Monitoring During Anesthesia

Objectives

At the end of the lecture you will be able to know the basics of anesthetic monitoring as follows:

- Definition
- Where, when, what to monitor
- The policies that govern modern monitoring (Standards I and Standards II)
- The basic monitors and the advanced monitors
- Arterial Oxygen Saturation- SpO2
- Expired CO2 - ETCO2
- Awareness under anesthesia
- Means to monitor the wakeful state of the brain
- Other somatosensory and motor monitoring
- The neuromuscular junction relaxation monitoring
- Brief introduction about invasive hemodynamic monitoring and oxygenation of the brain

Notes - Important - Golden Note - 436 Notes

What is monitoring?

Observe and check the progress or quality of (something) over a period of time (within required value), keep under systematic review.

What do you Monitor in a patient?

- Vitals
  - Q?: What vital sign had nowadays been measured very frequently ?
  - A: temperature in public areas during the pandemic
- Color/skin
- Wakefulness, First aspect in monitoring, is the patient awake and able to talk to you?

How and by which means do you Monitor in a patient?

- Physical exam
- Equipments (advances in Technology)

Where and when do you monitor a patient?

- Place and time
- Hospital vs Out-of-Hospital setting
- Safe vs Dangerous situations
  - (biologic, electric , chemical hazards, radioactive, etc...)

What are the Standards to follow for monitoring a patient Responsibilities?

For what are you legally Responsible? These standard were produced by some society that conducted studies on such patients with medico legal issues who had morbidity and mortality and investigated the causes e.g. blood pressure wasn't measuring regularly, then they put the legislation

لاز م يكون فيه معايير لأن إذا مافيه معايير كل شخص بيتحاسب بطريقة مختلفة عن الآخر وبمعرفة معايير مراقبة المريض كل شخص يعرف مسؤوليته

What determines the Standards of Care for monitoring a patient?

- Patient/ illness
- Equipments/ technology Is safer for the patients.
- Rules/ legislation There should be rules to follow.
  - Every institution or hospital may have its own policies that are based on evidence. Or adopted other national and international policies.
- Anesthesia type; GA or Regional
- Monitored Anesthesia Care/Sedation (the patient is awake but sedated he don't feel anything)
- Basic monitoring mandatory
- Advanced monitoring based on the case

What is Anesthesia?

- Hypnosis
- Analgesia
- Paralysis

What would happen to the body during anesthesia? We give something to the patient that disrupt his system. We need to monitor to make sure that the patient is in normal status,

- Neuro Depression/respiratory depression
- Cardio depression/alteration in BP, CO
- Vasodilation
  - Low BP affects perfusion to vital organs
  - Low Oxygen affects metabolism of organs

ASA Standards for Anesthetic Monitoring

- **Standard I:** Never leave the area

  Qualified anesthesia personnel shall be present in the room throughout the conduct of all general anesthetics, regional anesthetics and monitored anesthesia care.

- **Standard II:** we should have a vision not just butting the monitors.

  During all anesthetics, the patient's **oxygenation, ventilation, circulation and temperature** Those are the standards shall be continually evaluated.

- **These Standards:**

- Apply to all anesthesia care and to all intensive care as will although in emergency circumstances, appropriate life support measures take precedence.
  - So for example you may skip the temperature monitoring during the initial phases of ACLS or PALS
- May be exceeded at any time based on the **judgment** of the responsible anesthesiologist.
- They are intended to encourage quality patient care, but observing them cannot guarantee any specific patient outcome. You should put all the monitors so when something happens such as arrest no one will blame you.
- They are subject to revision from time to time, as warranted by the evolution of technology and practice. Practice means evidence, evidence is related to whatever we have in literature and if you see something interesting report it to attribute to literature.
- They apply to all **general anesthetics, regional anesthetics** and **monitored anesthesia care.**

- ➔ This set of standards addresses only the issue of **basic anesthetic monitoring** In basic You should monitor everything required either by simple or invasive techniques but in advanced you decide, which is one component of anesthesia care. In certain rare or unusual circumstances,

1) Some of these methods of monitoring may be clinically impractical,
2) Appropriate use of the described monitoring methods may fail to detect untoward clinical Developments. Even if you put all the monitors you might be missing something or you might do something that is not benefiting the patient this is why they say that we have to use our judgement.

- ➔ Brief interruptions of continual monitoring may be unavoidable. How frequent? As stated in standard II
- ➔ So you many not be able to monitor and document "continuously at every second interval"
- ➔ Hence the term "Continual" instead of "Continuous"
- ➔ Note that **"continual"** is defined as "repeated regularly and frequently in steady rapid succession", whereas **"continuous"** means "prolonged without any interruption at any Time." We record the values continually over frequent regular intervals 3-4 ms but we should be there around the patient continuously all the time!
- ➔ These standards are not intended for application on the care of the obstetrical patient in labor or in the conduct of pain management.

Standard I

- ➔ Due to the rapidity of occurrence of physiologic derangement during surgical interference
- ➔ In the event there is a direct known hazard, **e.g., radiation** If the patient is taking radiotherapy, to protect the anaesthesiologist he must monitor from a distance (like outside the room and he looks through a window or a camera) we used to put a camera on the patient and one on the monitor and a microphone to check the voices so we can be outside, and in case of events like hypotension they will stop the radiation and the anaesthesiologist can then enter the room, to the anesthesia personnel which might require intermittent remote observation of the patient, some provision for monitoring the patient must be made.
- ➔ In the event that an **emergency** requires the temporary absence of the person primarily responsible for the anesthetic, the best judgment of the anesthesiologist will be exercised in **comparing the emergency with the anesthetized patient's condition and in the selection** of the person left responsible for the anesthetic during the temporary absence. If you have two sick patients that are in different locations then use your judgement to manage the situation.

Standard II

- Brief interruptions of continual monitoring may be unavoidable
- On the general ward, documenting vitals routinely would be every 8 hrs or every nursing team shift.
- In closed observation units (intensive care units) documenting patient's status would be at least every one hour or more frequently as per patient's condition.
- Frequency of mandatory monitoring varies between each category, but never exceeds five minutes. In the ward every 6-8h
  - Otherwise, a reason should be documented on the patient's record (for medico-legal purposes).
  - Documented by the Qualified anesthesia personnel (that shall be present in the room)
- **The following are all specifically mandated:**

1. Oxygen analyzer with a low inspired concentration limit alarm during general anesthesia The alarm is imp in detecting low O2 if we're doing something else like preparing medication.

- Most modern anesthesia machines monitor both inspired and expired concentrations of O2
- This is essential during anesthesia because it is possible to deliver a hypoxic gas mixture when mixing O2, air, nitrous oxide, and/or volatile anesthetic agents.
  One of the patients was under flow machine and the O2 saturation was going down. I checked the tube and it was good so what to do in this case? We did manual oxygenation and then O2 saturation went higher.

2. Quantitative assessment of blood oxygenation

- Pulse Oximetry: Provides quantitative analysis of the patient's saturation of hemoglobin with O2

3. Ensuring adequate ventilation during all anesthetic care including verification of expired oxygen (when possible), quantitative measurement of tidal volume The monitor will measure the end tidal volume why? Because it is coming from alveoli, and capnography in all general anesthetics.

4. Qualitative evaluation of ventilation is required during all other care.

- Inspired and expired CO2 should be monitored.
- Expired CO2 is frequently displayed through capnography with a displayed value correlating to the peak expired CO2 of each breath.

5. Ensure correct placement of endotracheal tube or laryngeal mask airway via expired carbon dioxide (EtCO2) If CO2 is zero this is because the tube is in the stomach. Don't rely only on CO2.

- Observation of bilateral chest movement, air entry and auscultation the chest is also necessarily. If the tube is in the esophagus we will have few cycles of CO2 that are decreasing in intensity then just a flat line.

6. Alarms for breathing circuit disconnects or leak when a mechanical ventilator is used Every category has it is own sound so that we are able to differentiate between them. ex. High BP or low BP has a special sound different than other problems.

7. Continuous display of ECG

8. Determination of arterial BP By arterial line **and heart rate at least every 5 minutes.**

9. Adequacy of circulation is to be determined by quality of pulse either electronically, through palpation, or auscultation By the shape of pulse oximetry by your finger

10. The means to determine **Temperature** must be available and should be employed when changes in temperature are anticipated or intended. Especially in children, asthmatic and elderly patients

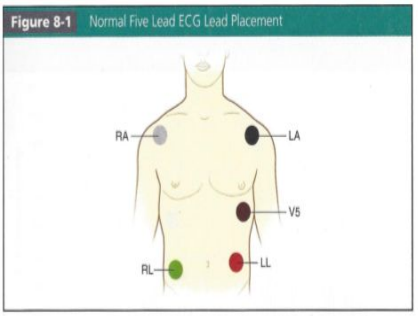
11. Multiple Expired Gas Analysis Allows determination of the percent inspired and expired of the volatile agents and nitrous oxide. This allows the ability to better determine the delivery of an adequate anesthetic without over or under dose**.**

