



Anesthetic Monitoring

{Color index: [Important](#) | [Notes](#) | [Book](#) | [Extra](#) | [Editing File](#) | [comments or errors](#)}

Anything grey in this lecture is from the doctors slide but he said it's extra

Resources: lecture slides, 435teamwork, Book(Julian stone)

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 rules and regulations that govern modern monitoring
- 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

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★ Definition: 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
- 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)

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

- 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

لازم 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?

- Basic monitoring mandatory
- Advanced monitoring based on the case
- Patient/ illness
- Equipments/ technology Is safer for the patients.
- Rules/ legislation There should be rules to follow.

What determines the Standards of Care for monitoring a patient?

anesthesia type

- General
- Regional/neuraxial
- Monitored Anesthesia Care/Sedation (the patient is awake but sedated he don't feel anything)

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
- Cardiodepression/BP CO
- Vasodilation
- Low BP affects perfusion to vital organs
- Low Oxygen affects metabolism of organs

★ Standards for Anesthetic Monitoring

- Apply to all anesthesia care and to all intensive care as well although in emergency circumstances, appropriate life support measures take precedence.
- 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 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.
- These standards are not intended for application on the care of the obstetrical patient in labor or in the conduct of pain management.
- 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!

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.
- 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.

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.
- Frequency of mandatory monitoring varies between each category, but never exceeds five minutes. If not used, a reason should be recorded on the patient record. In the ward every 6-8h
- **The following are all specifically mandated.**

1. Oxygen analyzer with a low inspired concentration limit alarm during general anesthesia

- 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 (CO₂) If CO₂ is zero this is because the tube is in the stomach.

6. Alarms for disconnects when a mechanical ventilator is used Every category has its 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 patients

★ Multiple expired gas analysis:

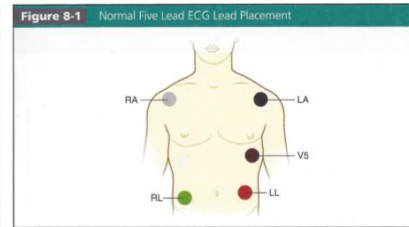
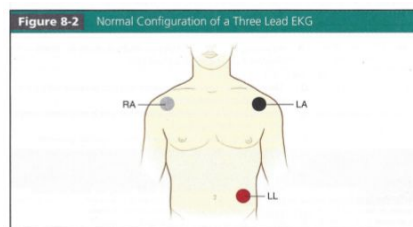
- Allows determination of the percent inspired and expired of the volatile agents and nitrous oxide.
- This allows the ability to better determine the delivery of an adequate anesthetic without over or under dose.

★ 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 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 III
- 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**
- **II is best used to monitor rhythm** because it provides the best visibility of the P wave such in Atrial fibrillation
- **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)

- BP can be monitored non-invasively or invasively.
- **Non-invasive methods:** include oscillometric cuff, and rarely palpation, auscultation, Doppler probe.

- Automatic oscillometric

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: Continues beat to beat

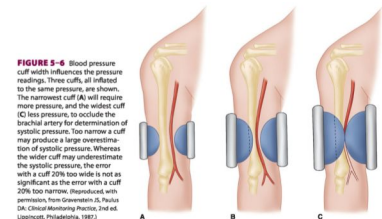


FIGURE 5-6 Blood pressure cuff width influences the pressure readings. Three cuffs, all inflated to the same pressure, are shown. The narrowest cuff (A) will require more pressure, and the widest cuff (C) less pressure. To occlude the brachial artery for determination of systolic pressure, the narrowest 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. (Reprinted, with permission, from Greenstein J, Poulos DE. Clinical Anesthesia Practice, 2nd ed. Lippincott, Philadelphia, 1987.)

