PARAMEDIC EDUCATION

Capnography

35–45

mmHg · normal $EtCO_2$

From the mitochondria to the monitor — physiology, waveform anatomy, interpretation and the calls where it changes what you do.

$EtCO_2$

Why it earns a place on every patient

Pulse oximetry tells you about oxygenation, and it tells you late. Capnography tells you about ventilation, and it tells you first.

SpO_2

A lagging indicator

A preoxygenated patient can stop breathing entirely and hold a saturation of 100% for several minutes. The desaturation, when it comes, is the end of the reserve — not the beginning of the problem.

$EtCO_2$

A real-time indicator

Apnea, obstruction, a displaced tube or a fall in cardiac output register on the very next breath — or on the breath that fails to arrive. Nothing else in the truck is that fast.

Ventilation · Perfusion · Metabolism

Every other monitor reads one system. Capnography sits at the intersection of three: CO_2 has to be produced by cells, carried by a circulation, and blown off by lungs. When the number changes, one of those three has changed — your job is to work out which.

PHYSIOLOGY

Where the number actually comes from

$EtCO_2$

The journey of a CO_2 molecule

Break any link in this chain and the waveform changes. That is the whole basis of interpretation.

01

PRODUCED

Aerobic metabolism in the mitochondria generates CO_2. Fever, sepsis, seizure and shivering raise output; hypothermia and sedation lower it.

02

CARRIED

Dissolved and as bicarbonate, CO_2 returns via the venous system to the right heart. This step requires a cardiac output.

03

DELIVERED

The pulmonary circulation carries it to the alveoli. Perfusion failure here — arrest, shock, PE — means CO_2 never arrives to be exhaled.

04

EXCHANGED

CO_2 diffuses into the alveolus, roughly 20 times more readily than oxygen. Diffusion is rarely the limiting step.

05

EXHALED

The last portion of the breath is alveolar gas. Sample it and you have end-tidal CO_2.

A low $EtCO_2$ therefore has three possible homes: the patient is making less CO_2, moving less blood, or blowing it off too fast. Reading the waveform and the patient together is how you decide which.

$EtCO_2$

One number, three questions

Before treating a value, decide which of these it is telling you about.

METABOLISM
How much CO_2 is being made

Rises: fever, sepsis, seizure, shivering, pain, malignant hyperthermia, bicarbonate administration.
Falls: hypothermia, sedation, paralysis, hypothyroidism.

PERFUSION
How much blood reaches the lungs

Falls: cardiac arrest, hypovolemia, hemorrhage, obstructive shock, pulmonary embolism.
Rises: ROSC, restored circulating volume, improving output.

VENTILATION
How much gas is moved per minute

Falls: hyperventilation, over-aggressive bagging.
Rises: hypoventilation, respiratory depression, airway obstruction, fatigue in an asthmatic.

The same reading of 25 mmHg means opposite things in a hyperventilating anxious patient and a pale trauma patient with a rising heart rate. The number is context-dependent — always.

$EtCO_2$

End-tidal is not arterial

Understanding the gap is what separates using the number from trusting it blindly.

The normal gradient

In a healthy adult, $PaCO_2$ runs about 2–5 mmHg above $EtCO_2$. That small gap exists because some alveoli are ventilated but poorly perfused, diluting the sample with gas that carries no CO_2.

2–5

mmHg

When the gap widens

Anything that increases dead space pulls $EtCO_2$ down and away from $PaCO_2$: pulmonary embolism, severe shock, cardiac arrest, advanced COPD. In these patients a normal-looking $EtCO_2$ may sit alongside a dangerously high arterial CO_2.

35–45

Normal adult range

< 35

Hypocapnia — hyperventilation, hypoperfusion, or reduced production

> 45

Hypercapnia — hypoventilation, obstruction, rising production

< 10

In arrest: inadequate compressions or a non-survivable state

EQUIPMENT

How the measurement is actually made

$EtCO_2$

Three ways to measure, one that teaches you anything

All three appear on ambulances. Only one gives you a waveform.

COLORMETRIC

Chemical paper

- Purple to yellow in the presence of CO_2 — remembered as “yellow is yes.”
- Gives presence or absence, no number and no trend.
- Fooled by gastric acid and by low-flow states; unreliable in prolonged arrest.
- A backup, not a monitoring tool.

