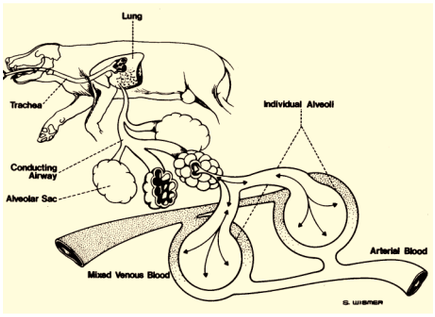
AAS Guide to End Tidal CO_2 Monitoring

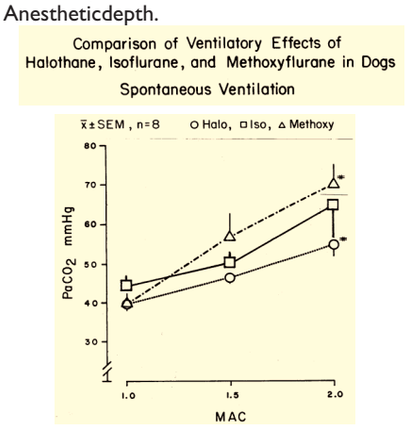
Deep anesthesia causes poor perfusion, hypoxia and hypoventilation which can result in death. Anestheticdepth is difficult to assess based on physical signs. Heart and respiratory rate changes don't correlate with changes in Anestheticdepth, although monitoring respiratory rate is important because apnoea can lead to hypoxia. Better indicators are cardiac function (blood flow or pressure) and respiratory function (CO_2 clearance) which are depressed in a dose-dependent

Respiratory Function

Adequacy of ventilation depends on the repiratory rate AND depth (tidal volume) which determine minute ventilation and therefore arterial CO_2. Normal minute ventilation (about 200 ml/kg/min for dogs and cats) in conscious animals with normal lungs results in an arterial and therefore alveolar CO_2 partial pressure of 35 to 45 mm Hg.



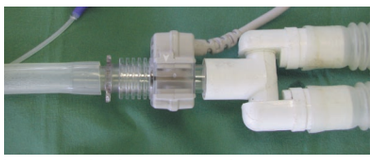
Ventilatory function (minute ventilation) decreases and therefore CO_2 increases in a dose-dependent fashion with increasing Anestheticdepth.



End Tidal CO_2 sampling

At the end of expiration, gas sampled from the trachea should be alveolar gas and the CO_2 level will equate to the alveolar and therefore arterial CO_2 in dogs and cats that don't have lung disease.

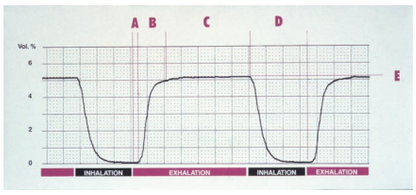
End Tidal CO_2 ($ETCO_2$) monitors measure the CO_2 partial pressure using proportional absorption of infrared light. The monitors continuously sample gas at the endotracheal tube connector. The CO_2 concentration can be measured directly via a sensor in-line, called mainstream sampling, as shown below.



Alternatively the gas sample may be continuously drawn via a long sample line (sidestream sampling) up to the monitor where the CO_2 concentration is measured

$ETCO_2$ pitfalls and interpretation

A continuous CO_2 wave form can be generated which will demonstrate the three phases of expiration during each respiratory cycle.



A = dead space gas, no CO_2

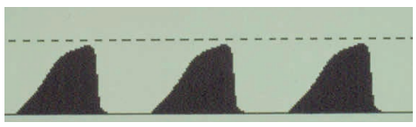
B = mixed gas, rising CO_2

C = alveolar gas, CO_2 plateau

D = inspiration no CO_2

The monitor will continuously read the CO_2 level (in % or mm Hg) and display the peak CO_2 value ($ETCO_2$) and respiratory rate.

The plateau observed at the end of the CO_2 expiratory waveform (phase "C") ensures that the peak $ETCO_2$ value is determined from an alveolar gas sample. **Small tidal volumes**, such as with cats, may not allow adequate sampling resulting in waveforms without an "alveolar gas plateau" such as below.



In this case the $ETCO_2$ may be underestimating the true alveolar and arterial CO_2.

Cardiac Oscillations

During expiration in animals with large chests, heart beats can force small puffs of gas up the trachea causing "bumps" in phase "C" of the $ETCO_2$ waveform.

The monitor will read each "bump" as a new breath, so give an erroneous respiratory rate and variable $ETCO_2$ values. The highest CO_2 level is in the arterial blood so when cardiac oscillations are present, observe the waveform and note the highest $ETCO_2$ reading which will be closest to the arterial CO_2.

Gasping respiration such as observed in animals at light planes of anesthesia, will cause similar problems due to variations in the waveform.

Lung disease or atelectasis such as seen during **thoracotomies** cause an increase in "dead space" ventilation, which dilutes the alveolar gas CO_2 concentration resulting in erroneously low $ETCO_2$ estimations. $ETCO_2$ values measured during a thoracotomy should be regarded as erroneous unless there is an arterial blood gas measurement to proove correlation. This dead space error also occurs in **anesthetized horses** where $ETCO_2$ values can underestimate arterial CO_2 by 5 to 15 mm Hg.

No $ETCO_2$ reading can be due to:

- failed intubation
- disconnection between the ET tube and Y piece/$ETCO_2$ sampling point
- airway occlusion
- lack of pulmonary blood flow (e.g. cardiac arrest, pulmonary air embolis)

Low $ETCO_2$ can be due to:

- light anesthesia and pain which increases spontaneous ventilation
- excessive mechanical ventilation
- small tidal volume causing a sampling error (eg cats)
- increasing dead space such as cause by alveolar collapse during a thorocotomy

High $ETCO_2$ can be due to:

- deep anesthesia
- increased dead space (eg long ET tubes)
- inadequate removal of CO_2 by exhausted soda-lime
- low fresh gas flows in non-rebreathing circuits
- rebreathing expired gas such as caused by defective 1-way valves

High CO_2 causes high HR, BP and injected mucous membranes

$ETCO_2$ Values, mm Hg
Anesthesia, Spontaneous Ventilation

	Conscious	Light GA	Deep GA
Dog	35 - 45	45 - 55	55 +
Cat	30 - 38	35 - 45	50 +
Foal 2 mo.	35 - 45	45 - 55	60 +
Horse	35 - 45	55 - 65	75 +