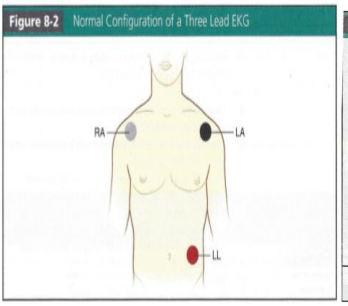
ECG

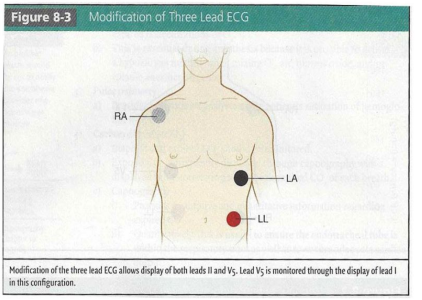
- The minimum of **three leads** is to be used, although **five leads** are used for most adults.
- Consideration must be taken for the surgical field and patient positioning.
- Lead placement is commonly altered for cases involving the chest,shoulders, back, and neck.
- **Five Lead ECG:** superior, it's more accurate because it measures all leads.
  - Includes the right arm (RA), left arm (LA), right leg (RL), left leg (LL), and V. (at least on on the chest and the rest on the limbs)
  - The five lead arrangement can be used to display I, II, III, aVR, aVL, aVF, and/or V
- **Three lead ECG:**
  - Includes the RA, LA, and LL leads and can be used to display leads I, II, and/or Ill
  - A three lead ECG can be modified to display V5 by moving the LA lead to the V5 position in the fifth intercostal space at the anterior axillary line
- **The most commonly monitored leads are II and V5**
- **Lead II is best used to monitor rhythm** because it provides the best visibility of the P wave such in Atrial fibrillation

➔ Lead V5 monitors for anterior and lateral ischemic events (important)

➔ If an **arrhythmia** or **ischemic event** appears to be present, the ability to view all leads simultaneously may be helpful for diagnostic purposes.







Arterial blood pressure (BP)

Mandated

➔ BP can be monitored non-invasively or invasively.

➔ **Non-invasive methods:** include **oscillometric cuff**, and rarely palpation, auscultation, Doppler probe.

- Automatic oscillometric For your information only

i. The cuff is able to sense oscillations in cuff pressure which correlate with arterial pulsation.

ii. Placement

1. Each cuff is labeled with an arrow pointing to where arterial pulsation is felt best.
2. The cuff is then placed on the arm over the brachial artery, forearm over the radial artery, or thigh/calf over the popliteal artery.

iii. Patient positioning

1. When monitoring non-invasive pressure, consideration must be taken of patient position.

➔ **Invasive pressure monitoring:**

- Arterial: allows for continuous beat to beat monitoring of arterial blood pressure displayed as a waveform and provides access for arterial sampling so i can know about ABG, electrolytes and hemoglobin.

Cannulation technique

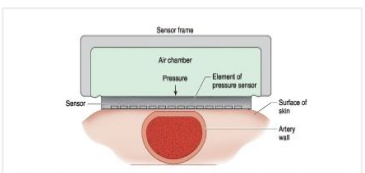


FIGURE 5-5 Tonometry is a method of continuous (beat-to-beat) arterial blood pressure determination. The sensors must be positioned directly over the artery.

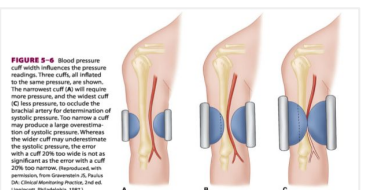


FIGURE 5-6 Blood pressure cuff width influences the pressure readings. Three cuffs, all inflated to the same pressure, are shown. The narrowest cuff (A) will require more pressure, and the widest cuff (C) less pressure, to occlude the brachial artery for determination of systolic pressure. Too narrow a cuff may produce a large overestimation of systolic pressure. Whereas the wider cuff may underestimate the systolic pressure, the error with a cuff 20% too wide is not as significant as the error with a cuff 20% too narrow. (Reproduced, with permission, from Gravenstein JS, Paulus DA: *Clinical Monitoring Practice*, 2nd ed. Lippincott, Philadelphia, 1987.)

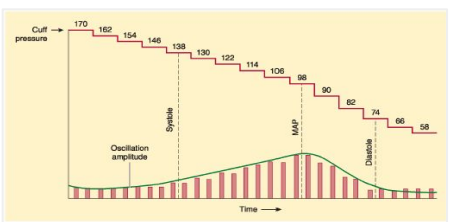


FIGURE 5-4 Oscillometric determination of blood pressure.

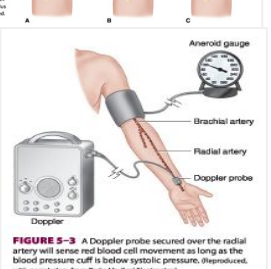


FIGURE 5-3 A Doppler probe secured over the radial artery will sense red blood cell movement as long as the blood pressure cuff is below systolic pressure. (Reproduced, with permission, from Parks Medical Electronics.)

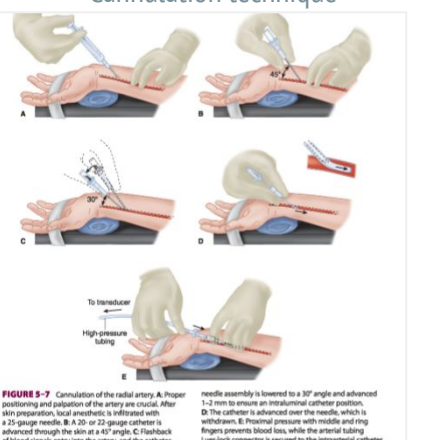


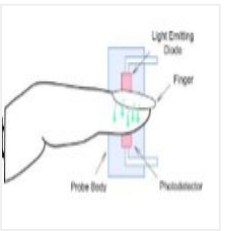
FIGURE 5-7 Cannulation of the radial artery. A: Proper positioning and palpation of the artery are crucial. After skin preparation, local anesthetic is infiltrated with a 25-gauge needle. B: A 20- or 22-gauge catheter is advanced through the skin at a 45° angle. C: Flashback of blood signals entry into the artery, and the catheter-needle assembly is lowered to a 30° angle and advanced 1–2 mm to ensure an intraluminal catheter position. D: The catheter is advanced over the needle, which is withdrawn. E: Proximal pressure with middle and ring fingers prevents blood loss, while the arterial tubing Luer-lock connector is secured to the intraarterial catheter.

Temperature

Mandated. If the patient is awake we should warm it with blankets and there is no need to put a monitor as long as he is talking to us.

- Temperature changes should be anticipated and expected under any general anesthetic and therefore any general anesthetic requires temperature measurement.
- Very brief procedures may be an exception, but the availability of temperature monitoring should be recorded. But in pediatric or geriatric even if its brief surgery it's important monitor. Any brief procedure can turn into a long procedure so it is recommended to monitor temperature.
- The temperature may be measured from many locations including: skin, nasopharynx, esophageal, bladder, rectal, or a pulmonary arterial catheter.
- **Core temperatures** obtained preferably from: a **pulmonary** catheter, **esophageal** probe, or **rectal** probe, we usually measure core temp not the skin temp because maybe the core temp is high but skin temp low bc of the vasoconstriction, Especially in cardiac surgery.

Pulse Oximetry (SpO2)



- Is one of the most commonly employed monitoring modalities in anesthesia.
- It is a **non-invasive** way to monitor the oxygenation of a patient's hemoglobin.
- A sensor with **both red and infrared wavelengths** is placed on the patient.
- Absorption of these wavelengths by the blood is measured and oxygen saturation (Sp02) can be calculated.

There are two main types of oximetry:	
Fractional oximetry Sa02	**Functional oximetry SpO2**
-Can only be measured by an **arterial blood Sample** -Oxyhemoglobin / (oxyhemoglobin + deoxyhemoglobin + methemoglobin + carboxyhemoglobin) -Fractional oximetry measures the arterial oxygen saturation **(SaO2)** 	-Can be measured noninvasively by a standard **pulse oximeter** -Oxyhemoglobin / (oxyhemoglobin + deoxyhemoglobin) = SpO2 Functional oximetry -gives you the **SpO2** 

➔ **How does pulse oximetry work?** For your information only

a) A pulse oximeter emits two wavelengths (high wavelength = low frequency and vice versa) of light: red (660 nm) and infrared (940 nm), Deoxyhemoglobin absorbs more light in the red band Oxyhemoglobin absorbs more light in the infrared band.

b) Sensors in the oximeter detect the amount of red and infrared light absorbed by the blood.

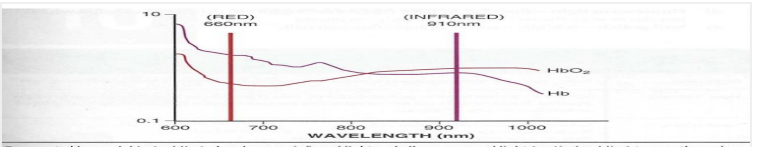
c) Photoplethysmography is then used to identify pulsatile arterial flow (alternating current [AC]) and non-pulsatile flow (direct current [DC]).

d) The ratio of AC/DC at both 66o and 94o nm is measured using the equation: (AC/DC)660/(AC/DC)940.

- The pulse oximeter calculates the SpO2 by taking the above equation and using an algorithm built into the software to derive the SpO2.

