Anesthetic Monitoring

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 neuro muscular junction relaxation monitoring
- Brief introduction about invasive hemodynamic monitoring and oxygenation of the brain

Anesthetic Monitoring

Definition

What is ***Monitoring*** ?

Anesthetic Monitoring

Definition

What is ***Monitoring*** ?

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

Anesthetic Monitoring

What do you **Monitor** in a patient?

Anesthetic Monitoring

What do you **Monitor** in a patient?

Vitals

Color/skin

Wakefulness

Anesthetic Monitoring

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

Anesthetic Monitoring

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

Physical exam

Equipments (advances in technology)

Anesthetic Monitoring

What are the **Standards to follow** for **monitoring** a patient

Responsibilities?

Anesthetic Monitoring

What **determines** the **Standards of Care** for **monitoring** a patient

Basic monitoring

Advanced monitoring

Anesthetic Monitoring

What **determines** the **Standards of Care** for **monitoring** a patient

Patient/ illness

Equipments/ technology

Rules/ legislation

Anesthetic Monitoring

What **determines** the **Standards of Care** for **monitoring** a patient

Anesthesia type?

General

Regional/neuraxial

Monitored Anesthesia Care/Sedation

Anesthetic Monitoring

What is Anesthesia?

Hypnosis

Analgesia

Paralysis

Anesthetic Monitoring

What would happen for the body during anesthesia?

Neurodepression/respiratory

Cardiodepression/BP CO

Vasodilation

Low BP affects perfusion to vital organs

Low Oxygen affects metabolism of organs

Anesthetic Monitoring

Standards for Anesthetic Monitoring

American Society of Anesthesiologists®

STANDARDS FOR BASIC ANESTHETIC MONITORING

Committee of Origin: Standards and Practice Parameters

(Approved by the ASA House of Delegates on October 21, 1986, last amended on October 20, 2010, and last affirmed on October 28, 2015)

These standards apply to all anesthesia care although, in emergency circumstances, appropriate life support measures take precedence. These standards 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. This set of standards addresses only the issue of basic anesthetic monitoring, which is one component of anesthesia care. In certain rare or unusual circumstances, 1) some of these methods of monitoring may be clinically impractical, and 2) appropriate use of the described monitoring methods may fail to detect untoward clinical developments. Brief interruptions of continual† monitoring may be unavoidable. These standards are not intended for application to the care of the obstetrical patient in labor or in the conduct of pain management.

1. STANDARD I

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

1.1 Objective –

Anesthetic Monitoring

Standards for Anesthetic Monitoring

These standards

•apply to all anesthesia care 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.

•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.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

This set of standards addresses only the issue of **basic anesthetic monitoring**, which is one component of anesthesia care.

In certain rare or unusual circumstances,

1) some of these methods of monitoring may be clinically impractical, and

2) appropriate use of the described monitoring methods may fail to detect untoward clinical developments.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Brief **interruptions** of continual monitoring may be unavoidable.

Note that “**continual**” is defined as “repeated regularly and frequently in steady rapid succession” whereas “**continuous**” means “prolonged without any interruption at any time.”

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard I

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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard I

In the event 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.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard I

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.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard II

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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard II

Frequency of mandatory monitoring varies between each category, but **never exceeds five minutes.**

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard II

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.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard II

iii. The following are all specifically mandated.

1. Oxygen analyzer with a low inspired concentration limit alarm during general anesthesia
2. Quantitative assessment of blood oxygenation
3. 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**.
4. Qualitative evaluation of ventilation is required during all other care.
5. Ensure correct placement of endotracheal tube or laryngeal mask airway via expired carbon dioxide (CO_2).
6. **Alarms** for disconnects when a mechanical ventilator is used

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Standard II

iii. The following are all specifically mandated.

7. Continuous display of ECG
8. Determination of arterial **BP 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
10. The means to determine temperature must be available and should be employed when changes in temperature are anticipated or intended.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Oxygen analyzer

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 O_2, air, nitrous oxide, and/or volatile anesthetic agents.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Pulse Oximetry

- Provides quantitative analysis of the patient's saturation of hemoglobin with O2.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Carbon dioxide (CO2)

a) Inspired and expired CO_2 should be monitored.

b) Expired CO2 is frequently **displayed** through capnography with a displayed value correlating to the **peak expired CO_2** of each breath

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Carbon dioxide (CO_2)

c) **Capnography**

i) Provides qualitative and quantitative information regarding expired CO_2.

ii) Quantitatively, this is **useful to ensure the endotracheal tube is within the respiratory tract as well as to ensure adequate cardiac output.**

d) Inspired CO_2

i) Monitored to ensure that the CO_2 absorber of the anesthesia machine is adequately removing all CO_2 from the circuit.

ii) If inspired CO_2 is greater than zero, changing of the absorbent should be considered. The color of absorbent turns blue when its capacity is exhausted.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Multiple expired gas analysis

a) Allows determination of the **percent inspired and expired** of the volatile agents and nitrous oxide.

b) This allows the ability to better determine the **delivery of an adequate anesthetic without over or under dose.**

Anesthetic Monitoring

Standards for Anesthetic Monitoring

ECG

a) The minimum of three leads is to be used, although **five leads** are used for most adults.

b) 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.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

ECG

c) Five Lead ECG

i) Includes the right arm **(RA)**, **left arm (LA), right leg (RL), left leg (LL), and V.**

ii) The five lead arrangement can be used to display **I, II, III, aVR, aVL, aVF, and/or V**

d) Three lead ECG

i) Includes the **RA, LA, and LL leads and can be used to display leads I, II,and/or III**

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Figure 8-1 Normal Five Lead ECG Lead Placement

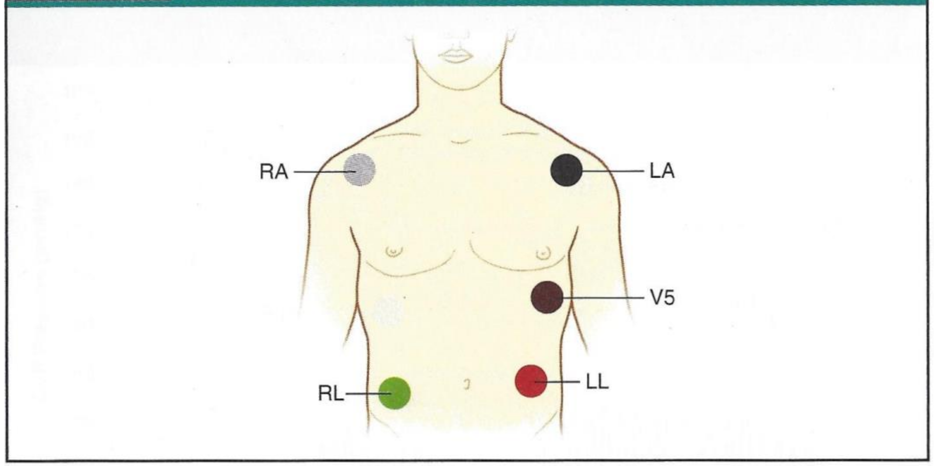
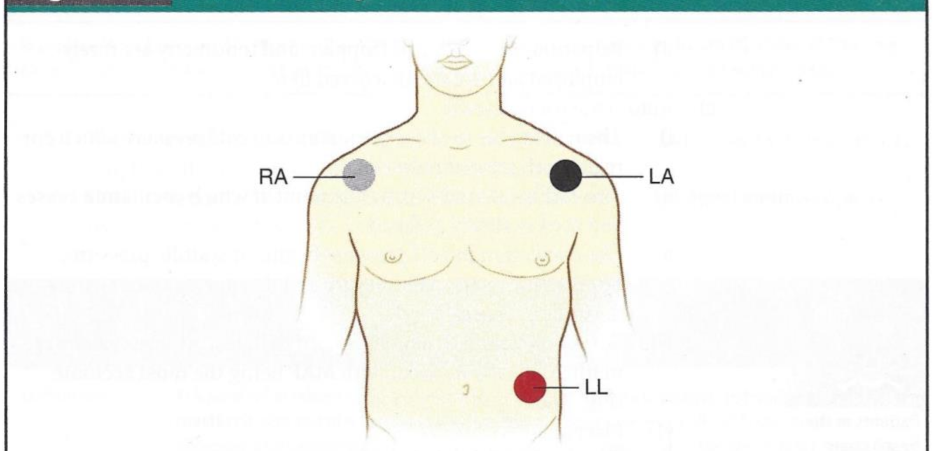


Figure 8-2 Normal Configuration of a Three Lead EKG



MONITORING

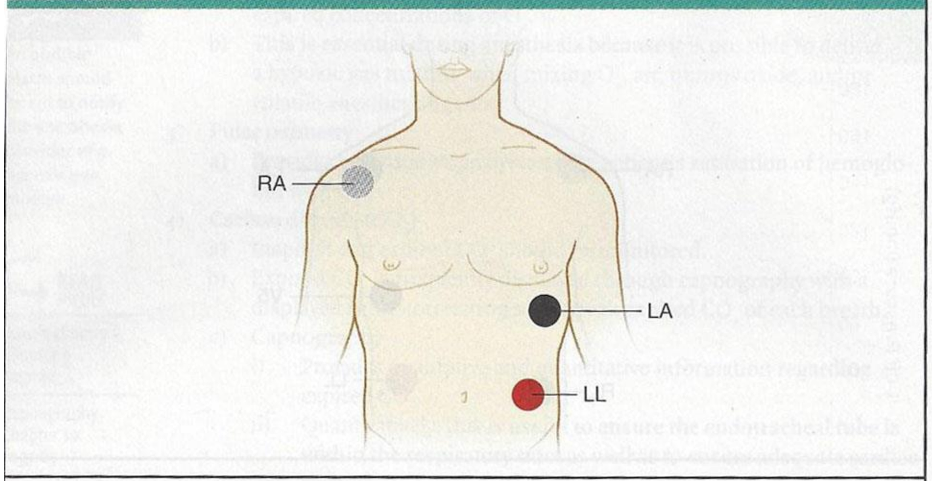
Anesthetic Monitoring

Standards for Anesthetic Monitoring

ECG

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

Figure 8-3 Modification of Three Lead ECG



Modification of the three lead ECG allows display of both leads II and V5. Lead V5 is monitored through the display of lead I in this configuration.

