Capnography: The Most Vital of Vital Signs

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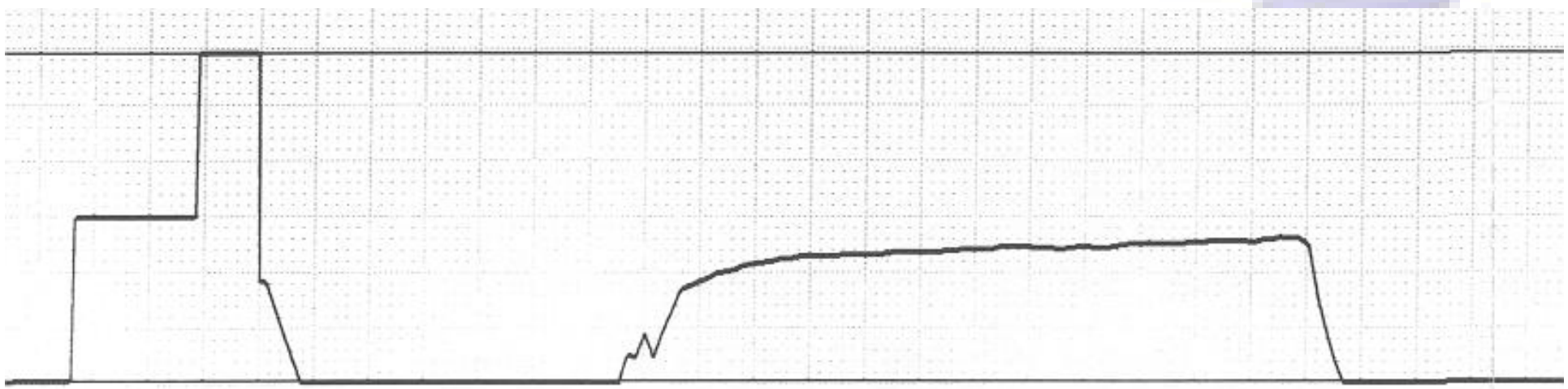
Assessing Ventilation and Blood Flow with Capnography

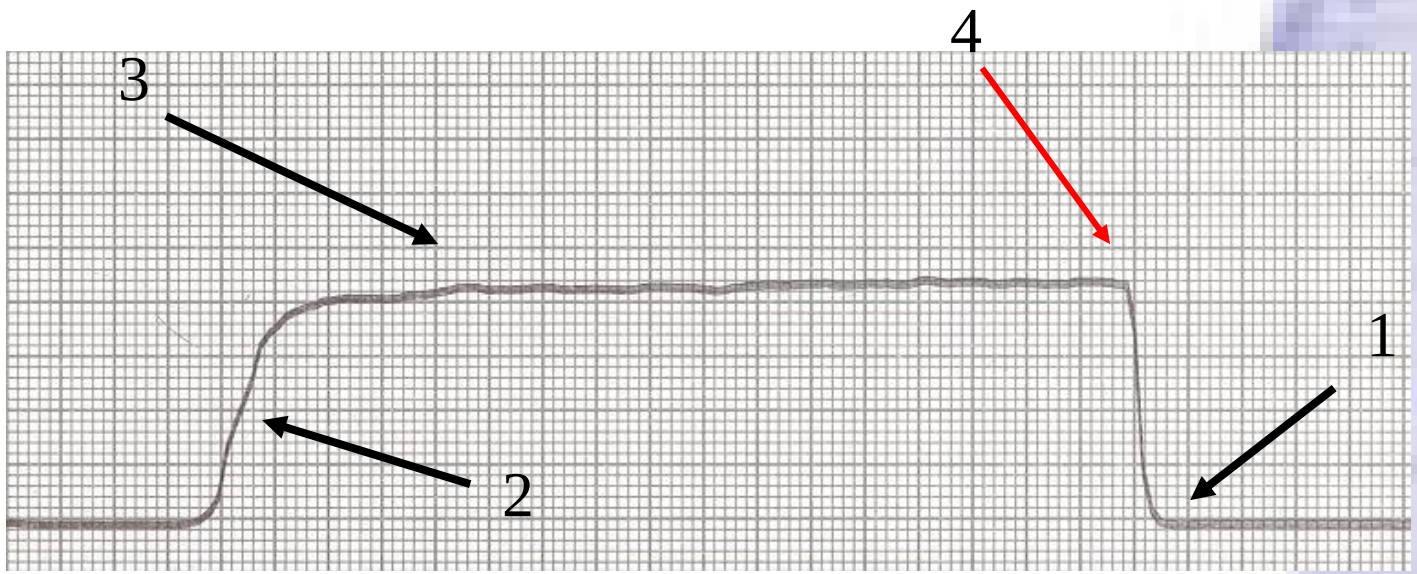
- Capnography - The only parameter that monitors both ventilation and perfusion
- The newest vital sign?
- Value lies in very simple application



