

Waveform Capnography

Application for the
prehospital provider

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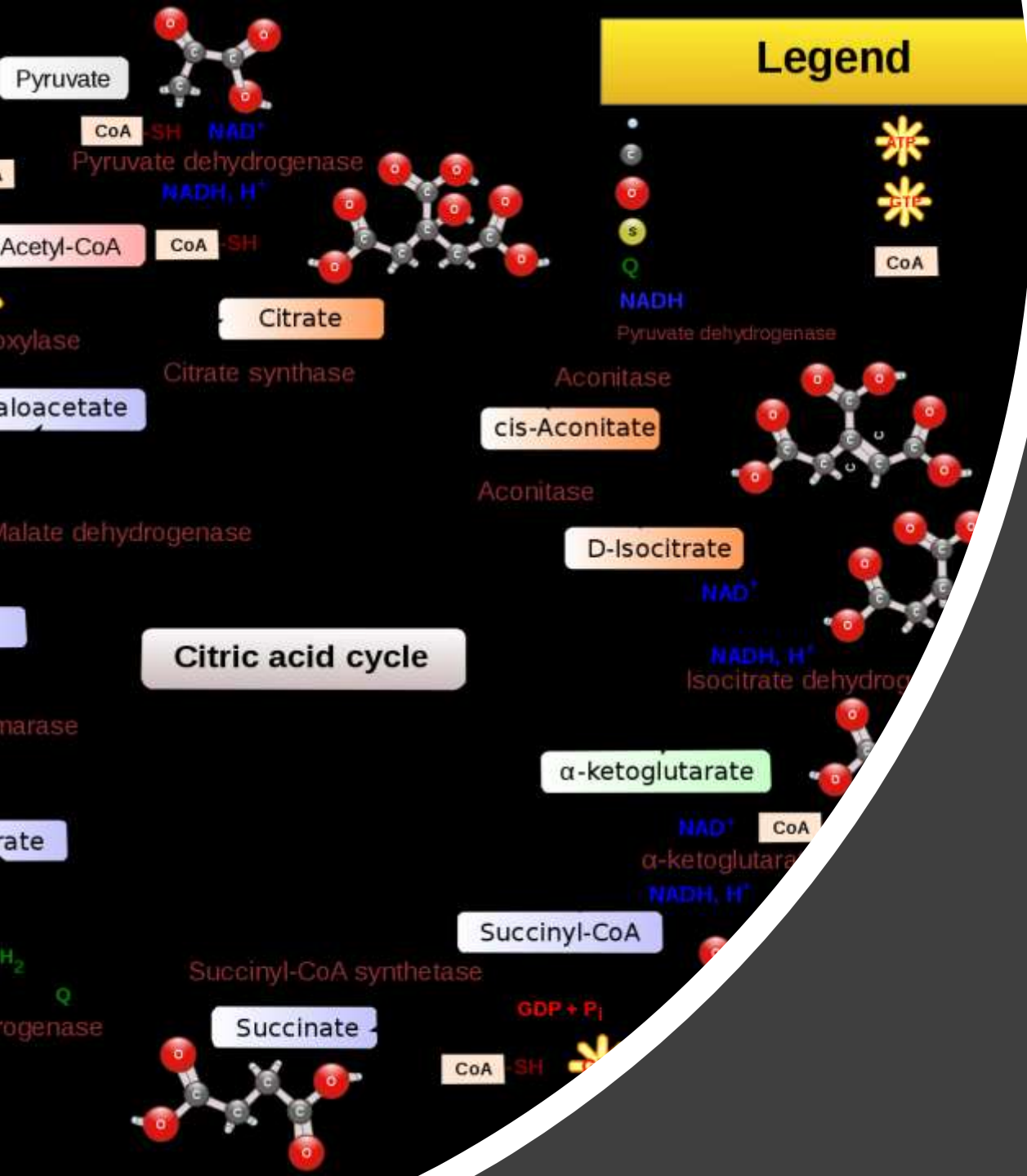
Overview

- Carbon Dioxide
- Waveform Capnography
- Physiology and Pathophysiology

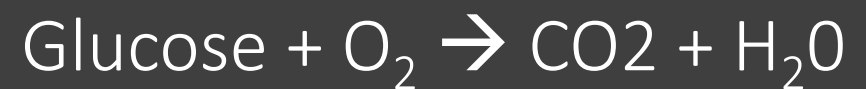


“Capnos” = Greek for smoke

“CO₂ is the smoke from the
flames of metabolism”
- Raymond Fowler, MD

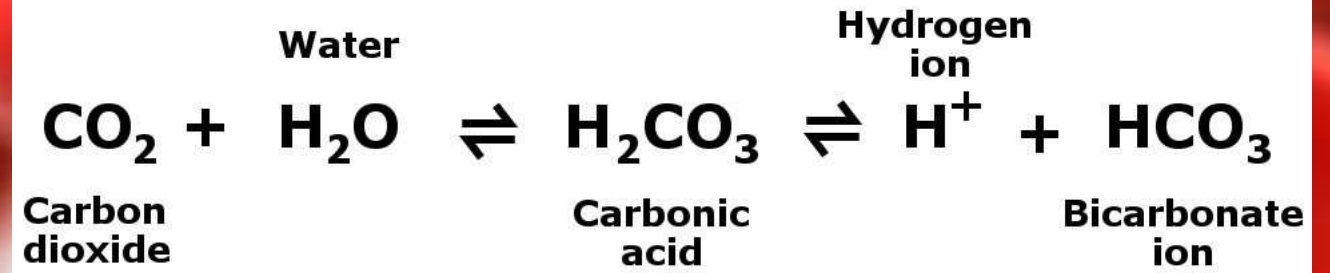


Carbon dioxide
byproduct of
cellular
metabolism

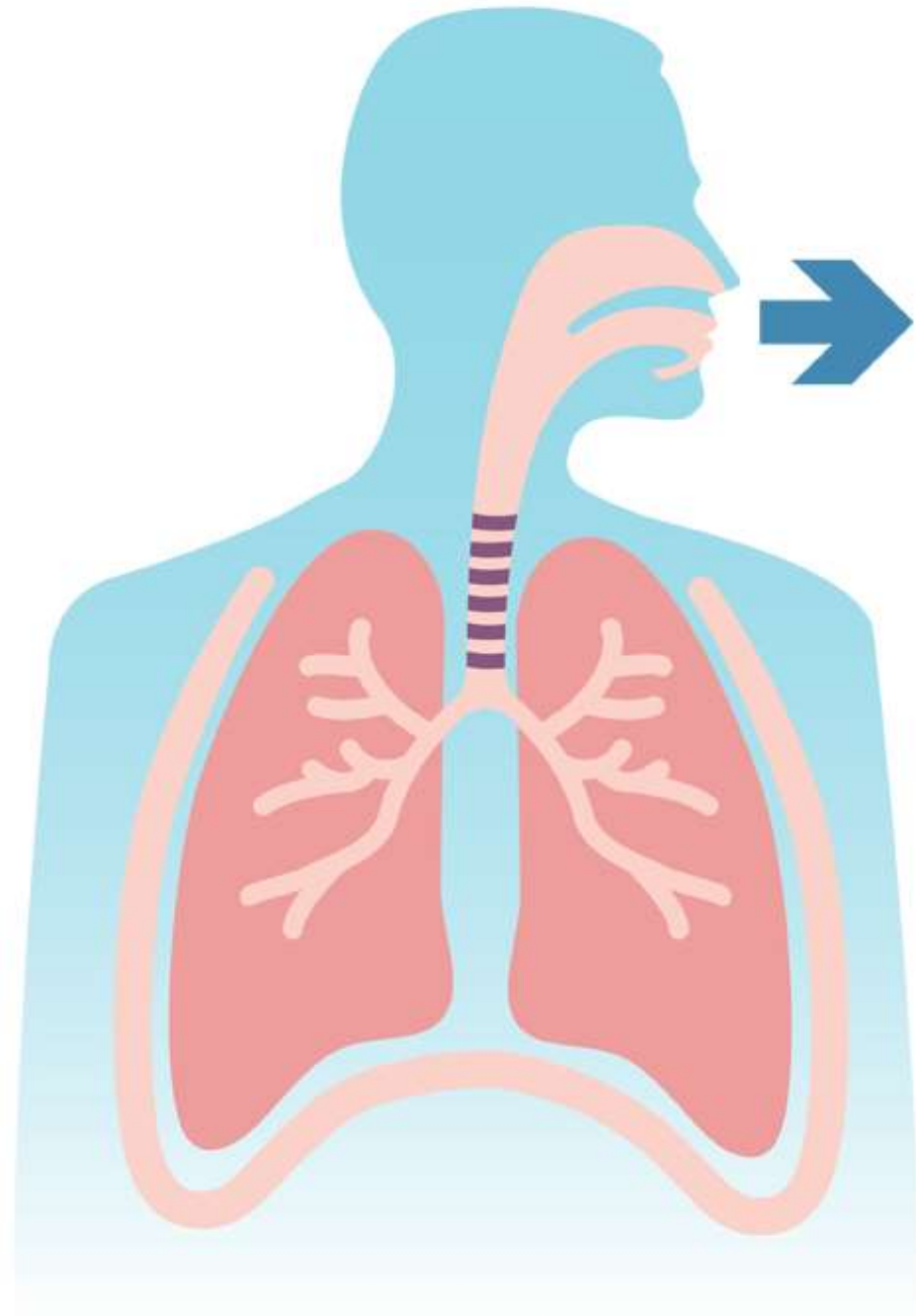


Carbon dioxide diffuses into the blood

- Bicarbonate – 70%
- Bound to hemoglobin – 20%
- Dissolved in blood – 10%



Carbon dioxide is eliminated
through the lungs



The Evolution of CO₂ Detection

Is there a pulse?

Colorimetric



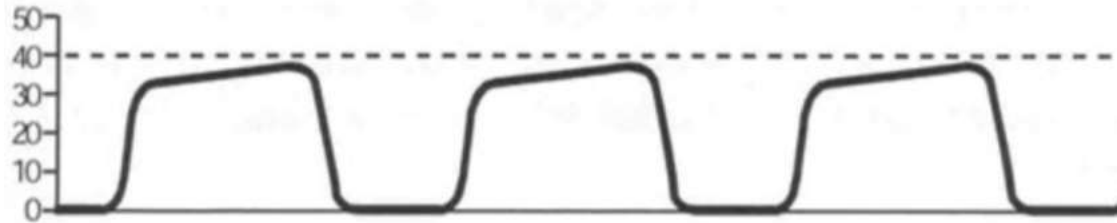
What is the rate?