Anesthetic Monitoring

Standards for Anesthetic Monitoring
ECG

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

Anesthetic Monitoring

Standards for Anesthetic Monitoring
ECG

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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

7) Arterial blood pressure (BP)

a) BP can be monitored invasively or non-invasively.

b) Non-invasive methods

i. Include oscillometric cuff , and rarely palpation, ausculatation, Doppler probe.

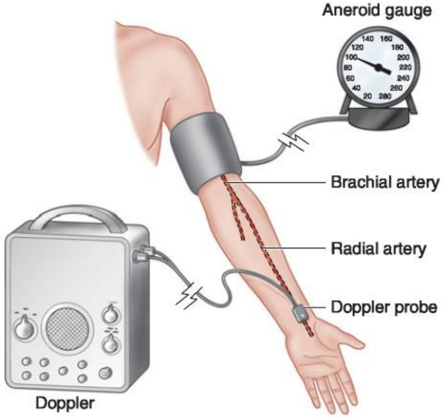


FIGURE 5–3 A Doppler probe secured over the radial artery will sense red blood cell movement as long as the blood pressure cuff is below systolic pressure. (Reproduced, with permission, from Parks Medical Electronics.)

Anesthetic Monitoring

Standards for Anesthetic Monitoring

7) Arterial blood pressure (BP)

c) 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.

iv. Invasive BP monitoring

Anesthetic Monitoring

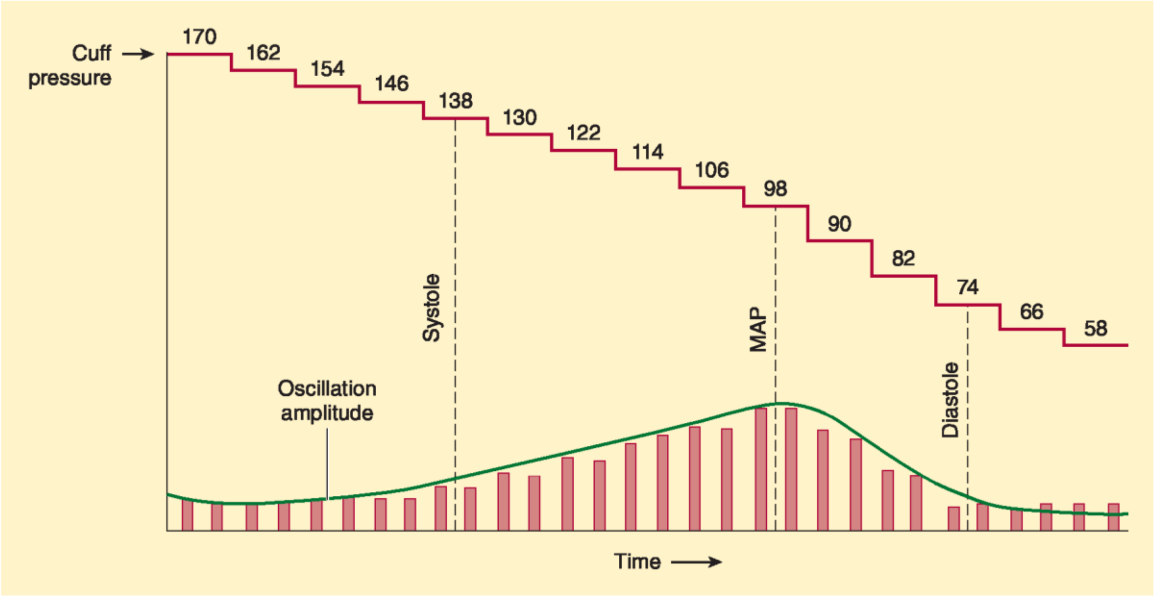


FIGURE 5–4 Oscillometric determination of blood pressure.

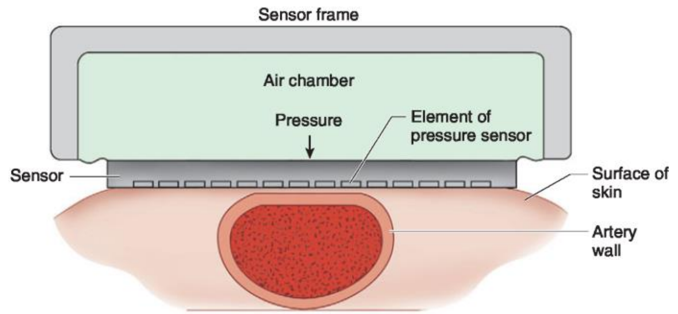


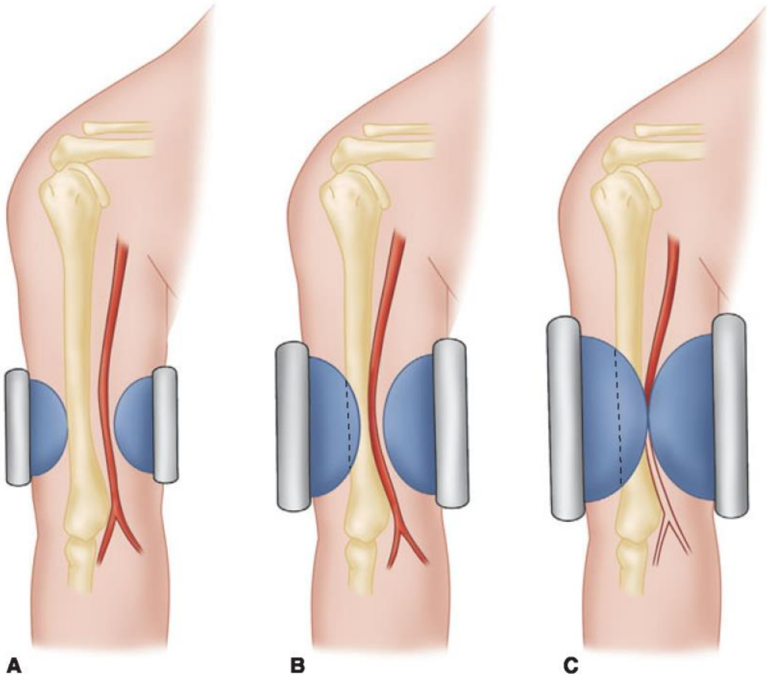
FIGURE 5–5 Tonometry is a method of continuous (beat-to-beat) arterial blood pressure determination. The sensors must be positioned directly over the artery.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Arterial blood pressure (BP)

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



Anesthetic Monitoring

Standards for Anesthetic Monitoring

Temperature

a. Temperature changes should be anticipated and expected under any general anesthetic and therefore **any general anesthetic requires temperature measurement.**

   i. Very brief procedures may be an exception, but the availability of temperature monitoring should be recorded.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

8) Temperature

b) The temperature may be measured from many locations including skin, nasopharynx, esophageal, bladder, rectal, or a pulmonary arterial catheter.

c) Core temperatures obtained from a pulmonary catheter, esophageal stethoscope, or rectal probe are preferable sources.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Pulse Oximetry

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 ($Sp0_2$)** can be calculated.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Oximetry

i) Basic Concepts

There are two main types of oximetry. **Fractional oximetry and functional oximetry**

Fractional oximetry. Oxyhemoglobin/(oxyhemoglobin + deoxyhemoglobin + methemoglobin + carboxyhemoglobin) Fractional oximetry measures the arterial oxygen saturation (SaO2)

(i) Can only be measured by an **arterial blood sample**

Functional oximetry

oxyhemoglobinl(oxyhemoglobin + deoxyhemoglobin) = SpO_2 Functional **oximetry gives you the SpO2**

Can be measured noninvasively by a **standard pulse oximeter**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

How pulse oximetry works

a) A pulse oximeter emits two wavelengths of light: red (660 nm) and infrared (940 nm)

Deoxyhemoglobin absorbs more light in the red band
Oxyhemoglobin absorbs more light in the infrared band

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

c) Photoplethysmography is then used to identify pulsatile arterial flow (alternating current [AC]) and non-pulsatile flow (direct current [DC])
d) The ratio of AC/DC at both 66o and 94o nm is measured using the equation: $(AC/DC)_{660}/(AC/DC)_{940}$

