Editing file

Anesthesia 438 Team

Monitoring During Anesthesia

Objectives:

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

- Definition
- What, When, How 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
- Brief introduction about invasive hemodynamic monitoring and oxygenation of the brain
- The neuromuscular junction relaxation monitoring

Color index:

- Red: important /
- Black: content slides
- Gray: extra
- Green: dr. Notes

Anesthesia 438 teamwork

What is anesthetic Monitoring?

Definition:

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

What do you Monitor in a patient?

- Vitals: blood pressure, heart rate, respiratory rate and temperature
  Q: What vital sign had nowadays been measured very frequently ?
  A: temperature in public areas during the pandemic
- Color/skin [1]
- Wakefulness state [2]

How & By Which Means do you Monitor in a patient?

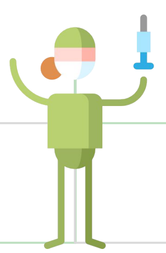
- Physical exam
- Equipments (advances in technology)

Where do you monitor a patient?

- Hospital **vs** Out-of-Hospital setting
- Safe **vs** Dangerous place (biologic, electric, chemical hazards, radioactive, etc…)

What determines the Standards of Care for monitoring a patient (What are you responsible for?)

Depends on:



Equipments/technology

Place: In-hospital Vs Out-of Hospital [3]

Patient/illness

Rules/legislation: every institution or hospital may have its own policies that are based on evidence. Or adopted other national and international policies.

1- Especially if you are resuscitating where you don't have a pulse oximeter present
2- By communicating with the pt & see if he's responding or not
3- In hospital you're responsible for monitoring everything but if you're Out of hospital you won't be responsible for monitoring pulse oximeter or BP because you won't have the necessary equipment

Standards for Anesthetic Monitoring

Theses Standards:

Apply to all anesthesia care although, in emergency circumstances, appropriate life support measures take precedence [1]
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

They are subject to revision from time to time, as warranted by the evolution of technology and practice

They apply to all general anesthetics, regional anesthetics and monitored anesthesia care

Brief interruptions of continual monitoring may be unavoidable

- So you may not be able to monitor and document "continuously at every second interval". Hence the term "Continual" instead of "Continuous" "continual" is defined as "repeated regularly and frequently in steady rapid succession [2]. "continuous" means "prolonged without any interruption at any time."

Standard I:[3]

01 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:

- Neurodepression / respiratory depression
- Bleeding
- Brain ischemia
- Hypoperfusion to vital organs
- Cardiodepression / alteration in BP, CO
- Hypothermia
- Anaphylaxis
- Vasodilation: low BP affects perfusion to vital organs, low oxygen affect metabolism of organs
- Acid and blood gases, fluid and electrolyte imbalance
- Myocardial infarction, acute heart failure and arrhythmias

02 If there is a direct known hazard, e.g., radiation, to the anesthesia personnel which might require intermittent remote observation of the patient, some provision for monitoring the patient must be made, via tele monitoring (cameras to the patient and monitor or satellite monitor out of the radiation area)

03 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 [4].

1- We'll give priority to chest compression & ventilation over temperature for example
2- Every 1 or 2 hrs
3- Why the frequency of anesthetic monitoring shouldn't exceed 5 mins
4- If the pt in the OR is stable you can go and make a resident monitor but if the pt is unstable let the resident go and you stay to monitor and resuscitate the pt

Standards for Anesthetic Monitoring

Standard II:

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

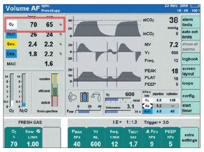
Q: Brief interruptions of monitoring may be unavoidable. So how frequent should it be? (as stated in Standard II)

A:
- On the general ward, documenting vitals routinely would be every 8 hours or every nursing team shift.
- In closed observation units (intensive care unit) documenting patient's status would be at least every one hour or more frequently as per patient's condition.
- during surgical anesthesia Frequency of mandatory monitoring varies between each category, but never exceeds five minutes. Otherwise, a reason should be documented on the patient's record (for medico-legal purposes).

The following are all specifically mandated: [1]

First

Oxygen analyzer with a low inspired concentration limit alarm during general anesthesia. Most modern anesthesia machines monitor both inspired and expired concentrations of O_2. This is essential during anesthesia because it is possible to deliver a hypoxic gas mixture when mixing O_2, air, nitrous oxide, and/or volatile anesthetic agents.



Second

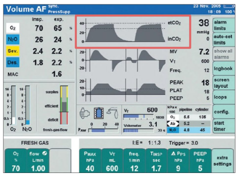
Quantitative assessment of blood oxygenation.
Pulse Oximetry: Provides quantitative analysis of the patient's saturation of hemoglobin with O_2.

Third [2]

Ensuring adequate ventilation during all anesthetic care including verification of expired oxygen (when possible), quantitative measurement of tidal volume, and capnography in all general anesthetics.

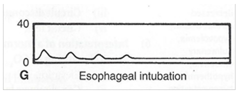
Forth

Quantitative evaluation of ventilation is required during all other care.
- Inspired and expired CO_2 should be monitored.
- Expired CO_2 is frequently displayed through capnography with a displayed value correlating to the peak expired CO_2 of each breath



Fifth [3]

Ensure correct placement of endotracheal tube or laryngeal mask airway via expired carbon dioxide (CO_2). Observation of bilateral chest movement and air entry, as well as auscultation of the chest is also necessary. [4]



Sixth

Alarms for breathing circuit disconnection or leak when a mechanical ventilator is used.