Capnometry



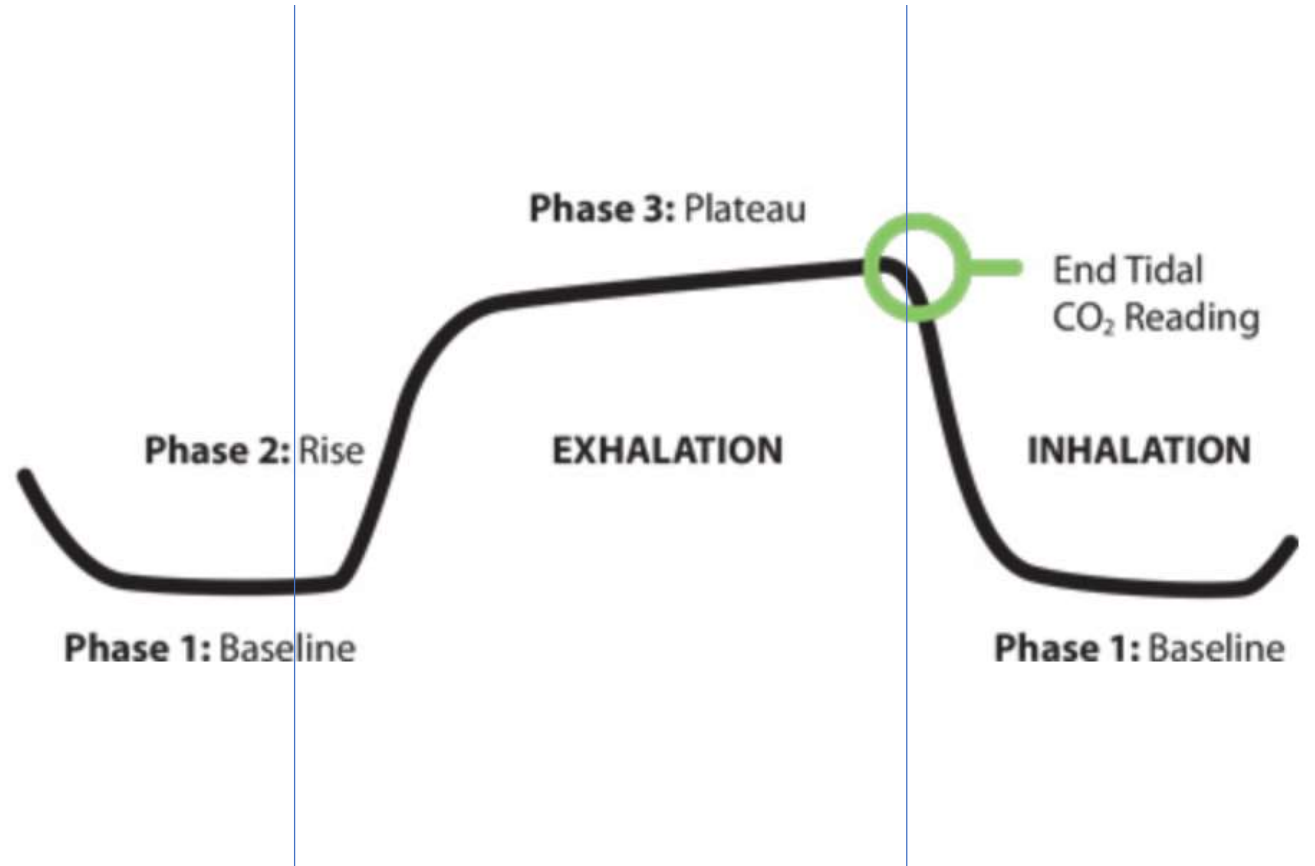
What is the rhythm?

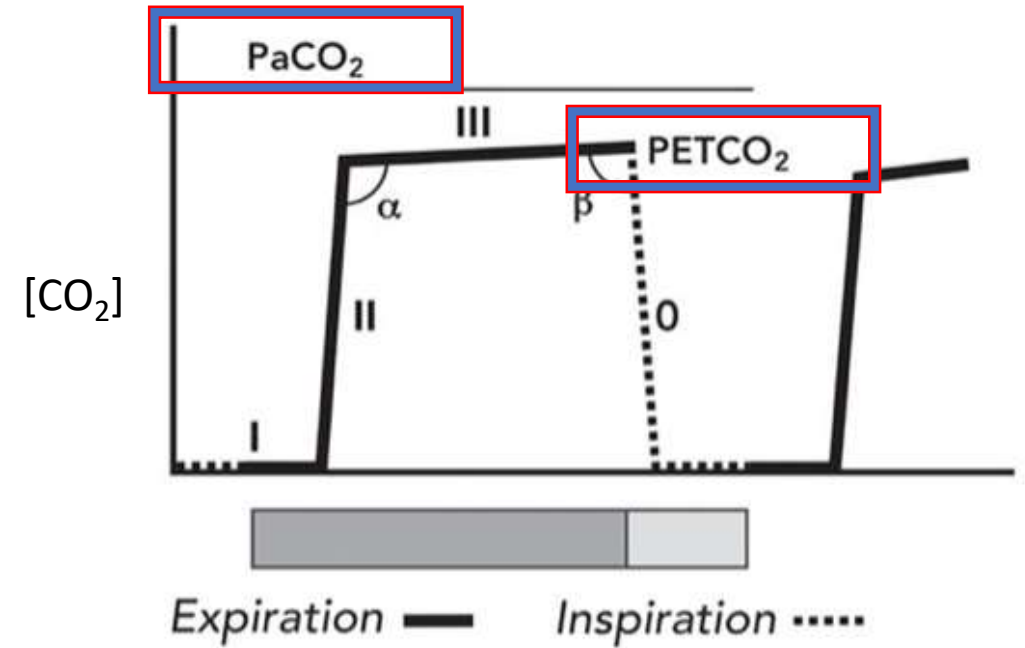
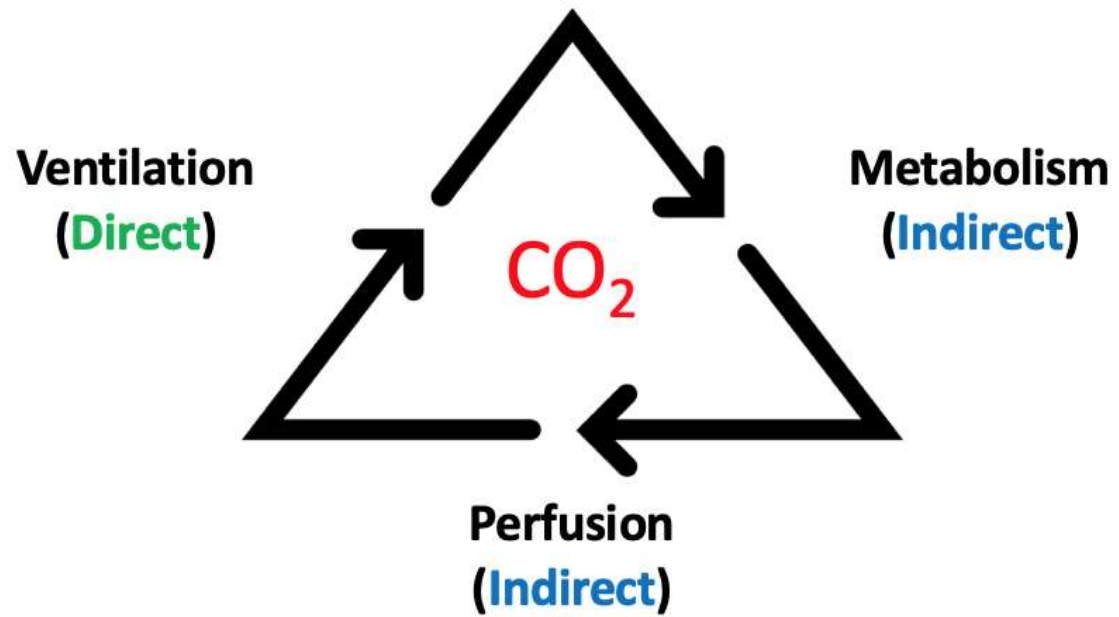
Capnography