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

How pulse oximetry works

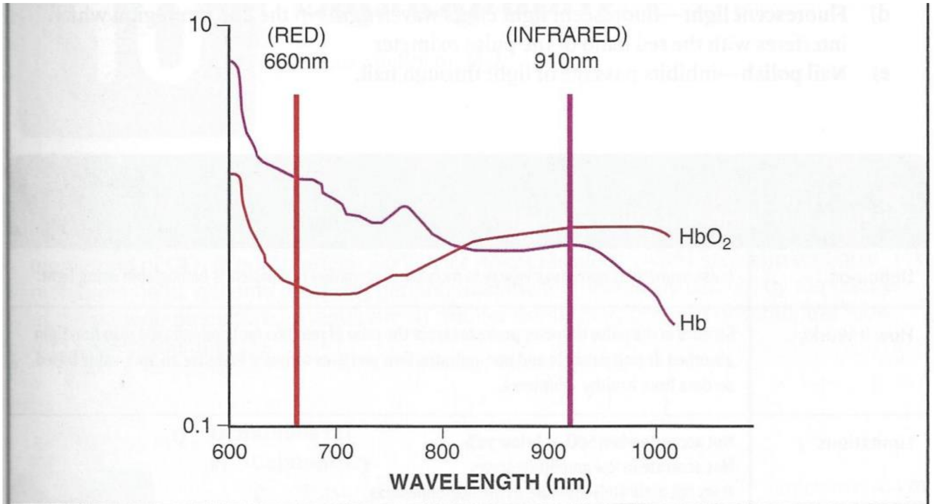
e) The pulse oximeter calculates the SpO_2 by taking the above equation and using an algorithm built into the software to derive the SpO2

•The calibration to derive SpO2 from the $(AC/DC)_{66}0/(AC/DC)_{940}$ ratio was made from studies of **healthy volunteers**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Light absorption with Oxygenated and Deoxygenated Hemoglobin



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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

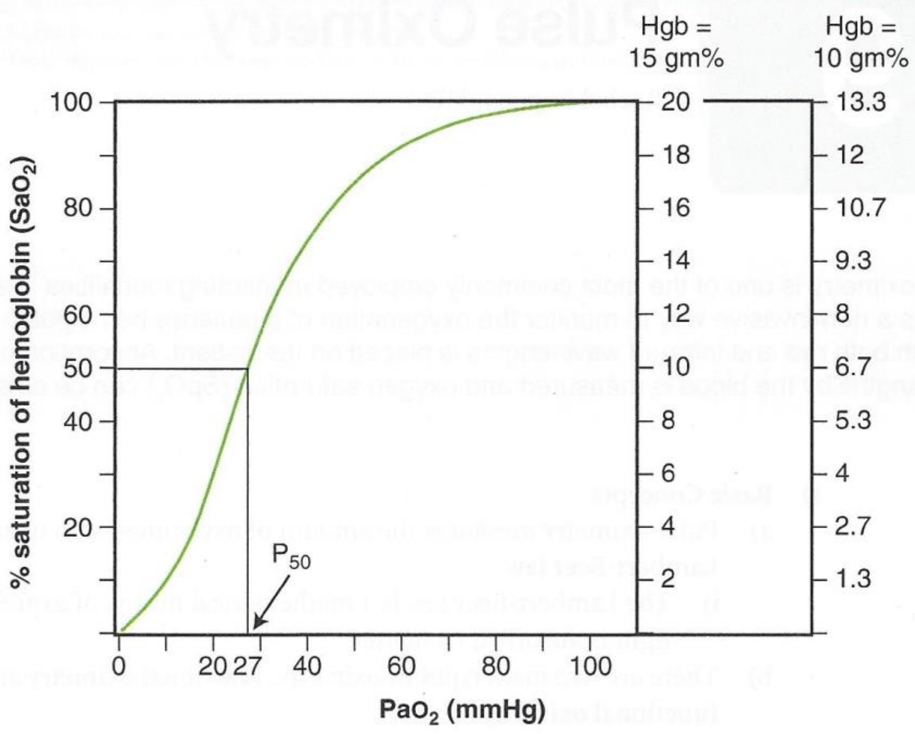
3) Accuracy of the pulse oximeter

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

i) It is not accurate below 70% because calibration of the pulse oximeter involved healthy volunteers whose SpO2 did not routinely reach levels <70%

Anesthetic Monitoring

Modalities for Anesthetic Monitoring



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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

For the relationship between SaO_2 and PaO_2

•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 SpO_2

•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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Low perfusion makes it difficult for the pulse oximeter to distinguish a true signal from background noise

Low Amplitude States
Hypovolemia
Hypothermia
Cardiac arrest
Arrhythmias
Cardiac bypass
Vasoconstriction
Tourniquet
BP cuff inflation

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

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

(2) The ferric state of iron displays a left shift on the oxygen dissociation curve and releases oxygen less easily

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Dyshemoglobinemias

- Methemoglobinemia can be caused by many drugs.
- Patients with sickle cell anemia presenting in a vasoocclusive crisis can have an inaccurate SpO2 reading
- High levels of bilirubin do not alter SpO_2 readings

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Dyshemoglobinemias

- Methemoglobinemia

Causes of Methemoglobinemia
Nitrates/Nitrites
Local anesthetics (e.g., Benzocaine or Hurricaine Spray)
Chlorates
Antimalarials
Antineoplastics
Sulfonamides
Dapsone
Metoclopramide

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Normal capnogram

a) Phase I

Initiation of expiration

CO_2 free gas from anatomic dead space

b) Phase II

Expiration of mixture of dead space and alveolar gas

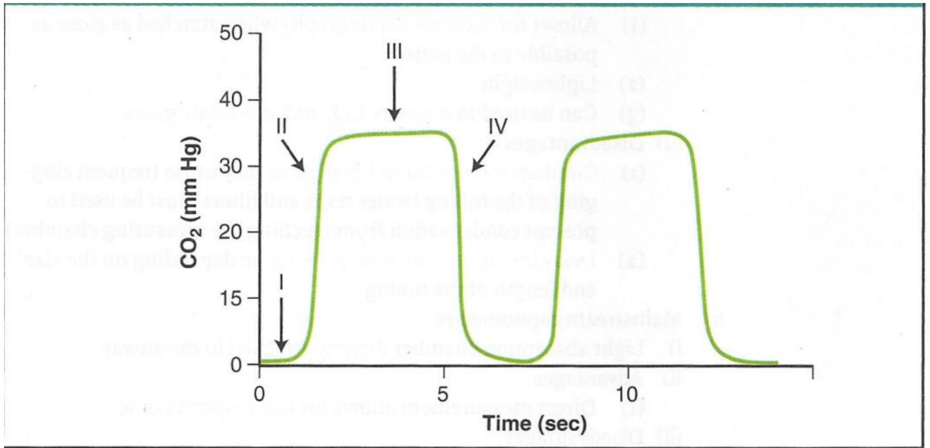
c) Phase **III**

Alveolar **plateau**

CO2-rich gas from alveoli

d) Phase IV or 0

Inspiration



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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

- **Confirmation of endotracheal intubation**

- **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 (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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Detection of patient disease

i) Causes of increased CO_2 production

- Fever
- Sepsis
- Malignant hyperthermia
- Hyperthyroidism
- Shivering

ii) Causes of decreased PETCO2

- Decreased cardiac output
- Hypovolemia
- Pulmonary embolism
- Hypothermia
- Hyperventilation

iii) Airway obstruction may be detected due to abnormalities in the capnography tracing.

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Detection of problems with the anesthetic breathing system

- Rebreathing
- Incompetent valves
- Circuit disconnect
- Circuit leak

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Interpretation of abnormal capnograms

