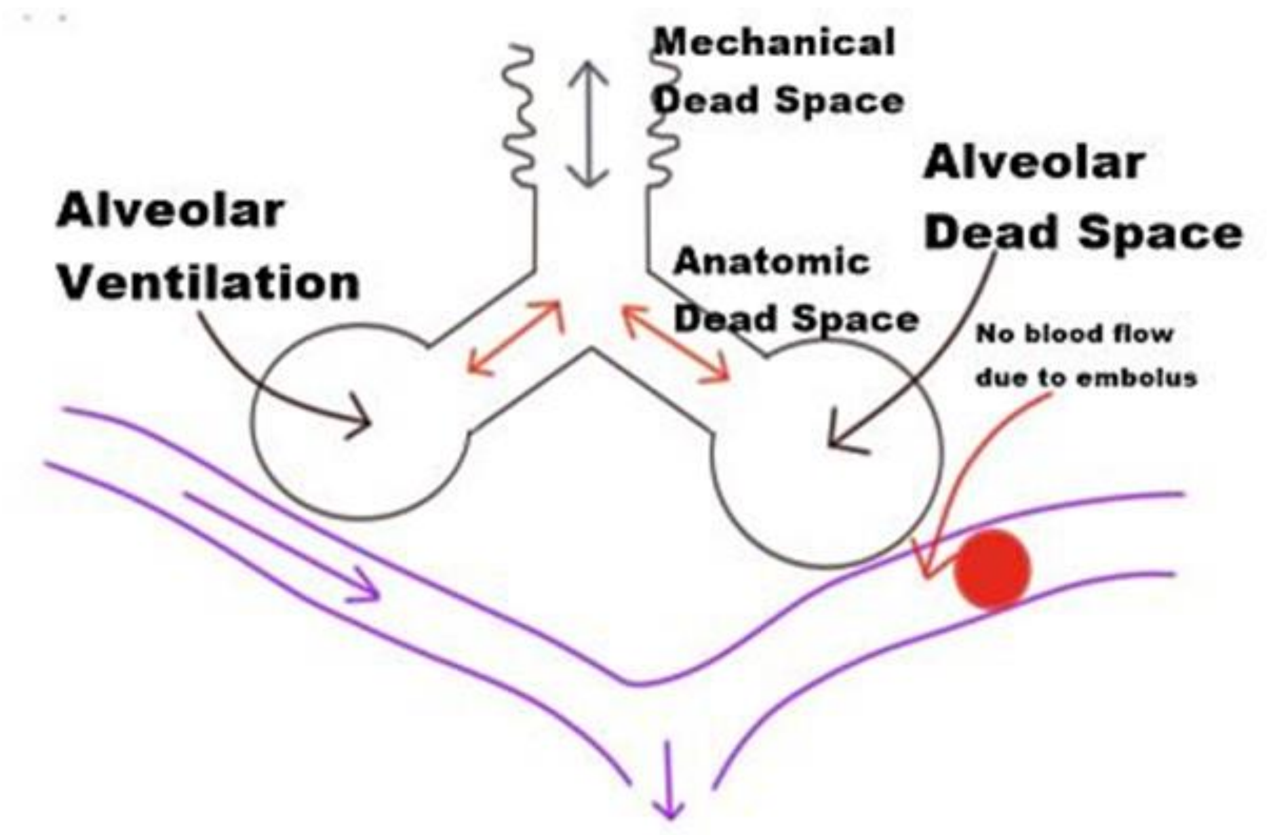


https://www.austincc.edu/apreview/PhysText/Respiratory.html

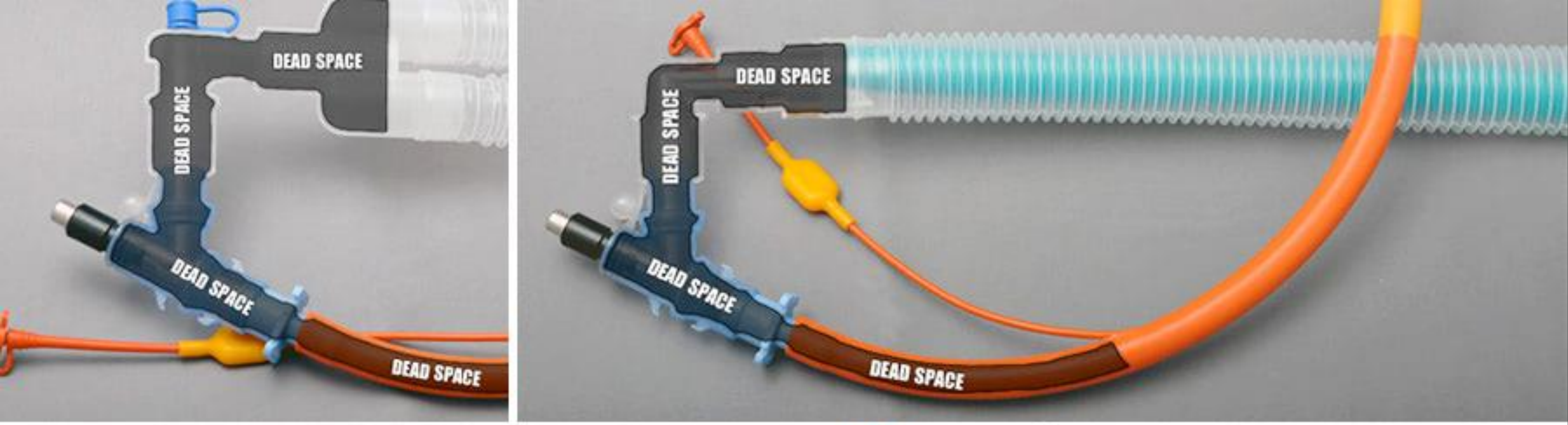
- Part of respiration that is associated with bulk movement of air into and out of the lungs
    - Commonly use carbon dioxide to measure ventilation
    - Measure of metabolic activity in the body
    - CO_2 is readily diffusible and can be measured both invasively and non-invasively (approximately 20-40x more diffusible than O_2 in water)
- Ventilation is a product of tidal volume and respiratory rate
    - Determines the minute ventilation
    - Average tidal volume is 6-15mL/kg
    - Normal total minute ventilation is 150-250mL/kg/min

Dead Space

- Portions of the large airways, equipment, or alveoli that don’t participate in gas exchange
- The larger the portion of dead space the less efficient respiration and ventilation is
- We have innate control over mechanical dead space



https://www.criticalcarepractitioner.co.uk/mechanical-ventilation-physiologic-effects-mechanical-ventilation/



Mechanical Dead Space

- The portion of the endotracheal tube which extends out of the trachea (from the mouth to the breathing circuit)
- The elbow on the breathing circuit
- Any connector used between the end of the tube and the breathing circuit (e.g., CO_2 adapters, apnea alarm adapters, etc.)
- The Y piece at the end of a Y circuit
- Tube Size does not play a role in dead space

https://www.dispomed.com/dead-space-in-breathing-circuit/

https://www.mindraynorthamerica.com/anesthesia-systems/anesthesia-machines/a5-anesthesia-machine/

Dead Space

- High measured total minute ventilation in combination with normal PaCO2 shows increased dead space ventilation
- Positive pressure ventilation
  - Some volume is taken up by compression of gases within the circuit
  - Breathing circuit expansion
  - Must be subtracted to determine the amount of compliance in the system and to determine the compliance and true tidal volume of the patient
    - Modern ventilators do this
    - Must be calibrated between each patient

Measuring Ventilation

- End tidal CO2
  - 3-6mmHg lower of PaCO2
- Arterial blood gas
  - $PaCO_2$ >60mmHg normally indicates need for ventilation
  - $PaCO_2$ <20mmHg is associated with respiratory alkalosis and decreased cerebral blood flow
- Venous blood gas
  - $PvCO_2$ is normally within 3 to 6mmHg of $PaCO_2$
  - $PvCO_2$ is higher in transition states and during hypovolemia, poor cardiac output, anemia

Table 4.8 Potential causes of hypocapnia and hypercapnia.