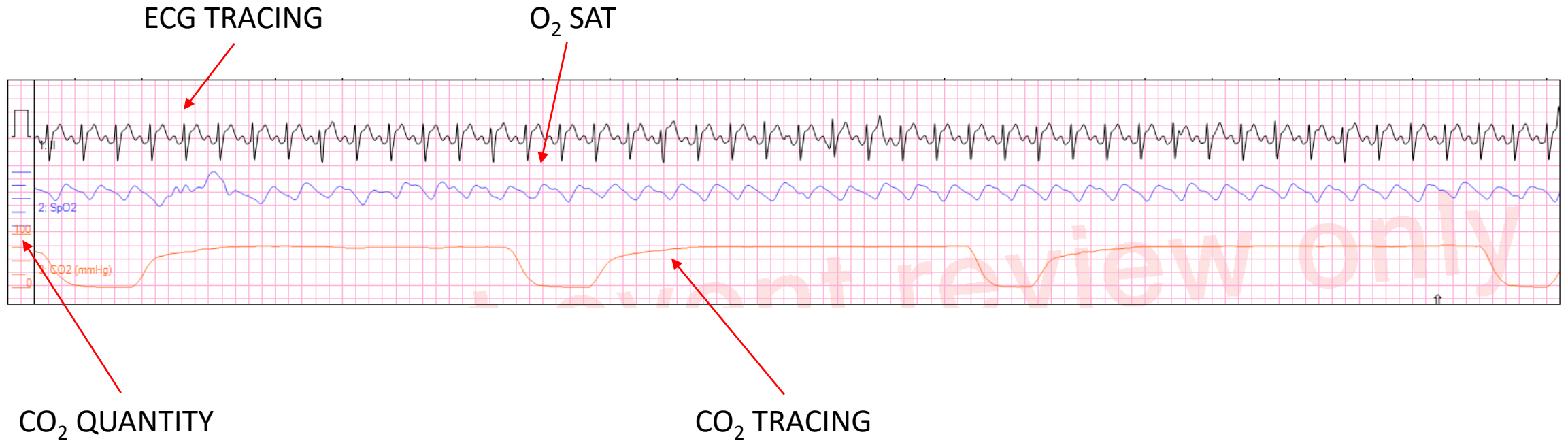
Capnography

- Continuous numerical and waveform measurement of exhaled CO_2 concentration





Lets Get Oriented

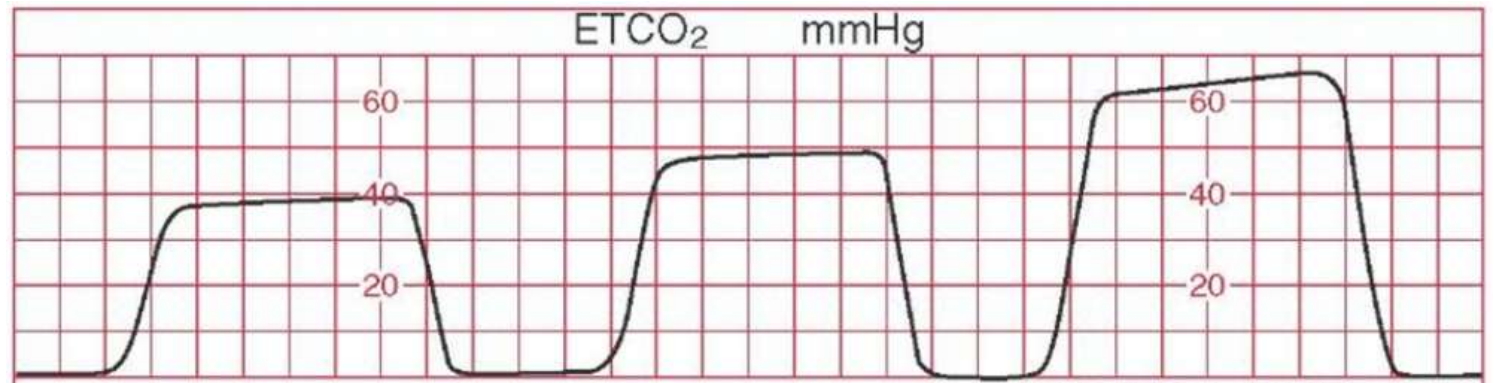




Capnography is not just for the ALS provider



Capnography
Most sensitive
for detecting
hypoventilation

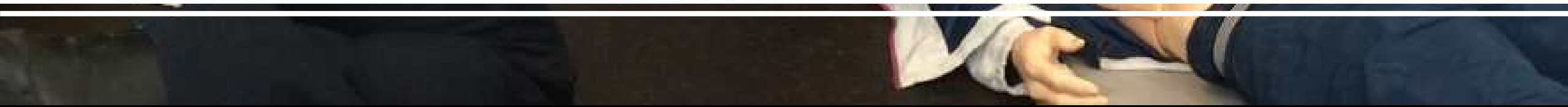


Emergency Department

Airway Monitoring
AMS
Procedural Sedation



Let's talk bagging





Effective Bagging

Effective Bagging

Two person bagging better than one

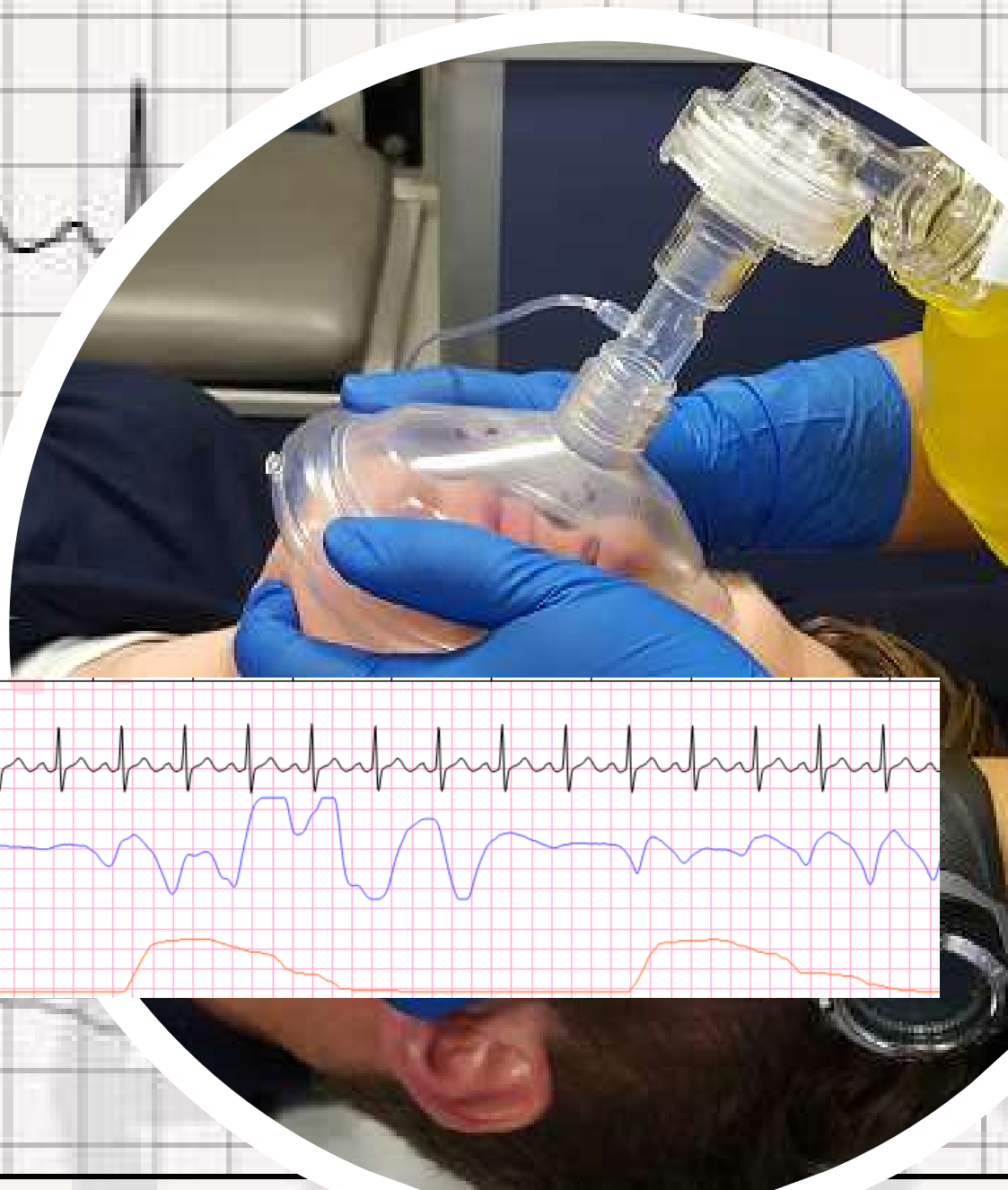
- Jaw Thrust
- Face into the mask
- Light downward pressure with thumbs
- Bring face into mask with upward pressure



EtCO_2

Quality of the mask seal

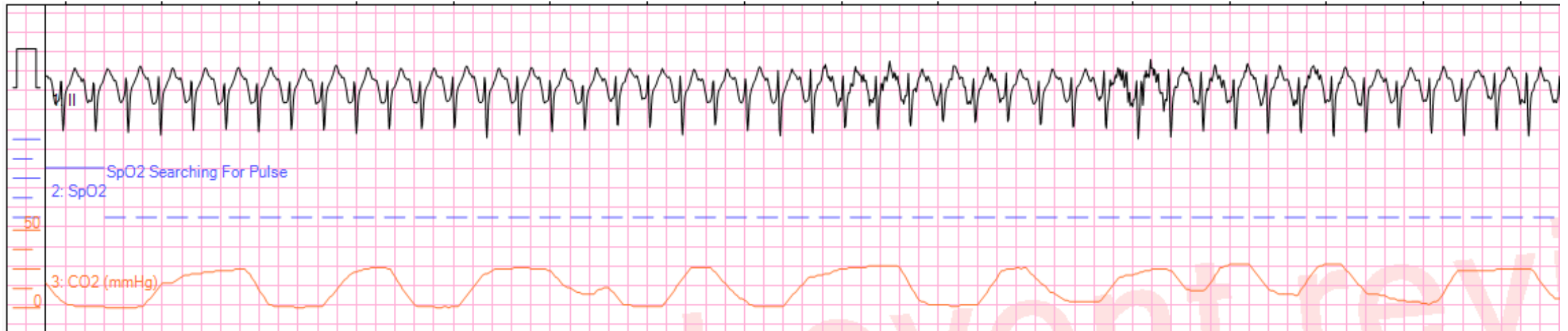
- Current ventilator status
- Potential EtCO_2 target



22 yo male reportedly took MDMA found seizing and hyperthermic
Requiring airway management

EXAMPLE USING EtCO₂ with BVM

Prior to intubation



End tidal ~ 25

Intubation

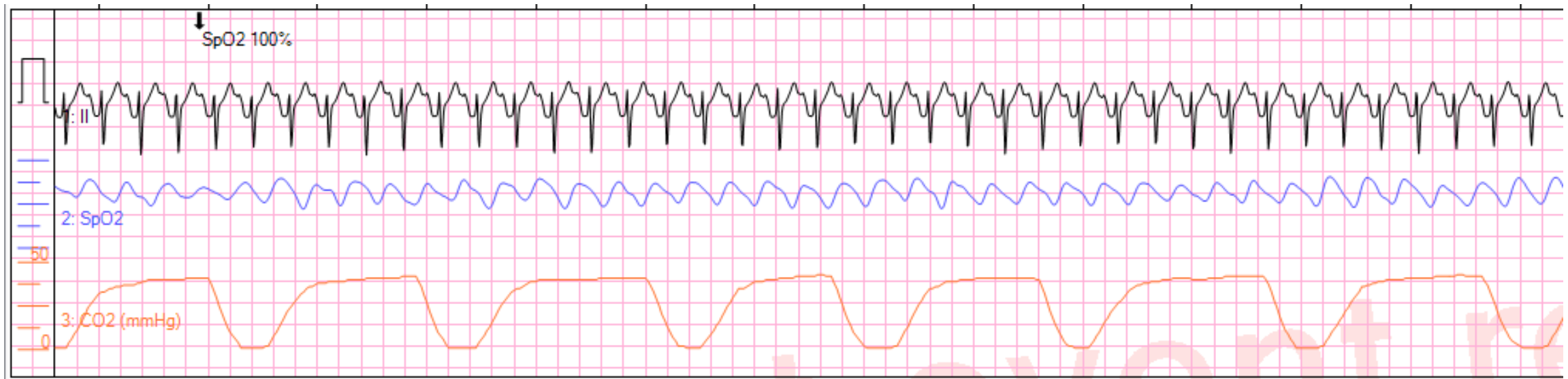
Approximately 45 seconds no ventilations during intubation