➔ The calibration to derive SpO2 from the (AC/DC)660/(AC/DC)940 ratio was made from studies of healthy volunteers

➔ Light absorption with Oxygenated and Deoxygenated Hemoglobin:

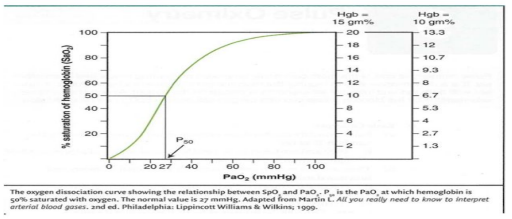


Oxygenated hemoglobin (*red line*) absorbs more infrared light and allows more red light (*vertical red line*) to pass through. Deoxygenated hemoglobin (*purple line*) absorbs more red light and allows more infrared light (*vertical purple line*) to pass through. Adapted from red and infrared light absorption. http://www.oximeter.org/pulseox/principles.htm accessed March 8, 2010

➔ **Accuracy of the pulse oximeter:**

a) If the SpO2 is between 70% and 100%, the pulse oximeter is accurate to within 5%

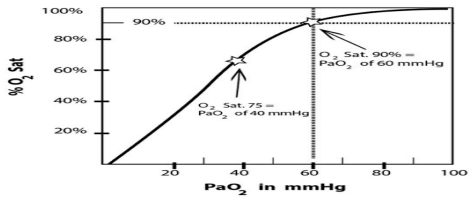
b) It is not accurate below 70% because calibration of the pulse oximeter involved healthy volunteers whose SpO2 did not routinely reach levels <70% We give hypoxic mixture to measure the accuracy. We reach 70% of SpO2 we can't go lower we don't want the patient to die.



The oxygen dissociation curve showing the relationship between SpO_2 and PaO_2. P_{50} is the PaO_2 at which hemoglobin is 50% saturated with oxygen. The normal value is 27 mmHg. Adapted from Martin L. *All you really need to know to interpret arterial blood gases*. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 1999.

TABLE 1. Values for standard human blood O_2 dissociation curve at 37°C, pH = 74, extrapolated between data in [7].

PO_2	%Sat	PO_2	%Sat	PO_2	%Sat
1	0.60	34	65.16	80	95.84
2	1.19	36	68.63	85	96.42
4	2.56	38	71.94	90	96.88
6	4.37	40	74.69	95	97.25
8	6.68	42	77.29	100	97.49
10	9.58	44	79.55	110	97.91
12	12.96	46	81.71	120	98.21
14	16.89	48	83.52	130	98.44
16	21.40	50	85.08	140	98.62
18	26.50	52	86.59	150	98.77
20	32.12	54	87.70	175	99.03
22	37.60	56	88.93	200	99.20
24	43.14	58	89.95	225	99.32
26	48.27	60	90.85	250	99.41
28	53.16	65	92.73	300	99.53
30	57.54	70	94.06	400	99.65
32	61.69	75	95.10	500	99.72



SaO2 %	PaO2 mmHg
99	175
95	80
94	70
90	60
85	50
80	45
75	40
70	37
65	34
60	31
55	29
50	27
45	25
40	23

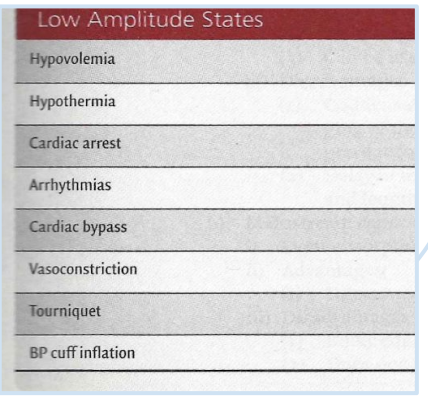
For the relationship between SaO2 and PaO2: The absorption spectrum of deoxygenated hemoglobin is very steep at 600 nm in the red range so small changes in the amount of deoxyhemoglobin can cause very wide variances in SpO2

➔ Pulse oximetry is affected by
- Low amplitude states
- Dyshemoglobinemia:
  - Patients with sickle cell anemia presenting in a vasoocclusive crisis can have an inaccurate SpO2 reading

➔ Pulse oximetry is **not as accurate in low amplitude states:** and also in dyshemoglobinemia

➔ Low perfusion makes it difficult for the pulse oximeter to distinguish a true signal from background noise How does measure the arterial not venues blood? Because it detects the pulsation if there is no pulsation it can't differentiate between an artery and a vain.

- Hypovolemia The graph: paO2 must be 80 to be safe, paO2 of 27 is very bad, Saturation of haemoglobin must not be below 90%, If the patient's haemoglobin saturation was 100% initially then started to drop we don't wait for it to reach 90%,we have to act immediately, PaO2 40 we should intubate the patient.
- Hypothermia
- Cardiac arrest
- Arrhythmias
- Vasoconstriction
- BP cuff inflation
- Tourniquet
- Cardiac Bypass



Dyshemoglobinemia

➔ Pulse oximetry only accurately measures oxyhemoglobin and deoxyhemoglobin, all other forms of hemoglobin are not accurately measured.

➔ **Carboxyhemoglobin is measured as 90% oxyhemoglobin and 10% deoxyhemoglobin**
- Thus, when there are high amounts of carboxyhemoglobin it will overestimate the SpO2.
- This is an important consideration in patients exposed to smoke or fires.

➔ **Methemoglobin absorbs equal amounts of red and infrared light so the SpO2 will read 85%** repeated measurements of spO2 shows 85% even when you're trying to improve the saturation.

➔ Methemoglobin is formed when iron goes from it's +2 ferrous form to the +3 ferric state.

➔ The ferric state of iron displays a left shift on the oxygen dissociation curve and releases oxygen less easily.

Methemoglobinemia can be caused by many drugs:

- Nitrates
- Nitrites
- Local anesthetics (eg Benzocaine)
- Chlorates
- Antimalarials
- Antineoplastics
- Sulfonamide
- Dapsone (antibiotic)
- Metoclopramide (antiemetic)

➔ High levels of bilirubin do not alter SpO2 readings.

Capnography

Normal capnogram

a) Phase I

- Initiation of expiration
- CO2 free gas from anatomic dead space. no CO2 bc it comes from the trachea

b) Phase II

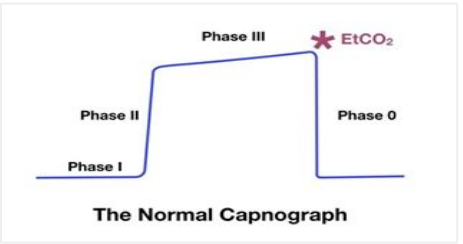
- Expiration of mixture of dead space and alveolar gas

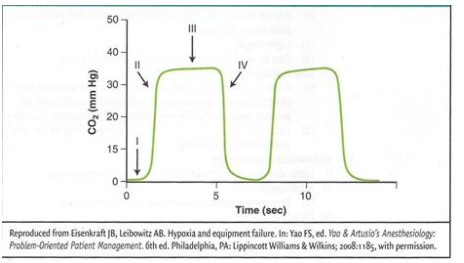
c) Phase III

- Alveolar plateau
- CO2-rich gas from alveoli

d) Phase IV or 0

- Inspiration





Reproduced from Eisenkraft JB, Leibowitz AB. Hypoxia and equipment failure. In: Yao FS, ed. *Yao & Artusio's Anesthesiology: Problem-Oriented Patient Management*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008:1185, with permission.

-CO2 is related to metabolism ⟶metabolism is related to O2+nutrients delivery⟶delivery is done by blood. (Delivery is done adequately only if cardiac output is adequate, too.) So any disturbance in cardiac output⟶disturbance in metabolism⟶disturbance in CO2

-Hypoventilation: (how do I know?) I would hyperventilate the pt. CO2 should drop. If it doesn't, I should check for other reasons

-If you see the wave then you're sure it is coming from the lung, not anywhere else.
-If the pt is inhaling CO2 that means it is coming from the anesthesia machine.
-Breathing back the CO2⟶respiratory acidosis risk⟶alarming sign to check the machine

Clinical uses of capnography

- Regarding expired CO_2; Provides **qualitative** and **quantitative** information
  - Qualitatively: this is useful to ensure the endotracheal tube is within the respiratory tract. Indicates adequacy of breathing in spontaneously ventilating non-intubated patients
  - Quantitatively, to ensure adequate cardiac output, Approximation of $PaCO_2$, Indicates adequacy of ventilation in controlled ventilating intubated patients.
- Regarding the inspired CO_2, it provides
  - Quantitative information ensure that the patient is not breathing back any CO_2 from the anesthesia ventilator, that would be a cause of respiratory acidosis
  - Otherwise CO_2 absorber of the anesthesia machine should be exchanged.
  - If inspired CO_2 is greater than zero, changing of the absorbent should be considered. The color of absorbent turns blue when its capacity is exhausted.
- Monitoring of adequacy of **ventilation** in controlled or spontaneously ventilating patients (1)
- Noninvasive estimate of $PaCO_2$
  - Assumes the normal 2 to 5 mm Hg difference between expired ($PETCO_2$) and arterial If $PETCO_2$ is 40 and the difference is 5 so $PaCO_2$ is 45 so there hypoventilation we need to increase the ventilation, $PaCO_2$ always higher than $PETCO_2$. (PaCapnography in the awake state is present) (2)
- The gradient between $PETCO_2$ and $PaCO_2$ may be increased with age, pulmonary disease, pulmonary embolism, low cardiac output, and hypovolemia. In those cases or when in doubt, we take $PaCO_2$ to confirm and to know the difference between $PaCO_2$ and $PETCO_2$.
- **Detection of patient disease:**