Hypocapnia – hyperventilation	Light level of anesthesia, hypoxemia, hyperthermia, hypotension, inappropriate ventilator settings, early pulmonary parenchymal disease Postoperation: excitement stage of recovery, delirium, pain, distended urinary bladder, sepsis
Hypercapnia – hypoventilation	Excessive depth of anesthesia, neuromuscular disease, airway obstruction, pleural space-filling disorder, late pulmonary parenchymal disease, inappropriate ventilator settings, malfunctioning anesthetic machine (unidirectional valves stuck, soda lime exhaustion), low fresh gas flow with non-rebreathing circuits

Terminology

- Capnometry – Measurement of CO2 in a gas mixture
- Capnometer – Device that performs the measurement of CO2 in the mixture and displays the information in numerical form
- Capnography – Recording of CO2 concentration vs time or volume
- Capnograph – Machine that generates the waveform over time or volume
- Capnogram – The actual waveform that is produced

https://www.concordhealthsupply.com/EMMA-Mainstream-Capnometer-p/mas-9632.htm

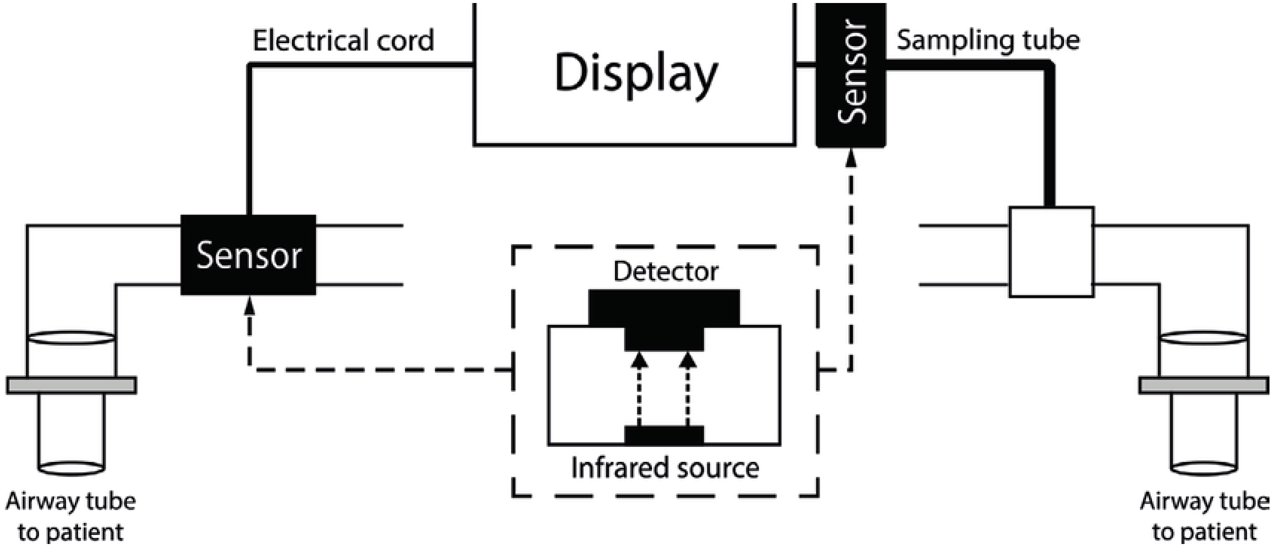
https://diamedicalusa.com/medical-equipment/parts/masimo/masimo-emma-capnograph/

Types of Capnometry

- Primarily use infrared light absorption with absorption being proportional to the partial pressure of the gas

- Mainstream capnometers
    - Breathes through cell or cuvette surrounded by infrared transmitter and photosensor

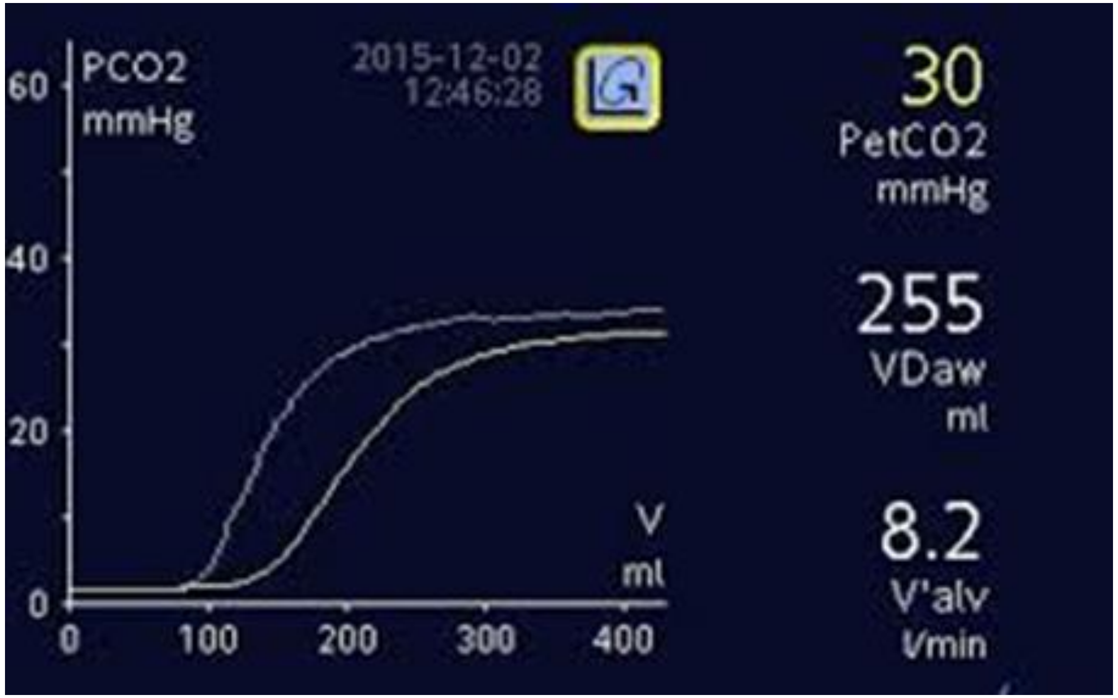
- Sidestream
    - Aspirate gas samples (variable rates 50-200mL/min) and analyzed at the module