Key Uses of Capnography

- If PetCO2 increases, ventilation is threatened and airway protection may be needed
- If PetCO2 suddenly falls to zero, airway is lost, breathing may have stopped or sensor is malpositioned
  - Included is determining tube placement by detection of CO2 (ET and NG)
- If PetCO2 suddenly falls (without a change in Ve), the loss of cardiac output is likely

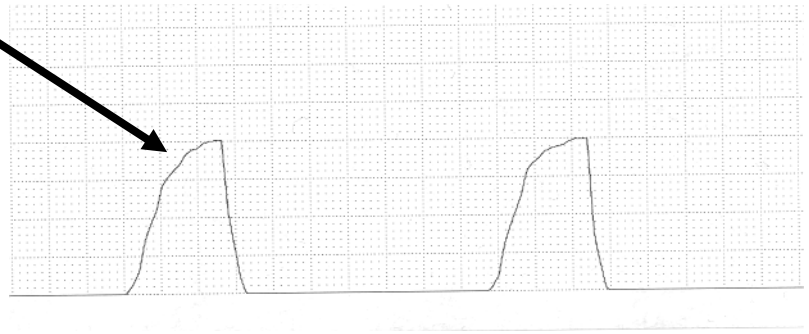
Capnography reflects CO2 as it is being exhaled from the lungs



- At the end of exhalation, called the end tidal CO2 or PetCO2 for pressure of CO2 at end tidal breathing, the exhaled CO2 is reflecting alveolar CO2. Normally, the PetCO2 value of 1-5 mm Hg below the arterial (or alveolar) CO2 level.

Identifying Adequate CO2 Emptying Pattern

Incomplete exhaled CO2 pattern



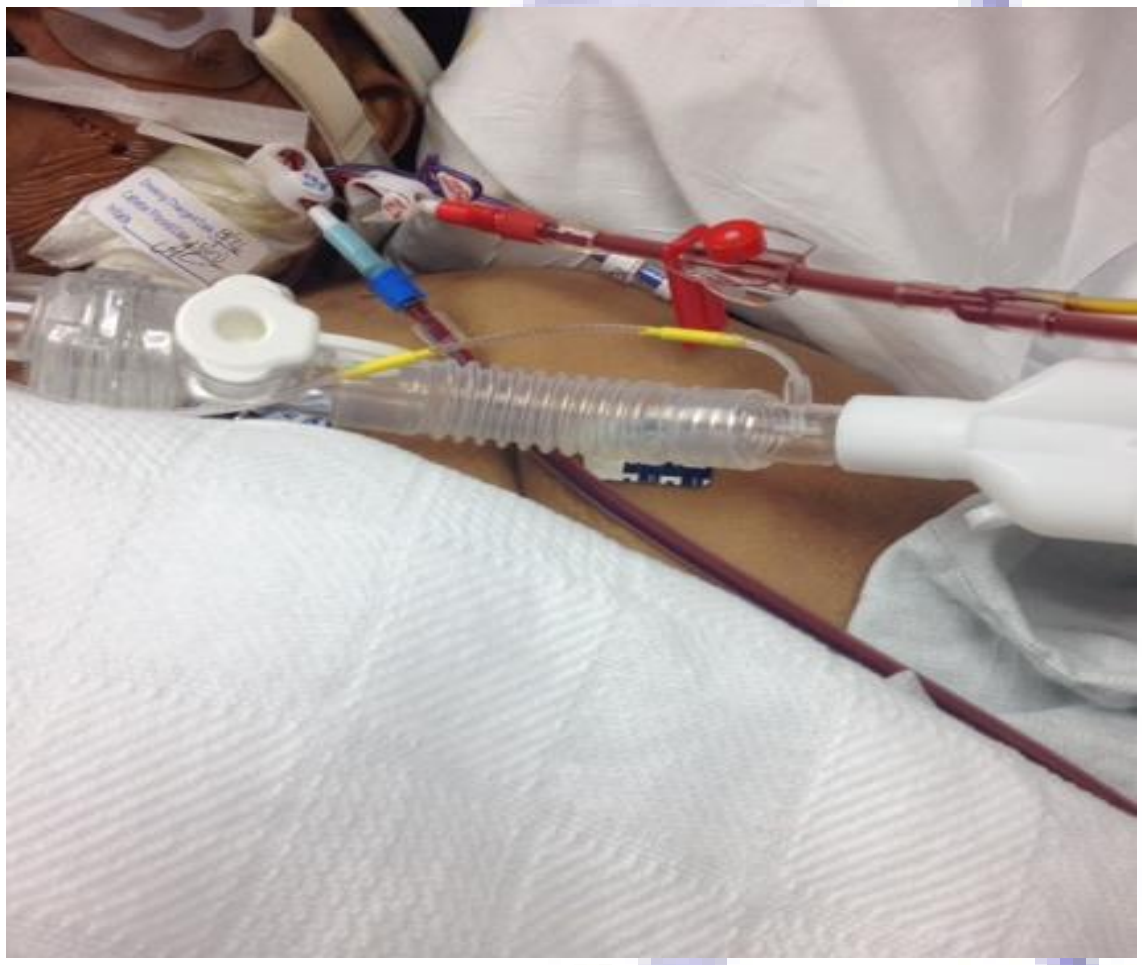
Adequate plateau Phase indicating good Alveolar emptying