SIDESTREAM

Sample drawn to the sensor

- A small pump pulls gas through tubing to an analyser inside the monitor.
- Works with nasal cannula on spontaneously breathing patients — its major advantage.
- Short delay; water and secretions can occlude the line.
- The common prehospital configuration.

MAINSTREAM

Sensor in the circuit

- The analyser sits directly in the exhaled gas stream at the airway.
- No lag, no sampling line to block.
- Adds weight at the tube and needs an advanced airway in place.
- Common on transport ventilators.

Nasal cannula sampling on a spontaneously breathing patient reads slightly lower than a sealed circuit because room air dilutes the sample. Read the shape and the trend rather than treating the absolute value as gospel.

THE NORMAL WAVEFORM

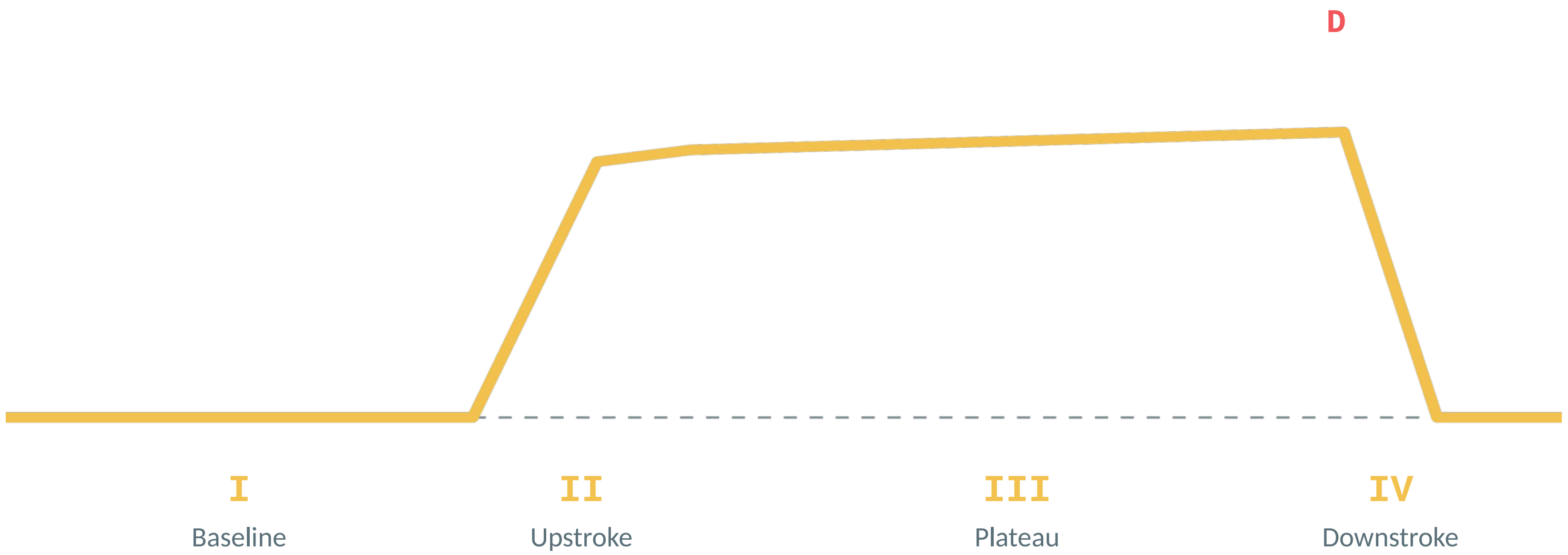
Anatomy of a single breath

$EtCO_2$

Anatomy of the capnogram

Four phases and two angles. Every abnormal strip is a distortion of this shape.

$EtCO_2$ is read here — the last of the alveolar gas



Phase I

Inspiratory baseline. Gas from anatomic dead space, containing no CO_2. It must return to zero.

Phase II

Expiratory upstroke. Dead space gas mixes with alveolar gas and the trace rises steeply.

Phase III

Alveolar plateau. Nearly pure alveolar gas, with a slight upslope as slower alveoli empty.

Phase IV

Inspiratory downstroke. Fresh gas washes the sensor and the trace falls sharply to baseline.

The two angles

Alpha, between phases II and III, is normally about 100–110° — it widens with obstructive disease, producing the shark fin.
Beta, between phase III and the downstroke, is about 90° — it increases with rebreathing.