➔ **Causes of increased CO_2 production**

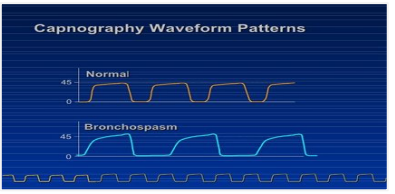
- Fever
- Sepsis
- Hypoventilation
- Malignant hyperthermia early manifestation doesn't show high temperature, CO_2 is the first signs and increase heart rate. Triggered by inhalational anesthetics + Succinylcholine.
- Hyperthyroidism
- Shivering increased metabolism ⟶ increased CO_2

(1) : If I put the Capnography near the pt's nose while they exhale, it would detect the CO_2 coming out. Which indicates on the monitor that they're really breathing while sedated (+also rising of chest is an indicator.)
E.g. ICU pt given Midazolam (risk of respiratory arrest)⟶The capnography helps in monitoring.
(2): Let's say the $PETCO_2$ is 32, what would be the $PaCO_2$? We add 5 (so the normal $PaCO_2$ would be 32-37).
We can rely on $PETCO_2$ to know if the pt is breathing adequately or not + if the CO_2 is normal or not. So the pt doesn't go into hyper or hypo -ventilation

➔ **Causes of decreased PETCO2** CO2 drop indicator for a low BP

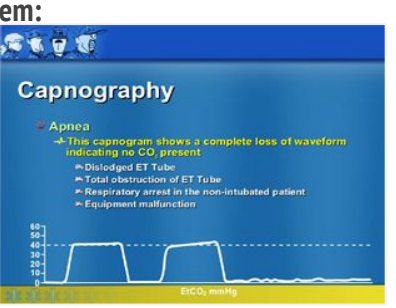
- Decreased cardiac output
- Hypovolemia
- Pulmonary embolism sudden decrease e.g immediate drop of paCO2 from 40 to 20
- Hypothermia decrease metabolism
- Hyperventilation

➔ **Airway obstruction may be detected due to abnormalities in the capnography tracing.**



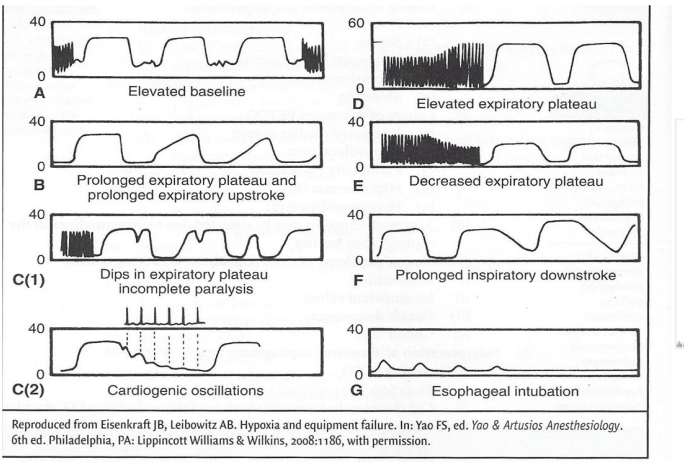
➔ **Detection of problems with the anesthetic breathing system:**

- Rebreathing of CO2
- Incompetent valves
- Circuit disconnect
- Circuit leak

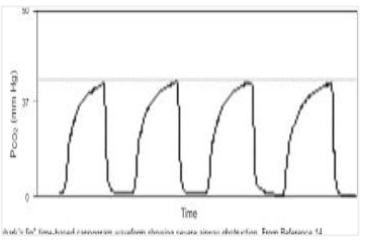


Interpretation of abnormal capnograms :

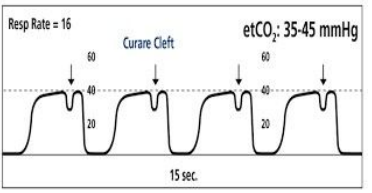
- **Rebreathing of CO2**
  - Elevation in baseline CO2 and Phase I
  - Can eliminate by increasing fresh gas flow or changing CO2 absorber
- **Obstruction to expiratory gas flow**
  - Prolonged Phase II and steeper Phase III slope
  - Occurs with bronchospasm, COPD, kinked endotracheal tube



Reproduced from Eisenkraft JB, Leibowitz AB. Hypoxia and equipment failure. In: Yao FS, ed. *Yao & Artusios Anesthesiology*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2008:1186, with permission.

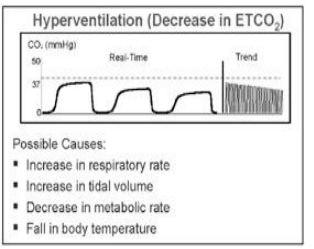


- **Curare Cleft**
  - Dip in Phase III
  - Indicates return of spontaneous Respiratory efforts.

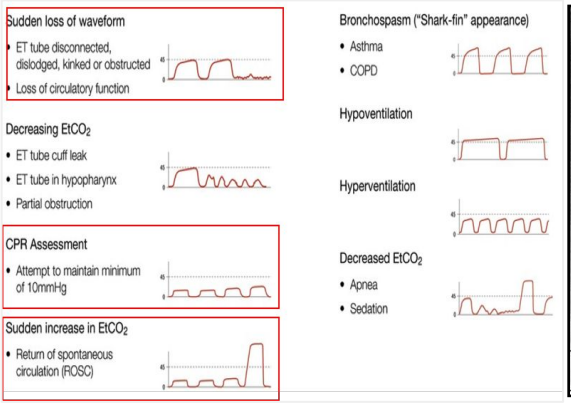


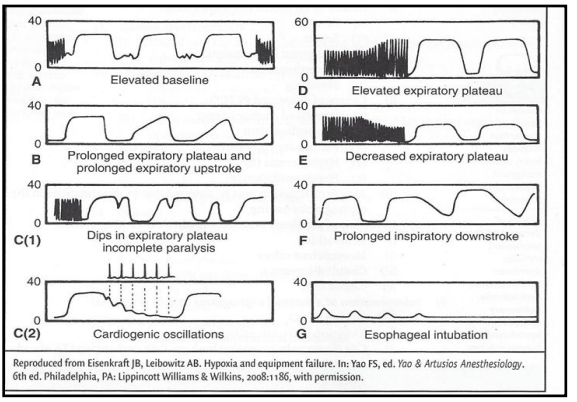
During recovery from muscle relaxants (pt trying to breathe but still weak)

- **Cardiogenic oscillations** for your knowledge
  - Oscillations of small gas movements during phase III and IV (or 0)
  - Produced by aortic and cardiac pulsations
- **Increased CO2**
  - Elevated plateau height
  - Indicates increased CO2 production states other source of CO2 (as in laparoscopic surgery: CO2 inside the abdomen⟶dissolves into blood⟶rise in CO2), or inadequate minute ventilation.
- **Decreased measured CO2**
  - Decreased plateau height
  - May indicated decreased CO2 production state or increased minute ventilation



- **Incompetent inspiratory valve**
  - Prolonged Phase III with elevation of baseline COz and plateau height
  - Results in rebreathing
  - May be difficult to detect without simultaneous analysis of flow waveforms
- **Esophageal intubation**
  - Initial presence of CO2 followed by no CO2





When you're resuscitating someone with ACLS. You get sudden increase, which means they have returned to spontaneous circulation⟶adequate cardiac output⟶adequate CO2

Processed EEG and Awareness Monitoring

- **Intraoperative awareness with recall involves** explicit recall of sensory perceptions during general anesthesia including aspects of their surgical environment, procedure, and even pain related to the intervention.
- Intraoperative awareness with recall is defined as a patient having an unexpected and undesirable recall of wakefulness.
- Processed EEG analysis has been developed as a method to monitor depth of anesthesia intraoperatively and can be used as an effect-site monitor to aid in titration of anesthetic drugs and may be useful in reducing the incidence of intraoperative awareness with recall.

  Not a regular EEG. (The regular is more complicated, can't be monitored and interpreted all the time, can be confusing and takes time) unlike the processed EEG where the computer interprets the signals and gives a certain value if the pt is awake or not (faster and more reliable)

Intraoperative awareness

❖ **Symptoms**:

- The most common symptoms reported by patients suggesting awareness with recall are auditory perceptions such as voices or noises, followed by loss of motor function (inability to move, sensation of weakness, or paralysis), pain, and feelings of helplessness, anxiety, panic, impending death, or catastrophe.
- Awareness with recall can lead to anxiety, sleep difficulties, insomnia, irritability, nightmares, and posttraumatic stress disorder. Pt should be referred to psychiatry

❖ Incidence of awareness:

- The incidence of awareness with recall varies among studies, countries, anesthetic techniques, patient characteristics, and types of surgery.
- The most commonly cited rate of intraoperative awareness is 0.2% . This figure is thought to reflect the incidence in routine cases but not including cardiac or obstetric surgeries. When further stratified, awareness occurs in approximately 1.14% to 1.5% of cardiac surgery cases, 0.4% of obstetric cases, and 11% to 43% of trauma surgeries.
- Why do they regain awareness ? Because we give low doses of anesthetic agents. why is that? Because They already have hypotension and the drugs will cause more hypotension so we don't give too much, same in cardiac patients we lower the doses of anesthetic drugs to decrease the side effects. Obstetric because there are factors associated with hemodynamic and safety to the baby, the drugs may cause hypoxia to the baby.
- Awareness with recall associated with pain is estimated to occur in 0.01% to 0.03% of cases.