Types of Capnometry

	Advantages	Disadvantages
Mainstream	1) No sampling tube 2) No obstruction 3) No affect due to pressure drop 4) No affect due to changes in water vapor pressure 5) No pollution 6) No deformity of capnograms due to non dispersion of gases 7) No delay in recording 8) Suitable for neonates and children	1) Contrary to the earlier versions, the newer sensors are light weight minimizing traction on the endotracheal tube. (see below) 2) Long electrical cord, but it is lightweight. 3) Sensor windows may clog with secretions. However, they can be replaced easily as they are disposable. 4) Difficult to use in unusual patient positioning such as in prone positions. 5) Add deadspace and resistance 6) $$$ 7) The newer versions use disposable sensor windows thereby eliminating sterilization problem (see below)
Sidestream	1) Easy to connect 2) No problems with sterilization 3) Can be used in awake patients 4) Easy to use when patient is in unusual positions such as in prone position 5) Can be used in collaboration with simultaneous oxygen administration via a nasal prong	1) Sampling tube obstruction 2) Water vapor pressure changes affect CO_2 concentrations 3) Pressure drop along the sampling tube affects CO_2 measurements 4) Deformity of capnograms in children due to dispersion of gases in sampling tubes 5) CO2 measured away from airway 6) Delay of 3s

https://www.emsuklearning.co.uk/how-to-read-and-interpret-end-tidal-capnography-waveforms/



https://www.hamilton-medical.com/es/E-Learning-and-Education/Knowledge-Base/Knowledge-Base-Detail~2019-02-04~Volumetric-capnography~1f2d8f8e-46d6-4fe5-86e4-bbd6bcd34306~.html

Types of Capnograms

- Time capnography (left): [Time:PCO_2] Most common type of capnograph. It measures amount of CO_2 over time. Better to assess trends, can be used on non-intubated patients
- Volumetric capnography (right): [Volume:PCO2] Measures amount of CO2 as compared to volume. It Resets after each breath. More accurate in V/Q mismatch and assessment of physiologic dead space

Literature

Abstract

Journal of the American Veterinary Medical Association
December 1, 2002, Vol. 221, No. 11, Pages 1582-1585
https://doi.org/10.2460/javma.2002.221.1582

Comparison of a sidestream capnograph and a mainstream capnograph in mechanically ventilated dogs

Francisco J. Teixeira Neto, MED VET, MScAdriano B. Carregaro, MED VET, MScRodrigo Mannarino, MED VET, MScMariângela L. Cruz, MED VET, MScStelio P. L. Luna, MED VET, PhD

Department of Veterinary Surgery and Anesthesiology, Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista, Botucatu, SP, 18618-000, Brazil. (Neto, Carregaro, Mannarino, Cruz, Luna)

Objective—To compare the ability of a sidestream capnograph and a mainstream capnograph to measure end-tidal CO_2 ($ETCO_2$) and provide accurate estimates of $PaCO_2$ in mechanically ventilated dogs.

Design—Randomized, double Latin square.

Animals—6 healthy adult dogs.

Procedure—Anesthesia was induced and neuromuscular blockade achieved by IV administration of pancuronium bromide. Mechanical ventilation was used to induce conditions of standard ventilation, hyperventilation, and hypoventilation. While tidal volume was held constant, changes in minute volume ventilation and $PaCO_2$ were made by changing the respiratory rate. Arterial blood gas analysis was performed and $ETCO_2$ measurements were obtained by use of either a mainstream or a sidestream capnographic analyzer.

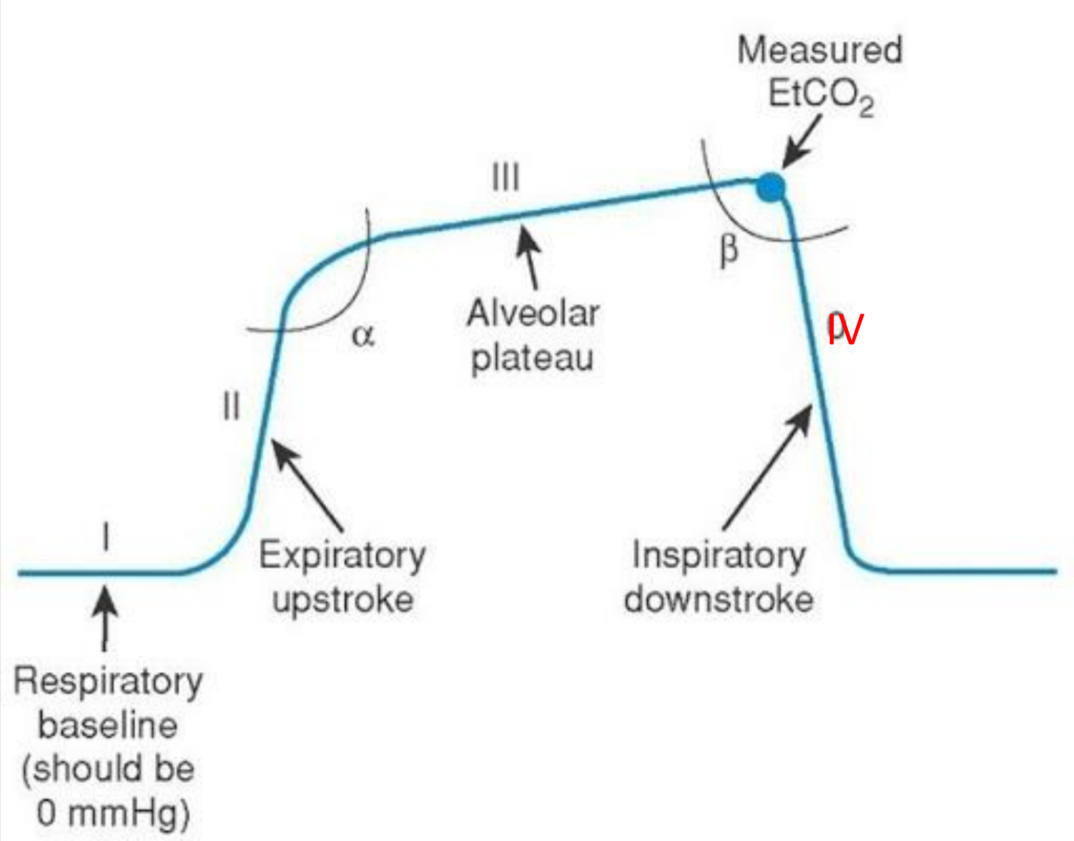
Results—A linear regression model and bias analysis were used to compare $PaCO_2$ and $ETCO_2$ measurements; $ETCO_2$ measurements obtained by both capnographs correlated well with $PaCO_2$. Compared with $PaCO_2$, mainstream $ETCO_2$ values differed by 3.15 ± 4.89 mm Hg (mean bias ± SD), whereas the bias observed with the sidestream $ETCO_2$ system was significantly higher (5.65 ± 5.57 mm Hg). Regardless of the device used to measure ETCO2, bias increased as $PaCO_2$ exceeded 60 mm Hg.

