Anesthesia monitoring systems
Objectives:

Not given

Please go back to the lecture, because not all slides are included here, deletion was due to: "It’s not important” Doctor said.
Patient Monitoring and Management:

- **Things you measure** (physiological measurement, such as BP or HR)
- **Things you observe** (e.g. observation of pupils)
- **Planning to avoid trouble** (e.g. planning induction of anesthesia or planning extubation)
- **Referring diagnoses** (e.g. unilateral air entry may mean endobronchial intubation)
- **Planning to get out of trouble** (e.g. differential diagnosis and response algorithm formulation). Need to solve the complications

Monitoring in the Past:

- Visual monitoring of respiration and overall clinical appearance
- Finger on pulse
- Blood pressure (sometimes)
Why anesthesia monitoring is important:

- The most important and serious side effect of anesthetic drugs is depression of respiration and the cardiovascular system.
- Occur at "therapeutic" doses
- Severe depression of either respiration or the cardiovascular system is life-threatening.

Standardized basic monitoring requirements (guidelines) from the ASA (American Society of Anesthesiologists):

<table>
<thead>
<tr>
<th>STANDARD I</th>
<th>STANDARD II</th>
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<tbody>
<tr>
<td>Qualified anesthesia personnel shall be presented in the room throughout</td>
<td>During all anesthetics, the patient’s oxygenation, ventilation, circulation</td>
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<tr>
<td>the conduct of all general anesthetics, regional anesthetics and monitored</td>
<td>and temperature shall be continually evaluated. Oxygenation: cellular level,</td>
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Basic Monitoring:

- **Oxygenation, ventilation, circulation, temperature:** should be preform for all patients
- **Cardiac:** Blood Pressure, Heart Rate, ECG
  - ECG: Rate, ST Segment (ischemia), Rhythm
- **Respiratory:** Airway Pressure, Capnogram, Pulse Oximeter, Spirometry, Visual Cues
- **Temperature** [pharyngeal, axillary, esophageal, etc.]
- **Urine output** (if Foley catheter has been placed)
- **Nerve stimulator** [face, forearm] (if relaxants used)
- **ETT cuff pressure** (keep < 20 cm H$_2$O). Because pressure ischemia.
- **Auscultation** (esophageal or precordial stethoscope)
- Visual surveillance of the anesthesia workspace and some exposed portion of the patient

Visual Surveillance:

- **Anesthesia machine / workspace checkout**
- **Patient monitor numbers and waveforms**
- **Bleeding/coagulation** (e.g., are the surgeons using a lot of suction or sponges?)
- **Diaphoresis / movements / grimaces**
  - Excessive sweating means MI
- **Line quality** (is my IV reliable?)
- **Positioning safety review** like pressure ulcer
- **Respiratory pattern** (e.g. tracheal tug, accessory muscle use etc.)
Low Tech Patient Monitoring:

In areas have no adequate monitoring devices
- Manual blood pressure cuff
- Finger on the pulse and forehead
- Monaural stethoscope (heart and breath sounds)
- Eye on the rebreathing bag (spontaneously breathing patient)
- Watch respiratory pattern
- Watch for undesired movements
- Look at the patient’s face
  - color OK?
  - diaphoresis present?
  - pupils

Special Monitoring:

Alarms: Purpose: Alarms serve to alert equipment operators that some monitored variable or combination of variables is outside some region

- Pulmonary artery lines (Swan Ganz)
- Transesophageal echocardiography
- Intracranial pressure (ICP) monitoring
- Electrophysiological CNS monitoring
- Renal function monitoring (indices)
- Coagulation monitoring (e.g. ACT, TEG)
- Acid-base monitoring (ABGs)
- Monitoring depth of anesthesia
Cardiac monitoring:

- Arterial blood pressure: direct and indirect or invasive or non invasive
  - Non invasive: blood pressure cuff
  - Invasive: use cannula, radial artery is most cannulated. It allows continuous beat-to-beat blood pressure measurements.
    - Direct blood pressure measurement involves placing a catheter in an artery and connecting it to a transducer via a fluid-filled line.
    - Tubing should be narrower and stiffer. No bubbles in the system. The transducer is connected to an amplifier and display unit.
    - Shows the waveform, systolic/diastolic/mean pressures calculated from the waveform.
    - The shape of the waveform gives useful information about the state of the circulation, in particular the peripheral resistance.
    - Indirect blood pressure involves inflating a cuff around the limb and monitoring the blood flow in the limb distal to the artery.