a) **Rebreathing of CO2**

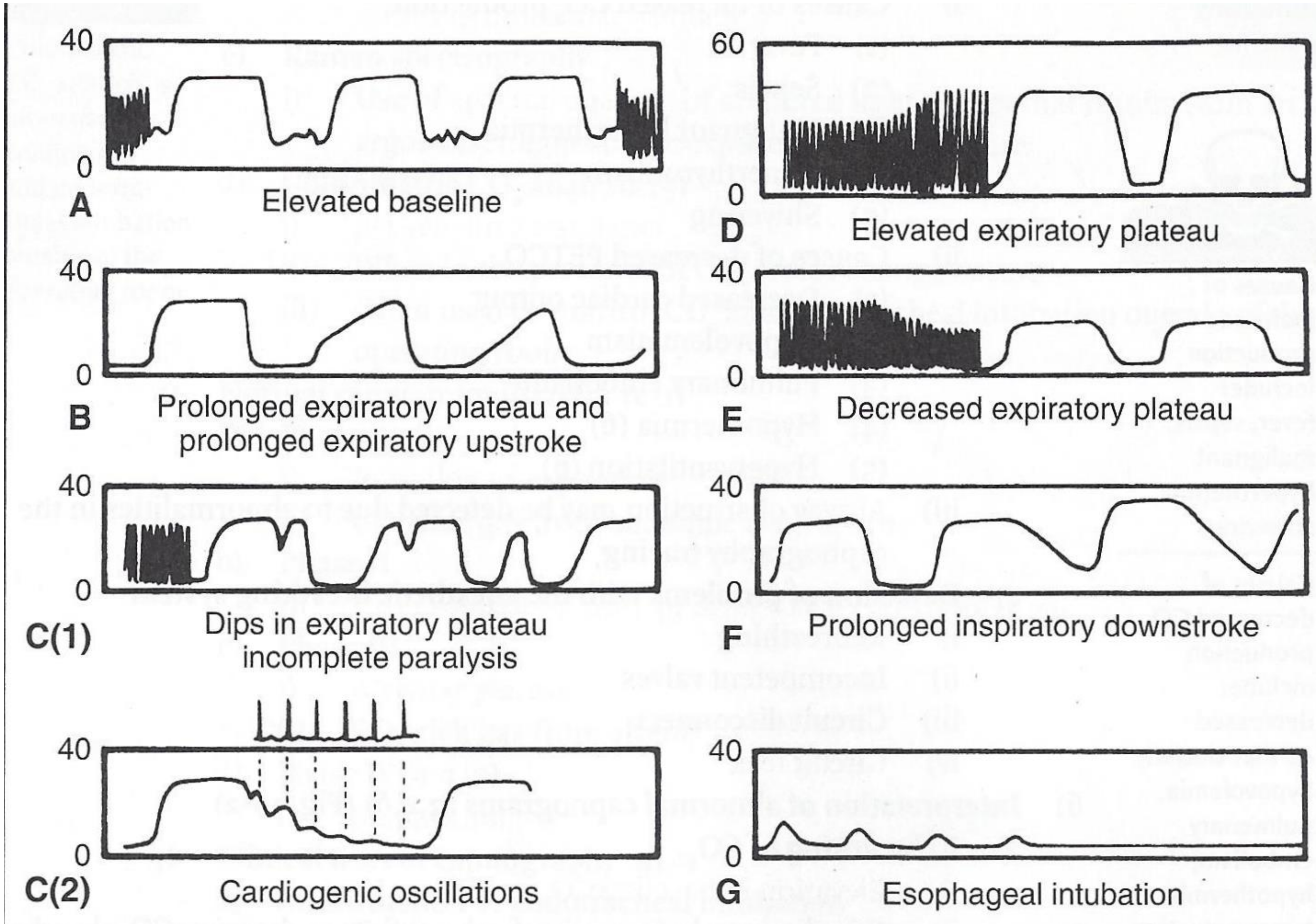
- Elevation in baseline CO_2 and Phase I
- Can eliminate by increasing fresh gas flow or changing CO2 absorber

b) **Obstruction to expiratory gas flow**

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

Anesthetic Monitoring

Standards for Anesthetic Monitoring



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Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Interpretation of abnormal capnograms

c) **Curare Cleft**

- 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

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Interpretation of abnormal capnograms

Increased CO_2

- Elevated plateau height
- Indicates increased CO_2 production states other source of CO_2 (as in laparoscopic surgery), or inadequate minute ventilation

Decreased measured CO_2

- Decreased plateau height
- May indicated decreased CO_2 production state or increased minute ventilation

Anesthetic Monitoring

Standards for Anesthetic Monitoring

Clinical uses of capnography

Interpretation of abnormal capnograms

Incompetent inspiratory valve

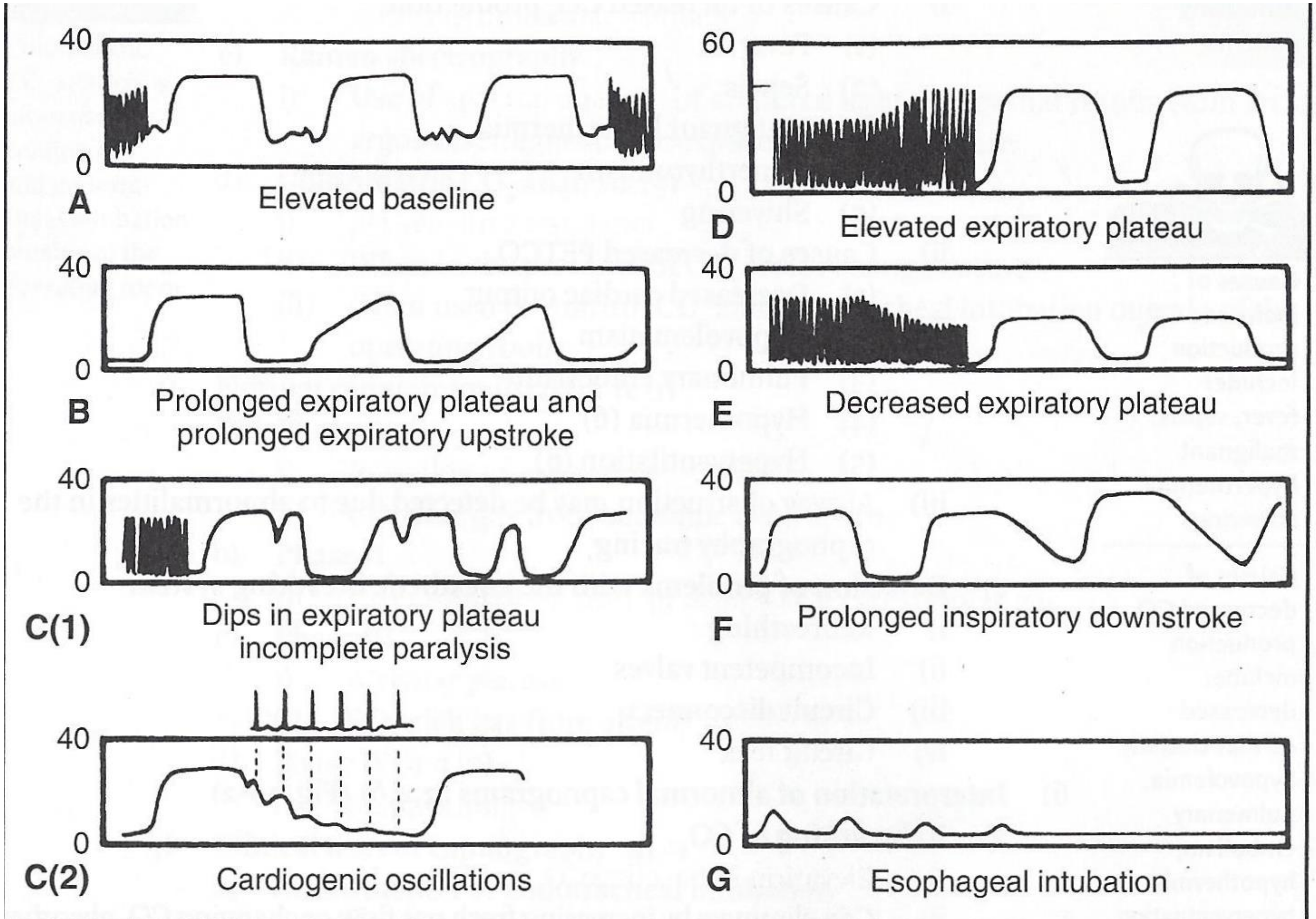
- Prolonged Phase III with elevation of baseline CO_z and plateau height
- Results in rebreathing
- May be difficult to detect without simultaneous analysis of flow waveforms

Esophageal intubation

- Initial presence of CO2 followed by no CO2

Anesthetic Monitoring

Standards for Anesthetic Monitoring



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Anesthetic Monitoring

Modalities for Anesthetic Monitoring

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

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.**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

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**.

Awareness with recall associated with pain is estimated to occur in 0.01% to 0.03% of cases.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

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
- chronic use of central nervous system depressants
- younger age
- obesity
- inadequate or misused anesthesia delivery systems

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

- 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.**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

d) Detecting episodes of intra-operative awareness

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).

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

Prevention or vigilance for detecting intraoperative awareness

a) 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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

Prevention or vigilance for detecting intraoperative awareness

b) 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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

Prevention or vigilance for detecting intraoperative awareness

b) Monitor processed EEG signals

Depth of anesthesia monitors

Several brain-function monitors based on the processed electroencephalogram

(EEG) or evoked potentials have been developed to assess anesthetic depth.

i) **BIS (Aspect Medical Systems). The most widely used monitor is the BIS monitor. This device integrates several parameters of an EEG into a calculated, dimensionless variable (o to 10o).**

ii) 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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

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.

i) **The term bispectral applies because it incorporates both power and phase spectrums of an EEG into the calculated 0 to 100 value.**

ii) **BIS values between 40 and 60 purportedly indicate adequate general anesthesia for surgery, and values below 40 indicate a deep hypnotic state. Targeting a range of BIS values between 40 and 60 is marketed to help prevent anesthesia awareness while allowing for minimization the anesthetic dose.**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

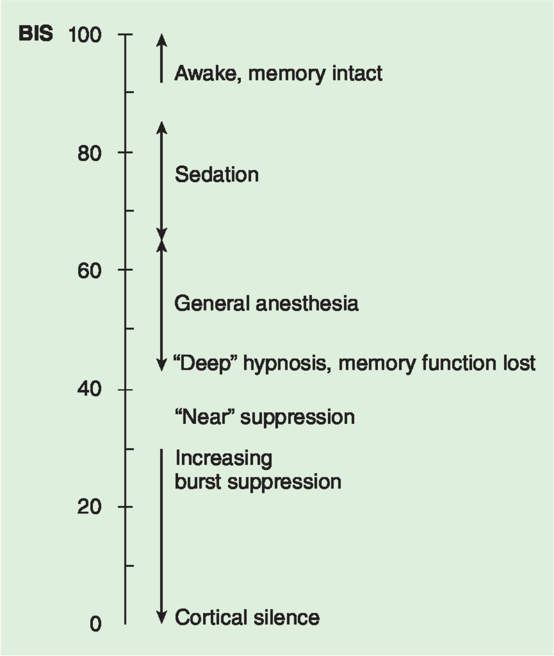


FIGURE 6–10 The Bispectral Index Scale (BIS versions 3.0 and higher) is a dimensionless scale from 0 (complete cortical electroencephalographic suppression) to 100 (awake). BIS values of 65–85 have been recommended for sedation, whereas values of 40–65 have been recommended for general anesthesia. At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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Processed EEG and Awareness Monitoring

M-Entropy Module (GE-Healthcare). 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). This method is thought to be an alternative to the use of EEG monitoring.