❖ Factors associated with increased risk of awareness with recall include:

1. "light" anesthesia (e.g., delivering a low level of inhaled anesthetic minimum alveolar concentration), Whether because the vaporizer is empty or no alarm or problem with the anesthetics circuit... That's why checking the (ETCO2, wave from, inhalational agent...) is important
2. History of intraoperative awareness maybe they are less sensitive to anesthetic drugs, as we said 1MAC is for 50% of population, the other 50% could have some kind of less responsive
3. Chronic use of central nervous system depressants
4. Younger age
5. Obesity
6. Inadequate or misused anesthesia delivery systems

❖ Detecting episodes of intraoperative awareness:

- Often it is **difficult to know for sure** that intraoperative awareness with recall occurred. If the patient is not asked specifically about it they may **not report it voluntarily.**
- Or, the patient may **recollect hearing sounds** during surgery, when in fact they are remembering something **that occurred in the recovery room.**
- One accepted method to assess intraoperative awareness with recall is to conduct three structured interviews with open ended questions at intervals of 24 hours, between 24 and 72 hours, and at 30 days after surgery (awareness may not arise until days to weeks postoperatively).

❖ **Prevention or vigilance for detecting intraoperative awareness:**

➔ **Monitor delivered volatile anesthetic levels:**

- The unintended inadequate delivery of volatile anesthetic agents ("light anesthesia") during maintenance of anesthesia may be avoided by the addition of a low alarm limit to end-tidal gas monitoring settings Ex.end tidal sevoflurane, as well as use of a "near empty" alarm in anesthetic vaporizers.

➔ **Monitor processed EEG signals**

- Depth of anesthesia monitoring, via the processed EEG, has proved useful in reducing the amount of anesthetic drugs, optimizing extubation times, and in some studies reducing awareness with recall. Although most anesthesiologists in the UK, USA, and Australia accept that clinical signs are unreliable indicators of awareness, few believe that monitors of anesthetic depths should be used for all routine cases.
- Several brain-function monitors based on the processed electroencephalogram (EEG) or evoked potentials have been developed to assess anesthetic depth.
  - i) The term bispectral applies because it incorporates both power and phase spectrum of an EEG into the calculated 0 to 100 value.
  - ii) BIS values between 40 and 60 purportedly indicate adequate general anesthesia for surgery, and values below 40 indicate a deep hypnotic state. Targeting a range of BIS values between 40 and 60 is marketed to help prevent anesthesia awareness while allowing for minimization the anesthetic dose.

➔ BIS (Aspect Medical Systems). Extra: Indicate depth of anesthesia

- The most widely used monitor is the BIS monitor. This device integrates several parameters of an EEG into a calculated, dimensionless variable (0 to 100).
- It is important to note that bispectral index (BIS) is a probability distribution where a measure of 40 does not provide a 100% guarantee of no awareness. We would rely on other factors like body temperature and heart rate and blood pressure

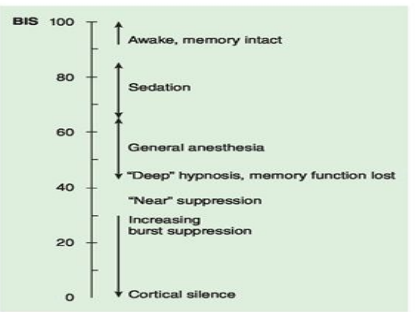


FIGURE 6–10 The Bispectral Index Scale (BIS versions 3.0 and higher) is a dimensionless scale from 0 (complete cortical electroencephalographic suppression) to 100 (awake). BIS values of 65–85 have been recommended for sedation, whereas values of 40–65 have been recommended for general anesthesia. At BIS values lower than 40, cortical suppression becomes discernible in a raw electroencephalogram as a burst suppression pattern. (Reproduced, with permission, from Johansen JW et al: Development and clinical application of electroencephalographic bispectrum monitoring. Anesthesiology 2000;93:1337.)

<30 is undesirable

M-Entropy Module (GE-Healthcare) Just for your knowledge

- A mathematical approach that quantifies EEG using non-linear dynamics. This mode measures spectral entropy and applies it to the power spectrum of EEGs. Two variables, state and response entropy, which measure EEG and combined EEG/EMG activity respectively, are displayed on the awareness monitor as a dimensionless unit (0 to 100)

Mid-latency auditory evoked potentials (MLAEPs) Just for your knowledge

- This method is thought to be an alternative to the use of EEG monitoring.
- MLAEP are electroencephalographic responses to auditory stimuli.

The graphs below are for your knowledge, too

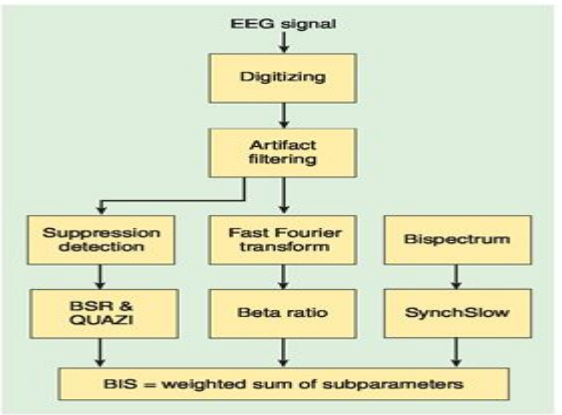


FIGURE 6–9 Calculation of the Bispectral Index. EEG, electroencephalogram; BSR, burst suppression ratio; BIS, Bispectral Index Scale. (Reproduced, with permission, from Rampil IJ: A primer for EEG signal processing in anesthesia. Anesthesiology 1998;89:980.)

TABLE 6–2 Checklist for preventing awareness.

- ✓ Check all equipment, drugs, and dosages; ensure that drugs are clearly labeled and that infusions are running into veins.
- ✓ Consider administering an amnesic premedication.
- ✓ Avoid or minimize the administration of muscle relaxants. Use a peripheral nerve stimulator to guide minimal required dose.
- ✓ Consider using the isolated forearm technique if intense paralysis is indicated.
- ✓ Choose potent inhalation agents rather than total intravenous anesthesia, if possible.
- ✓ Administer at least 0.5 to 0.7 minimum alveolar concentration (MAC) of the inhalation agent.
- ✓ Set an alarm for a low anesthetic gas concentration.
- ✓ Monitor anesthetic gas concentration during cardiopulmonary bypass from the bypass machine.
- ✓ Consider alternative treatments for hypotension other than decreasing anesthetic concentration.
- ✓ If it is thought that sufficient anesthesia cannot be administered because of concern about hemodynamic compromise, consider the administration of benzodiazepines or scopolamine for amnesia.
- ✓ Supplement hypnotic agents with analgesic agents such as opioids or local anesthetics, which may help decrease the experience of pain in the event of awareness.
- ✓ Consider using a brain monitor, such as a raw or processed electroencephalogram but do not try to minimize the anesthetic dose based on the brain monitor because there currently is insufficient evidence to support this practice.
- ✓ Monitor the brain routinely if using total intravenous anesthesia.
- ✓ Evaluate known risk factors for awareness, and if specific risk factors are identified consider increasing administered anesthetic concentration.
- ✓ Redose intravenous anesthesia when delivery of inhalation anesthesia is difficult, such as during a long intubation attempt or during rigid bronchoscopy.

Reproduced, with permission, from Mashour GA, Orser BA, Avidan

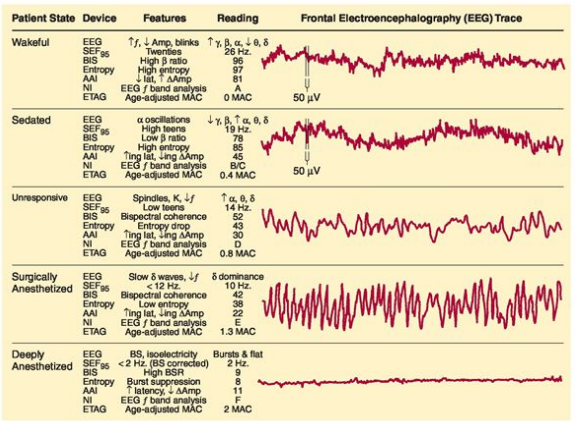


FIGURE 6–8 Patient states, candidate depth of anesthesia devices or approaches, key features of different monitoring approaches, and possible readings at different depths of anesthesia. The readings shown represent examples of possible readings that may be seen in conjunction with each frontal electroencephalography trace. The electroencephalography traces show 3-s epochs (x-axis), and the scale (y-axis) is 50 μV. AAI, A-Line Autoregressive Index (a proprietary method of extracting the mid-latency auditory evoked potential from the electroencephalogram); Amp, amplitude of an EEG wave; BIS bispectral index; blinks, eye blink artifacts; BS, burst suppression; BSR, burst suppression ratio; EEG, electroencephalography; ETAG, end-tidal anesthetic gas concentration; *f*, frequency; γ β α θ δ EEG waves in decreasing frequencies (γ more than 30 hertz [Hz]; β,12–30 Hz; α, 8–12 Hz; θ, 4–8 Hz; δ, 0–4 Hz); K, K complexes; Lat, latency between an auditory stimulus and an evoked EEG waveform response; MAC, minimum alveolar concentration; NI, Narcotrend index; SEF_{95}, spectral edge frequency below which 95% of the EEG frequencies reside; Spindles, sleep spindles. (Reproduced, with permission, from Mashour GA, Orser BA, Avidan MS: Intraoperative awareness: from neurobiology to clinical practice. Anesthesiology 2011;114:1218.)