Seventh

Continuous display of ECG

Eighth

Determination of arterial BP and heart rate at least every 5 minutes.

Ninth [5]

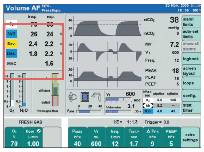
Adequacy of circulation is to be determined by quality of pulse either electronically, through palpation, or auscultation

Tenth [6]

The means to determine temperature must be available and should be employed when changes in temperature are anticipated or intended.

1- Basic monitors
2- End tidal volume is the most accurate and important value of CO_2, it can determine many things including cardiac output
3- If tube is in the airway, the CO_2 will come out but if it's in the esophagus there will be no CO_2 coming out, there will be residual CO_2 coming in the primary basis first two cycles then it will stop so it's important to monitor the CO_2 for a while after you intubate
4- Because end tidal CO_2 might not detect that we are in one lung or two lungs ventilation
5- For example if the pt is having hypotension you check if there is problem with the machine or if it's true situation but be careful not to press to hard in the carotids
6- In cardiac surgeries or in ACLS when the pt doesn't recover well you induce hypothermia up to 32 C to protect organs

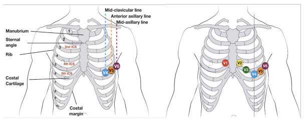
Modalities for Anesthetic Monitoring



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 [1]

ECG

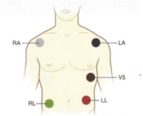


External chest landmark for the V leads

- 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.

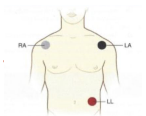
Five Lead [2] ECG More useful

right arm (RA), left arm (LA), right leg (RL), left leg (LL), and V display I, II, III, aVR, aVL, aVF, and/or V



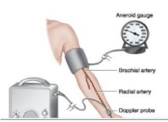
Three lead ECG

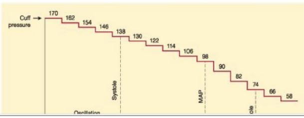
Includes the RA, LA, and LL leads and can be used to display leads I, II, and/or Ill, Can be modified to display V5 by moving the LA lead to the V5 , position in the fifth intercostal space at the anterior axillary line

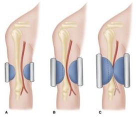


- The most commonly monitored leads are II and V5
- II is best used to monitor rhythm because it provides the best visibility of the P wave
- V5 monitors for anterior and lateral ischemic events
- If an arrhythmia or ischemic event appears to be present, the ability to view all leads simultaneously may be helpful for diagnostic purposes.

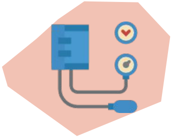
Arterial blood pressure







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



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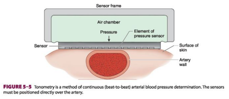
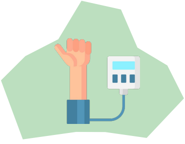
The cuff

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





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Placement

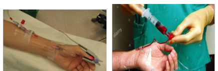
1. Each cuff is labeled with an arrow pointing to where arterial pulsation is felt best.
2. The cuff is then placed on the arm over the brachial artery, forearm over the radial artery, or thigh/calf over the popliteal artery.

Skipped by doctor

Patient positioning

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

- **Invasive pressure monitoring [3].** Arterial : allows for continuous beat to beat monitoring of arterial blood pressure displayed as a waveform and provides access for arterial sampling



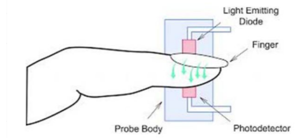
1- If it's decreased it will cause awareness during anesthesia / if increased the pt may not wake up as it supposed to be because there is still anesthetics in his system. So it can tell you when the pt will waking up
2- You can detect any ischemic event by 100%, very important in any suspected MI patients
3- Important in critical pts it can detect immediate changes before the pt become ischemic

Modalities for Anesthetic Monitoring

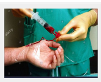
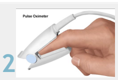
Temperature [1]

- Temperature changes should be anticipated and expected under any general anesthetic and therefore any general anesthetic requires temperature measurement.
- Very brief procedures [2] may be an exception, but the availability of temperature monitoring should be recorded.
- 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.

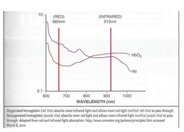
Pulse oximetry (SpO2)



- 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 SaO_2 	Functional oximetry SpO_2 
Oxyhemoglobin/(oxyhemoglobin + deoxyhemoglobin + methemoglobin + carboxyhemoglobin) Skipped by doctor	Oxyhemoglobin/(oxyhemoglobin + deoxyhemoglobin) Skipped by doctor
-Can only be measured by an **arterial blood sampling**	- Can be measured noninvasively by a standard **pulse oximeter**

How pulse oximetry works



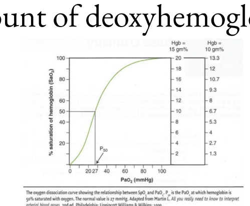
A) A pulse oximeter emits two wavelengths of light: red (660 nm) and infrared (940 nm)
B) Deoxyhemoglobin absorbs more light in the red and reflect less red, so it's color is darker red
C) Oxyhemoglobin absorbs more light in the infrared and reflect more red, so it's color is red