MLAEP are electroencephalographic responses to auditory stimuli.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

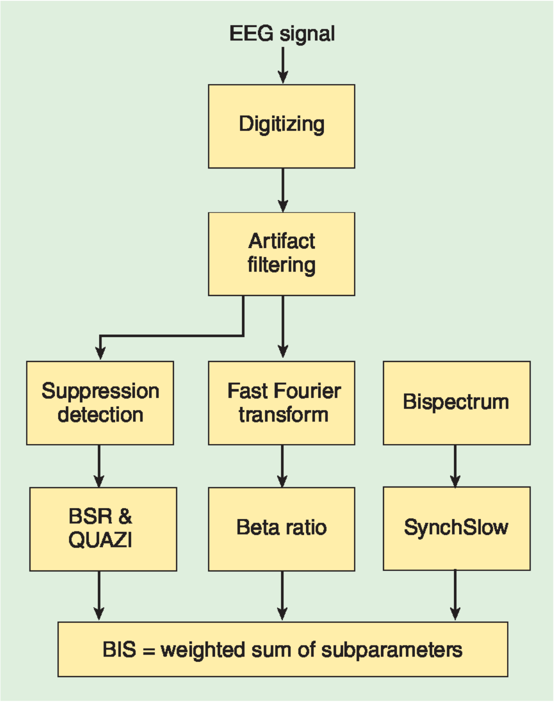


FIGURE 6–9 Calculation of the Bispectral Index. EEG, electroencephalogram; BSR, burst suppression ratio; BIS, Bispectral Index Scale. (Reproduced, with permission, from Rampil IJ: A primer for EEG signal processing in anesthesia. Anesthesiology 1998;89:980.)

Anesthetic Monitoring

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

Pro

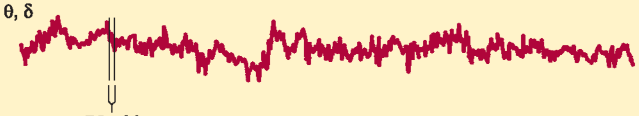
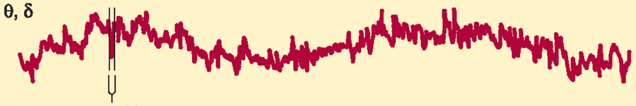
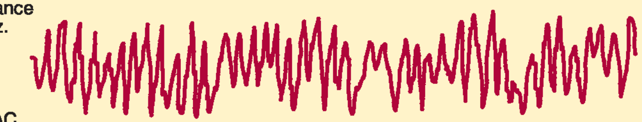
Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG SEF_{95} BIS Entropy AAI NI ETAG	↑*f*, ↓ Amp, blinks Twenties High β ratio High entropy ↓ lat, ↑ ΔAmp EEG *f* band analysis Age-adjusted MAC	↑ γ, β, α, ↓ θ, δ 26 Hz. 96 97 81 A 0 MAC	
Sedated	EEG SEF_{95} BIS 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, θ, 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} BIS Entropy AAI NI ETAG	BS, isoelectricity < 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; SEF_{95}, spectral edge frequency below which 95% of the EEG frequencies reside; Spindles, sleep spindles. (Reproduced, with permission, from Mashour GA, Orser BA, Avidan MS: Intraoperative awareness: from neurobiology to clinical practice. Anesthesiology 2011;114:1218.)

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and Anesthetic Management

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

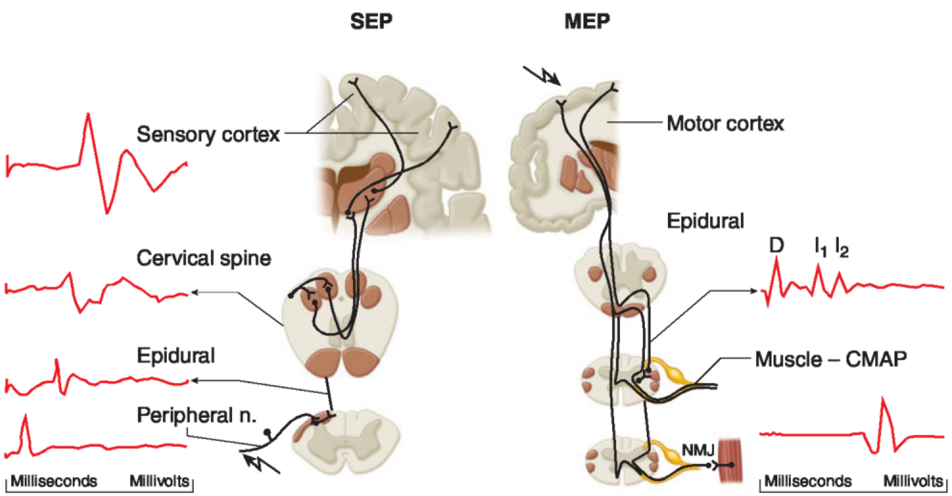


FIGURE 6–11 Neuroanatomic pathways of somatosensory-evoked potential and motor-evoked potential. The somatosensory-evoked potential (SEP) is produced by stimulation of a peripheral nerve wherein a response can be measured. The electrical volley ascends the spinal cord by the posterior columns and can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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and Anesthetic Management

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and
Anesthetic Management

•**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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and
Anesthetic Management

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 brain stem to the cerebral cortex.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and Anesthetic Management

- 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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and Anesthetic Management

Electroencephalography (EEG)

i) 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

ii) EEG is a standard of care in many institutions for carotid endarterectomy.

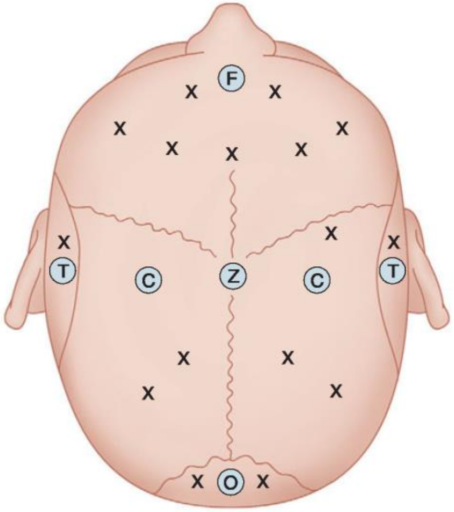


FIGURE 6–7 International 10–20 system. Montage letters refer to cranial location. F, frontal; C, coronal; T, temporal; O, occipital; Z, middle.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Neurophysiologic Monitoring and Anesthetic Management

Electroencephalography (EEG)

iii) EEG is the recording of brain electrical activity and is highly dependent on anesthetic depth.

(I) 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.

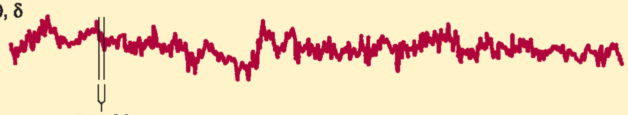
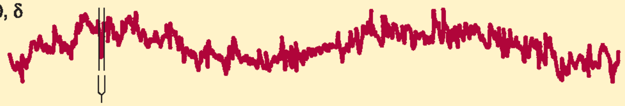
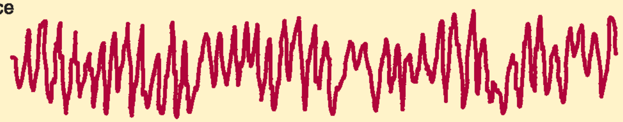
Patient State	Device	Features	Reading	Frontal Electroencephalography (EEG) Trace
Wakeful	EEG	↑*f*, ↓ Amp, blinks	↑ γ, β, α, ↓ θ, δ	
	SEF_{95}	Twenties	26 Hz.	
	BIS	High β ratio	96	
	Entropy	High entropy	97	
	AAI	↓ lat, ↑ ΔAmp	81	
	NI	EEG *f* band analysis	A	
	ETAG	Age-adjusted MAC	0 MAC	
Sedated	EEG	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	
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	

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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

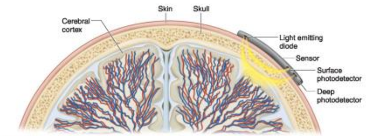


FIGURE 6–12 Principle of the INVOS® near-infrared spectroscopy technique. (Reproduced, with permission, from Rubio A, Hakami L, Münch F, Tandler R, Harig F, Weyand M: Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the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

CEREBRAL OXIMETRY

Cerebral oximetry uses near infrared spectroscopy (NIRS).