Why Monitor Capnography?

- Literature is overwhelming on it’s impact on patient outcome as a safety monitor
  - Airway management
    - Ventilator standard
  - Sedation and analgesia
  - Resuscitation and blood flow monitor

Clinical Application #1
Detecting Tube placement – Endotracheal and Esophageal tubes

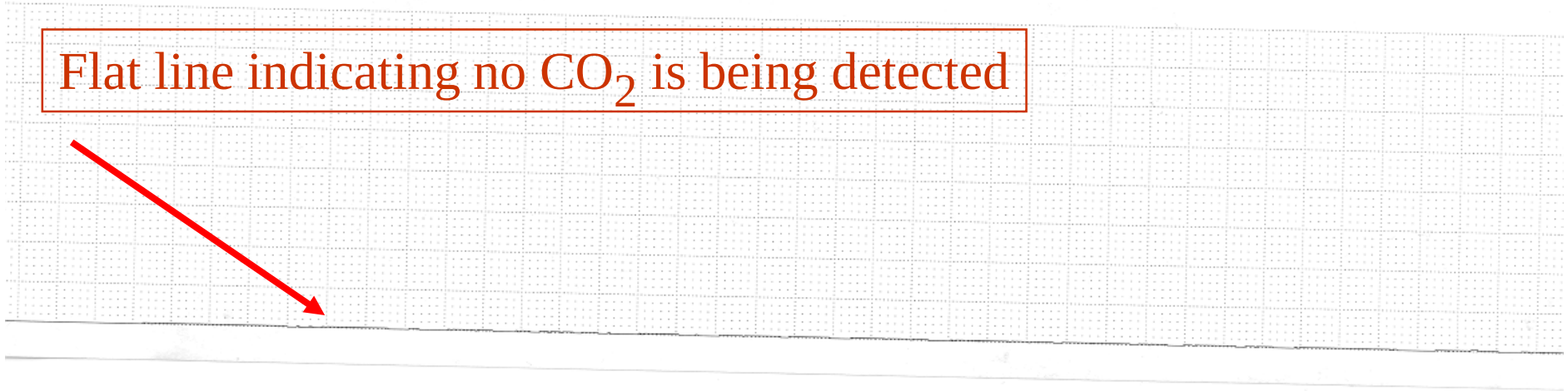
- Capnography detects carbon dioxide from lungs
- Endotracheal tubes placed in the esophagus do not produce capnography waveform
- Nasogastric tubes placed in trachea will produce a capnogram



Clinical Application #1
Detecting airway loss and ventilator disconnection

- Current Alarms to Identify Patient Disconnection from the Ventilator are Very Accurate. However, they are ventilator monitors, not patient monitors
- The capnogram is the fastest, most reliable method to identify if a patient has lost the airway or is disconnected from the mechanical ventilator
- When a patient loses the airway or is disconnected from the ventilator, the capnogram immediately goes flat.

Case study - A 57 year old female is admitted to the ICU following a cervical approach for a spinal fusion. Her weight is 152 kg's. She has a tracheostomy in place. As you and two other nurses are helping turn her, her capnogram alarm sounds. What should you do?