Accuracy of the pulse oximeter

The calibration to deliver SpO2 from $(AC/DC)_{940}$ ratio was made from studies of healthy volunteers
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%

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



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

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

1- It's mandatory monitor in neonates and infants it can detect neonatal arrest and acidosis
2- Surgeries less than an hour

Modalities for Anesthetic Monitoring

Pulse oximetry (SpO2)

Accuracy of the pulse oximeter

- Pulse oximetry is affected by: low amplitude state and dyshemoglobinemia
- Patients with sickle cell anemia presenting in a vaso occlusive crisis can have an inaccurate SpO2 reading
- Pulse oximetry is not as accurate in low amplitude states
- **Low perfusion** makes it difficult for the pulse oximeter to distinguish a true signal from background noise

- Arrhythmias
- Hypovolemia
- Vasoconstriction
- Cardiac arrest
- BP cuff inflation [1]
- Hypothermia
- Cardiac Bypass
- Tourniquet

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%.
- 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:

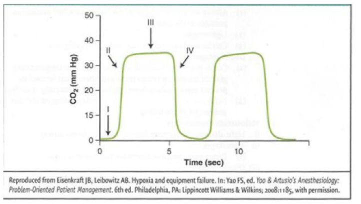
1. Nitrates / Nitrites
2. Local anesthetics (eg. Benzocaine)
3. Chlorates
4. Antimalarials
5. Antineoplastics
6. Sulfonamide & Dapsone (antibiotic)
7. Metoclopramide (antiemetic)

1- Occlude the artery for a while when used. So, a problem will be shown in the oximetry

Modalities for Anesthetic Monitoring

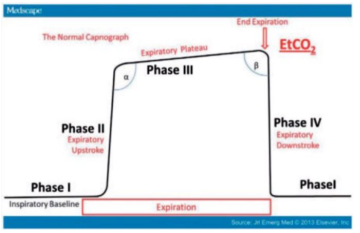
Capnography

Normal Capnogram:



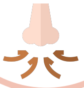
Reproduced from Eisenkraft JB, Leibowitz AB. Hypoxia and equipment failure. In: Yao FS, ed. *Yao & Artusio's Anesthesiology: Problem-Oriented Patient Management*. 6th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2008:1185, with permission.

- **Phase I**
  Initiation of expiration, CO2 free gas from anatomic dead space
- **Phase II**
  Expiration of mixture of dead space and alveolar gas
- **Phase III**
  Alveolar plateau, CO2-rich gas from alveoli
- **Phase IV or 0**
  Inspiration



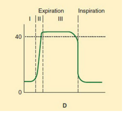
Clinical Uses of Capnography:

inspired CO2
it provides:



Quantitative information

- Ensure that the patient is not breathing back any CO2 from the anesthesia ventilator, that would be a cause of respiratory acidosis. Otherwise CO2 absorber of the anesthesia machine should be exchanged [1]



Expired CO2
it provides:

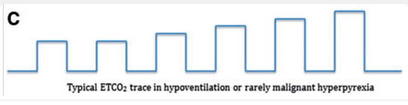
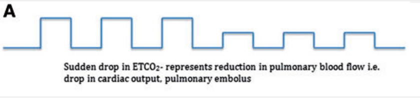
Qualitative information

- Ensure the endotracheal tube is within the respiratory tract
- Indicates adequacy of breathing in spontaneously ventilating non-intubated patients [2]

Quantitative information

- Ensure adequate cardiac output
- Indicate adequacy of ventilating intubated patients [3]
- Non-invasive estimate of PaCO2: assumes the 2-5 mmHg difference between expired (PETCO2) and arterial (PaCO2)

- The gradient between PETCO2 and PaCO2 may be increased with age, pulmonary disease, pulmonary embolism, low cardiac output, and hypovolemia.
- **Detection of Patient Disease:**

Causes increased CO_2 production	Causes of decreased P_{ETCO2}
 Typical ETCO₂ trace in hypoventilation or rarely malignant hyperpyrexia	 Sudden drop in ETCO₂- represents reduction in pulmonary blood flow i.e. drop in cardiac output, pulmonary embolus
Fever, sepsis, malignant hyperthermia [5], hypoventilation (CO2 accumulation), hyperthyroidism (↑ metabolism) and shivering	Decreased cardiac output, hypovolemia, pulmonary embolism, hypothermia and hyperventilation

- **Detection of problems with the anesthetic breathing system:** Rebreathing of CO2, Incompetent valves, Circuit disconnect and Circuit leak.