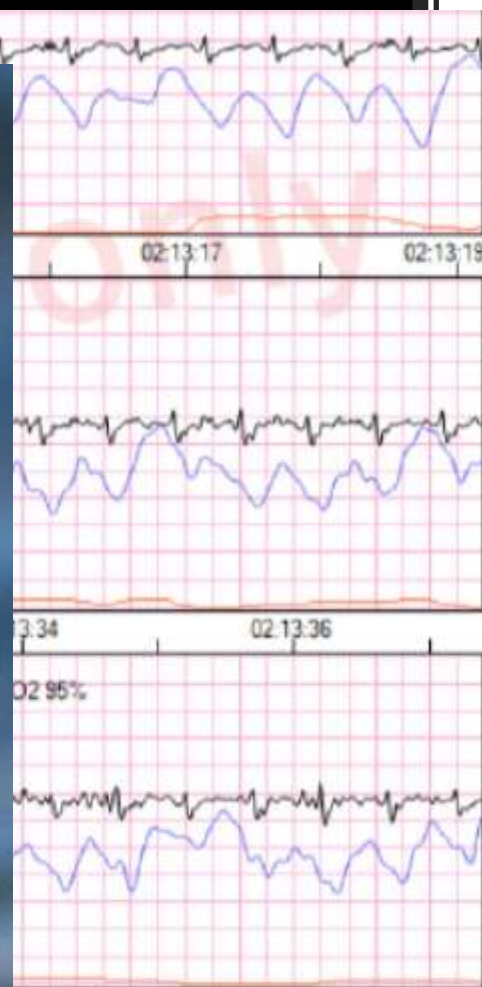


End tidal ~ 70

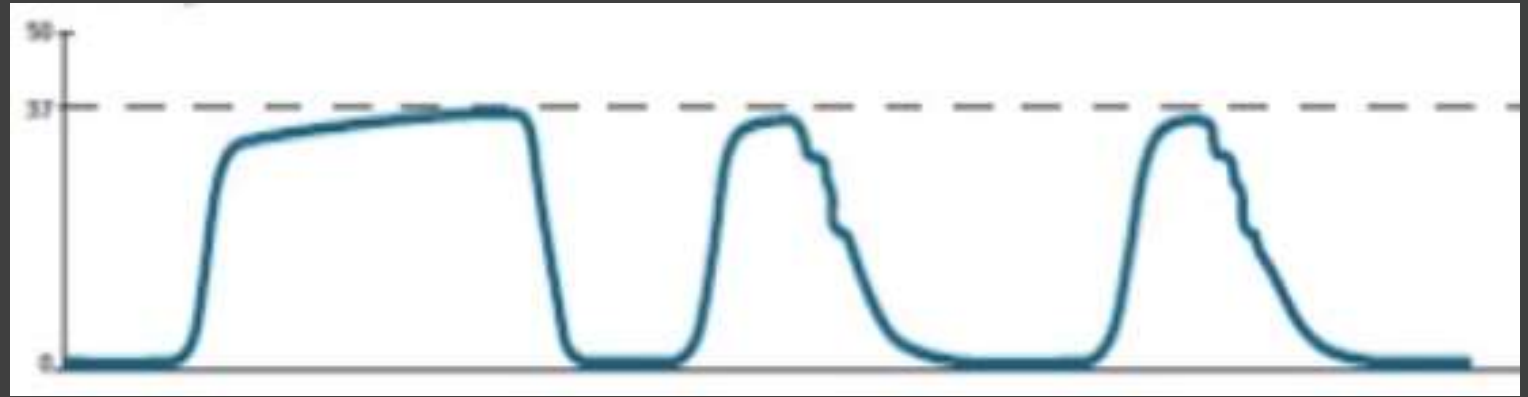
Arrival to hospital

What do you think of this patient's metabolic state?
How do you want to ventilate this patient?





The Second Attempt



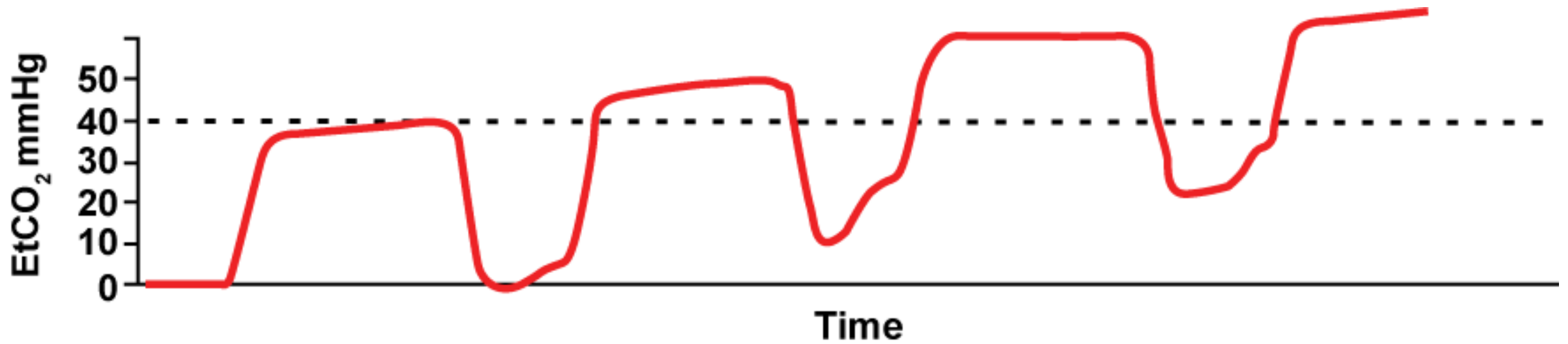
- Second pass attempt a success!
- What is happening here?

Cuff leak or hypopharyngeal ETT

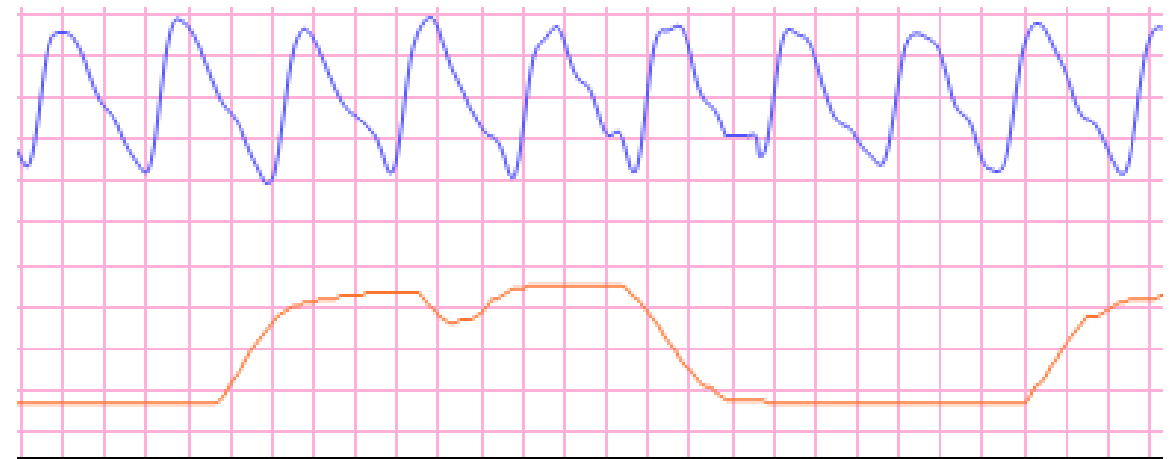
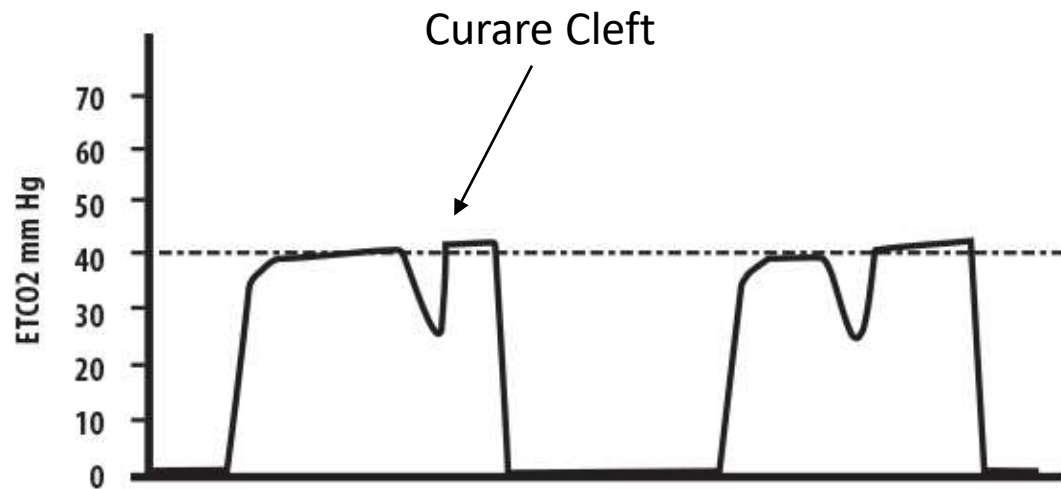


Waveform prior inflating balloon

Rebreathing



Return of spontaneous respirations



The sixth
vital sign

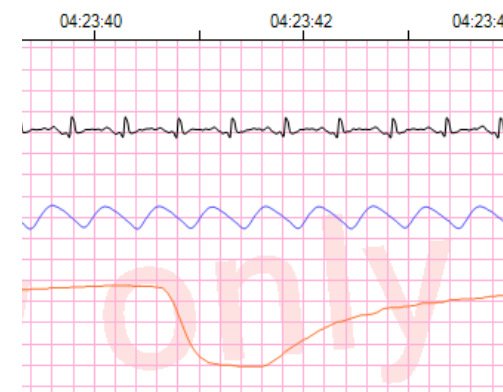
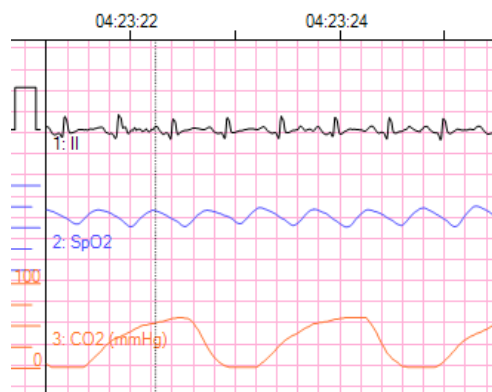