Clinical Application #2
Assessing adequacy of ventilation

- If PetCO2 increases, ventilation is threatened and airway protection is needed
- Capnography is more valuable than oximetry in assessing ventilation

Ventilation Assessment

- The main reason for a PetCO2 value to increase is reduced alveolar ventilation
  - Obtaining a blood gas can confirm this possibility
- During sedation, weaning from ventilation or managing reactive airway patients, the PetCO2 is the first indication of danger
  - If the PetCO2 increases by 10 mm Hg, airway protection should be implemented
  - If sedation or analgesia is being administered, stop the infusion until the PetCO2 returns to near baseline
    - Monitoring patient simultaneously for comfort and awareness

Limited Role of Pulse Oximetry in Assessing Ventilation

- Normal SaO2 determined by PaO2
- If patient hypoventilates, PaCO2 increases and will drive PaO2 downward in direct proportion to PaCO2 increase
  - If PaCO2 increases by 10, PaO2 will decrease by 10
  - If PaO2 is 90, will decrease to 80 mm Hg
    - SaO2 will decrease from 98 to 97.
- Oximeter is not sensitive to rises in PaCO2
- When oxygen therapy is added or increased, rise in PaCO2 is completely obscured

Case Example of Limited Role of Oximetry in Hypoventilation

PaO2	95	80	99
SpO2	.98	.96	.98
FIO2	RA	RA	.30
PetCO2	39	54	60

Case 1

Outpatient colonoscopy – 66 year old male, no previous history of heart or lung disease. Any concerns?					
Admission	HR 64	RR 16	BP 148/84	SpO2 97	PetCO2 35
5 minutes into procedure	62	10	146/84	96	40
10 minutes into procedure	67	10	144/82	96	47

Case 2

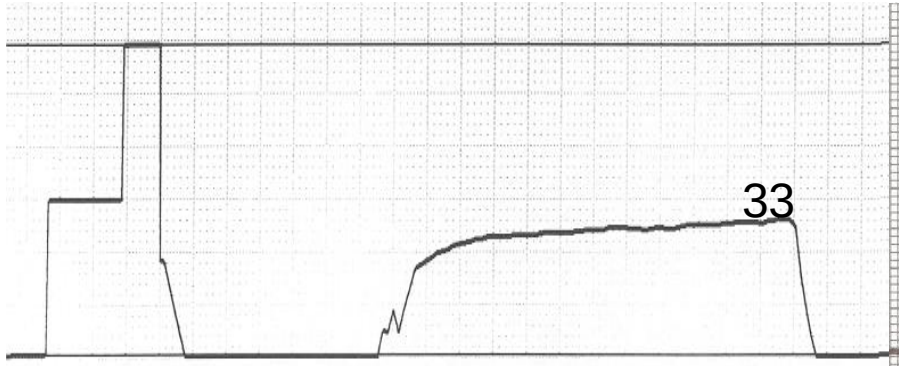
A 76 year old female is being weaned from mechanical ventilation. He has a mainstream CO2 analyzer in his ventilator circuit. Fifteen minutes into the weaning attempt, the following information is available. Based on this information, what would you do?

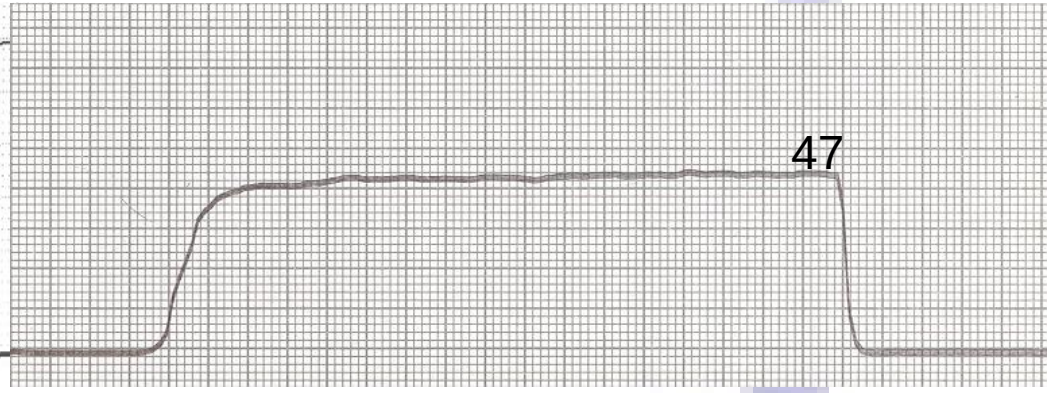
	P	RR	BP	SpO2	PetCO2
0730 (weaning initiated)	71	15	130/86	98	35
0745	82	19	128/88	97	51

Case 3

A 44 yr old male admitted to MICU with unknown fever, SOB, hypoxemia. pH 7.34, PaCO2 38, PaO2 44, SpO2 .78. He is intubated, IMV 12/44. Extubates himself, is reintubated. Sedation is increased. RR decreases to 12. .What is the effect of sedation on ventilation?