EtCO$_2$

Four questions, asked in order

A repeatable method beats pattern recognition when the strip is unfamiliar.

01

IS THERE A WAVEFORM?

Presence confirms that CO_2 is being produced, circulated and exhaled. Absence in an intubated patient is an emergency until proven otherwise.

02

WHAT IS THE RATE?

Count the breaths. Ventilatory rate is on the strip whether or not anyone is counting the chest.

03

WHAT IS THE HEIGHT?

The value at the end of the plateau. High, low or normal — then ask which of the three variables explains it.

04

WHAT IS THE SHAPE?

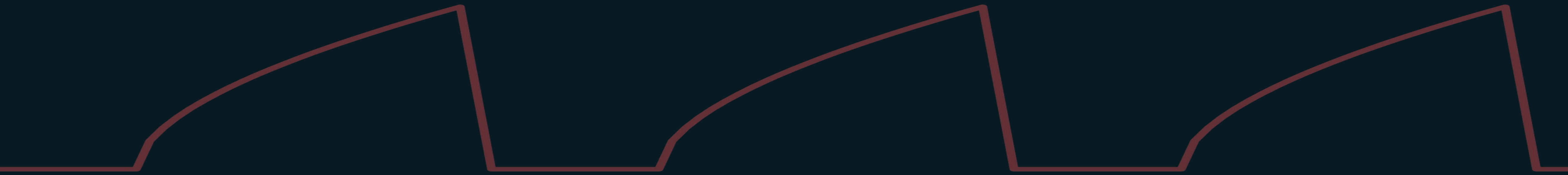
Square is normal. A sloped upstroke, a notched plateau or a baseline off zero each point to a specific problem.

Then ask the only question that matters

Does this match my patient? A capnogram that disagrees with the chest you are watching and the pulse you are feeling is either telling you something you have missed, or it is an artefact. Resolve the disagreement before you act on the number.

ABNORMAL PATTERNS

Reading what the shape is telling you

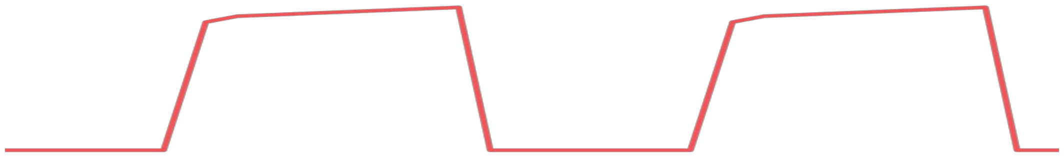


EtCO$_2$

Height: the value itself

Same square shape, wrong altitude. Start by deciding whether ventilation or perfusion moved.

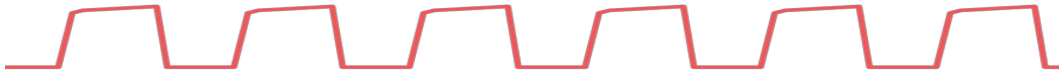
Hypoventilation — EtCO$_2$ rising



Tall waveforms, slow rate. CO_2 is accumulating because minute volume has fallen: opioid or sedative effect, exhaustion, head injury, or a rate you set too low on the bag.

Intervention: support ventilation, raise the rate or tidal volume, treat the cause. Reassess on the next breath — the waveform responds immediately.

Hyperventilation — EtCO$_2$ falling



Short waveforms, fast rate. CO_2 is being blown off faster than it is produced: anxiety, pain, compensatory breathing in acidosis, or an overenthusiastic bag.

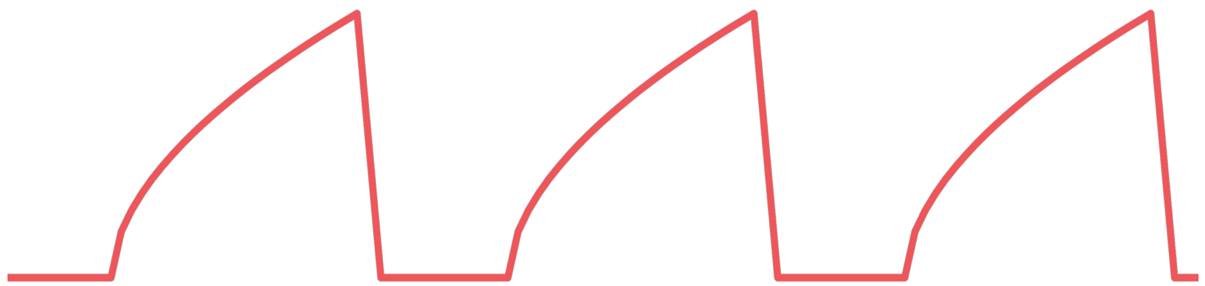
Intervention: slow the rate if you are ventilating. If the patient is doing it themselves, find out why before you try to stop it — it may be the only thing keeping their pH survivable.