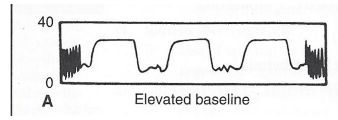
1- As it might be malfunctioning or exhausted causing the pt to rebreath CO2
2- You want to make sure that your intubation is not too deep to the point that the patient stops breathing spontaneously
3- If the value of CO2 is too high it means we're hypoventilating the pt but if it's too low then we're washing too much CO2 and hyperventilating the pt
4- For example if the PETCO2 is 32 then PaCO2 will be between 34-37
5- CO2 will start to increase and never drop we have to manage the pt immediately by cooling the pt & giving muscle relaxants or he will suffocate & die

Modalities for Anesthetic Monitoring

Capnography

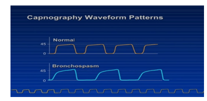
Interpretation of abnormal capnograms:

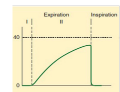
A) Rebreathing of CO2



- Elevation in baseline CO2 and Phase I
- Can be eliminated by increasing fresh gas flow or changing CO2 absorber

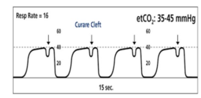
B) Obstruction to expiratory gas flow





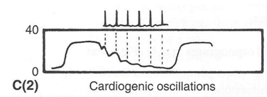
- Prolonged Phase II and steeper Phase III slope
- Occurs with bronchospasm, COPD, kinked endotracheal tube

C) Curare Cleft Skipped by doctor



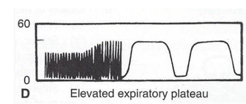
- Dip in Phase III
- Indicates return of spontaneous respiratory efforts

D) Cardiogenic oscillations



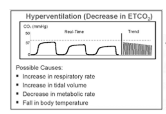
- Oscillations of small gas movements during phase III and IV (or 0)
- Produced by aortic and cardiac pulsations

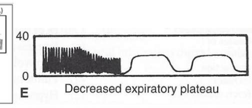
E) Increased CO2



- Elevated plateau height
- Indicates increased CO2 production states
- Other sources of CO2 (as in laparoscopic surgery [1]), or inadequate minute ventilation

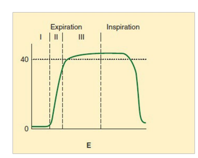
F) Decreased measured CO2





- Decreased plateau height
- May indicates decreased CO2 production states or increased minute ventilation

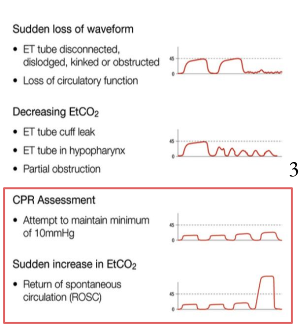
G) Incompetent inspiratory valve: Skipped by doctor

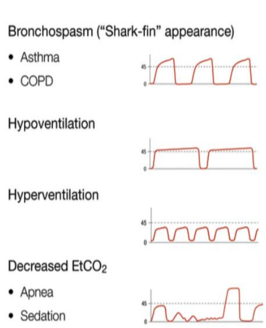


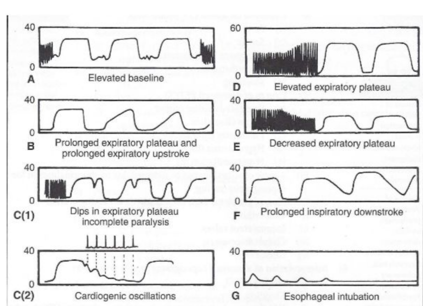
- Prolonged Phase III with elevation of baseline CO2 and plateau height
- Results in rebreathing
- May be difficult to detect without simultaneous analysis of flow waveforms

H) Esophageal intubation:

- Initial presence of CO2 followed by no CO2 [2]







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.

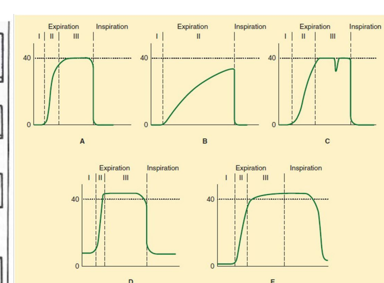


FIGURE 6–5 **A**: A normal capnograph demonstrating the three phases of expiration: phase I—dead space; phase II—mixture of dead space and alveolar gas; phase III—alveolar gas plateau. **B**: Capnograph of a patient with severe chronic obstructive pulmonary disease. No plateau is reached before the next inspiration. The gradient between end-tidal CO_2 and arterial CO_2 is increased. **C**: Depression during phase III indicates spontaneous respiratory effort. **D**: Failure of the inspired CO_2 to return to zero may represent an incompetent expiratory valve or exhausted CO_2 absorbent. **E**: The persistence of exhaled gas during part of the inspiratory cycle signals the presence of an incompetent inspiratory valve.

1- CO2 inside the abdomen→ dissolve into blood→ go to the lung → rise in CO2

2- Because there's no source of CO2 in the stomach, you have to manage the patient and re-intubate the patient adequately

3- When you're resuscitating someone with ACLS you get sudden increase which means the heart took over and returned to spontaneous circulation→ adequate cardiac output→ adequate CO2

Intraoperative awareness with recall

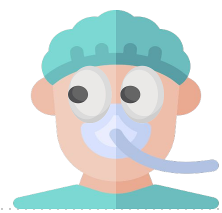
Intraoperative awareness with recall involves explicit recall of sensory perceptions during general anesthesia including aspects of their surgical environment, procedure, and even pain related to the intervention.

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 in titration of anesthetic drugs and may be useful in reducing the incidence of intraoperative awareness with recall.