	Pulse	RR	NIBP	SpO2	PetCO2	Meds
Pre extubation	114	44	132/64	98	34	2 mg Midazolam, 50 mcg/Fentanyl
Extubated	102	38	138/60	97	33	5 mg bolus Gtt to 4 mg Midazolam, Gtt to 100 mcg/Fentanyl
Post reintubation and sedation	76	12	128/88	99	47	





STANDARDS FOR BASIC ANESTHETIC MONITORING

- **Committee of Origin: Standards and Practice Parameters (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010 with an effective date of July 1, 2011)**

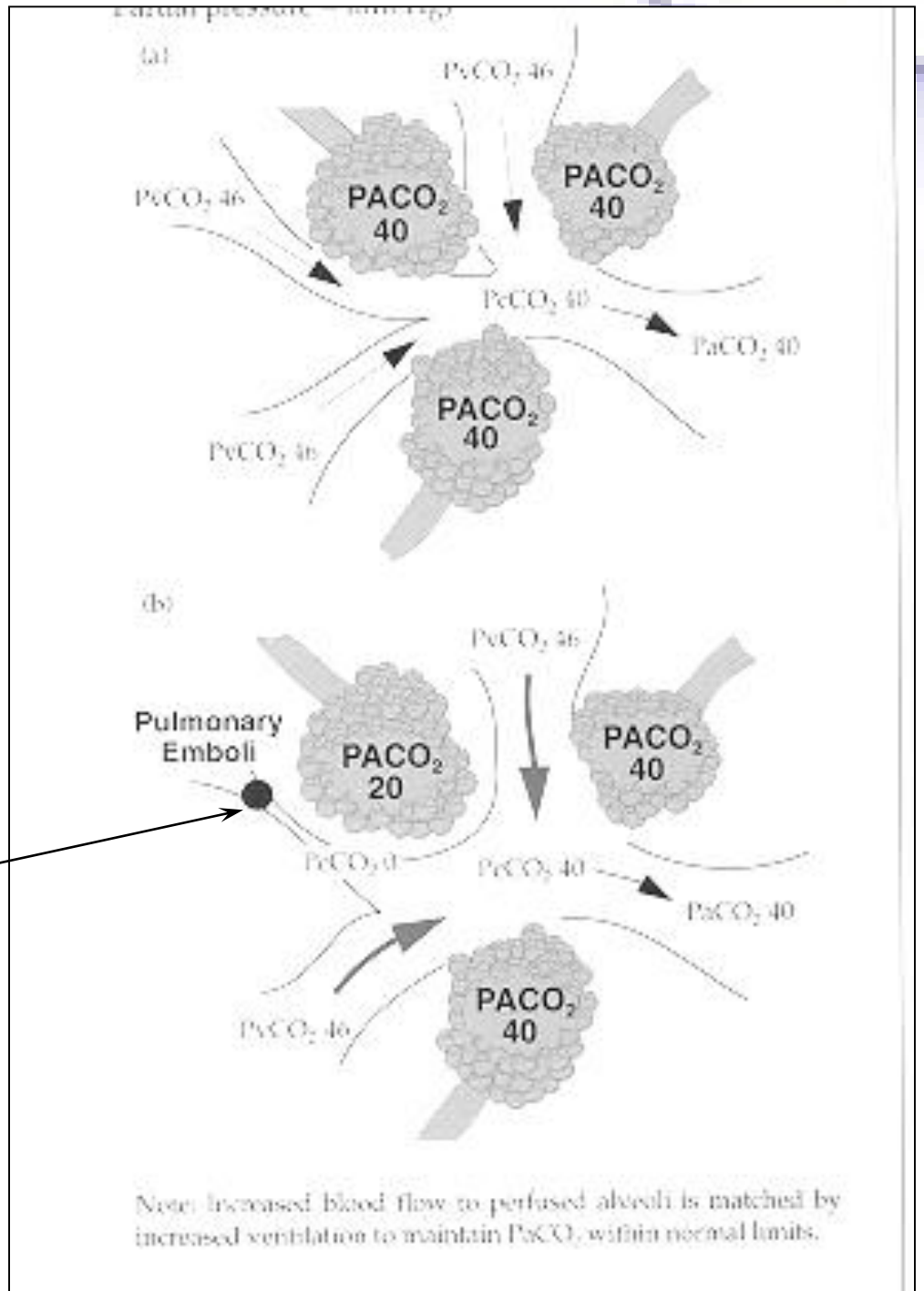
- In October 2010, the ASA House of Delegates approved a change to the ASA "Standards for Basic Anesthetic Monitoring". Specifically, Standard 3.2.4 under VENTILATION, METHODS was changed to read: "During regional anesthesia (with no sedation) or local anesthesia (with no sedation), the adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs. During moderate or deep sedation the adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs and monitoring for the presence of exhaled carbon dioxide unless precluded or invalidated by the nature of the patient, procedure, or equipment." **The intent is that during moderate or deep sedation (regardless of location), the adequacy of ventilation be evaluated by <u>both</u> continual observation of qualitative clinical signs and by monitoring for the presence of exhaled carbon dioxide.** The House of Delegates recognized that there might be rare circumstances when it was not possible to accomplish this and added the following qualifier "unless precluded or invalidated by the nature of the patient, procedure, or equipment."