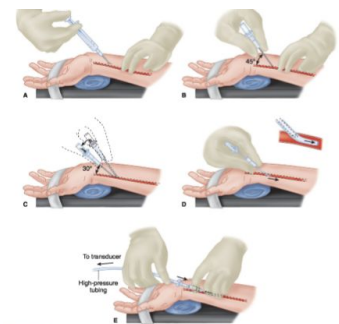
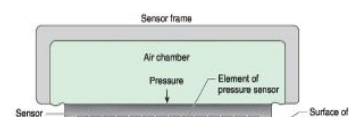
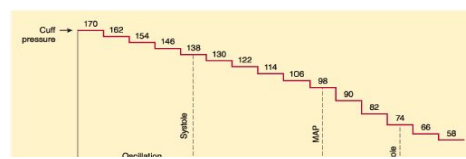
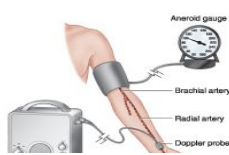


FIGURE 5-7 Cannulation of the radial artery. A. Proper cleansing and isolation of the artery are crucial. After skin preparation, local anesthetic is infiltrated with a 27-gauge needle. B. A 20- or 22-gauge catheter is advanced through the skin at a 45° angle. C. Flushback of blood signals entry into 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 intraluminal catheter.

Arterial: allows for continuous beat to beat monitoring of arterial blood pressure displayed as a waveform and provides access for arterial sampling

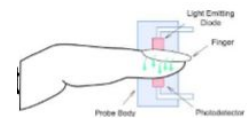


★ **Temperature** If the patient is awake we should warm it with blankets and there is no need to put a monitor as long as he is talking to us.

- 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 (SpO2) can be calculated.



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

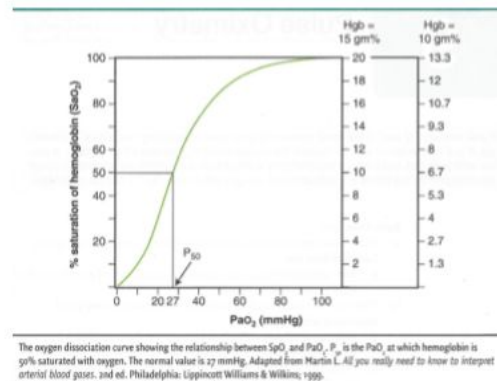
• **How pulse oximetry works?**

- 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**
- Sensors in the oximeter detect the amount of red and infrared light absorbed by the blood
- Photoplethysmography is then used to identify pulsatile arterial flow (alternating current [AC]) and non-pulsatile flow (direct current [DC])
- The ratio of AC/DC at both 660 and 940 nm is measured using the equation:

$$\frac{(AC/DC)_{660}}{(AC/DC)_{940}}$$

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
- **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.
- 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
- **Low perfusion** makes it difficult for the pulse oximeter to distinguish a true signal from background noise How does measure the arterial not venous blood? Because it detects the pulsation if there is no pulsation it can't differentiate between an artery and a vein.
- **Pulse oximetry is not as accurate in low amplitude states:**
 - 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



Dyshemoglobinemias:

- 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 its +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)
- Patients with sickle cell anemia presenting in a vasoocclusive crisis can have an **inaccurate** SpO2 reading
- 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

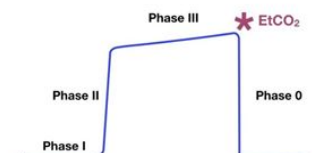
Expiration of mixture of dead space and alveolar gas

c) Phase III

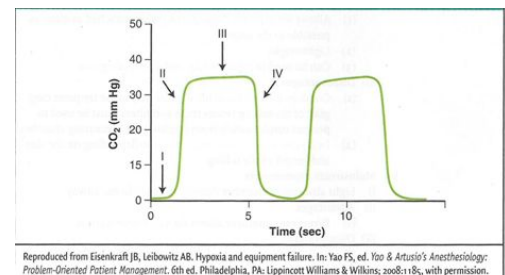
Alveolar plateau CO2-rich gas from alveoli

d) Phase IV or 0

Inspiration



The Normal Capnograph



Clinical uses of capnography

- Provides qualitative and quantitative information regarding expired CO2.
- Quantitatively, this is **useful to ensure the endotracheal tube is within the respiratory tract**
- Quantitatively, to ensure adequate cardiac output.