Conclusions and Clinical Relevance—Although the mainstream capnograph was slightly more accurate, both methods of $ETCO_2$ measurement correlated well with $PaCO_2$ and reflected changes in the ventilatory status. However, $ETCO_2$ values > 45 mm Hg may inaccurately reflect the severity of hypoventilation as $PaCO_2$ may be underestimated during conditions of hypercapnia ($PaCO_2$ > 60 mm Hg). (*J Am Vet Med Assoc* 2002;221:1582–1585)

Both work fine, but mainstream may be better
Both are inaccurate in severe hypercapnia

Time Capnogram

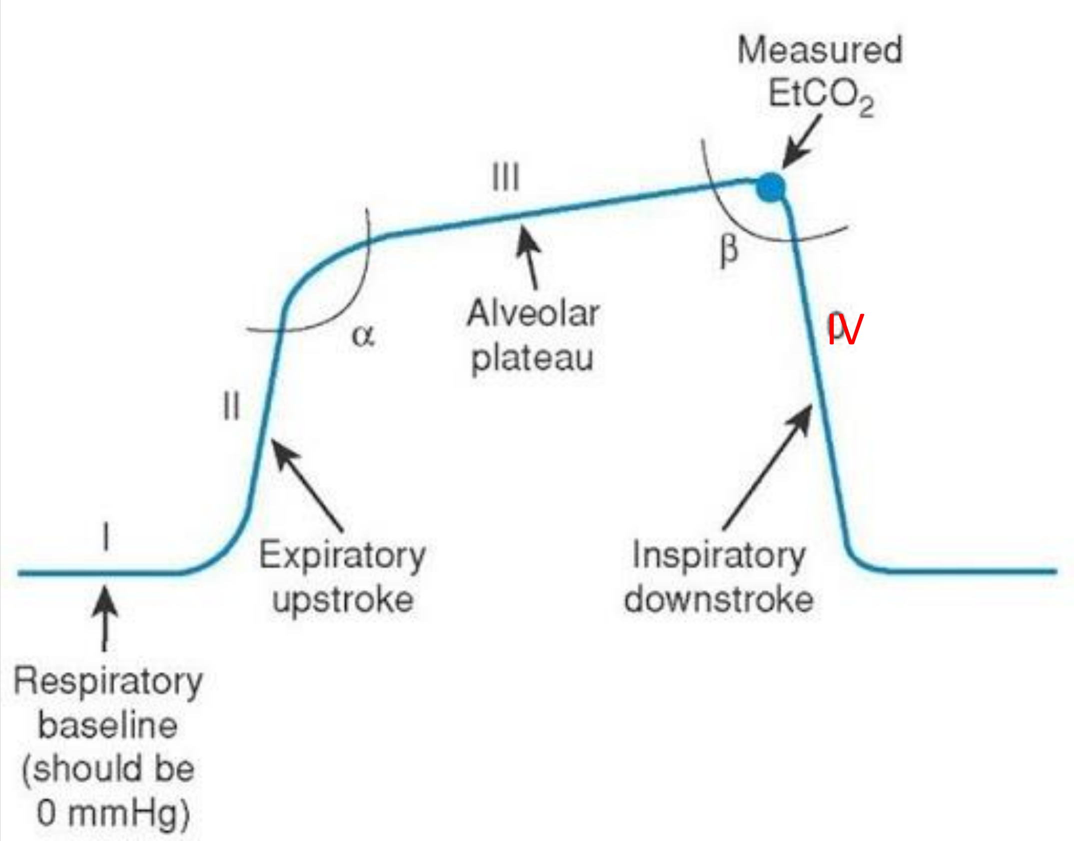
- Must examine the waveform for height, frequency, rhythm, baseline, and shape
- Baseline should always be at 0mmHg
- Phase I – Inspired gas (no CO_2 present)
- Phase II – Transition of dead space gas to alveolar gas (dilutes out the CO_2)
- Phase III – Alveolar gas that results in plateau
  - Influence by V/Q relationship
- Phase IV – Patient begins inhaling



http://www.emdocs.net/interpreting-waveform-capnography-pearls-and-pitfalls/

Time Capnogram

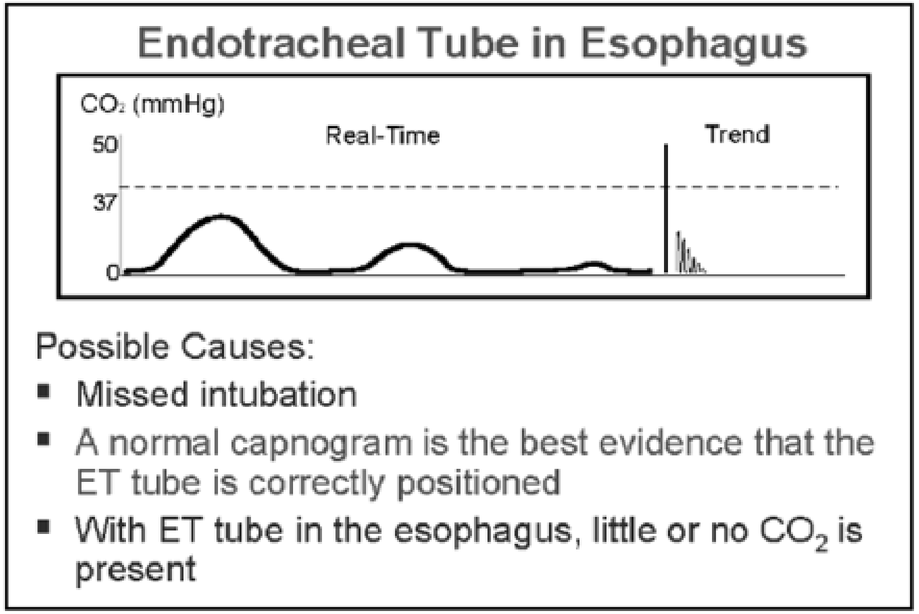
- α (takeoff, elevation) angle – Normally between 100-110°
  - Increased in obstructive lung disease
  - Influenced by capnometer response time, sweep speed, respiratory cycle time
- β angle – Approximately 90°
  - Increased with rebreathing or prolonged response time compared with respiratory cycle time



http://www.emdocs.net/interpreting-waveform-capnography-pearls-and-pitfalls/

The Use of Capnometry

- It is required in human medicine to confirm supraglottic airway device or endotracheal tube with expired gases
- Very useful in veterinary medicine
- Can be misleading (human patients with carbonated drinks/Alka Seltzer; GDV? Aerophagic patients. Ruminants)



https://openairway.org/capnography/

Literature

JOURNAL OF Veterinary Emergency AND Critical Care

Capnographic documentation of nasoesophageal and nasogastric feeding tube placement in dogs

Paula A. Johnson DVM, F. A. Mann DVM, MS, DACVS, DACVECC, John Dodam DVM, MS, PhD, DACVA, Keith Branson DVM, MS, DACVA, Colette Wagner-Mann DVM, PhD, Mark A. Brady DVM, Elizabeth Dunphy DVM