Clinical Application #3
Capnography and Assessment of Blood Flow

Use in Critical Care

Illustration of the Formation of Deadspace in the Lungs

Normal Ventilation & Perfusion



Reduced blood flow decreases alveolar CO2 - this decrease is detected in the exhaled breath by capnography

Capnography and Deadspace

- Normally, the end portion of the capnography wave (end tidal PCO_2 or $PetCO_2$) is slightly lower than the arterial PCO_2 level
- The normal $PaCO_2$ -$PetCO_2$ gradient is 1-5 mm Hg.
- The primary reason for the gradient to widen is an increase in physiologic deadspace (such as occurs with a change in perfusion)
- Sudden change in $PetCO_2$ and the $PaCO_2$-$PetCO_2$ gradient is usually due to sudden drop in pulmonary blood flow

Capnography and Resuscitation

AHA Guidelines

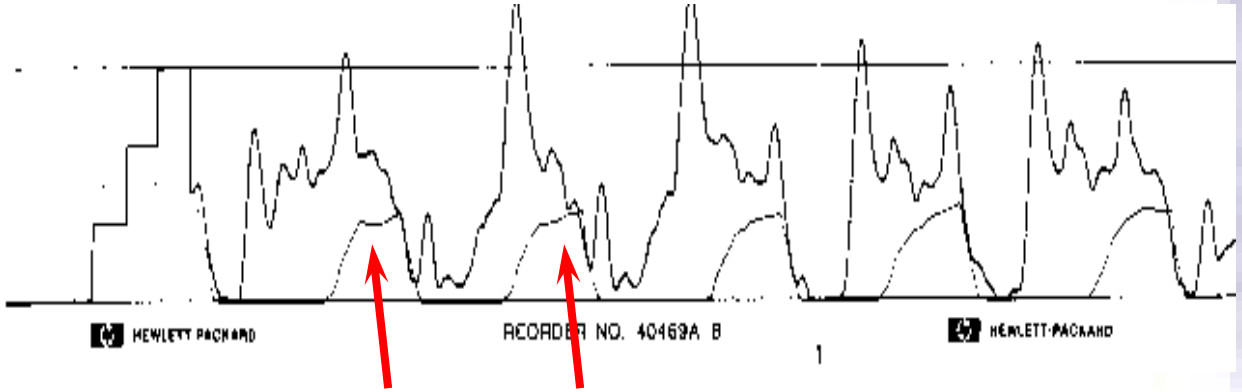
- “Continuous quantitative waveform capnography is now recommended for intubated patients throughout the periarrest period. When quantitative waveform capnography is used for adults, applications now include recommendations for confirming tracheal tube placement and for monitoring CPR quality and detecting ROSC based on end-tidal carbon dioxide (PETCO2) values.”

PetCO2 Levels During Cardiac Arrest

- PetCO2 values should rise to > 10mm Hg-14 mm Hg during successful resuscitation efforts.
- Prolonged PetCO2 levels < 10 have been shown to correlate with low cardiac outputs and poor survival.

Case Study

A 66-year-old female is brought into the ER. CPR is in progress. She was found "down" in her house by her husband. Paramedics have been doing CPR for > 20 minutes. Her capnography wave shows a value of 6 mm Hg.