Symptoms

- Auditory perceptions such as voices or noises [1] most common
- loss of motor function (inability to move, sensation of weakness, or paralysis)
- pain
- feelings of helplessness
- anxiety & panic
- impending death
- catastrophe



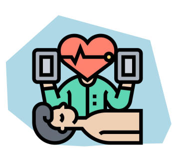
can lead to

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.

Routine surgeries: **0.2%**



Cardiac surgeries: **1.14-1.5%**

Obstetric surgeries: **0.4%**

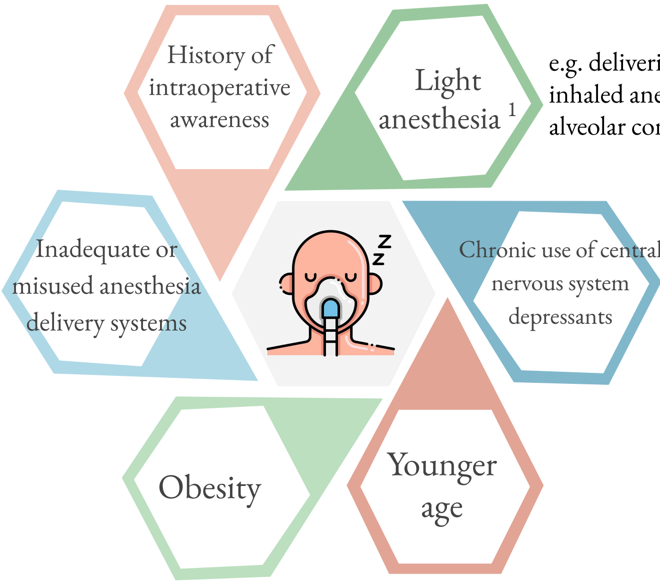
Trauma surgeries: **11-43%**

Awareness with recall associated with pain: **0.01-0.03%**

1- Voices & noises should be controlled as much as possible so that if the pt had intraoperative awareness he/she will suffer less

Intraoperative Awareness with recall

Factors associated with increased risk of awareness with recall



e.g. delivering a low level of inhaled anesthetic minimum alveolar concentration (MAC) [2]

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 [3] (awareness may not arise until days to weeks postoperatively).

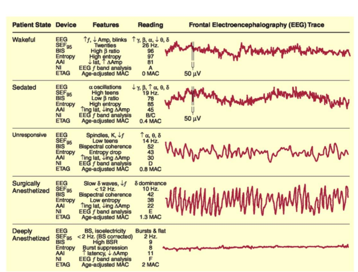
Prevention or vigilance for detecting intraoperative awareness

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, 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.



Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG	↑*f*, ↓Amp, blinks	↑γ, β, α, ↓θ, δ	
	SEF_{95}	Twenties	26 Hz.	
	BIS	High β ratio	96	
	Entropy	High entropy	97	
	AAI	↓lat, ↑ΔAmp	81	
	NI	EEG *f* band analysis	A	
	ETAG	Age-adjusted MAC	0 MAC	50 μV
Sedated	EEG	α oscillations	↓γ, β, ↑α, θ, δ	
	SEF_{95}	High teens	19 Hz.	
	BIS	Low β ratio	78	
	Entropy	High entropy	85	
	AAI	↑ing lat, ↓ing ΔAmp	45	
	NI	EEG *f* band analysis	B/C	
	ETAG	Age-adjusted MAC	0.4 MAC	50 μV
Unresponsive	EEG	Spindles, K, ↓*f*	↑α, θ, δ	
	SEF_{95}	Low teens	14 Hz.	
	BIS	Bispectral coherence	52	
	Entropy	Entropy drop	43	
	AAI	↑ing lat, ↓ing ΔAmp	30	
	NI	EEG *f* band analysis	D	
	ETAG	Age-adjusted MAC	0.8 MAC	
Surgically Anesthetized	EEG	Slow δ waves, ↓*f*	δ dominance	
	SEF_{95}	< 12 Hz.	10 Hz.	
	BIS	Bispectral coherence	42	
	Entropy	Low entropy	38	
	AAI	↑ing lat, ↓ing ΔAmp	22	
	NI	EEG *f* band analysis	E	
	ETAG	Age-adjusted MAC	1.3 MAC	
Deeply Anesthetized	EEG	BS, isoelectricity	Bursts & flat	
	SEF_{95}	< 2 Hz. (BS corrected)	2 Hz.	
	BIS	High BSR	9	
	Entropy	Burst suppression	8	
	AAI	↑ latency, ↓ΔAmp	11	
	NI	EEG *f* band analysis	F	
	ETAG	Age-adjusted MAC	2 MAC	

TABLE 6–2 Checklist for preventing awareness.

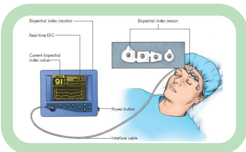
- ✓ Check all equipment, drugs, and dosages; ensure that drugs are clearly labeled and that infusions are running into veins.
- ✓ Consider administering an amnesic premedication.
- ✓ Avoid or minimize the administration of muscle relaxants. Use a peripheral nerve stimulator to guide minimal required 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

1- MAC targets 50% of the population, if you give only 1 MAC it will target 50% of the population and the other 50% might go to awareness
2- For example if the pt has hypotension and we need to decrease the anesthetic
3- We don't do it in every patient, just if we suspect anything happened or if the patient complains

Processed EEG and Awareness Monitoring

Several brain-function monitors based on the processed electroencephalogram (EEG) or evoked potentials have been developed to assess anesthetic depth.