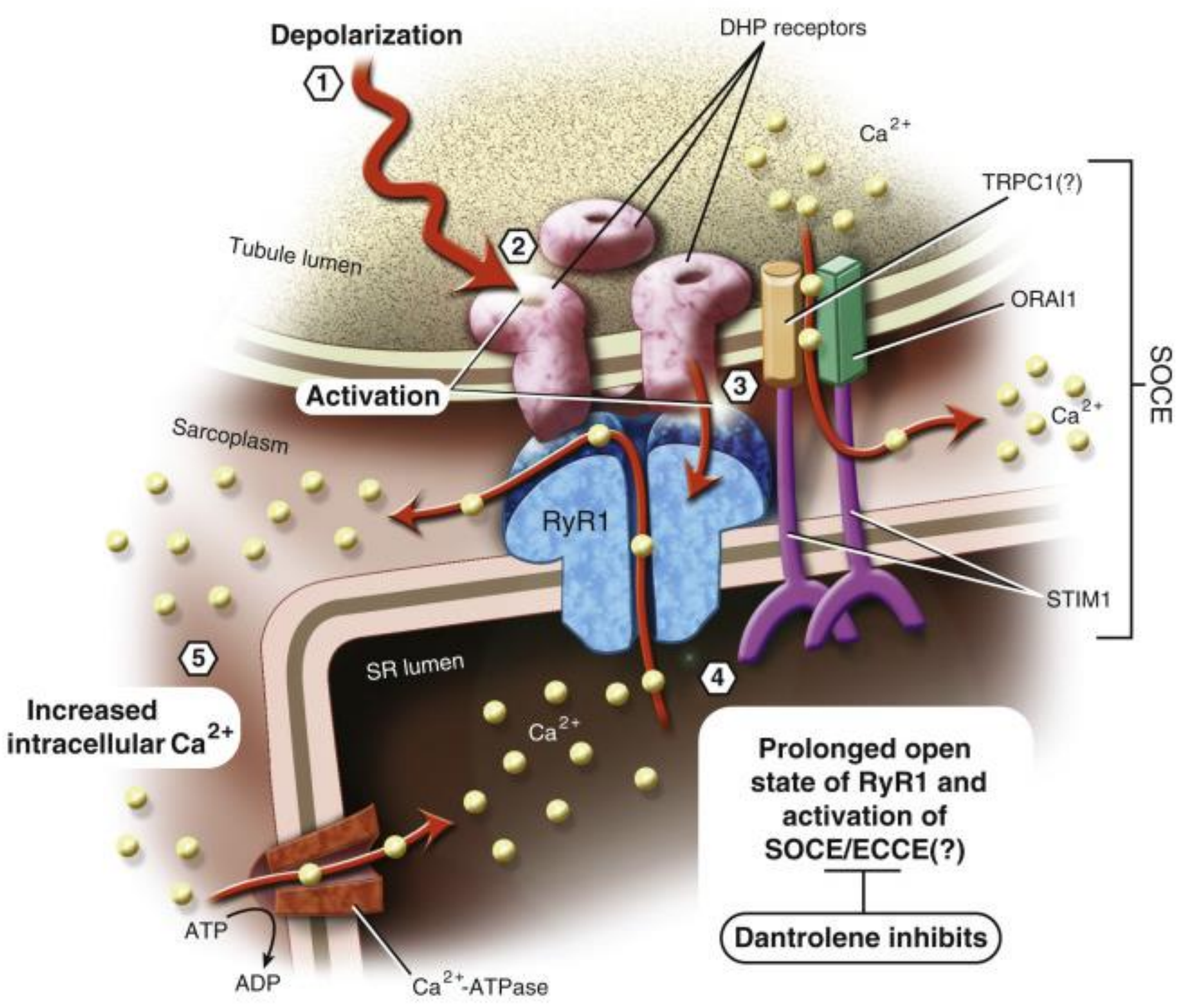
First published: 17 December 2002 | https://doi.org/10.1046/j.1435-6935.2002.00042.x |

Measurements and main results: Phase I measurements included respiratory rate and CO_2 from the trachea, esophagus, and stomach and pH of gastric fluid sample. Phase II measurements included respiratory rate and CO_2 from the endotracheal tube, feeding tube in the endotracheal tube, feeding tube in the distal esophagus, and feeding tube in the stomach. Phase III data collection included respiratory rate and CO_2 as the tube was passed through the nasal cavity, nasopharynx, esophagus and stomach. Phase I fluid samples were collected from 5 of the 9 dogs and had pH values from 1.68 to 4.20. In both phases, values for the respiratory rate and CO_2 from the esophagus and stomach were 0 ± 0, significantly lower ($P < 0.001$) than the values from the trachea. In Phase II, there was no significant difference between the respiratory rates ($P = 0.886$) and CO_2 ($P = 0.705$) readings obtained from the endotracheal tube compared to readings from the feeding tube in the endotracheal tube. In Phase III, there was a significant difference ($P < 0.001$) between the respiratory rates and CO_2 readings obtained from the nasal cavity and the nasopharynx when compared to those readings obtained from the esophagus and stomach. Measurement of CO_2 and respiratory rate resulted in a reading of 0 every time the feeding tube was in the esophagus or stomach.

Conclusions: Capnography may be used in order to detect airway placement of NE and NG tubes.

Uses of Capnometry

- Used as an early indicator of malignant hyperthermia (super rare!)
- $ETCO_2$ will increase dramatically before any other sign
- Metabolically active tissues create CO_2 more



https://www.sciencedirect.com/science/article/pii/B9780323429740000410

Uses of Capnometry

TABLE 22.1

Capnography and Capnometry with Altered Carbon Dioxide Production[a]

	Waveform on Capnograph	End-tidal Carbon Dioxide	Inspiratory Carbon Dioxide	End-tidal to Arterial Gradient
Absorption of CO_2 from peritoneal cavity	Normal	↑	0	Normal
Injection of sodium bicarbonate	Normal	↑	0	Normal
Pain, anxiety, shivering	Normal	↑	0	Normal
Increased muscle tone (as from muscle relaxant reversal)	Normal	↑	0	Normal
Convulsions	Normal	↑	0	Normal
Hyperthermia	Normal	↑	0	Normal
Hypothermia	Normal	↓	0	Normal
Increased depth of anesthesia (in relation to surgical stimulus)	Normal	↓	0	Normal
Use of muscle relaxants	May see curare cleft	↓	0	Normal
Increased transport of CO_2 to the lungs (restoration of peripheral circulation after it has been impaired, e.g., after release of a tourniquet)	Normal	↑	0	Normal

[a] Normal end-tidal CO_2 is 38 torr (5%). Inspired CO_2 is normally 0. The arterial to end-tidal gradient is normally less than 5 torr

Dorsch and Dorsch. Understanding Anesthesia Equipment 5th Ed.

- Metabolic changes
  - Must be monitored in a mechanically ventilated patient
  - Spontaneous ventilating patients may increase minute ventilation in response to increased metabolic production
  - Malignant hyperthermia would also increase through an increase in metabolic production of carbon dioxide

TABLE 22.2

Capnographic and Capnometric Alterations as a Result of Circulatory Changes

	Waveform on Capnograph	*End-tidal Carbon Dioxide*	*Inspiratory Carbon Dioxide*	*End-tidal to Arterial Gradi*
Decreased transport of CO_2 to the lungs (impaired peripheral circulation)	Normal	↓	0	Normal
Decreased transport of CO_2 through the lungs (pulmonary embolus, either air or thrombus; surgical manipulations)	Normal	↓	0	Elevated
Increased patient dead space	Normal	↓	0	Elevated

Dorsch and Dorsch. Understanding Anesthesia Equipment 5th Ed.