EtCO₂
25 mmHg

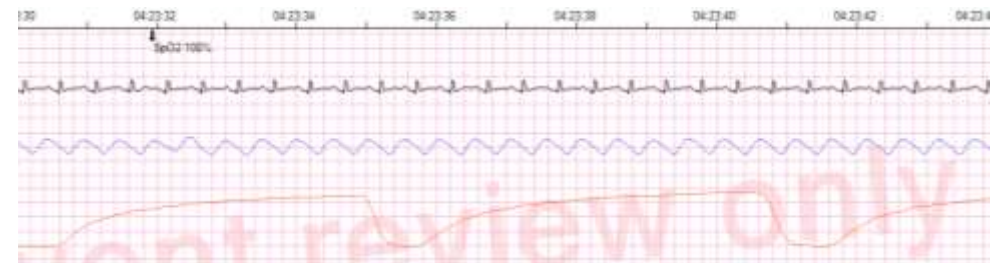
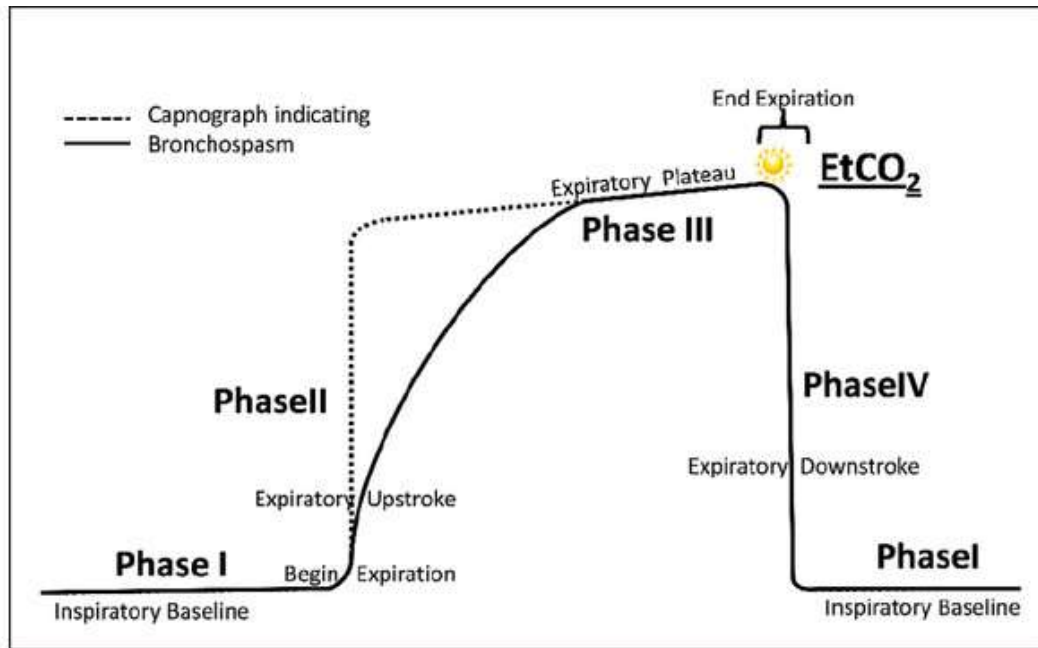
DKA
Sepsis

What is going on here?

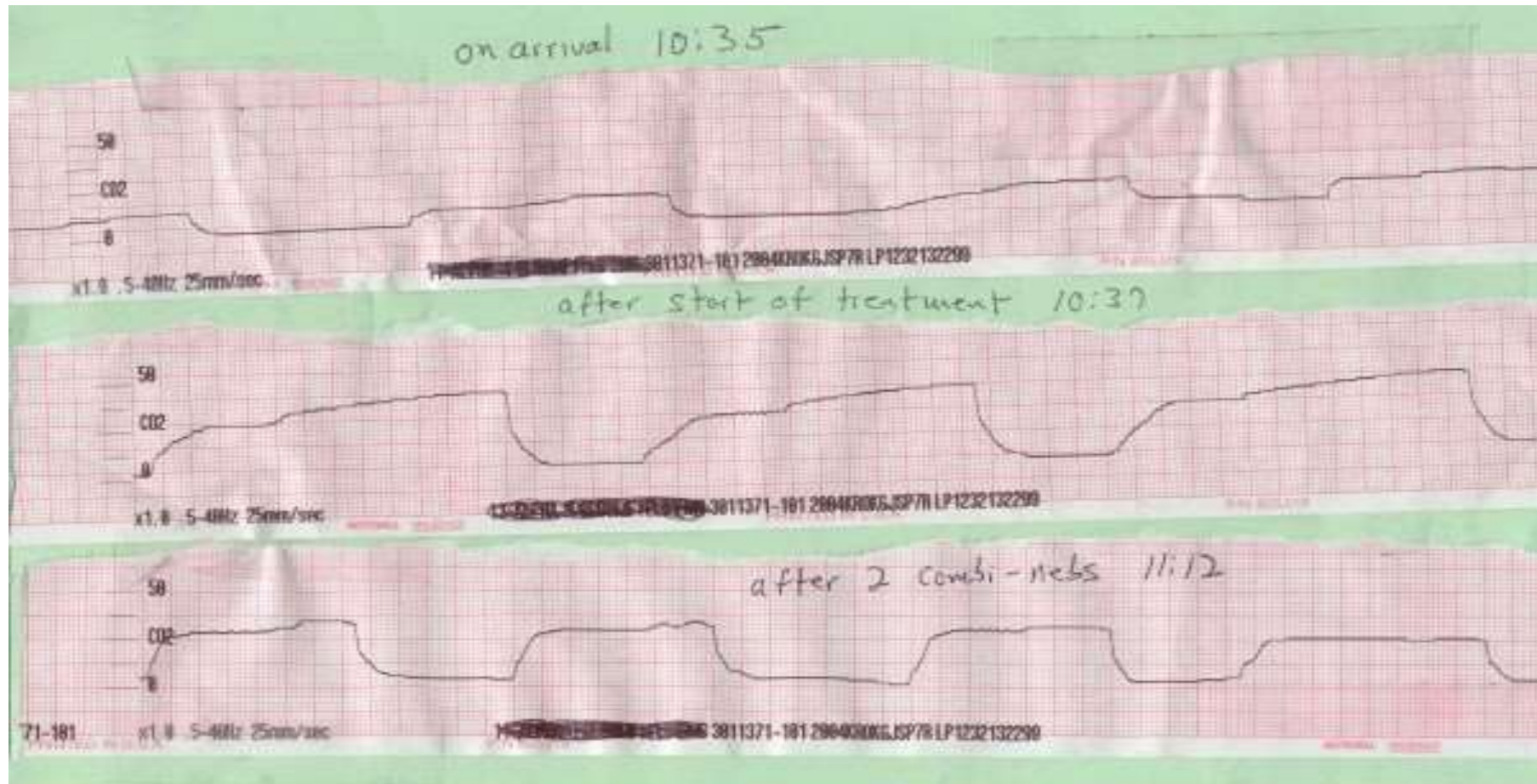
Case of difficulty breathing



Bronchospasm



Changes with treatment

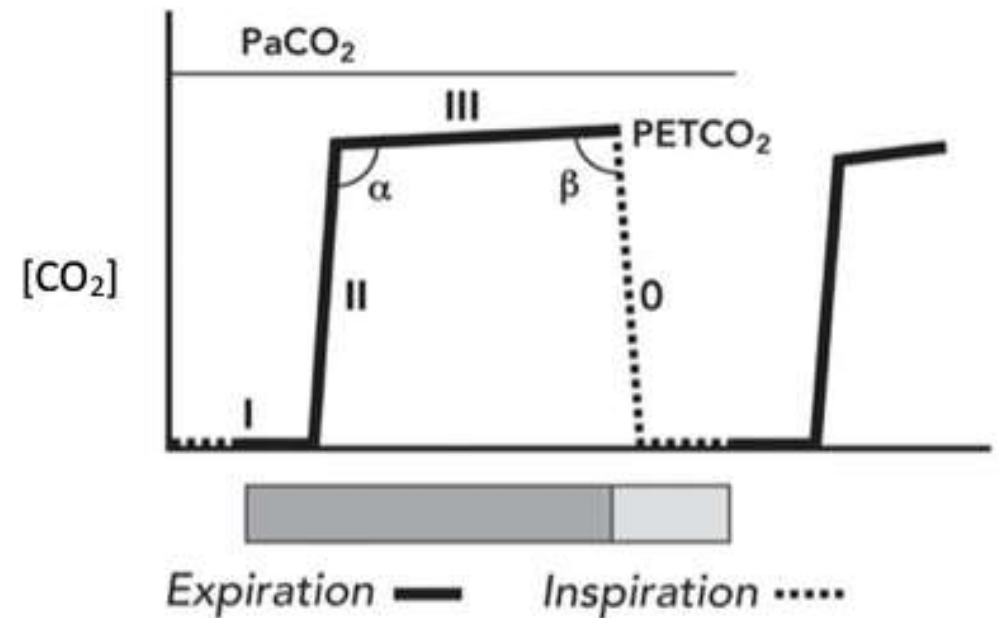
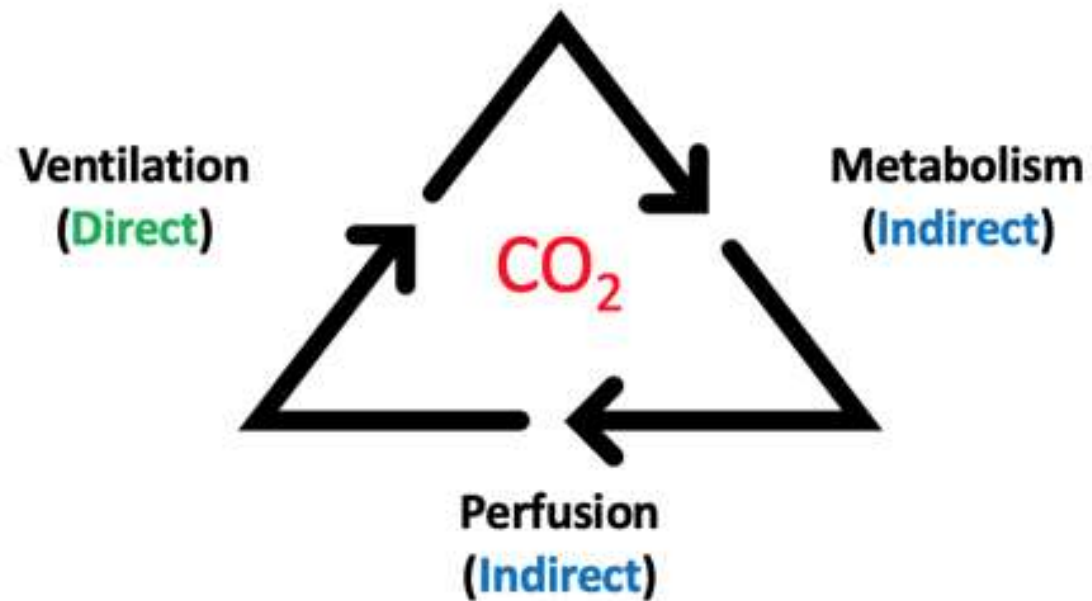




$\text{PaCO}_2 - \text{EtCO}_2$ gradient

When the end tidal reading does not accurately reflect the arterial CO_2

Normal $\text{PaCO}_2 - \text{EtCO}_2$ gradient is within 5 mmHg



EtCO₂ accurately
reflects PaCO₂ when

Normal perfusion state
(delivery)