The trap

A low EtCO$_2$ with a normal square waveform and a normal respiratory rate is not a ventilation problem — it is a perfusion problem until proven otherwise. Look at the skin, the pulse and the blood pressure before you touch the ventilation.

Shape: the shark fin

Bronchospasm, drawn on the monitor — and the earliest objective measure of whether your treatment is working.



What you are seeing

- The alpha angle has widened — phase II slurs into phase III with no clean corner.
- Obstructed alveoli empty at different rates, so there is never a true plateau.
- Seen in asthma, COPD exacerbation, anaphylaxis and any lower airway obstruction.

Interpretation

The degree of slurring tracks the severity of obstruction. The height tells you something separate: a rising $EtCO_2$ in a tiring asthmatic is an ominous sign that minute volume is failing, and it often precedes the silent chest.

What to do

Treat the bronchospasm per protocol and watch the fin. As obstruction resolves the corner sharpens and the plateau flattens — often before the wheeze changes and before the patient reports feeling better. This is objective evidence of response.

EtCO₂

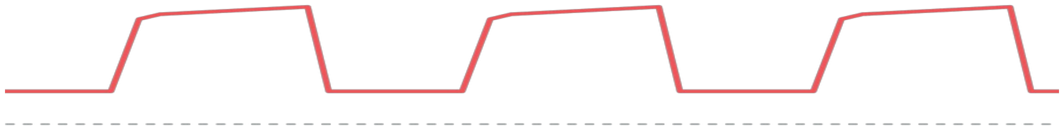
Shape: notches and lifted baselines

Two patterns that look subtle on the strip and matter a great deal at the airway.

Curare cleft

A notch dropping out of the plateau. The patient is making a spontaneous inspiratory effort partway through a delivered breath — paralytic wearing off, or ventilation out of sync with the patient.

Elevated baseline



Phase I never returns to zero — the dashed line marks where it should be. The patient is inhaling CO_2 they just exhaled: inadequate expiratory time, a faulty expiratory valve, or an exhausted absorber.

Action

Reassess sedation and paralysis and synchronise your ventilations with the patient's effort. Read it as a warning about awareness, not as a monitor fault.

Action

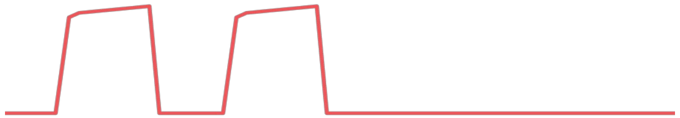
Lengthen expiratory time, check the circuit and valves, and reduce the rate if you are bagging. A baseline off zero is always abnormal — it is never a display artifact to be ignored.

$EtCO_2$

Trend: how it changed matters as much as what it reads

Sudden versus gradual points you at completely different problems.

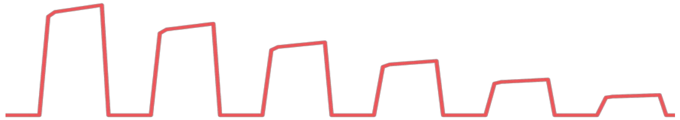
Sudden loss to zero



Mechanical or catastrophic. In an intubated patient: displacement, obstruction, disconnection — or loss of circulation.

Check tube position and chest rise, check the circuit, check a pulse. Assume the tube until you have proven otherwise.

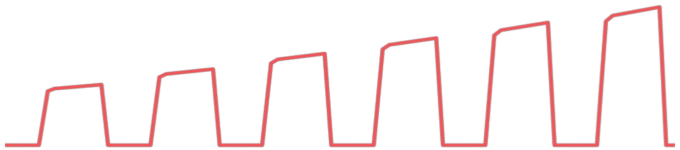
Gradual decline



Falling cardiac output is the first concern: hemorrhage, worsening shock, developing tamponade or tension.

Also seen with progressive hyperventilation, falling temperature and deepening sedation. Look at perfusion first.