Uses of Capnometry

- Circulation changes
  - Decreases in end-tidal carbon dioxide coincide with decreases in cardiac output
  - Must be monitored in mechanically ventilated patients
  - Can detect air emboli in the lungs
  - ROSC – will discuss later
    - Epinephrine
    - Bicarbonate

Uses of Capnometry

CHAPTER 22 | GAS MONITORING 707

TABLE 22.3

Capnometry and Capnography with Respiratory Problems

	Waveform on Capnograph	*End-tidal Carbon Dioxide*	*Inspiratory Carbon Dioxide*	*End-tidal to Alveolar Gradient*
Disconnection	Absent		0	
Apneic patient, stopped ventilator	Absent		0	
Hyperventilation	Normal	↓	0	Normal
Hypoventilation, mild to moderate	Normal	↑	0	Normal
Upper airway obstruction	Abnormal[a]	↑	0	Elevated
Rebreathing, e.g., (under drapes)	Baseline elevated	↑	↑	Normal
Esophageal intubation	Absent		0	

[a]See Figure 18.34.

- Respiration
  - Important to determine if your patient is no longer connected to the tube
  - Able to determine esophageal intubation, but not necessarily endobronchial intubation
  - Can monitor ventilation in non-intubated patients (easier with sidestream up the nares)

Uses of Capnometry

- Breathing system
  - Oftentimes these are specific to the breathing system
  - Important to understand increased mechanical dead space
  - Unidirectional valve capnographs should also be learned

TABLE 22.4

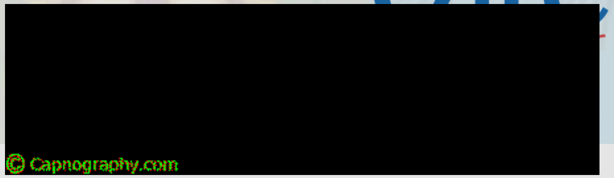
Capnographic and Capnometric Alterations with Equipment

Problem	Waveform on Capnograph	End-tidal Carbon Dioxide	Inspiratory Carbon Dioxide	End-tidal to Arterial Gradient
Increased apparatus dead space	Baseline Elevated	↑	↑	Normal
Rebreathing with circle system: faulty or exhausted absorbent, bypassed absorber (may be masked by high fresh gas flow)	Baseline Elevated See Figure 18.35	↑	↑	Normal
Rebreathing with Mapleson system (inadequate fresh gas flow, misassembly, problem with inner tube of Bain system)	Baseline Elevated See Figure 18.35	↑	↑	Decreased
Rebreathing due to malfunctioning nonrebreathing valve	Baseline Elevated See Figure 18.35	↑	↑	Decreased
Obstruction to expiration in the breathing system	See Figure 18.34	↑	0	Decreased
Blockage of sampling line	Absent	0	0	
Leakage in sampling line	See Figure 18.39	↓	0	Increased
Low sampling rate with diverting device	See Figure 18.41	↓	↑	Increased
Too high a sampling rate with diverting device	See Figure 18.42	↓	0	Increased
Inadequate seal around tracheal tube	See Figure 18.44	↓	0	Increased

Dorsch and Dorsch. Understanding Anesthesia Equipment 5th Ed.

Valve Malfunction

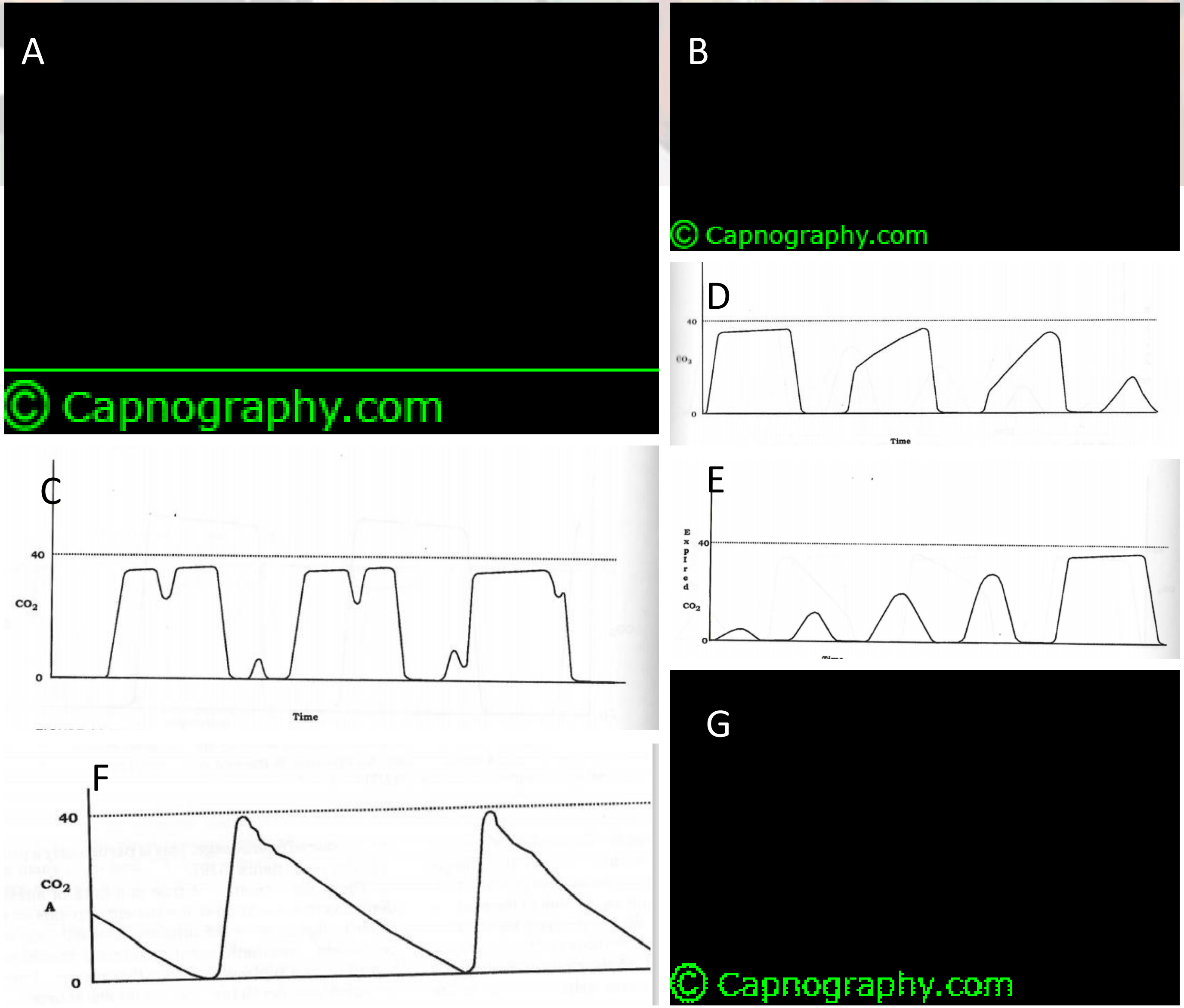
- The top two are inspiratory valve malfunction. Note the normal plateau in the top image, but the increasing inspired CO_2 and the change in phase 0
- The bottom clip is of the expiratory valve incompetence with increase in phase II, slanting descending limb, and increased inspired CO_2