BIS bispectral index scale

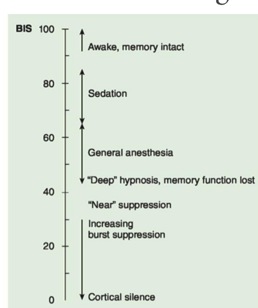
Aspect medical system

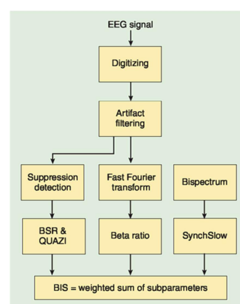
The most widely used monitor is the BIS monitor. This device integrates several parameters of an EEG into a calculated, dimensionless variable (0 to 100). BIS is a probability distribution where a measure 40 does not provide a 100% guarantee of no awareness.

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

1. BIS values between 40 and 60 purportedly indicate adequate general anesthesia for surgery
2. 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.





M-entropy module GE healthcare

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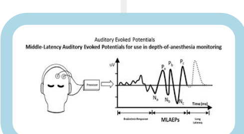

Mid-latency auditory evoked potentials MLAEPS

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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[2]	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	Nacrotrend monitor/ Monitor-Technik, Bad Bramstedt, Germany	Ordinary ECG electrode	1–2 channel EEG	Narcotrend stage D_{0-2} to C_1, which corresponds to an index of 40–60	The Narcotrend monitor classifies EEG signals into different stages of anesthesia (A = awake; B_{0-2} = sedated; C_{0-2} = light anesthesia; D_{0-2} = general anesthesia; $E_{0,1}$ = general anesthesia with deep hypnosis; $F_{0,1}$ = 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/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.
Aline autore-gressive 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 2–6 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 [1]

- 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.

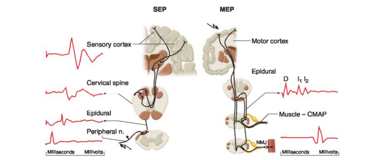

FIGURE 6–11 Neuroanatomic pathways of somatosensory-evoked potential and motor-evoked potential. The somatosensory-evoked potential (SEP) is produced by stimulation of a peripheral nerve wherein a response can be measured. The electrical volley ascends the spinal cord by the posterior columns and can 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 internuncial 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)

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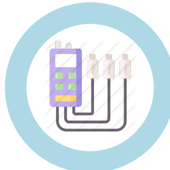

EMG is the recording of electrical activity of muscle and therefore an indirect indicator of function of the innervating peripheral nerve.
This technique is also used to identify and verify the integrity of a peripheral nerve, including cranial nerves as well as pedicle screw testing during spine surgery.
EMG is only sensitive to neuromuscular blocking agents.

Somatosensory evoked potentials (SSEP)

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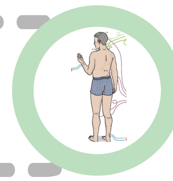

SSEP are the recording, usually at the cerebral cortex, of responses from electrically stimulated peripheral afferent nerves.
The most commonly used peripheral nerves are median, ulnar, posterior tibial, and common peroneal nerves.

Brainstem auditory evoked potentials (BAEP)

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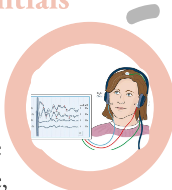

BAEP are the recording of brainstem responses to auditory stimuli.
BAEP monitors the function of the entire auditory pathway along the acoustic nerve, through the brainstem to the cerebral cortex.

Motor evoked potentials (MEP)

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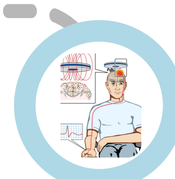
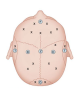


MEP is the recording obtained from electrical stimulation of the motor cortex, which elicits potentials in the spinal cord or (myogenic) potentials from the innervated muscle.
Monitors motor pathway function.

Electroencephalography (EEG)



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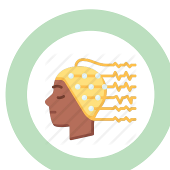
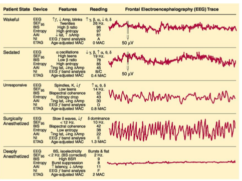


- EEG monitoring can be a useful supplement to surgery when:
  - Seizure foci need to be identified
  - The general state of cerebral metabolism needs monitoring
  - Cerebral ischemia can occur
- EEG is a standard of care in many institutions for carotid endarterectomy
- EEG is the recording of brain 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



Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG	↑ƒ, ↓ Amp, blinks	↑ γ, β, α, ↓ θ, δ	50 μV
	SEF_{95}	Twenties	26 Hz.	
	BIS	High β ratio	96	
	Entropy	High entropy	97	
	AAI	↓ lat, ↑ ΔAmp	81	
	NI	EEG ƒ band analysis	A	
	ETAG	Age-adjusted MAC	0 MAC	
Sedated	EEG	α oscillations	↓ γ, β, ↑ α, θ, δ	50 μV
	SEF_{95}	High teens	19 Hz.	
	BIS	Low β ratio	78	
	Entropy	High entropy	85	
	AAI	↑ing lat, ↓ing ΔAmp	45	
	NI	EEG ƒ band analysis	B/C	
	ETAG	Age-adjusted MAC	0.4 MAC	
Unresponsive	EEG	Spindles, K, ↓ƒ	↑ α, θ, δ	
	SEF_{95}	Low teens	14 Hz.	
	BIS	Bispectral coherence	52	
	Entropy	Entropy drop	43	
	AAI	↑ing lat, ↓ing ΔAmp	30	
	NI	EEG ƒ band analysis	D	
	ETAG	Age-adjusted MAC	0.8 MAC	
Surgically Anesthetized	EEG	Slow δ waves, ↓ƒ	δ dominance	
	SEF_{95}	< 12 Hz.	10 Hz.	
	BIS	Bispectral coherence	42	
	Entropy	Low entropy	38	
	AAI	↑ing lat, ↓ing ΔAmp	22	
	NI	EEG ƒ band analysis	E	
	ETAG	Age-adjusted MAC	1.3 MAC	
Deeply Anesthetized	EEG	BS, isoelectricity	Bursts & flat	
	SEF_{95}	< 2 Hz. (BS corrected)	2 Hz.	
	BIS	High BSR	9	
	Entropy	Burst suppression	8	
	AAI	↑ latency, ↓ ΔAmp	11	
	NI	EEG ƒ band analysis	F	
	ETAG	Age-adjusted MAC	2 MAC	

1- 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 the surgeon affect the normal pathway it will be showed in our monitor. Same goes for motor, but we stimulate from the brain area and catch the response in the peripheral muscle area. So 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

Modalities for anesthetic monitoring

Cerebral oximetry

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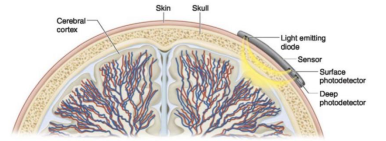


FIGURE 6–12 Principle of the INVOS® near-infrared spectroscopy technique. (Reproduced, with permission, from Rubio A, Hakami L, Münch F, Tandler R, Harig F, Weyand M: Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the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

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 be a sign of neurological events secondary to decreased cerebral oxygenation

Invasive pressure monitoring

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).

Indications [1]:

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
- significant reduction in LV compliance (ischemia/diastolic dysfunction).

Pulmonary artery Pressure

The pulmonary artery (PA) catheter is a controversial but potentially powerful tool.

Offer information about:

- cardiac filling pressures
- mixed venous oxygen saturation (Sv02)
- cardiac output (CO)
- derived parameters of cardiac performance

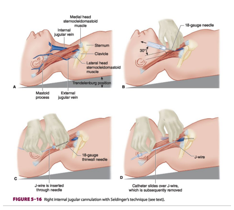
ASA consensus opinion is that “PA catheter monitoring may reduce perioperative complications if critical hemodynamic data obtained are accurately interpreted and appropriate treatment is instituted.”

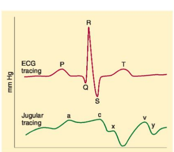
Pulmonary artery catheter:

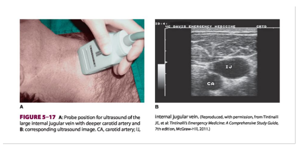
CO = SV × HR

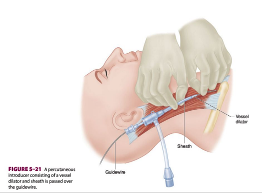
SV = CO/HR

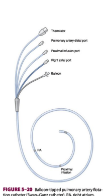
Blood pressure = CO × systemic vascular resistance (SVR)

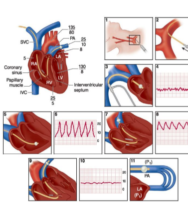


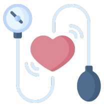








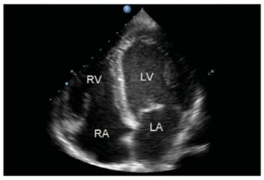




1- Gives an idea how much fluids you should give the patient, but if the heart is abnormal it will not be useful, you need to put pulmonary artery catheter.

Modalities for anesthetic monitoring

Transesophageal echocardiography (TEE [1])



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

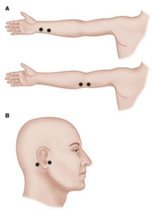
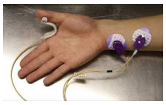


FIGURE 6–13 A: Stimulation of the ulnar nerve causes contraction of the adductor pollicis muscle. B: Stimulation of the facial nerve leads to orbicularis oculi contraction. The orbicularis oculi recovers from neuromuscular blockade before the adductor pollicis. (Reproduced, with permission, from Dorsch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

Indications

- all patients receiving intermediate- or long-acting neuromuscular blocking agents should be monitored
- assessing paralysis during rapid-sequence inductions or during continuous infusions of short-acting agents.
- can help locate nerves to be blocked by regional anesthesia.

Contraindications



- There are no contraindications to neuromuscular monitoring [2].
- Atrophied muscles in areas of hemiplegia 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.