Using reflectance spectroscopy near infrared light is emitted by a probe on the scalp

Receptors are likewise positioned to detect the reflected light from both deep and superficial structures.

As with pulse oximetry, oxygenated and deoxygenated hemoglobin absorb light at different frequencies.

Likewise, cytochrome absorbs infrared light in the mitochondria.

The NIRS saturation largely reflects the absorption of venous hemoglobin, as it does not have the ability to identify the pulsatile arterial component.

Regional saturations of less than 40% on NIRS measures, or changes of greater than 25% of baseline measures, may herald neurological events secondary to decreased cerebral oxygenation.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

CEREBRAL OXIMETRY

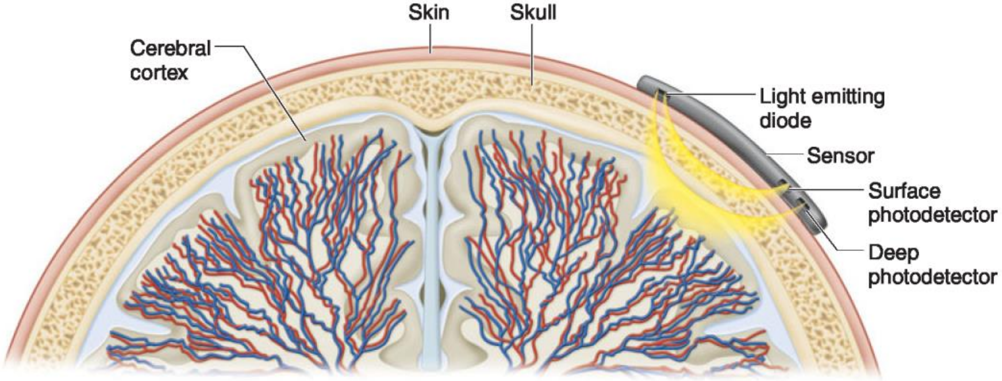


FIGURE 6–12 Principle of the INVOS® near-infrared spectroscopy technique. (Reproduced, with permission, from Rubio A, Hakami L, Münch F, Tandler R, Harig F, Weyand M: Noninvasive control of adequate cerebral oxygenation during low-flow antegrade selective cerebral perfusion on adults and infants in the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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Invasive pressure monitoring

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

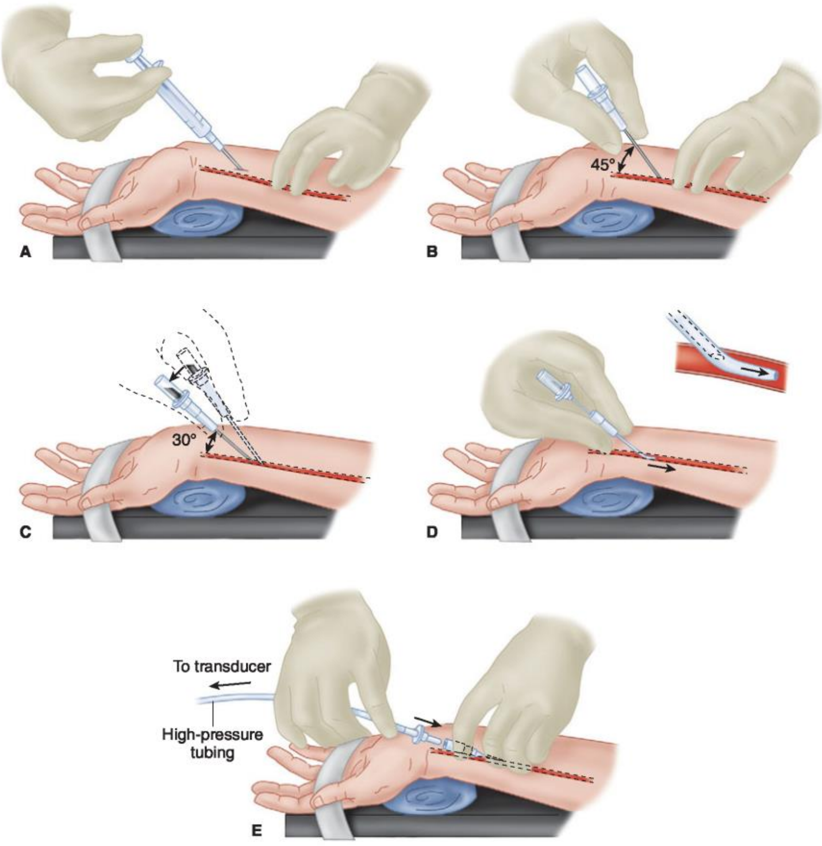


FIGURE 5–7 Cannulation of the radial artery. **A:** Proper positioning and palpation of the artery are crucial. After skin preparation, local anesthetic is infiltrated with a 25-gauge needle. **B:** A 20- or 22-gauge catheter is advanced through the skin at a 45° angle. **C:** Flashback of blood signals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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

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).

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).

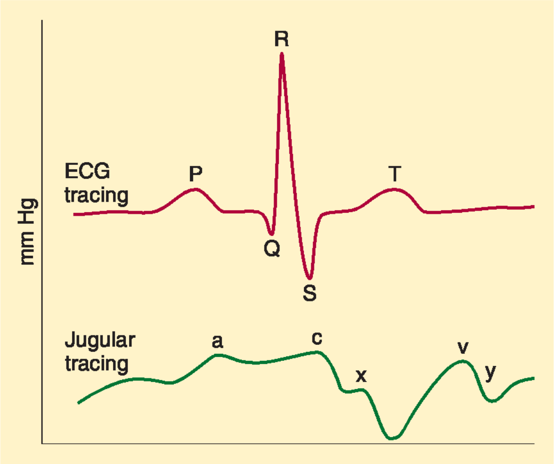


FIGURE 5–19 The upward waves (*a*, *c*, *v*) and the downward descents (*x*, *y*) of a central venous tracing in relation to the electrocardiogram (ECG).

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

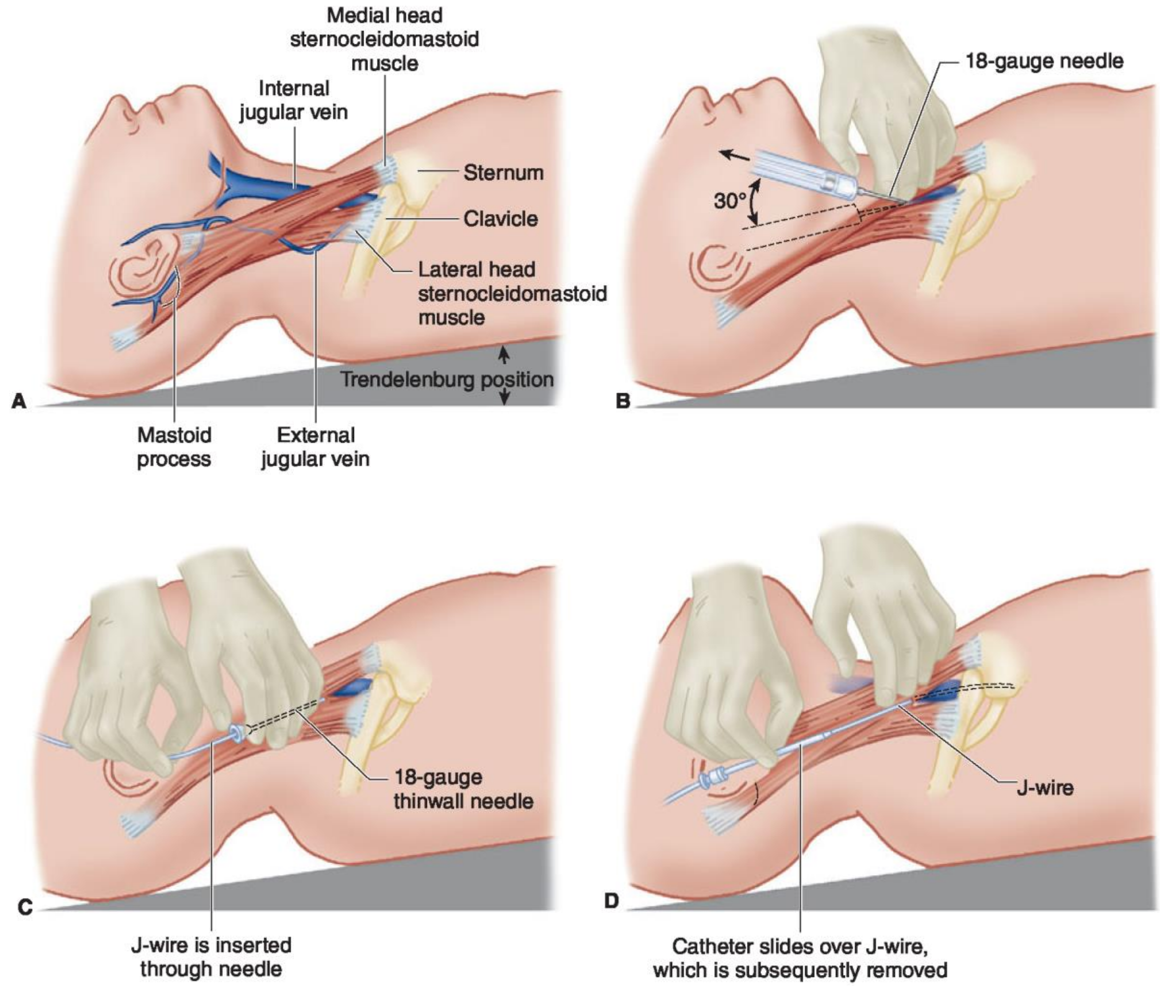


FIGURE 5–16 Right internal jugular cannulation with Seldinger's technique (see text).