Gradual rise



Hypoventilation from sedation or fatigue, rising CO_2 production from fever or sepsis, or partial airway obstruction developing.

In an arrest, a sustained rise is the earliest sign of return of circulation.

Set the monitor to display the trend, not just the instantaneous number. A single reading is a data point; the slope over five minutes is a clinical picture.

CLINICAL APPLICATION

The calls where it changes what you do

$EtCO_2$

Airway confirmation: the standard of care

Continuous waveform capnography is the accepted method of confirming and monitoring advanced airway placement.

Why the waveform, not the number

A sustained, square, four-phase waveform over successive breaths is the finding. Residual CO_2 in the stomach can produce a few small deflections after an esophageal intubation — but it washes out within several breaths and never forms a persistent plateau.

It keeps confirming

Auscultation confirms placement once; at the moment you listen. Capnography confirms it continuously — through every log roll, lift, stair chair and transfer, which is exactly when tubes move. Leave it attached for the entire call.

Confirm at insertion

Watch for a sustained square waveform over several breaths, not a single blip.

Confirm after every move

Re-check the waveform after each patient movement and at handover.

Document the strip

Record the value and the trace at insertion and on arrival.

Never ignore a loss

A waveform that disappears is a displaced tube until you have proven it is not.

$EtCO_2$

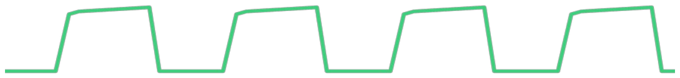
Cardiac arrest: the feedback loop

During arrest, $EtCO_2$ is essentially a cardiac output monitor — ventilation is fixed, so the number tracks pulmonary blood flow.

Under 10 mmHg

Compressions are not generating enough flow. Check depth, rate, recoil and hand position, and change the compressor. Treat it as a coaching signal, not a prognosis.

Above 10–20 mmHg



Compressions are producing meaningful pulmonary blood flow. This is the target to maintain and the reason to minimise every pause.

Abrupt sustained rise

A sudden jump — often to 35–40 — is the earliest indicator of return of spontaneous circulation, appearing before a palpable pulse. Do not stop compressions to check; finish the cycle.

Three uses, one monitor

- CPR quality — real-time feedback on whether this compressor is generating flow right now.
- ROSC detection — an abrupt sustained rise, without interrupting compressions to look for it.
- Prognostication — a persistently low value after prolonged resuscitation is one input into termination decisions, per your protocol and medical direction.

$EtCO_2$

The perfusion and metabolism calls

Where a low number in a patient who looks reasonable is the most useful thing on the monitor.

SHOCK	A falling $EtCO_2$ in a bleeding or septic patient reflects falling pulmonary blood flow. It often moves before blood pressure does, because pressure is defended by compensation while flow is already dropping.
SEPSIS	A low $EtCO_2$ correlates with elevated lactate and with worse outcomes. Several systems use it as a prehospital screening adjunct to identify patients who need aggressive early treatment.
DKA	Kussmaul respirations blow off CO_2 to compensate for metabolic acidosis, and $EtCO_2$ falls in proportion to the acidosis. A low value in a hyperglycemic patient supports the diagnosis and gauges severity.
SEIZURE	Distinguishes true apnea from the noisy, ineffective breathing of the postictal patient, and confirms ventilation is returning without waiting for saturation to catch up.

In each of these, the value is a window onto a physiology you cannot otherwise see in the field — not a target to be normalised.

$EtCO_2$

Two places it prevents harm

Monitoring the patient you have sedated, and ventilating the head injury correctly.

SEDATION & OPIOIDS

Respiratory depression shows on the capnogram before saturation falls, and long before anyone notices the chest. Rising $EtCO_2$ with a falling rate is the signature of a patient being over-sedated.

Use it on every procedural sedation, every opioid administration in a compromised patient, and on anyone you have chemically restrained — they are at real risk and often positioned poorly.

HEAD INJURY

CO_2 is a potent cerebral vasodilator. Hyperventilation constricts cerebral vessels and reduces already marginal perfusion; hypoventilation raises CO_2 and worsens intracranial pressure. Both cause harm.

Target normal values — commonly 35–40 mmHg — and use the waveform to hold the rate steady. Routine prophylactic hyperventilation is not indicated.