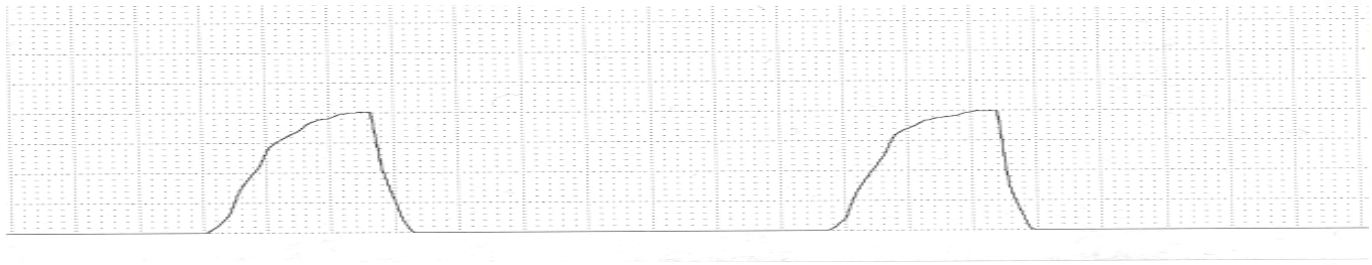
Capnography wave with value of about 6

Question: How would you assess the adequacy of the resuscitation effort?
a) The resuscitation is proceeding adequately.
b) Ventilation is great but blood flow is poor.
c) Ventilation is poor but blood flow is adequate.
d) The patient is likely dead.

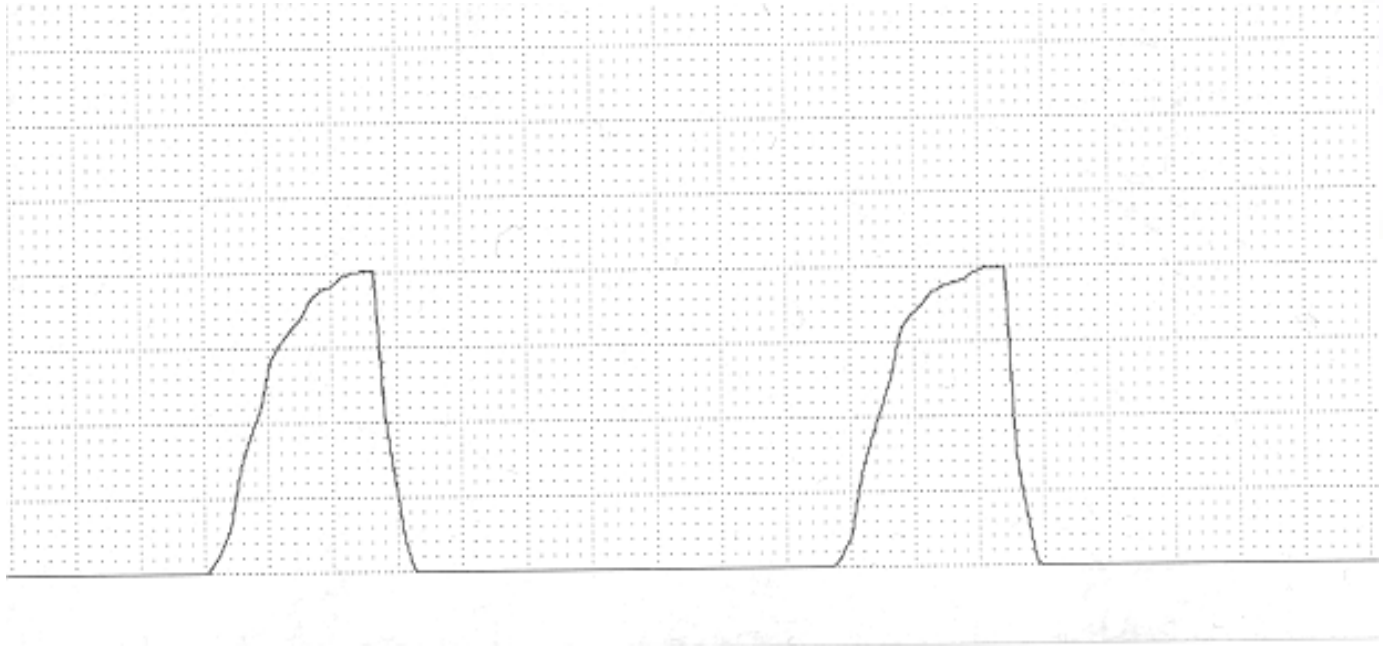
Return of Circulation

- No need for pulse checks if a capnogram is available.
- A sudden increase in the PetCO2 will indicate a return of circulation.