Inspired CO2

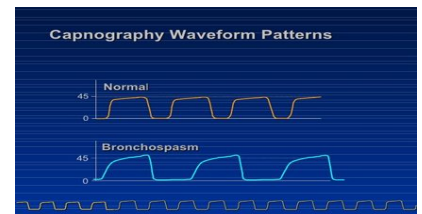
- Monitored to ensure that the CO2 absorber of the anesthesia machine is adequately removing all CO2 from the circuit.
- If inspired CO2 is greater than zero, changing of the absorbent should be considered.

The color of absorbent turns blue when its capacity is exhausted.

- **Monitoring of adequacy of ventilation** in controlled or spontaneously ventilating patients
- Noninvasive estimate of PaCO₂
- Assumes the normal 2 to 5 mm Hg difference between expired (PETCO₂) and arterial If PETCO₂ is 40 and the difference is 5 so PaCO₂ is 45 so there hypoventilation we need to increase the ventilation, PaCO₂ always higher than PETCO₂. (PaCapnography in the awake state is present)
- The gradient between PETCO₂ and PaCO₂ may be increased with age, pulmonary disease, pulmonary embolus, low cardiac output, and hypovolemia.

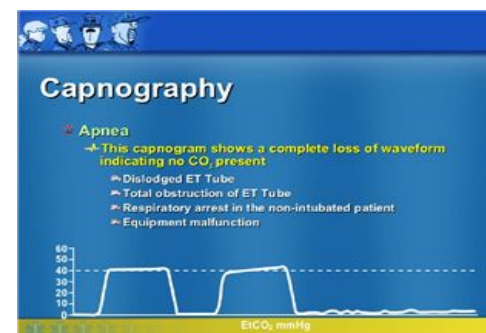
Detection of patient disease:

- **Causes of increased CO₂ production**
 - Fever
 - Sepsis
 - Malignant hyperthermia early manifestation doesn't show high temperature, CO₂ is the first signs and increase heart rate.
 - Hyperthyroidism
 - Shivering increased metabolism → increased CO₂
- **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:

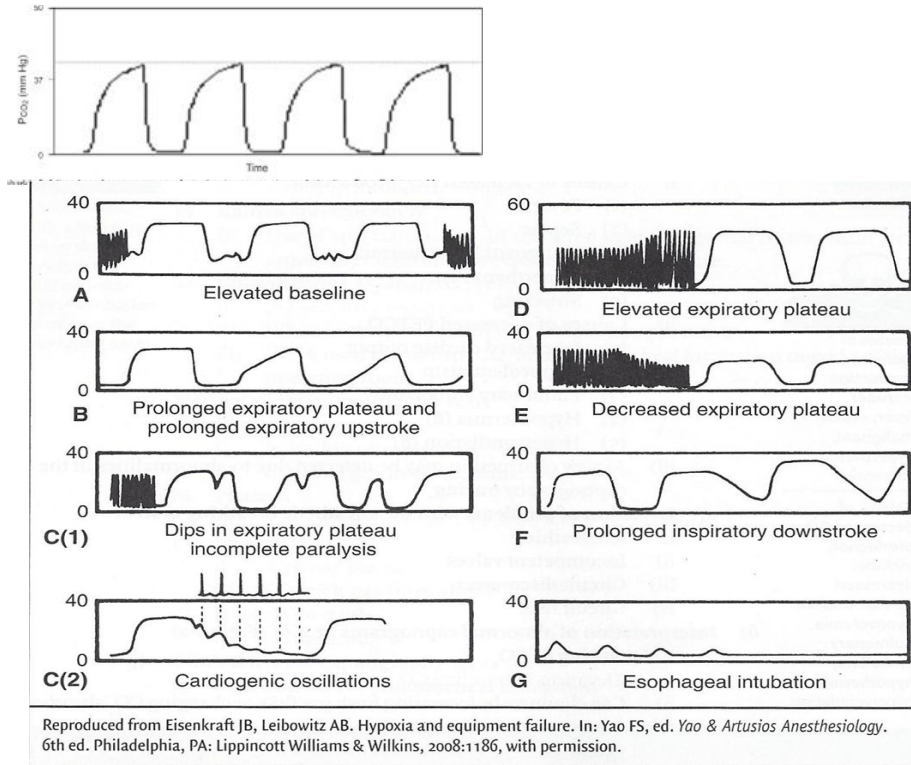
- Rebreathing of CO₂
- Incompetent valves
- Circuit disconnect
- Circuit leak