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Invasive pressure monitoring

Central Venous Pressure

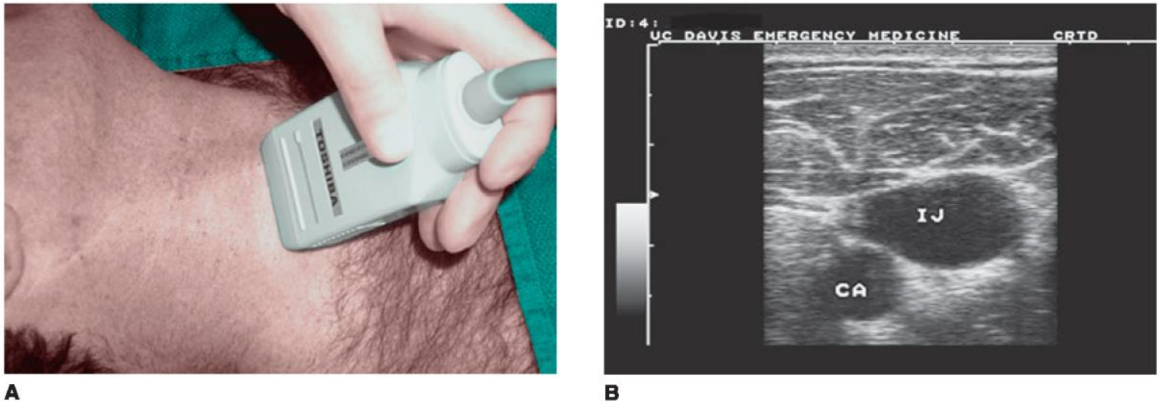


FIGURE 5–17 **A**: Probe position for ultrasound of the large internal jugular vein with deeper carotid artery and **B**: corresponding ultrasound image. CA, carotid artery; IJ, internal jugular vein. (Reproduced, with permission, from Tintinalli JE, et al: *Tintinalli's Emergency Medicine: A Comprehensive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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Invasive pressure monitoring

Pulmonary artery Pressure

The pulmonary artery (PA) catheter is a controversial but potentially powerful tool, offering information about cardiac filling pressures, cardiac output (CO), derived parameters of cardiac performance, and mixed venous oxygen saturation ($Sv0_2$).

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Invasive pressure monitoring

Pulmonary artery Pressure

$$CO = SV \times HR$$

$$SV = CO/HR$$

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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Invasive pressure monitoring

Pulmonary artery Pressure

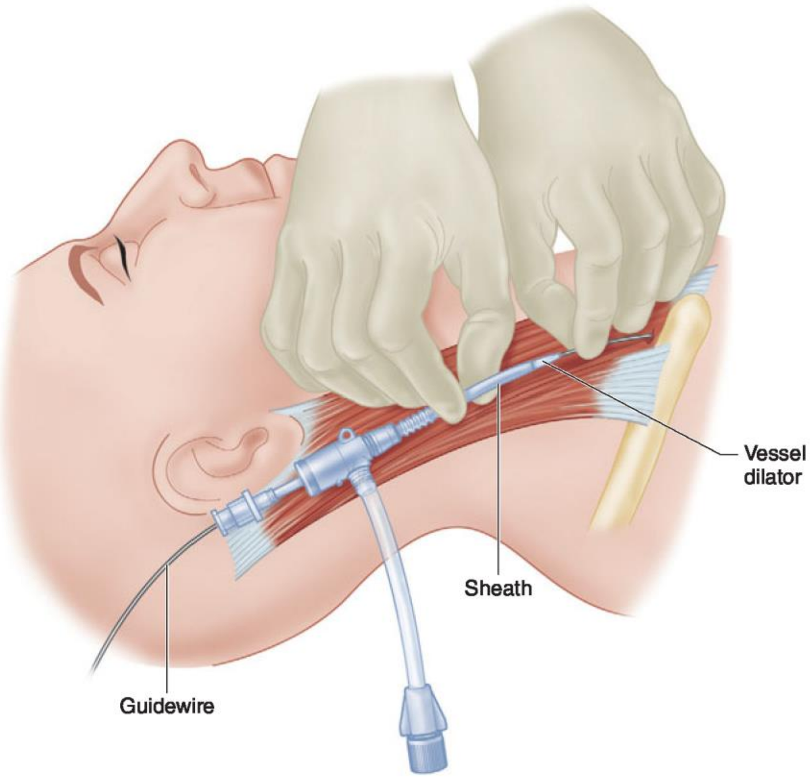


FIGURE 5–21 A percutaneous introducer consisting of a vessel dilator and sheath is passed over the guidewire.

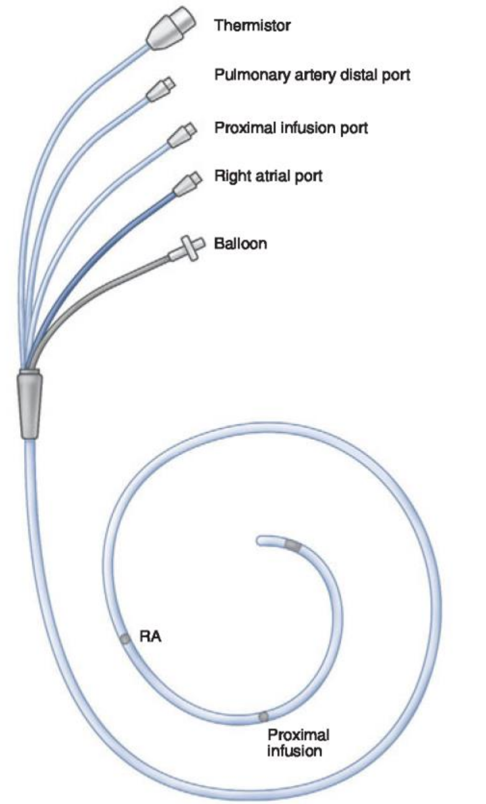


FIGURE 5–20 Balloon-tipped pulmonary artery flotation catheter (Swan–Ganz catheter). RA, right atrium.

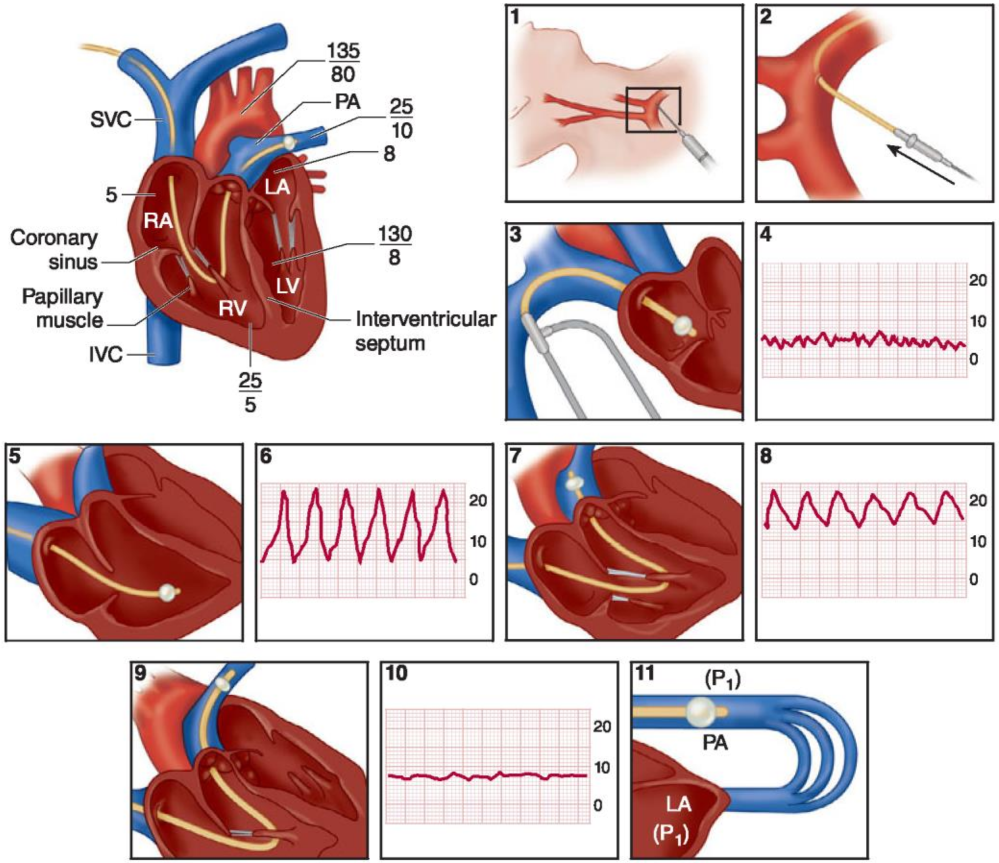


FIGURE 5–22 Although its utility is increasingly questioned, pulmonary artery catheters continue to be a part of perioperative management of the cardiac surgery patient. Following placement of a sheath introducer in the central circulation (panels 1 and 2), the pulmonary artery catheter is floated. Central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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

TransEsophageal Echocardiography

Transesophageal echocardiograpy (TEE) 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 <u>a mainstay in intraoperative cardiac anesthesia and its utility is extending into other areas as well.</u>

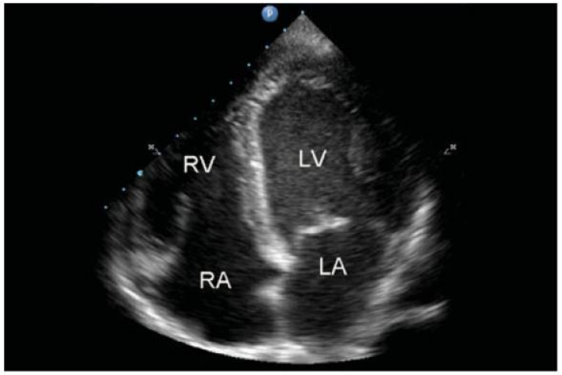


FIGURE 5–27 Normal apical four-chamber view. RV, right ventrical; LV, left ventricle; RA, right atrium; LA, left atrium. (Reproduced, with permission, from Carmody KA, et al: *Handbook of Critical Care and Emergency Ultrasound*. McGraw-Hill, 2011.)