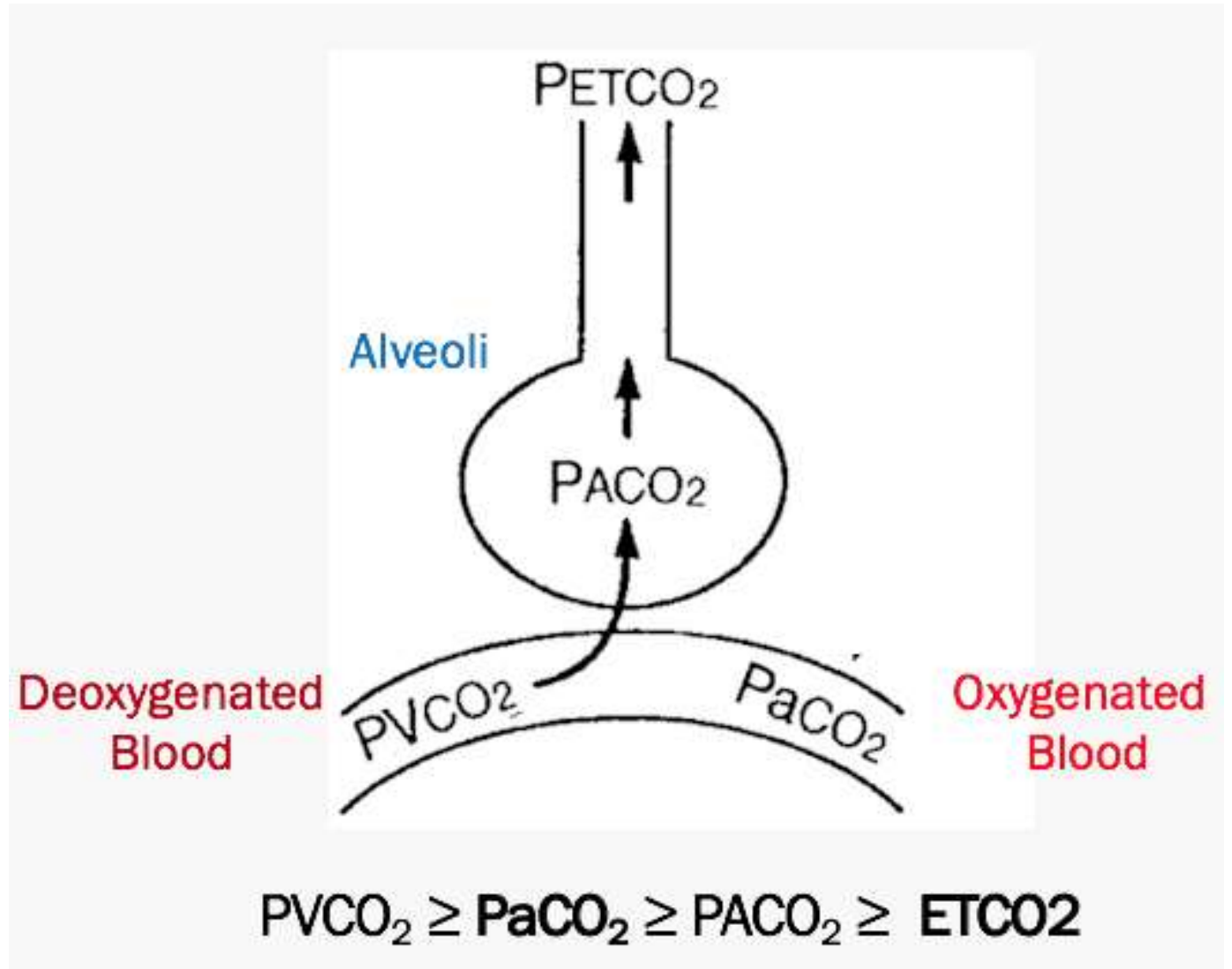
AND

Normal ventilatory state
(gas exchange)

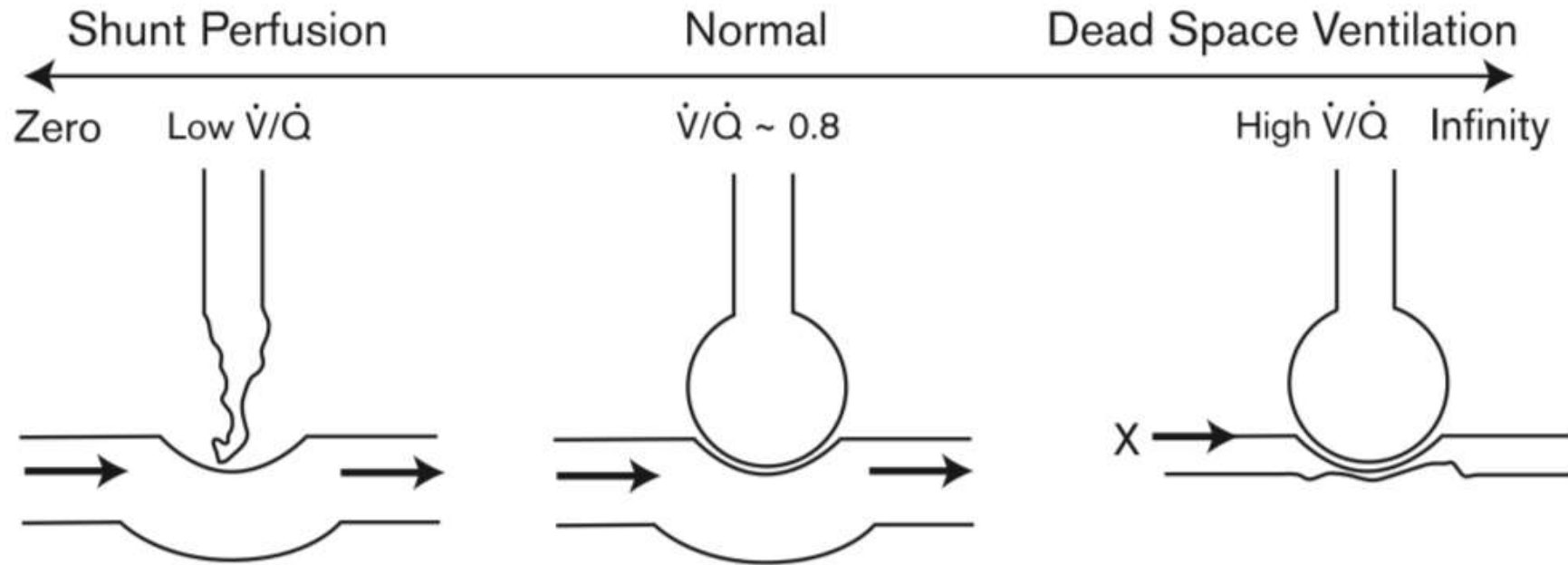


This gradient is
invariable
positive

$$\underline{\text{PaCO}_2 \geq \text{EtCO}_2}$$



The CO₂ Gradient is determined at the level of the alveoli



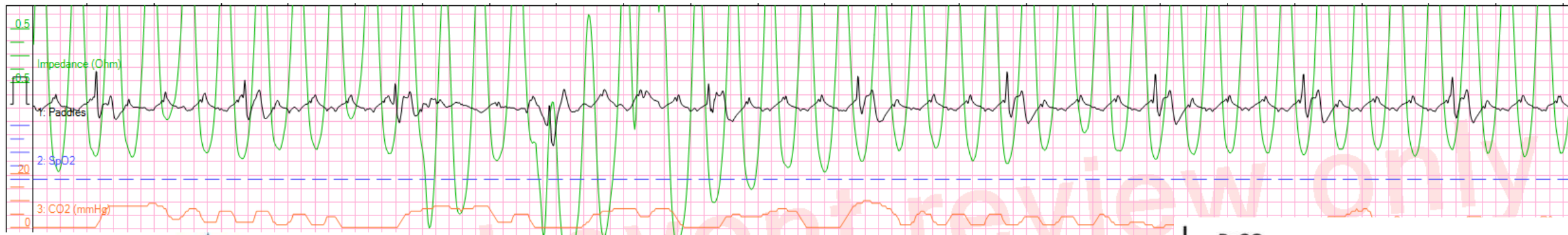
Ventilation-Perfusion Spectrum

Atelectasis
Mucus plug
Pulmonary edema
Pneumonia
Mainstem ETT
ETC...

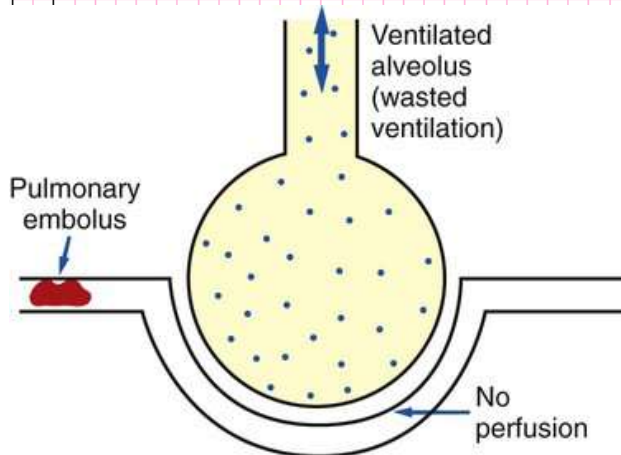
PE
Reduced CO
Shock
Cardiac arrest
ETC...

And
as your are collecting his history he arrests in front of you...