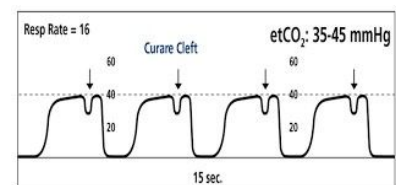
Interpretation of abnormal capnograms :

- Rebreathing of CO₂
 - Elevation in baseline CO₂ and Phase I
 - Can eliminate by increasing fresh gas flow or changing CO₂ absorber

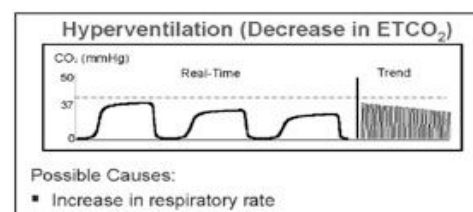
- Obstruction to expiratory gas flow
 - Prolonged Phase II and steeper Phase III slope
 - Occurs with bronchospasm, COPD, kinked endotracheal tube



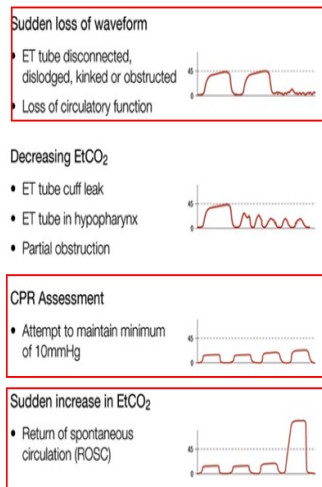
- Curare Cleft
 - Dip in Phase III
 - Indicates return of spontaneous respiratory efforts



- Cardiogenic oscillations
 - 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), or inadequate minute ventilation
- Decreased measured CO₂
 - Decreased plateau height
 - May indicated decreased CO₂ production state or increased minute ventilation

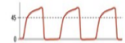


- Incompetent inspiratory valve
 - Prolonged Phase III with elevation of baseline CO₂ and plateau height
 - Results in rebreathing
 - May be difficult to detect without simultaneous analysis of flow waveforms
- Esophageal intubation
 - Initial presence of CO₂ followed by no CO₂

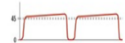


Bronchospasm ("Shark-fin" appearance)

- Asthma
- COPD



Hypoventilation

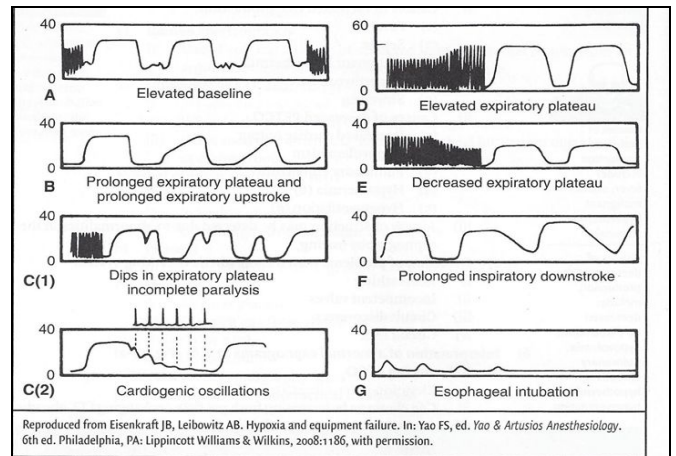
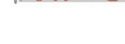


Hyperventilation



Decreased EtCO₂

- Apnea
- Sedation



★ Processed EEG and Awareness Monitoring

- **Intra-operative 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.
- **Intra-operative 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 intra-operative awareness with recall.