Each company has its own equipment , they all serve the same purpose

TABLE 6-1 Characteristics of the commercially available monitors of anesthetic depth.

Parameters	Machine/ Manufacturer	Consumable	Physiologic Signals	Recommended Range of Values for Anesthesia	Principles of Measurement
Bispectral index (BIS)	A-2000/Aspect Medical Systems, Newton, MA	BIS sensor	Single channel EEG	40–60	BIS is derived from the weighted sum of three EEG parameters: relative α/β ratio; bio-coherence of the EEG waves; and burst suppression. The relative contribution of these parameters has been tuned to correlate with the degree of sedation produced by various sedative agents. BIS ranges from 0 (asleep)–100 (awake).
Patient state index (PSI)	Patient state analyzer (PSA 400)/ Physiometrix, Inc, N. Billerica, MA	PSArray²	4-channel EEG	25–50	PSI is derived from progressive discriminant analysis of several quantitative EEG variables that are sensitive to changes in the level of anesthesia, but insensitive to the specific agents producing such changes. It includes changes in power spectrum in various EEG frequency bands; hemispheric symmetry; and synchronization between brain regions and the inhibition of regions of the frontal cortex. PSI ranges from 0 (asleep)–100 (awake).
Narcotrend stage Narcotrend index	Nacotrend monitor/ Monitor-Technik, Bad Bramstedt, Germany	Ordinary ECG electrode	1–2 channel EEG	Narcotrend stage $D_{0,0}$ to C_0 which corresponds to an Index of 40–60	The Narcotrend monitor classifies EEG signals into different stages of anesthesia (A = awake; $B_{0,0}$ = sedated; $C_{0,0}$ = light anesthesia; $D_{0,0}$ = general anesthesia; $E_{0,0}$ = general anesthesia with deep hypnosis; $F_{0,0}$ = burst suppression). The classification algorithm is based on a discriminant analysis of entropy measures and EEG spectral variables. More recently the monitor converts the Narcotrend stages into a dimensionless number from 0 (asleep) to 100 (awake) by nonlinear regression.
Entropy	S/5 Entropy Module, M-ENTROPY/ Datex-Ohmeda, Instrumentarium Corp., Helsinki, Finland	Special entropy sensor	Single-channel EEG	40–60	Entropy described the 'irregularity' of the EEG signal. As the dose of anesthetic is increased, EEG becomes more regular and the entropy value approaches zero. M-ENTROPY calculates the entropy of the EEG spectrum (spectral entropy). In order to shorten the response time, it uses different time windows according to the corresponding EEG frequencies. Two spectral parameters are calculated: state entropy (frequency band 0–32 Hz) and response entropy (0–47 Hz), which also includes muscle activity. Both entropy variables have been re-scaled, so that 0 is asleep and 100 is awake.
Alline autoregressive index (AAI)	AEP/2 monitor/ Danmeter A/S, Odense, Demark	Ordinary ECG electrode	AEP	10–25	AAI is derived from the middle latency AEP (20–80 ms). AAI is extracted from an autoregressive model with exogenous input (ARX model) so that only 18 sweeps are required to reproduce the AEP waveform in 2–4 s. The resultant waveform is then transformed into a numeric index (0–100) that describes the shape of the AEP. AAI > 60 is awake, AAI of 0 indicates deep anesthesia.
Cerebral state index (CSI)	Cerebral state monitor (CSM), Danmeter A/S, Odense, Demark	Ordinary ECG electrode	Single-channel EEG	40–60	CSI is a weighted sum of (1) α ratio, (2) β ratio, (3) difference between the two and (4) burst suppression. It correlates with the degree of sedation by an 'adaptive neuro-fuzzy inference system'. CSI ranges from 0 (asleep) to 100 (awake).

EEG, electroencephalogram; ECG, electrocardiogram; AEP, auditory evoked potential.
Reproduced, with permission, from Chan MTV, Gin T, Goh KYC: Interventional neurophysiologic monitoring. Curr Opin Anaesthesiol 2004;17:389.

Neurophysiologic Monitoring and Anesthetic Management

Modalities

Neurophysiologic monitoring or neuromonitoring allows **early detection of events that may increase postoperative neurological morbidity**. The aim of monitoring is **to identify changes in brain, spinal cord, and peripheral nerve function prior to irreversible damage**.
Neuromonitoring is also useful in identifying anatomical structures. If there is a spinal cord surgery how to make sure that the surgeon is only taking the tumor without normal tissue? By neurophysiological monitoring

E.g. The surgeon is removing a tumor from the spinal cord, we need to know if he's going too far into normal tissue or not.
If it's a sensory area we stimulate the peripheral nerve from the legs and we will catch the signal going to the brain (sensory cortex) If this signal is effected it means the surgeon has affected it. Same goes for motor.

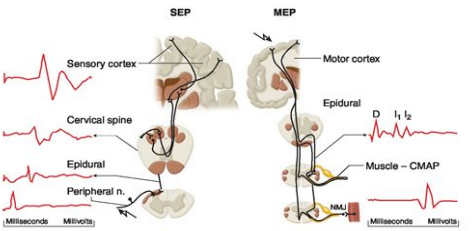


FIGURE 6–11 Neuroanatomic pathways of somatosensory-evoked potential and motor-evoked potential. The somatosensory-evoked potential (SEP) is produced by stimulation of a peripheral nerve wherein a response can be measured. The electrical volley ascends the spinal cord by the posterior columns and can be recorded in the epidural space and over the posterior cervical spine. It crosses the mid-line after synapsing at the cervicomedullary junction and ascends the lemniscal pathways having a second synapse in the thalamus. From there, it travels to the primary sensory cortex where the cortical response is measured. The motor-evoked potential (MEP) is produced by stimulation of the motor cortex leading to an electrical volley that descends to the anterior horn cells of the spinal cord via the corticospinal tract. After synapsing there it travels via a peripheral nerve and crosses the neuromuscular junction (NMJ) to produce a muscle response. The MEP can be measured in the epidural space as D and I waves produced by direct and indirect (via interneuronal neurons) stimulation of the motor cortex, respectively. It can also be measured as a compound muscle action potential (CMAP) in the muscle. (Reproduced, with permission, from Sloan TB, Janik D, Jameson L: Multimodality monitoring of the central nervous system using motor-evoked potentials. Curr Opin Anaesthesiol. 2008;21:560.)

- **Electromyography (EMG)** skipped
  - EMG is the recording of electrical activity of muscle and therefore an indirect indicator of function of the innervating peripheral nerve.
  - This technique is also used to identify and verify the integrity of a peripheral nerve, including cranial nerves as well as pedicle screw testing during spine surgery.
  - EMG is only sensitive to neuromuscular blocking agents.
- **Somatosensory evoked potentials (SSEP)** skipped
  - SSEP are the recording, usually at the cerebral cortex, of responses from electrically stimulated peripheral afferent nerves.
  - The most commonly used peripheral nerves are median, ulnar, posterior tibial, and common peroneal nerves.

- **Brainstem auditory evoked potentials (BAEP)** skipped
  - BAEP are the recording of brainstem responses to auditory stimuli.
  - BAEP monitors the function of the entire auditory pathway along the acoustic nerve, through the brainstem to the cerebral cortex.
- **Motor evoked potentials (MEP)** skipped
  - MEP is the recording obtained from electrical stimulation of the motor cortex, which elicits potentials in the spinal cord or (myogenic) potentials from the innervated muscle. Monitors motor pathway function

❖ Electroencephalography (EEG) skipped

- EEG monitoring can be a useful supplement to surgery when:
  - Seizure foci need to be identified
  - The general state of cerebral metabolism needs monitoring
  - Cerebral ischemia can occur.
- EEG is a standard of care in many institutions for carotid endarterectomy.
- EEG is the recording of brain electrical activity and is highly dependent on anesthetic depth.
  - Alpha waves are rhythmically regular waves of 8 to 12 Hz seen in a lightly anesthetized Patient.
  - A faster, disorganized beta (>12 Hz) rhythm is seen upon awakening.
  - Slower theta waves (4 to 8 Hz) are seen with deep inhalation or moderate dose narcotic anesthesia.
  - Slow delta waves (<4 Hz) indicate deep anesthesia, or ischemia if the amplitude is low.

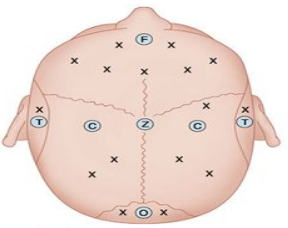


FIGURE 6–7 International 10–20 system. Montage letters refer to cranial location. F, frontal; C, coronal; T, temporal; O, occipital; Z, middle.