Post Intubation Initial EtCO₂ 10



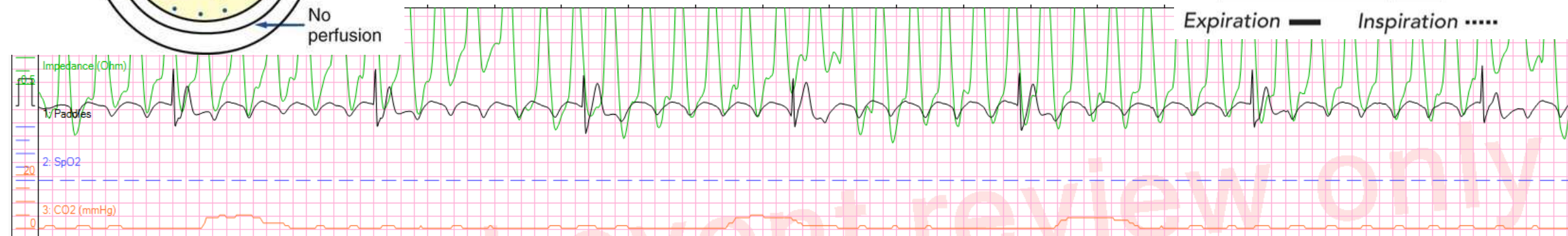
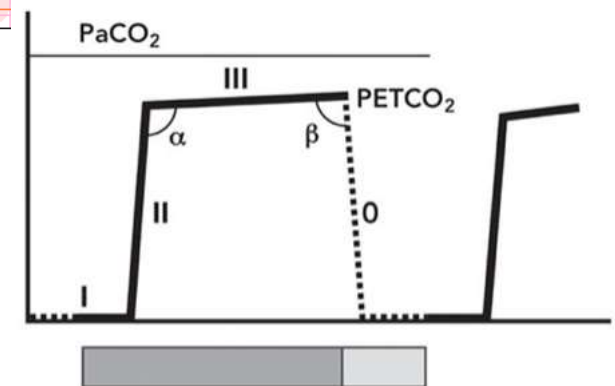
Transported to emergency department with ongoing CPR



After 50 minutes of resuscitation

EtCO₂ 5-10

However, ABG pH 6.9 and PaCO₂ 135

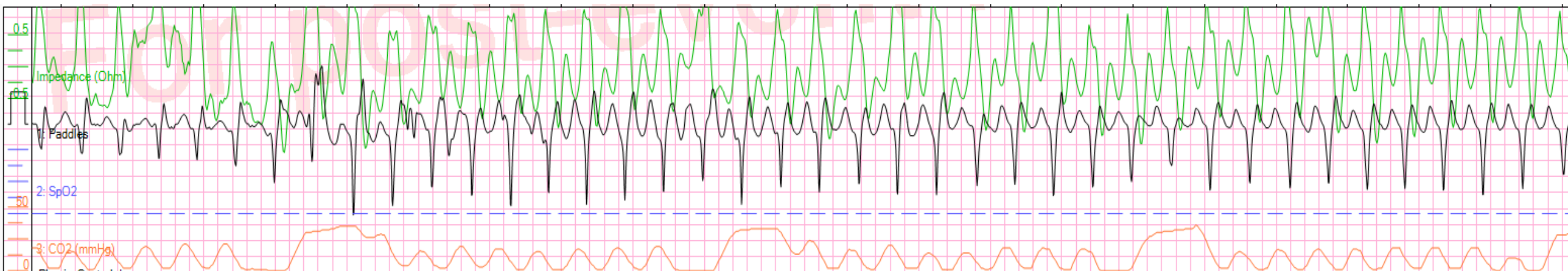


Expiration — Inspiration

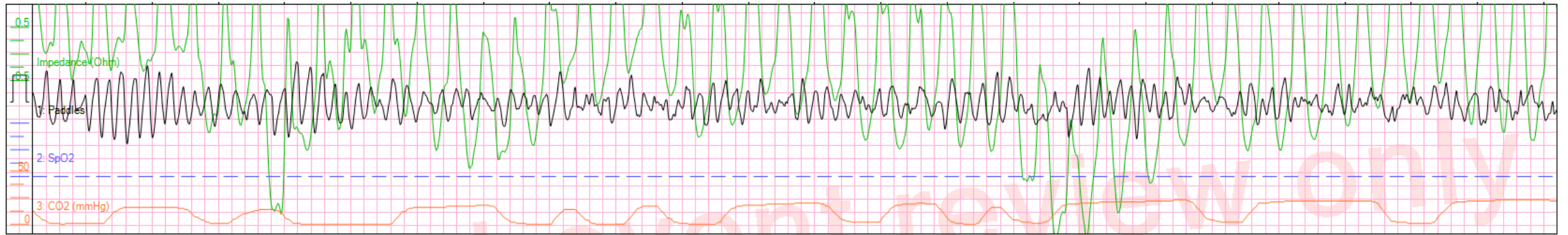
CARDIAC ARREST



- ✓ Verification of ETT
- ✓ Visualization of ventilations
- ✓ Quality of chest compressions
- ✓ ROSC
- ✓ Prognostication



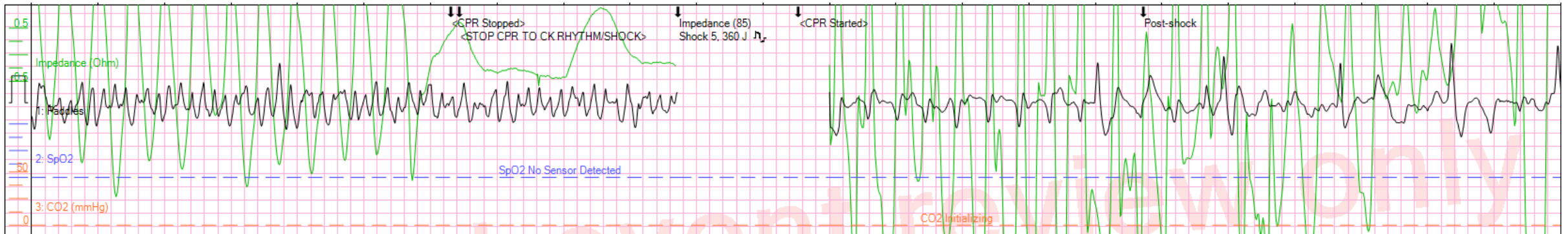
Ventricular Fibrillation



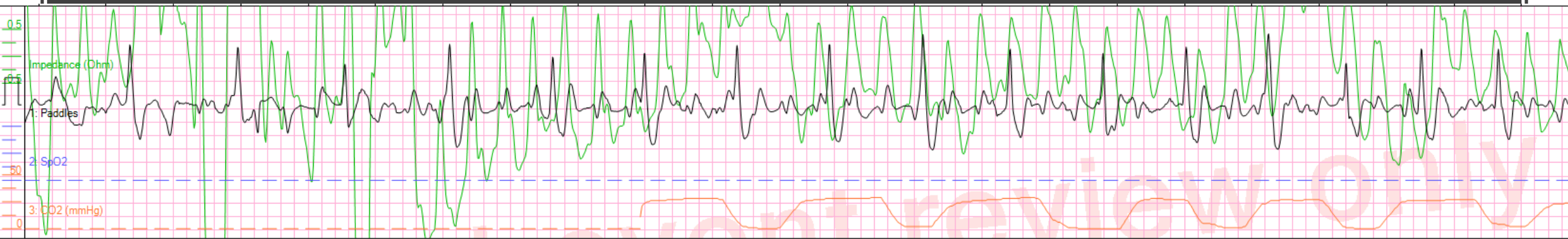
End tidal ~ 20-25

What do you do with this?

Bring the lightning!



ROSC



End tidal ~ 50 (EtCO_2 25 prior to defibrillation)

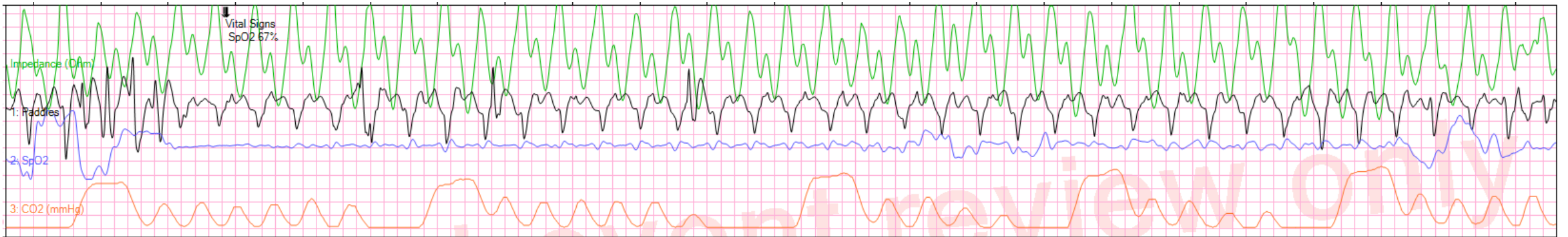
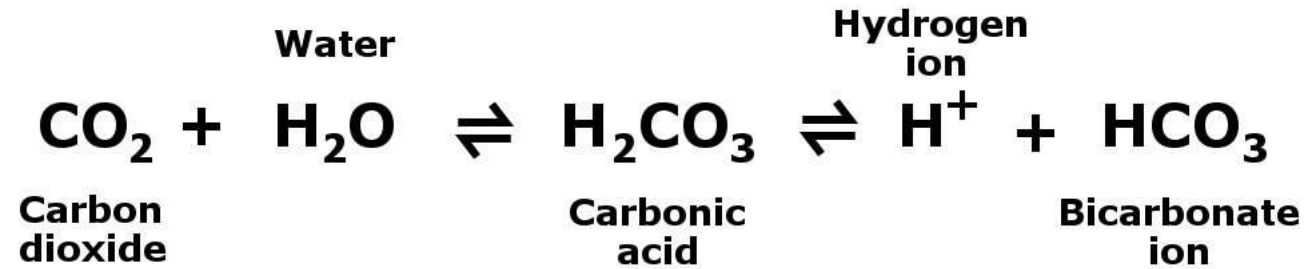


EtCO_2 rise > 10 mmHg specific but not sensitive for ROSC

LOOK FOR TRENDS

Bicarb administration

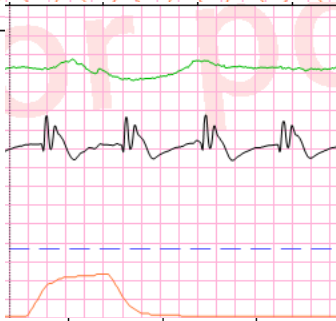
Don't be fooled...