Incompetent inspiratory valve

Poor inspiratory valve seal

Incompetent expiratory valve



Example Waveforms

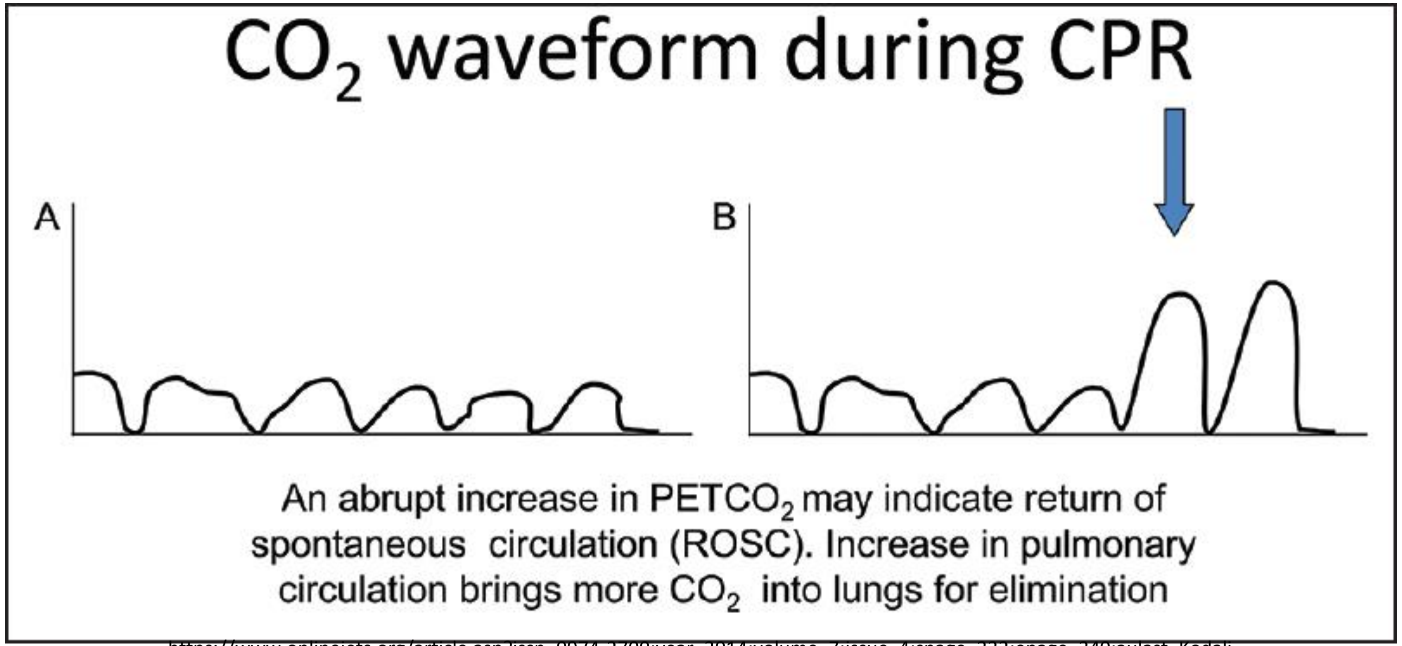
A) Endobronchial intubation
B) Lungs with different compliance (position)
C) Patient ventilator dyssynchrony
D) Obstructive pattern (bronchospasm)
E) Return to spontaneous ventilation (propofol induction, hyperventilate)
F) Large leak in anesthetic circuit (check your ETT)
G) Fresh gas flow dilution

Problems with Capnography

- In normal healthy patients PaCO2 and ETCO2 are very close together
  - Gradient reduced in obese or pregnant patients (reductions in functional residual capacity), and in rebreathing
- Influenced by sampling volumes (too much may dilute it, too slow may not give accurate measure)
- Influenced by poor connections
- Not accurate in all non-rebreathing systems
- Dramatic changes in V/Q will alter capnography
- Changes in body position (lateral, dorsal recumbency)
- Patients with pulmonary disease
- Patients on acetazolamide
- Patients who are hypothermic

The Use of Capnometry

- Strong evidence for its use in CPCR
  - Not influenced by motion
  - Not influenced by random electrical activity
  - Indirect indicator of how good your compressions are (you will never be as good as the body…)
  - May be associated with prognosis for ROSC



An abrupt increase in $PETCO_2$ may indicate return of spontaneous circulation (ROSC). Increase in pulmonary circulation brings more CO_2 into lungs for elimination

https://www.onlinejets.org/article.asp?issn=0974-2700;year=2014;volume=7;issue=4;spage=332;epage=340;aulast=Kodali

Literature

› J Am Vet Med Assoc. 2009 Jul 1;235(1):50-7. doi: 10.2460/javma.235.1.50.

Prognostic indicators for dogs and cats with cardiopulmonary arrest treated by cardiopulmonary cerebral resuscitation at a university teaching hospital

Erik H Hofmeister[1], Benjamin M Brainard, Christine M Egger, Sangwook Kang

Affiliations + expand

PMID: 19566454 DOI: 10.2460/javma.235.1.50

Abstract

Objective: To determine the association among signalment, health status, other clinical variables, and treatments and events during cardiopulmonary cerebral resuscitation (CPCR) with the return of spontaneous circulation (ROSC) for animals with cardiopulmonary arrest (CPA) in a veterinary teaching hospital.

Design: Cross-sectional study.

Animals: 161 dogs and 43 cats with CPA.

Procedures: Data were gathered during a 60-month period on animals that had CPA and underwent CPCR. Logistic regression was used to evaluate effects of multiple predictors for ROSC.

Results: 56 (35%) dogs and 19 (44%) cats had successful CPCR. Twelve (6%) animals (9 dogs and 3 cats) were discharged from the hospital. Successfully resuscitated dogs were significantly more likely to have been treated with mannitol, lidocaine, fluids, dopamine, corticosteroids, or vasopressin; had CPA while anesthetized; received chest compressions while positioned in lateral recumbency; and had a suspected cause of CPA other than hemorrhage or anemia, shock, hypoxemia, multiple organ dysfunction syndrome, cerebral trauma, malignant arrhythmia, or an anaphylactoid reaction and were less likely to have been treated with multiple doses of epinephrine, had a longer duration of CPA, or had multiple disease conditions, compared with findings in dogs that were not successfully resuscitated. Successfully resuscitated cats were significantly more likely to have had more people participate in CPCR and less likely to have had shock as the suspected cause of CPA, compared with findings in cats that were not successfully resuscitated.

Conclusions and clinical relevance: The prognosis was grave for animals with CPA, except for those that had CPA while anesthetized.

- Found that a reasonable descriminator between animals who had ROSC and those who did not was $ETCO_2$:
  - Dogs >= 15mmHg
  - Cats >=20mmHg

Literature

Evaluation of end-tidal carbon dioxide as a predictor of return of spontaneous circulation in dogs and cats undergoing cardiopulmonary resuscitation

Talli Hogen [1], Steven G Cole [1], Kenneth J Drobatz [2]

Affiliations + expand

PMID: 30117723 DOI: 10.1111/vec.12755

Abstract

Objective: To determine whether the partial pressure of end-tidal carbon dioxide ($PetCO_2$) could predict return of spontaneous circulation (ROSC) in patients with cardiopulmonary arrest (CPA) undergoing CPR.