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.

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 intra-operative 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:

- **"light" anesthesia** (e.g., delivering a low level of inhaled anesthetic minimum alveolar concentration),
- **history of intra-operative 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
- **chronic use of central nervous system depressants**
- younger age

- Obesity
- inadequate or misused anesthesia delivery systems

Detecting episodes of intra-operative awareness:

- Often it is **difficult to know for sure** that intra- operative 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 intra-operative 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 sevoflurene**, 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.

- **BIS¹ (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**.

- The term bispectral applies because it incorporates both power and phase spectrum of an EEG into the calculated 0 to 100 value.

- BIS values between 40 and 60 purportedly indicate adequate general anesthesia for surgery, and values below 40 indicate a deep hypnotic**

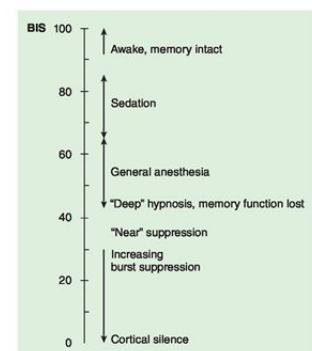


FIGURE 6-10 The Bispectral Index Scale (BIS versions 3.0 and higher) is a dimensionless scale from 0 (complete cortical electroencephalographic suppression) to 100 (awake). BIS values of 65–85 have been recommended for sedation, whereas values of 40–65 have been recommended for general anesthesia. At 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.)

¹ Bispectral index system

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.

- 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.

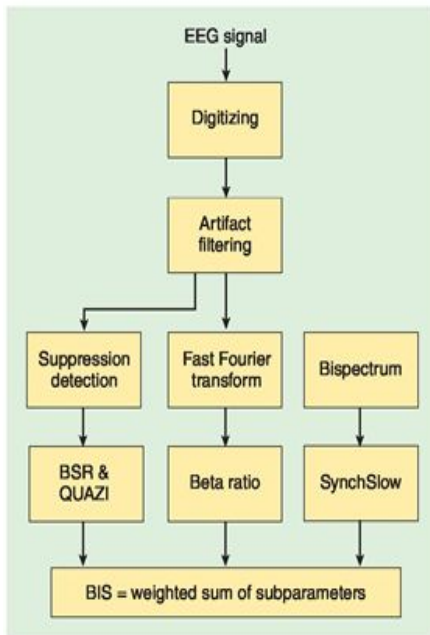


FIGURE 6-9 Calculation of the Bispectral Index. EEG, electroencephalogram; BSR, burst suppression ratio; BIS, Bispectral Index Scale. (Reproduced, with permission, from Rampill U: A primer for EEG signal processing in anesthesia. Anesthesiology 1998;89:980.)