Technique

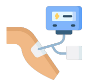
- Peripheral nerve stimulator delivers current (60- 80 mA) to a pair of either ECG silver chloride pads or subcutaneous needles placed over a peripheral motor nerve.
- The evoked mechanical or electrical response of the innervated muscle is observed.
- Although electromyography provides a fast, accurate, 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.
- Direct stimulation of muscle should be avoided.

Complications

- Complications of nerve stimulation are limited to skin irritation and abrasion at the site of electrode attachment.

1- C.I. in case of esophageal varices
2- Except if the pt has allergy to the electrodes

Modalities for anesthetic monitoring



Peripheral nerve stimulation

Modes of transmission

- Single twitch
- Train of four
- Double burst stimulation
- Post tetanic count

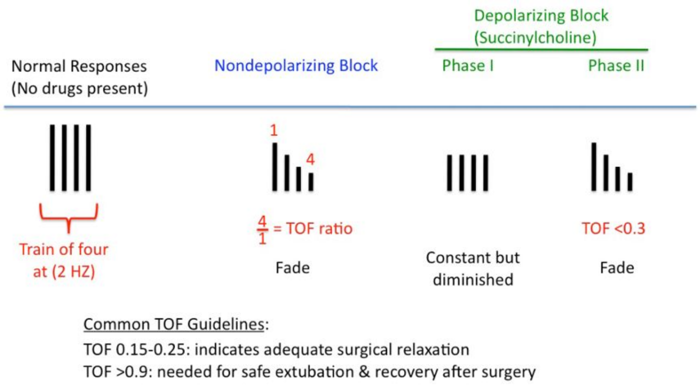
Train of four:

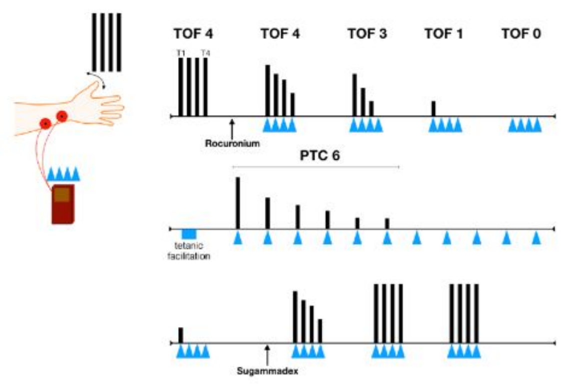
◦ denotes four successive 200-μs stimuli in 2 sec (2 Hz).
◦ The twitches in a train-of-four pattern progressively fade as nondepolarizing muscle relaxant block increases.
◦ The ratio of the responses to the first and fourth twitches is a sensitive indicator of nondepolarizing muscle paralysis.
◦ Ratio o fourth twitch over the first twitch should be greater than or equal to 90% to give the reversal (neostigmine and glycopyrrolate)
◦ 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,
- the second twitch a 90% block.

◦ Clinical relaxation usually requires 75% to 95% neuromuscular blockade





Modalities for anesthetic monitoring

Peripheral nerve stimulation

Extubation Criteria and clinical considerations

1. The diaphragm, rectus abdominis, laryngeal adductors, and orbicularis oculi muscles recover from neuromuscular blockade sooner than do the adductor pollicis

2. Other indicators of adequate recovery include sustained (≥5 s) head lift, the ability to generate an inspiratory pressure of at least −25 cm H_2O, and a forceful hand grip
3. Twitch tension is reduced by hypothermia of the monitored muscle group (6%/°C)
4. 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
5. Postoperative residual curarization remains a problem in post- anesthesia care, producing potentially injurious airway and respiratory function compromise.
6. Reversal of neuromuscular blocking agents is warranted, as is the use of intermediate acting neuromuscular blocking agents instead of longer acting drugs.

Electrolyte/Acid Base

Coagulation

Urine output

Lecture Quiz

answers: 1(C) 2(B) 3(D) 4(C)

Question 1: A 28-year-old female patient is scheduled for correction of kyphoscoliosis and insertion of Harrington rods. Which of the following intraoperative monitoring is most useful in detecting neurological injury during instrumentation of the spine?

A. Wake-up test.
B. Bispectral index.
C. Somatosensory evoked potentials.
D. Invasive blood pressure monitoring.
E. Peripheral nerve stimulation.

Question 2: A 70-year-old male patient with type II diabetes, hypertension and ischaemic heart disease is undergoing a laparotomy for carcinoma of the sigmoid colon. Which of the following monitors would be the most sensitive detector of intraoperative myocardial ischaemia?

A. Electrocardiography
B. Transesophageal echocardiography.
C. Pulmonary capillary wedge pressure measurement.
D. ECG monitoring with CM5 configuration.
E. Dipyridamole-thallium scanning.

Question 3: What is the most reliable way to ascertain correct placement of an endotracheal tube?

A. Detection of a pressure waveform on inflation
B. Direct visualization
C. Detection of breath sounds on auscultation
D. Measurement of end-tidal carbon dioxide concentration
E. Movement of the chest wall on manual inflation

Question 4: how frequent the anesthesiologist should monitor the patient during appendicitis surgery at minimum ?

A. Every hour
B. Every half hour
C. Every 5 minutes
D. During emergency the nurse have to page the anesthesiologist
E. No need, the surgeon can monitor the patient himself
F. Only in pediatric cases the anesthesiologist has to be monitoring the whole time

Explanation File

Good Luck

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