PetCO2 Indicating ROSC

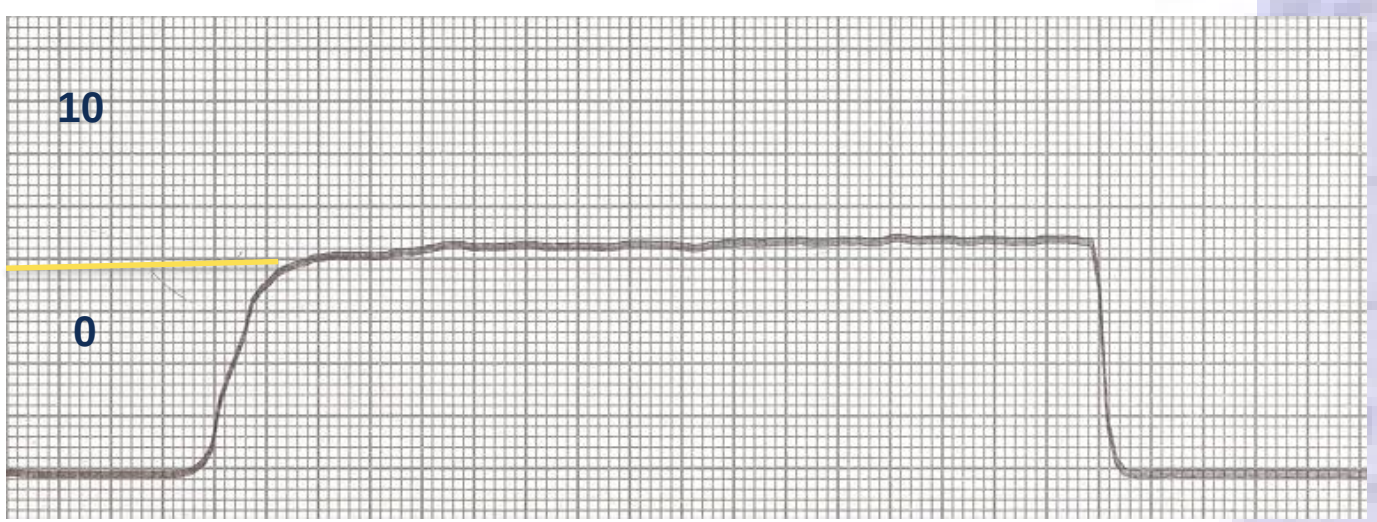


PetCO2 - 15



PetCO2 - 30

Case Study



Question: ***During a cardiac resuscitation effort, is there a need to assess for a pulse (to validate return of circulation)?***

a) No. Circulation has not been reestablished.

b) Yes. Spontaneous circulation may have been reestablished.

Use of Capnography to Indicate Hypovolemia

- Passive leg raise with a subsequent increase in the PetCO2 can indicate hypovolemia

Case Study

	P	RR	BP	SpO2	PetCO2
Prior to leg raise	102	21	110/70	100	27
1 minute after leg raise	98	19	114/72	100	38

Question: Is this patient hypovolemic?

a) Yes

b) No

Use of Capnography to Indicate Hypovolemia

- Passive leg raise with a subsequent increase in the PetCO2 can indicate hypovolemia

Case Study

A 69 year old male with esophageal variceal bleeding. Varicies have been ligated via endoscopy and no active bleeding at this time. Does the patient show evidence of hypovolemia? Is treatment needed?

	P	RR	BP	SpO2	PetCO2
Prior to leg raise	102	21	110/70	100	27
1 minute after leg raise	98	19	114/72	100	38

Case Study

A 40 year old male is admitted to the ED from home with a change in behavior and LOC. He has a penetrating wound on his left foot, where his wife states he stepped on a broken board and had part of the board penetrate his foot. At this point, does he show signs of hypovolemia?

	P	**RR**	**BP**	**SpO2**	**PetCO2**
Prior to leg raise	110	23	104/66	95	29
1 minute after leg raise	102	20	118/70	96	37

Summary

- Capnography is an indicator of cardiac output.
  - Increases in the PetCO2 indicates hypovolemia (with passive leg raise)
  - Decreases in PetCO2 in patients with heart failure can be an early warning sign of cardiac decompensation

- Capnography is the only assessment tool that can indicate both ventilation and perfusion

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