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

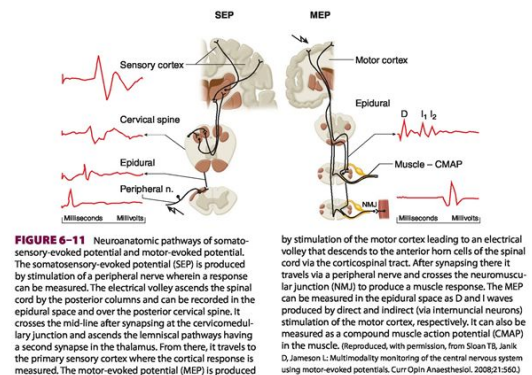
Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	↑ f, ↓ Amp, blinks Twenties High β ratio High entropy ↑ lat, ↑ ΔAmp EEG f band analysis Age-adjusted MAC	↑ γ, β, α, ↓ δ 26 Hz 96 97 81 A 0 MAC	
Sedated	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	α oscillations High teens Low β ratio High entropy ↑ ing lat, ↓ ing ΔAmp EEG f band analysis Age-adjusted MAC	↓ γ, β, ↑ α, ↓ δ 19 Hz 78 85 45 B/C 0.4 MAC	
Unresponsive	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	Spindles, K, ↓ f Low teens Bispectral coherence Entropy drop ↑ ing lat, ↓ ing ΔAmp EEG f band analysis Age-adjusted MAC	↑ α, θ, δ 14 Hz 52 43 30 D 0.8 MAC	
Surgically Anesthetized	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	Slow δ waves, ↓ f < 12 Hz Bispectral coherence Low entropy ↑ ing lat, ↓ ing ΔAmp EEG f band analysis Age-adjusted MAC	δ dominance 10 Hz 42 38 22 E 1.3 MAC	
Deeply Anesthetized	EEG SEF ₉₅	BS, isoelectricity < 2 Hz, (BS corrected)	Bursts & flat 2 Hz	

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	PSArray ⁺	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	Narcotrend monitor/Monitor-Technik, Bad Bramstedt, Germany	Ordinary EEG electrode	1-2 channel EEG	Narcotrend stage D ₀ to C ₄ which corresponds to an index of 40-60	The Narcotrend monitor classifies EEG signals into different stages of anesthesia (A = awake; B ₀ = sedated; C ₀ = light anesthesia; D ₀ = general anesthesia; F ₀ = general anesthesia with deep hypnosis; F ₁ = 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/S Entropy	Special array	Single-channel	40-60	Entropy described the 'regularity' of the EEG signal. As the dose of anesthetic is increased EEG becomes more regular and the entropy value approaches

★ Neurophysiologic Monitoring and Anesthetic Management

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 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.



Electromyography (EMG)

- 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)

- 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)

- 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)

- 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)

- 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.

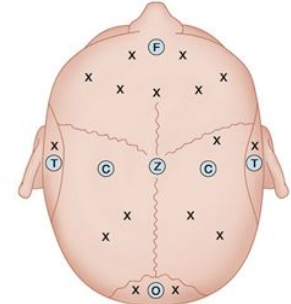


FIGURE 6-7 International 10-20 system. Montage letters refer to cranial location. F, frontal; C, coronal; T, temporal; O, occipital; Z, middle.

Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	↑f, ↓Amp, blinks Twenties High β ratio ↓lat, ↑ΔAmp EEG f band analysis Age-adjusted MAC	↑γ, β, α, ↓δ 26 Hz 96 97 91 A 0 MAC	
Sedated	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	α oscillations High teens Low β ratio High entropy ↑ing lat, ↓ing ΔAmp EEG f band analysis Age-adjusted MAC	↓γ, β, ↑α, θ, δ 19 Hz 79 85 45 B/C 0.4 MAC	
Unresponsive	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	Spindles, K, J/f Low teens Bispectral coherence Entropy drop ↑ing lat, ↓ing ΔAmp EEG f band analysis Age-adjusted MAC	↑α, θ, δ 14 Hz 52 43 30 D 0.8 MAC	
Surgically Anesthetized	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	Slow δ waves, J/f <12 Hz Bispectral coherence Low entropy ↑ing lat, ↓ing ΔAmp EEG f band analysis Age-adjusted MAC	δ dominance 10 Hz 42 38 22 E 1.3 MAC	
Deeply Anesthetized	EEG SEF ₉₅ BIS Entropy AAI NI ETAG	BS, isoelectroly <2 Hz (BS corrected) High BSR Burst suppression ↑latency, ↓ΔAmp EEG f band analysis Age-adjusted MAC	Bursts & flat 2 Hz 9 8 11 F 2 MAC	

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; SEF₉₅, spectral edge frequency below which 95% of the EEG frequencies reside; Spindles, sleep spindles. (Reproduced, with permission, from Mashour GA, Orser BA, Avvidan 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

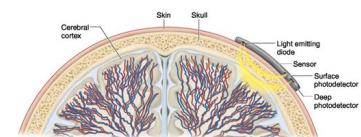


FIGURE 6-12 Principle of the INVOS® near-infrared spectroscopy technique. (Reproduced, with permission, from Rubin A, Meekins L, Meach K, Tiedler R, Young J: *Wiley-Blackwell*. Control of adequate cerebral oxygenation during low-flow anesthetic selective cerebral perfusion in adults and infants in the aortic arch surgery. *Crit Care Surg* 2008;3:474.)