EtCO₂ 50



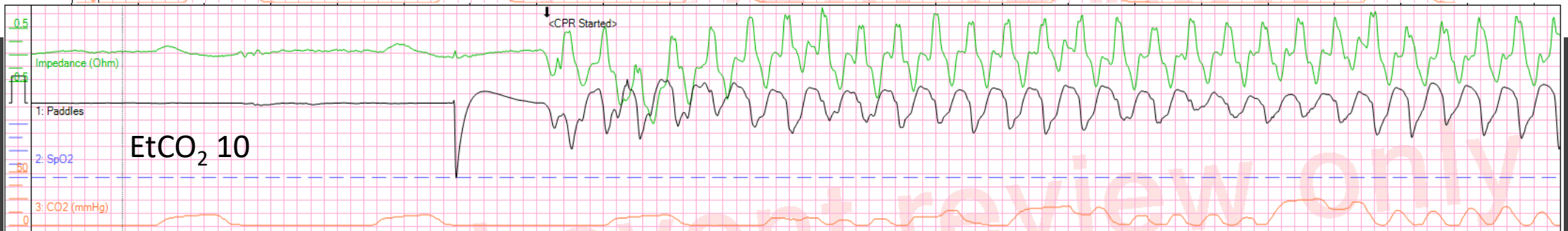
EtCO₂ 30



EtCO₂ 20



EtCO₂ 10



Termination of resuscitation

$\text{EtCO}_2 \leq 10 \text{ mmHg}$ after 20 mins 100% mortality



“ACLS is for dentist”



Last case: A fender bender... Polytrauma + TBI = bad day

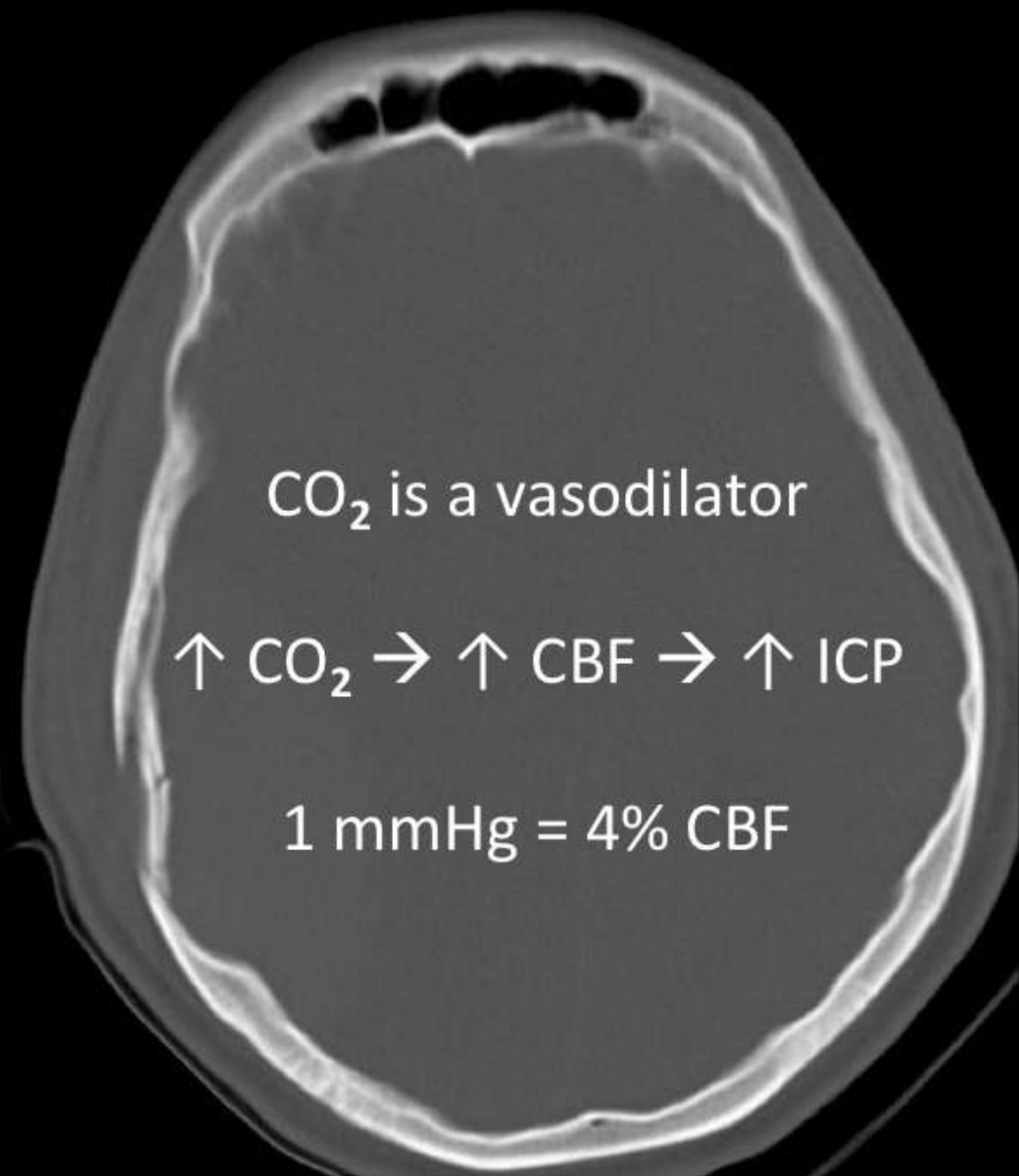
22 yo male MVC. Unresponsive, initial GCS 3 sluggish pupils. Large hematoma right temple with bruising to chest and abdomen and a right closed femur deformity.

Intubate with ketamine and rocuronium

- HR 125
- BP 90/60
- O₂ 95% BVM w/ RR 18 at 100 FiO₂

How are you going to ventilate your patient if?

1. EtCO₂ 70
2. EtCO₂ 20

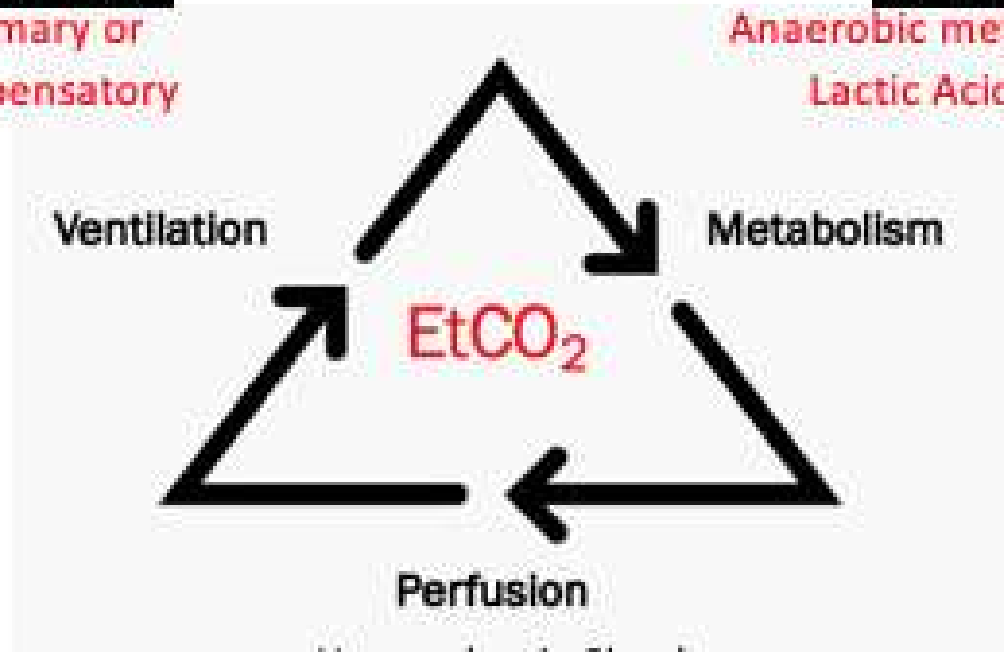


Hyper vs Hypo

Primary or
Compensatory

Acidosis

Anaerobic metabolism
Lactic Acidosis



Hypovolemic Shock

Hemorrhage

Obstructive Shock

Tamponade

PTX

Cardiac contusion

Trauma

PaCO_2 - EtCO_2 gradient

EtCO₂ accurately
reflects PaCO₂ when

Normal perfusion state
(delivery)

AND

Normal ventilatory state
(gas exchange)

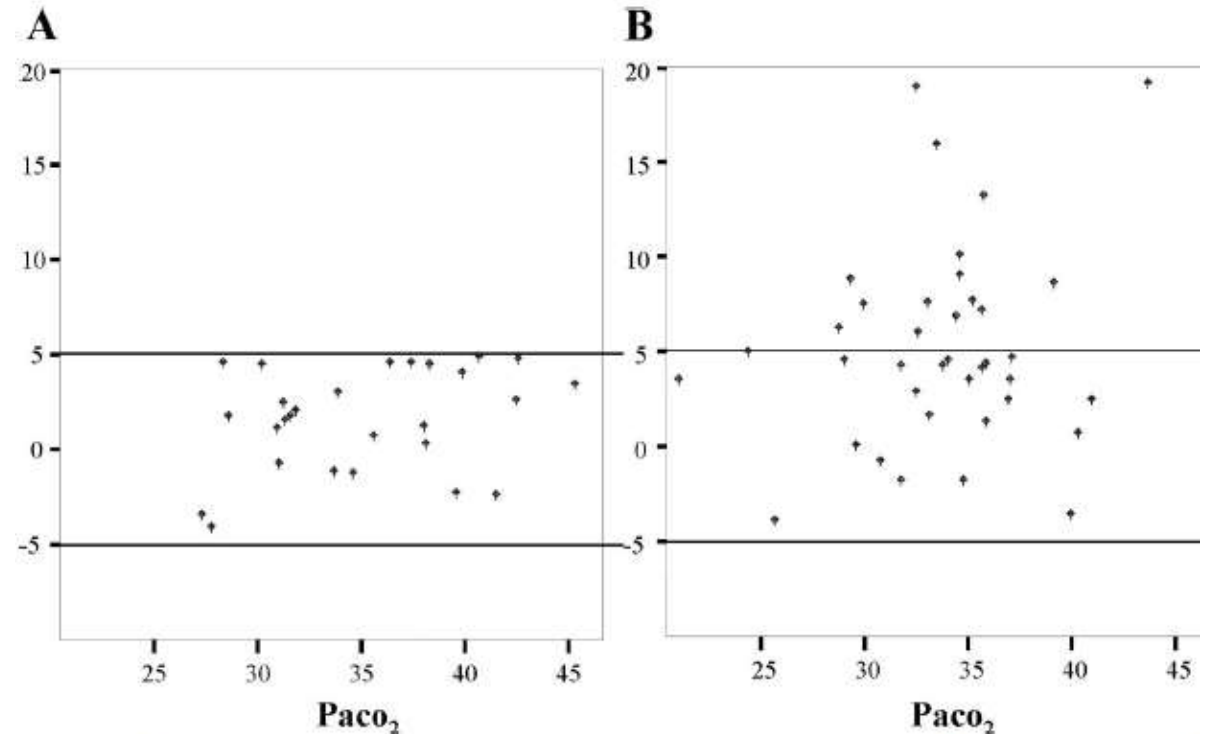


Figure 2. The concordance between PaCO₂ and PetCO₂ by Bland-Altman method. (A) Patients who had no severe chest trauma, no hypotension, and no metabolic acidosis. (B) Patients who had severe chest trauma, hypotension, or metabolic acidosis. (C) All nontraumatic patients with normal P(a-et)CO₂.



Polytrauma with TBI

How are you going to ventilate your patient if?

1. EtCO₂ 70
2. EtCO₂ 20

If EtCO₂ is **high** → target eucapnia

If EtCO₂ is **low** → “Let it go”



Summary



Waveform capnography
reflects

Ventilation
Perfusion
Metabolism



Waveform capnography
is the 6th vital sign

Use it to guide ventilations
Recognize common waveforms
Guide therapeutics
Diagnostic utility



Understand the PaCO_2 - EtCO_2 gradient and
how to apply to your patient

www.escholarship.org/uc/item/5qz744fv