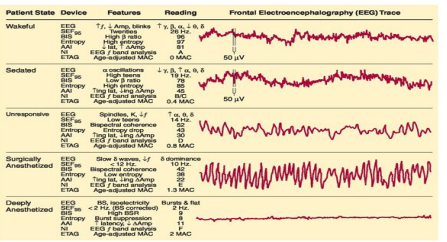


FIGURE 6–8 Patient states, candidate depth of anesthesia devices or approaches, key features of different monitoring approaches, and possible readings at different depths of anesthesia. The readings shown represent examples of possible readings that may be seen in conjunction with each frontal electroencephalography trace. The electroencephalography traces show 3 s epochs (x-axis), and the scale (y-axis) is 50 μV. AAI, A-Line Autoregressive Index (a proprietary method of extracting the mid-latency auditory evoked potential from the electroencephalogram); Amp, amplitude of an EEG wave; BIS bispectral index; blinks, eye blink artifacts; BS, burst suppression; BSR, burst suppression ratio; EEG, electroencephalography; ETAG, end-tidal anesthetic gas concentration; *f*, frequency; χ, β, α, θ, δ EEG waves in decreasing frequencies (χ more than 30 hertz [Hz]; β,12–30 Hz; α, 8–12 Hz; θ, 4–8 Hz; δ, 0–4 Hz); K, K complexes; Lat, latency between an auditory stimulus and an evoked EEG waveform response; MAC, minimum alveolar concentration; NI, Narcotrend Index; SEF_{95}, spectral edge frequency below which 95% of the EEG frequencies reside; Spindles, sleep spindles. (Reproduced, with permission, from Mashour GA, Orser BA, Avidan MS: Intraoperative awareness: from neurobiology to clinical practice. Anesthesiology 2011;114:1218.)

❖ CEREBRAL OXIMETRY

- Cerebral oximetry uses near infrared spectroscopy (NIRS).
- Using reflectance spectroscopy near infrared light is emitted by a probe on the scalp.
- Receptors are likewise positioned to detect the reflected light from both deep and superficial structures.
- As with pulse oximetry, oxygenated and deoxygenated hemoglobin absorb light at different frequencies. Likewise, cytochrome absorbs infrared light in the mitochondria.
- The NIRS saturation largely reflects the absorption of venous hemoglobin, as it does not have the ability to identify the pulsatile arterial component.
- Regional saturations of less than 40% on NIRS measures, or changes of greater than 25% of baseline measures, may herald neurological events secondary to decreased cerebral oxygenation. Indicate cerebral hypoxia

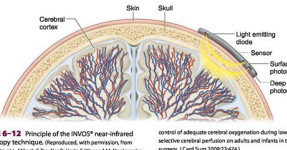


FIGURE 6–12 Principle of the INVOS® near-infrared spectroscopy technique. (Reproduced, with permission, from Rubio A, Hakami L, Münch F, Tandler R, Harig F, Weyand M: Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the aortic arch surgery. J Card Surg 2008;23:474.)

Invasive pressure monitoring Modalities

No need to know the details.

Central Venous Pressure

- Central venous catheterization involves placement of a sterile catheter into one of the large central veins and allows for multiple modalities of intervention along with the option of monitoring central venous pressure (CVP).
- CVP monitoring can be a useful tool for **evaluating intravascular volume and preload** in the absence of left ventricular (LV) dysfunction (ejection fraction <40%), severe mitral valve disease, pulmonary hypertension, or significant reduction in LV compliance (ischemia/diastolic dysfunction). If CVP is not useful because of heart failure we use Pulmonary artery pressure.

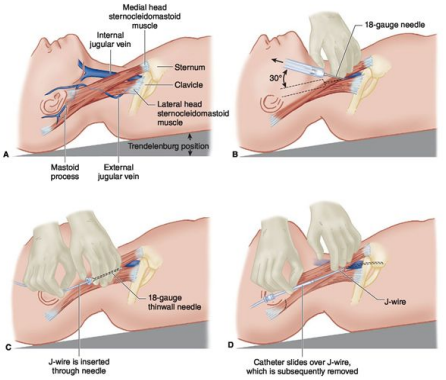


FIGURE 5–16 Right internal jugular cannulation with Seldinger's technique (see text).

It's malpractice to insert central line blindly without US

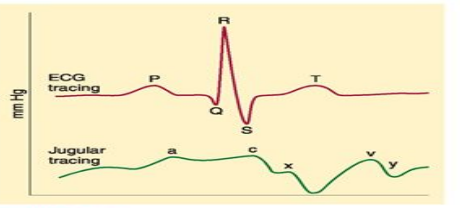


FIGURE 5–19 The upward waves (*a*, *c*, *v*) and the downward descents (*x*, *y*) of a central venous tracing in relation to the electrocardiogram (ECG).

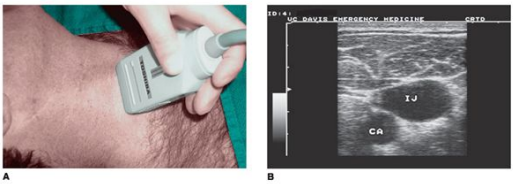


FIGURE 5–17 **A:** Probe position for ultrasound of the large internal jugular vein with deeper carotid artery and **B:** corresponding ultrasound image. CA, carotid artery; IJ, internal jugular vein. (Reproduced, with permission, from Tintinalli JE, et al: *Tintinalli's Emergency Medicine: A Comprehensive Study Guide*, 7th edition, McGraw-Hill, 2011.)

Pulmonary artery Pressure

- The pulmonary artery (PA) catheter is a controversial but potentially powerful tool, offering information about **cardiac filling pressures**, **cardiac output (CO)**, derived parameters of **cardiac performance**, and **mixed venous oxygen saturation (Sv02)** pulmonary artery pressure: it measures both right heart as well as left.
- heart pressure so you will know everything about the heart that's why it's a better estimate, and it's usually done for cardiac patients.
- ASA consensus opinion is that "PA catheter monitoring may reduce perioperative complications if critical hemodynamic data obtained are accurately interpreted and appropriate treatment is instituted.
- Pulmonary artery catheter.

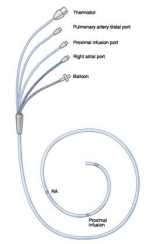


FIGURE 5–20 Balloon-tipped pulmonary artery flotation catheter (Swan–Ganz catheter). RA, right atrium.

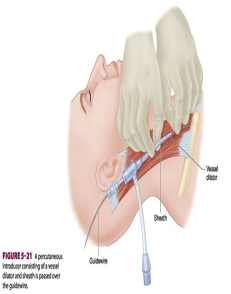


FIGURE 5–21 A percutaneous introducer consisting of a vessel dilator and sheath is passed over the guidewire.

Pulmonary artery catheter:

$$CO = SV \times HR$$

$$SV = CO/HR$$

$$\text{Blood pressure} = CO \times \text{systemic vascular resistance (SVR)}$$

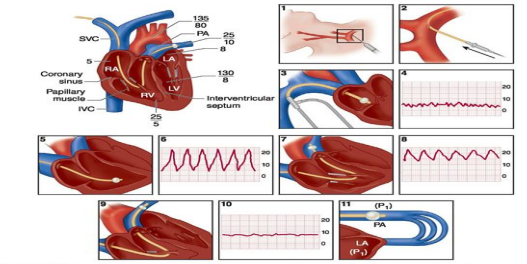


FIGURE 5–22 Although its utility is increasingly questioned, pulmonary artery catheters continue to be a part of perioperative management of the cardiac surgery patient. Following placement of a sheath introducer in the central circulation (panels 1 and 2), the pulmonary artery catheter is floated. Central line placement should always be completed using rigorous sterile technique, full body draping, and only after multiple, redundant confirmations of the correct localization of the venous circulation. Pressure guidance is used to ascertain the localization of the PA catheter in the venous circulation and the heart. Upon entry into the right atrium (panels 3 and 4), the central venous pressure tracing is noted. Passing through the tricuspid valve (panels 5 and 6) right ventricular pressures are detected. At 35 to 50 cm depending upon patient size, the catheter will pass from the right ventricle through the pulmonic valve into the pulmonary artery (panels 7 and 8). This is noted by the measurement of diastolic pressure once the pulmonic valve is passed. Lastly, when indicated the balloon-tipped catheter will wedge or occlude a pulmonary artery branch (panels 9, 10, and 11). When this occurs, the pulmonary artery pressure equilibrates with that of the left atrium which, barring any mitral valve pathology, should be a reflection of left ventricular end-diastolic pressure. (Redrawn and reproduced, with permission, from Soni N. *Practical Procedures in Anaesthesia and Intensive Care*. Butterworth Heinemann, 1994.)

Modalities for Anesthetic Monitoring

Transesophageal echocardiography (TEE)

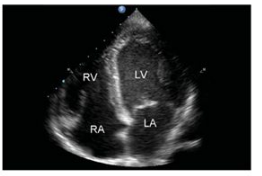
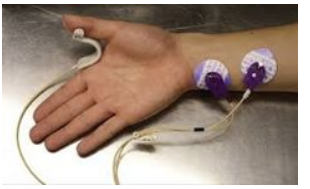


FIGURE 5–27 Normal apical four-chamber view. RV, right ventrical; LV, left ventricle; RA, right atrium; LA, left atrium. (Reproduced, with permission, from Carmody KA, et al: *Handbook of Critical Care and Emergency Ultrasound*. McGraw-Hill, 2011.)

- Useful for critical patients. Contraindicated in esophageal varices or any problem with the esophagus
- Is a monitoring modality gaining popularity in the field of anesthesiology due to its versatility, reliability, and safety. It was initially used as a diagnostic tool primarily by cardiologists but has become a mainstay in intraoperative cardiac anesthesia and its utility is extending into other areas as well.

Peripheral Nerve Stimulation



- We stimulate the nerve and see the muscle movement. It's one of the main monitoring techniques in anesthesia for muscle relaxant component
- **Indications**

➔ Because of the variation in patient sensitivity to neuromuscular blocking agents, the neuromuscular function of all patients receiving intermediate- or long-acting neuromuscular blocking agents should be monitored.