- 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**

★ **Invasive pressure monitoring** 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.

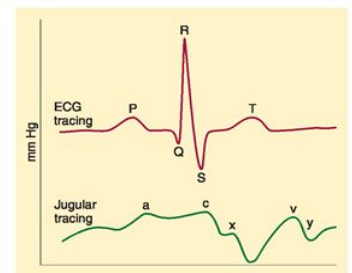


FIGURE 5-19 The upward waves (a, c, y) and the downward descents (x, y) of a central venous tracing in relation to the electrocardiogram (ECG).

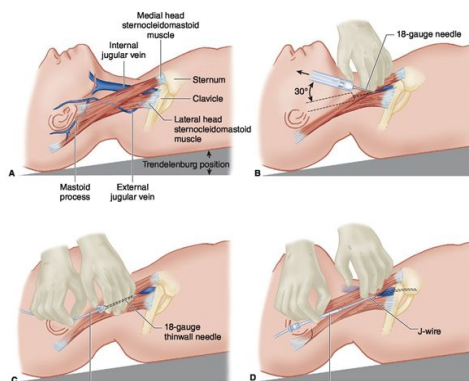


FIGURE 5-16 Right internal jugular cannulation with Seldinger's technique (see text).

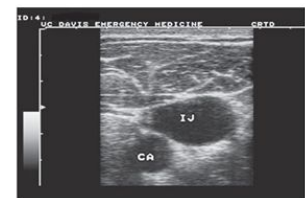


FIGURE 5-17 A: Probe position for ultrasound of the large internal jugular vein with deeper carotid artery and B: corresponding ultrasound image. CA, carotid artery; IJ, internal jugular vein. (Reproduced, with permission, from Tintinalli JE, et al: *Tintinalli's Emergency Medicine: A Comprehensive Study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

using US is important to monitor the technique to prevent hitting the carotid artery which if happen will cause hypoxia, also it will prevent the repeated palpation because if the patient has plaque in the carotid artery the plaque might rupture and the patient will develop ischemic events

Pulmonary artery Pressure

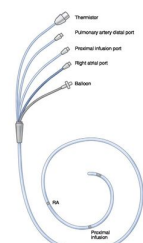


FIGURE 5-20 Balloon-tipped pulmonary artery (PA) catheter.

- 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 (SvO2)** 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

$$CO = SV \times HR$$

$$SV = CO/HR$$

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

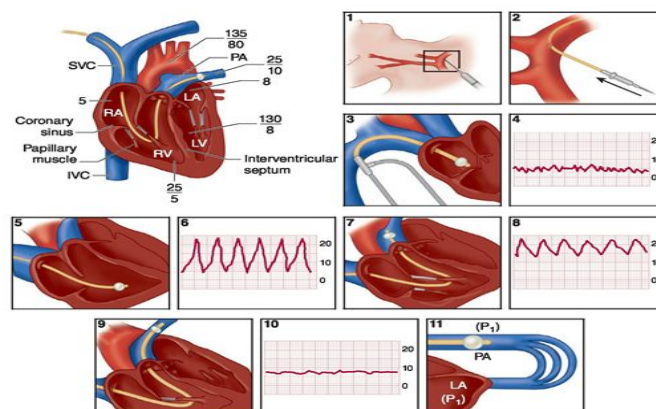


FIGURE 5-22 Although its utility is increasingly questioned, pulmonary artery catheters continue to be a part of perioperative management of the cardiac surgery patient. Following placement of a sheath introducer in the central circulation (panels 1 and 2), the pulmonary artery catheter is floated. Central 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 ballooned 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.)