Brief controlled hyperventilation

Some protocols permit brief, targeted hyperventilation for signs of active herniation — a blown pupil, extensor posturing, an abrupt drop in GCS with Cushing's response. Where it is permitted it is a short, monitored intervention with a defined $EtCO_2$ target, not a default setting on the bag. Follow your own protocol and medical direction, and use the waveform to hit the number deliberately rather than by feel.

$EtCO_2$

Pitfalls, artifacts and limitations

Knowing where the monitor lies is part of knowing how to use it.

Wide gradient in low flow

In arrest, shock and pulmonary embolism, $EtCO_2$ substantially underestimates arterial CO_2. Do not use it for fine ventilation targeting in these patients.

Dilution on nasal cannula

A spontaneously breathing patient on cannula sampling reads lower than the true value. Mouth breathing makes it worse. Trend and shape stay reliable.

Occluded sampling line

Water, secretions or vomit block the line and flatten the trace. Check the tubing before you believe a sudden loss.

It is not an oxygen monitor

A perfect capnogram tells you nothing about oxygenation. Capnography and pulse oximetry answer different questions — use both.

Values are not universal

Ranges and targets vary between services, devices and patient groups. Pediatric and pregnant patients differ from the adult figures used here.

The patient outranks the monitor

If the strip and the patient disagree, look at the patient, then find the reason for the disagreement. Never treat the display.

PRACTICE

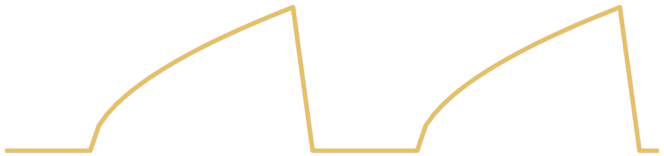
Three strips, three decisions

$EtCO_2$

Read the strip, then decide

Work each one through the four questions before turning the page.

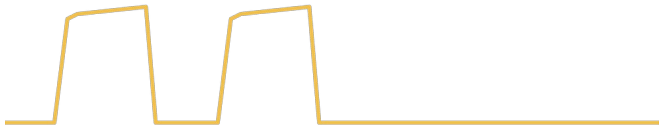
CASE 1



A 24-year-old asthmatic, audible wheeze, speaking in short phrases. $EtCO_2$ reads 52 and the trace looks like this after two nebulisers.

What does the shape tell you, and what does the value add?

CASE 2



An intubated overdose patient. The waveform was square and steady at 38. During the lift to the stretcher, this happened.

What is your differential, and what do you check first?

CASE 3

A 68-year-old with abdominal pain, HR 118, BP 104/78, skin cool. $EtCO_2$ reads 24 with a normal square waveform at a rate of 18.

Is this a ventilation problem? What does the number suggest?

Working through them

The reasoning matters more than the pattern name.

CASE 1

Shark fin with a rising value

The slurred upstroke and absent plateau confirm ongoing bronchospasm despite two treatments. The value is the more worrying finding: an $EtCO_2$ of 52 in an asthmatic means minute volume is now failing and the patient is tiring. Escalate treatment, prepare to support ventilation, and expect deterioration. A falling wheeze here is not reassurance.

CASE 2

Sudden loss during movement

Displacement is the leading diagnosis — the timing is diagnostic. Work through DOPE: displaced tube, obstruction, pneumothorax, equipment. Verify the tube with direct visualisation if you can, confirm chest rise, check the circuit and sampling line, and check a pulse, because loss of circulation produces the same trace. Do not assume equipment failure without excluding the airway.

CASE 3

Normal shape, low value

The square waveform and normal rate exclude a ventilation problem, which leaves perfusion. A value of 24 with cool skin, tachycardia and a narrow pulse pressure is compensated shock — the blood pressure has not yet declared it. This patient warrants a high-priority disposition and treatment for shock, not reassurance based on the systolic.

$EtCO_2$

If you remember five things

01

Presence proves three systems

A waveform means CO_2 is being made, circulated and exhaled. Its absence in an intubated patient is an emergency.

02

Shape before number

Square is normal. A slurred upstroke, a notched plateau or a baseline off zero each name a specific problem.

03

A low value is often perfusion

Normal shape, normal rate, low number means look at the circulation — not the ventilation.

04

It responds on the next breath

Faster than saturation, faster than blood pressure, faster than your assessment. Use it to judge whether treatment worked.

05

Reconcile it with the patient

When the monitor and the patient disagree, find out why before you act.