➔ In addition, peripheral nerve stimulation is helpful in assessing paralysis during rapid-sequence inductions or during continuous infusions of short-acting agents. Furthermore, peripheral nerve stimulators can help locate nerves to be blocked by regional anesthesia.

- **Contraindications**
  - There are no contraindications to neuromuscular monitoring.
  - Although certain sites may be precluded by the surgical procedure. Additionally, atrophied muscles in areas of hemiplegia or nerve damage may appear refractory to neuromuscular blockade secondary to the proliferation of receptors. ACh nicotinic receptors in the end motor plate muscle causes Action Potential that allows the K goes out and Na goes in, In denervated muscle "atrophied": there are many ACh receptors, If we gave succinylcholine they will stimulate the release of K from every receptor and bc there are too many receptors there will be a massive K release from the cells to the blood "hyperkalemia" that may lead to arrest, important !
  - Determining the degree of neuromuscular blockade using such an extremity could lead to potential overdosing of competitive neuromuscular blocking agents.

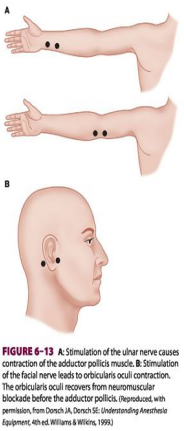


FIGURE 6–13 A: Stimulation of the ulnar nerve causes contraction of the adductor pollicis muscle. B: Stimulation of the facial nerve leads to orbicularis oculi contraction. The orbicularis oculi recovers from neuromuscular blockade before the adductor pollicis. (Reproduced, with permission, from Dorsch JA, Dorsch SE: *Understanding Anesthesia Equipment*, 4th ed. Williams & Wilkins, 1999.)

- **Techniques & Complications**
  - A peripheral nerve stimulator delivers current (60- 80 mA) to a pair of either ECG silver chloride pads or subcutaneous needles placed over a peripheral motor nerve.
  - The evoked mechanical or electrical response of the innervated muscle is observed.
  - Although electromyography provides a fast, accurate, and quantitative measure of neuromuscular transmission, visual or tactile observation of muscle contraction is usually relied upon in clinical practice.
  - Ulnar nerve stimulation of the adductor pollicis muscle and facial nerve stimulation of the orbicularis oculi are most commonly monitored.
  - Because it is the inhibition of the neuromuscular receptor that needs to be monitored, **direct stimulation of muscle should be avoided** by placing electrodes over the course of the nerve and not over the muscle itself. Otherwise we would be stimulating the muscle itself not the neuromuscular transmission
  - Complications of nerve stimulation are limited to skin irritation and abrasion at the site of electrode attachment.
  - Because of concerns of residual neuromuscular blockade, increased attention has been focused on providing quantitative measures of the degree of neuromuscular blockade perioperatively.
  - Acceleromyography uses a piezoelectric transducer on the muscle to be stimulated. Movement of the muscle generates an electrical current that can be quantified and displayed.
  - Indeed, acceleromyography can better predict residual paralysis, compared with routine tactile train-of-four monitoring used in most operating rooms, if calibrated from the beginning of the operative period to establish baselines prior to administration of neuromuscular blocking agents.

- **Clinical Considerations**

➔ The degree of neuromuscular blockade is monitored by applying various patterns of electrical stimulation.

➔ All stimuli are 200 μs in duration and of square-wave pattern and equal current intensity.

➔ A twitch is a single pulse that is delivered from every 1 to every 10 sec (1–0.1 Hz).

➔ Increasing block results in decreased evoked response to stimulation.

➔ **Train-of-four stimulation** denotes four successive 200-μs stimuli in 2 sec (2 Hz).

➔ The twitches in a train-of-four pattern progressively fade as nondepolarizing muscle relaxant block increases. The ratio of the responses to the first and fourth twitches is a sensitive indicator of nondepolarizing muscle paralysis. Ratio o fourth twitch over the first twitch should be greater than or equal to 90% to give the reversal (neostigmine and glycopyrrolate) We get 4 twitches: if equal= no relaxant . Not equal= relaxant . Disappearing = deep relaxant. Reappearing= recovery from relaxant.

➔ Because it is difficult to estimate the train-of-four ratio, it is more convenient to visually observe the sequential disappearance of the twitches, as this also correlates with the extent of blockade. Disappearance of the fourth twitch represents a 75% block, the third twitch an 80% block, and the second twitch a 90% block.

➔ Clinical relaxation usually requires 75% to 95% neuromuscular blockade. It means if pts is breathing he still have 75% of NM blocked. Always will have the first one being the most forceful and the fourth one being the least forceful. We wait until the fourth becomes almost equal to the first so the ratio 4/1 (TOF ratio) = 90% or more⟶to give the muscle relaxant reversal, otherwise the reversal might not be efficient , which is needed for safe extubation and recovery.

➔ Tetany at 50 or 100 Hz is a sensitive test of neuromuscular function. Sustained contraction for 5 sec indicates adequate— but not necessarily complete— reversal from neuromuscular blockade.

➔ Double-burst stimulation (DBS) represents two variations of tetany that are less painful to the patient.

➔ The DBS 3,3 pattern of nerve stimulation consists of three short (200-μs) high-frequency bursts separated by 20 ms intervals (50 Hz) followed 750 ms later by another three bursts.

➔ DBS 3,2 consists of three 200-μs impulses at 50 Hz followed 750 ms later by two such impulses.

➔ DBS is more sensitive than train-of-four stimulation for the clinical (ie, visual) evaluation of fade.

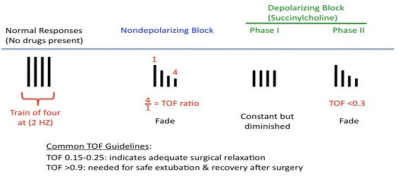
◆ Single Twitch

◆ Train of four

◆ Double Burst Stimulation

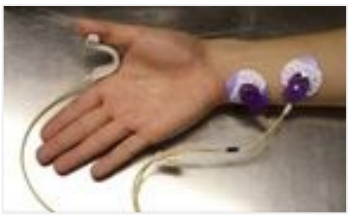
◆ Post Tetanic Count

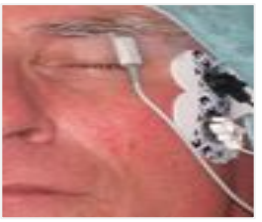
- Because muscle groups differ in their sensitivity to neuromuscular blocking agents, use of the peripheral nerve stimulator cannot replace direct observation of the muscles (eg, the diaphragm) that need to be relaxed for a specific surgical procedure.
- Furthermore, recovery of adductor pollicis function does not exactly parallel recovery of muscles required to maintain an airway.

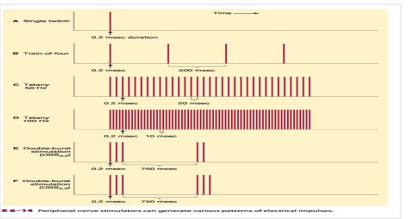


Clinical Considerations and Extubation Criteria (important)

- The diaphragm, rectus abdominis, laryngeal adductors, and orbicularis oculi muscles recover from neuromuscular blockade sooner than do the adductor pollicis.
- Other indicators of adequate recovery include sustained (≥5 s) head lift, the ability to generate an inspiratory pressure of at least −25 cm H 2 O, and a forceful hand grip.
- Twitch tension is reduced by hypothermia of the monitored muscle group (6%/°C).
- Decisions regarding adequacy of reversal of neuromuscular blockade, as well as timing of extubation, should be made only by considering both the patient's clinical presentation and assessments determined by peripheral nerve stimulation.
- Postoperative residual curarization remains a problem in post-anesthesia care, producing potentially injurious airway and respiratory function compromise.
- Reversal of neuromuscular blocking agents is warranted, as is the use of intermediate acting neuromuscular blocking agents instead of longer acting drugs.







Electrolytes/Acid Base

Coagulation

Urine output

Questions

Q1, Lead II of an ECG is represented by placing the

A. Positive electrode on the right arm and the negative electrode on the left leg
B. Negative electrode on the right arm and the positive electrode on the left leg
C. Positive electrode on the right arm and the negative electrode on the left
D. Negative electrode on the right arm and the positive electrode on the left arm

Q2. The accuracy of pulse oximetry can be significantly reduced by all of the following, except

A. Intravenous bolus of methylene blue
B. Intravenous bolus of heparin
C. Severe acidosis
D. Low blood flow

Q3. What is a non-invasive way to monitor the oxygenation of a patient's hemoglobin?

A. Oscillometer Cuff
B. Capnography
C. Pulse Oximetry
D. Arterial blood sample

Q4. Capnography can help detect all of the following, except

A. Endobronchial intubation
B. Esophageal intubation
C. Bronchospasm
D. Pulmonary embolism

Q5. During a complex mitral valve replacement, it is determined that the patient will benefit from brief protective hypothermia. Of the options listed below, core temperature is best measured via the

A. Pulmonary Catheter
B. Bladder
C. Nasopharynx
D. Skin

Q1 : B | Q2 : B | Q3 : C | Q4 : A | Q5 : A

Thank You

Sarah Alkathiri

Lama Alotaibi

Hadeel Almukaynzi

Danah Alkadi

Special thank you to team
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