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Contraindications

There are no contraindications to neuromuscular monitoring, although certain sites may be precluded by the surgical procedure.

Additionally, atrophied muscles in areas of hemiplegia or nerve damage may appear refractory to neuromuscular blockade secondary to the proliferation of receptors.

Determining the degree of neuromuscular blockade using such an extremity could lead to potential overdosing of competitive neuromuscular blocking agents.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

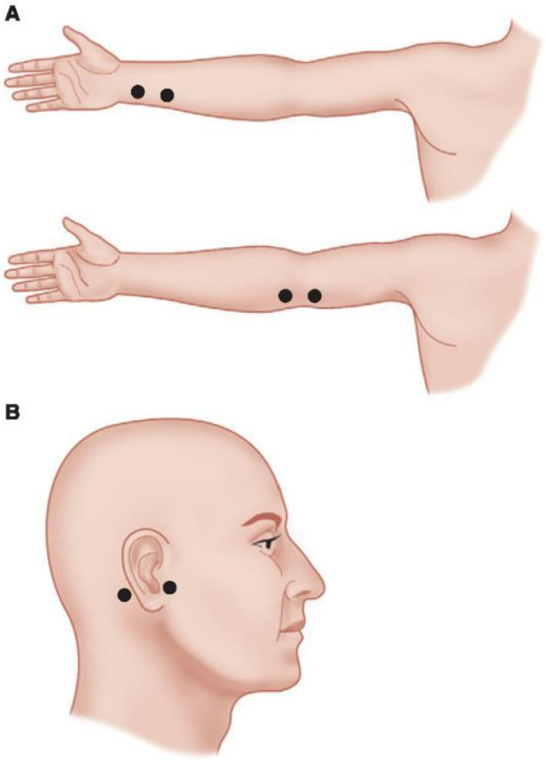


FIGURE 6–13 **A:** Stimulation of the ulnar nerve causes contraction of the adductor pollicis muscle. **B:** Stimulation of the facial nerve leads to orbicularis oculi contraction. The orbicularis oculi recovers from neuromuscular blockade before the adductor pollicis. (Reproduced, with permission, from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

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Techniques & Complications

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Techniques & Complications

- 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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Clinical Considerations

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

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

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

Increasing block results in decreased evoked response to stimulation.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Clinical Considerations

- **Train-of-four stimulation** denotes four successive 200-µs stimuli in 2 sec (2 Hz).
- The twitches in a train-of-four pattern progressively fade as nondepolarizing muscle relaxant block increases. The ratio of the responses to the first and fourth twitches is a sensitive indicator of nondepolarizing muscle paralysis. Ratio 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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

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

- Double-burst stimulation (DBS) represents two variations of tetany that are less painful to the patient.
- The DBS $_{3,3}$ pattern of nerve stimulation consists of three short (200-μs) high-frequency bursts separated by 20 ms intervals (50 Hz) followed 750 ms later by another three bursts.
- DBS $_{3,2}$ consists of three 200-μs impulses at 50 Hz followed 750 ms later by two such impulses.
- DBS is more sensitive than train-of-four stimulation for the clinical (ie, visual) evaluation of fade.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

- **Clinical Considerations**

- **Single Twitch**
- **Train of four**
- **Double Burst Stimulation**
- **Post Tetanic Count**

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Clinical Considerations

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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Clinical Considerations

- The diaphragm, rectus abdominis, laryngeal adductors, and orbicularis oculi muscles recover from neuromuscular blockade sooner than do the adductor pollicis.
- Other indicators of adequate recovery include sustained (≥5 s) head lift, the ability to generate an inspiratory pressure of at least –25 cm H_2O, 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.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

PERIPHERAL NERVE STIMULATION

Clinical Considerations

Postoperative residual curarization remains a problem in post-anesthesia care, producing potentially injurious airway and respiratory function compromise.

Reversal of neuromuscular blocking agents is warranted, as is the use of intermediate acting neuromuscular blocking agents instead of longer acting drugs.

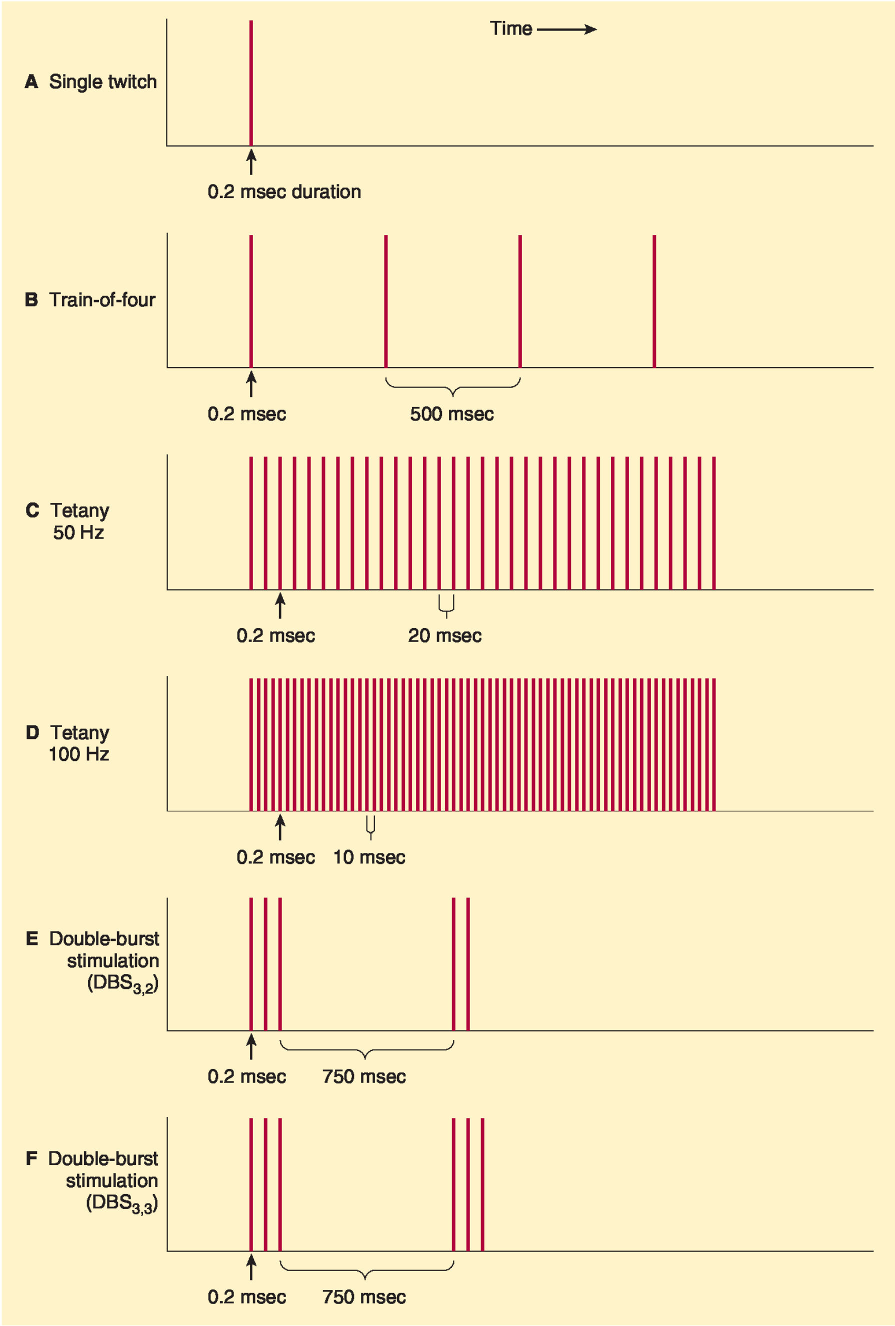


FIGURE 6–14 Peripheral nerve stimulators can generate various patterns of electrical impulses.

Anesthetic Monitoring

Modalities for Anesthetic Monitoring

Electrolytes/Acid Base

Coagulation