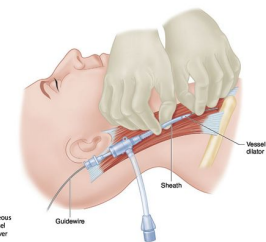


FIGURE 5-21 A percutaneous catheter consisting of a vessel dilator and sheath is passed over the guidewire.

★ Transesophageal echocardiography (TEE) useful for critical patients

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.

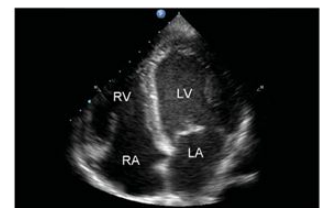


FIGURE 5-27 Normal apical four-chamber view. RV, right ventricle; LV, left ventricle; RA, right atrium; LA, left atrium. (Reproduced, with permission, from Carmody KA, et al: *Handbook of Critical Care and Emergency Ultrasound*. McGraw-Hill, 2011.)

- ★ **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 **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 !** or nerve damage may appear refractory to neuromuscular blockade secondary to the proliferation of receptors.
- Determining the degree of neuromuscular blockade using such an extremity could lead to potential overdosing of competitive neuromuscular blocking agents.

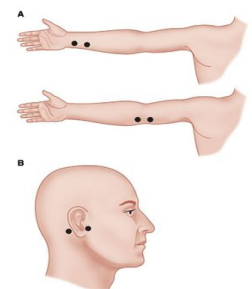


FIGURE 6-13 A: Stimulation of the ulnar nerve causes contraction of the adductor pollicis muscle. B: Stimulation of the facial nerve leads to orbicularis oculi contraction. The orbicularis oculi recovers from neuromuscular blockade before the adductor pollicis. (Reproduced, with permission, from Dorsch JA, Dorsch SE: *Understanding Anesthesia Equipment*, 4th ed. Williams & Wilkins, 1993)

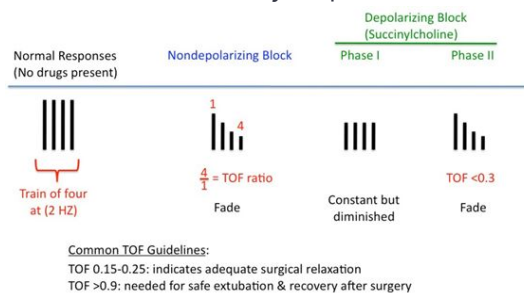
Techniques & Complications

- 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.
- 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 μ s 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- μ s 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 of fourth twitch over the first twitch should be greater than or equal to 90% to give the reversal (neostigmine and glycopyrrolate)**
- 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.**



- 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- μ s) 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- μ s 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 H₂O, 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.

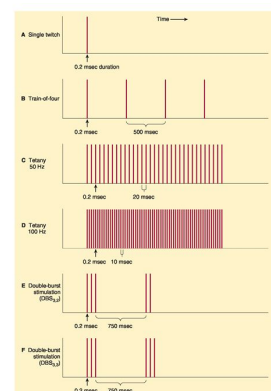


FIGURE 6-14 Peripheral nerve stimulators can generate various patterns of electrical impulses.

- 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**

Practice Questions:

Q1: What is the equipment for checking the neuromuscular blockade?

- A. Capnograph
- B. Pulse oximeter
- C. Bi spectral index
- D. Peripheral nerve stimulator

Q2: Which one of the following is the standard monitor to detect anesthesia circuit disconnection?

- A. A. ECG
- B. B. Pulse oximeter
- C. C. EtCo₂
- D. D. FiO₂

Q3: Which lead in ECG is used to detect rhythm?

- A. Lead 1
- B. Lead 2
- C. Lead 3

Answers:

Q1: D | Q2: C | Q3: B |