Design: Prospective observational study.

Setting: Two private specialty referral hospitals.

Animals: Thirty-five client-owned dogs and cats in CPA in which CPR was performed and pertinent data recorded on a purpose-made form.

Interventions: None.

Measurements and main results: $PetCO_2$ was recorded at 1-minute intervals during CPR. Hospital, animal, arrest, and outcome variables were also reported in the Utstein style where possible. Twelve animals (7 dogs and 5 cats) achieved ROSC; 4 of these (2 dogs and 2 cats) had sustained ROSC, of which 1 dog was discharged alive. Patients that achieved ROSC had significantly higher initial $PetCO_2$ ($P = 0.0083$), peak $PetCO_2$ ($P < 0.0001$), average $PetCO_2$ ($P < 0.0001$), and $\Delta PetCO_2$ (difference between last and first recorded $PetCO_2$; $P = 0.0004$) than patients not resuscitated. The $PetCO_2$ accurately discriminated between ROSC and failure to achieve ROSC at minutes 3, 4, 5, 6, 7, and 8 of CPR with area under the receiver operating characteristic curve of 0.926, 0.967, 0.938, 0.933, 0.956, and 1.00, respectively. The optimal cutoff $PetCO_2$ was 18 mm Hg (2.4 kPa), with a sensitivity of ≥80% and a specificity of ≥95% at minutes 3, 4, 5, 6, and 8, correctly classifying 91-100% of cases.

Conclusions: The results of this small study support previous recommendations to monitor $PetCO_2$ during CPR and suggest that $PetCO_2$ during CPR may be useful for determining the probability of ROSC. Absolute values and trends of $PetCO_2$ may assist clinicians and owners in making decisions for pets with CPA.

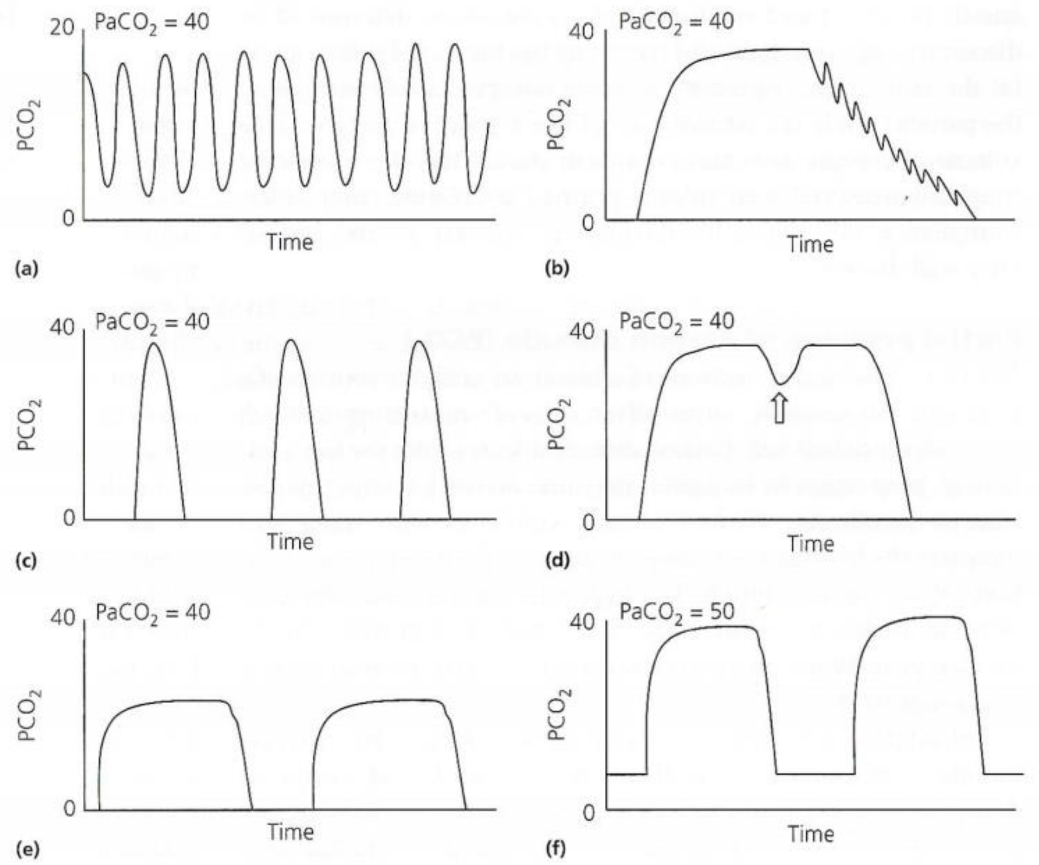
- Similarly found that there was a “cut off” that would make ROSC likely:
  - 18mmHg $ETCO_2$
  - The authors discuss likely don’t need that high to continue CPCR, but that 10mmHg may represent a good cutoff point to stop CPCR
    - If below 10mmHg then it is unlikely that ROSC will be achieved

Practice

Oscillation with ventilation, but not representative of PaCO2 and doesn't return to baseline = Tachypnea

Rises with exhalation, but does not plateau and returns to phase I before patient inhalation = Sample port too close to FGF

Shape is normal, but plateau is very low = Excessive alveolar dead space (hypovolemia, PTE)



Lumb and Jones Veterinary Anesthesia and Analgesia. 5^{th} Ed.

Cardiac oscillations of airway pressure

Small inspiratory effort prior to proper inspiration (patient-ventilator dysynchrony)

Shape is normal, but the baseline never returns to 0 = Dead space rebreathing

Summary

- Identify what the difference between capnometry, capnometer, capnography, capnograph, and a capnogram is
  - -try or –phy is the measure of carbon dioxide and either a resultant number or graphical representation, the –meter or –graph is the actual unit, the capnogram is the picture
- Identify and describe the different types of capnometry/capnography used in modern anesthetic practice. What is the benefit of one over the other?
  - Mainstream versus sidestream – One is faster, maybe more accurate, but can get contaminated, damaged, etc. Sidestream is normally sufficient for most veterinary practices and is very acceptable for anesthetic use. Time capnography versus volumetric capnography – Time capnography is the standard and is used for trends, but likely can't give you as much subtle information as volumetric
- Identify the different parts of the capnogram
  - Know the 4 phases. Know the angles. It is most important that you understand where inspiration is occurring, and where expiration is occurring (phase 0 and I vs. II and III)

Summary

- Interpret several common capnogram waveforms and list potential differentials for them
  - Practice, practice, practice
  - Capnography.com
  - Books on ventilation and monitoring
- Discuss relevant literature involving capnometry and capnography in veterinary practice
  - Literature is also sparse, and mostly old looking if it was applicable in veterinary medicine (it is)
  - More accurate in small patients than large patients
  - Likely useful in CPCR (ROSC >10-20mmHg)
  - Likely not accurate in severe hypoventilation ($PaCO_2$ >60mmHg)

Questions?

https://www.machinedesign.com/community/article/21836908/what-questions-should-you-ask-during-the-product-lifecycle

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Centerville, OH 45459
PH: 937.428.0911
FAX: 937.428.6667