Indications:
- Elective hypotension
- Anticipation of wide intra-operative blood pressure swings and blood gases
- (ENT surgery and neurosurgery), aortic aneurysm, frequent ABG

Contraindications:
- Catheterization should be avoided in arteries without documented adequate collateral blood flow.
- Indirect: best to be avoided in patient vascular abnormalities (A-V fistula).
Electrocardiogram:

- The electrocardiogram only monitors the electrical activity of the heart and the heart rate.
- Tell nothing about the mechanical function of the heart or the state of the circulation.
- Essential for diagnosis and treatment of arrhythmias.

Artifacts in ECG Monitoring:

- Loose electrodes or broken leads
- Misplaced leads
- Wrong lead system selected
- Emphysema, pneumothorax, pericardial effusion
- Shivering or restlessness
- Respiratory variation and movement
- Monitor Pulse Oximetry, Invasive ABP
Central venous catheterization:

- Indicated for monitoring CVP for fluid management (Hypovolemia, shock)
- Infusion of drugs
- Infusion of TPN
- Aspiration of air embolism
- Insertion of pacemaker
- Giving venous access in pt with poor peripheral vein
- Access for insertion of pulmonary artery catheter
- Usually we choose the right internal jugular vein

**Contraindicated in:**

1. Renal cell tumor extended to RT ventricle
2. PT with anticoagulation
3. Ipsilateral carotid end-arterectomy

**Complications:**

- Air embolism
- Infection
- Thrombus embolism
- Dysrhythmia
- Hematoma
- Pneumothorax, hemothorax
- Cardiac tamponade
- Trauma to nearby tissue
Pulmonary artery catheter:

- Indicated to monitor CO, PAP, SVR, mixed venous oxygenation
- Contraindicated:
  1. Complete LBBB
  2. Sever arrhythmia

**IMP: numbers**

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*Entry of the PA catheter into the pulmonary artery is recognized by a change in diastolic pressure. The systolic pulmonary artery pressure is usually equivalent to right ventricular systolic pressure. Therefore, normal pulmonary artery systolic pressure is between 15-30 mmHg, whereas normal diastolic pulmonary artery pressure is between 5-15 mmHg. The mean pulmonary artery pressure (MPAP) ranges between 10-20 mmHg.*
Respiratory system.

- **Pulse oximeter:**
  - combines the principles of oximetry and plethysmography to noninvasively measure oxygen saturation in arterial blood.
  - The pulse oximeter probe contains two light emitting diodes at wavelengths of 940nm and 660 nm.
  - Oxygenated and reduced hemoglobin differ in light absorption (940 and 660 nm respectively).
  - Thus the change in light absorption during arterial pulsation is the basis of oximetry determination.
  - The ratio of the absorption at the two wavelengths is analyzed by a microprocessor to record the oxygen saturation.

- Pulse Oximeter Wavelengths: Red (660 nm)
  - absorbed by unoxygenated hemoglobin

- Near infrared (940 nm)
- absorbed by oxygenated hemoglobin

False Readings:
- Nail polish
- Intravenous dyes
- Diminished pulse
- Movement of finger
- Ambient light
Abnormal Hemoglobin:

- Carboxyhemoglobin: false high reading in carbon monoxide patients
- Methemaglobin: reads 85% regardless of actual saturation
- Fetal hemoglobin: little effect on pulse oximetry

A normal capnography demonstrating the three phases of expiration:
- phase A—dead space. No gas exchange
- Phase B—mixture of dead space and alveolar gas.
- Phase C—alveolar gas plateau.
Capnometry:
- Is the measurement of end-tidal carbon dioxide tension.
- This provides valuable information to the anesthesiologist.
- The presence of end tidal CO2 aids in confirming endotracheal intubation.
- Alteration in the slope of the graph can give clues to the presence of airway obstruction.
- A rapid fall in reading may signify extubation, air embolism or low cardiac output with hypovolemia.

Monitoring ETCO2:
- Confirms the movement of air in and out of the lungs
- Assumed to reflect alveolar CO2
- Assumed to indicate adequacy of ventilation and cardiac output
- Better indicator of ventilation
- Measures high point of the expiratory plateau
- Normally less than the PaCO2
- Normal gradient about 5-8
CO2 Increases with:

- Hypoventilation
- Malignant hyperthermia
- Sepsis and fever
- Rebreathing
- Bicarbonate administration
- Insufflation of CO\textsubscript{2} \text{ in laparoscopic surgeries}

CO2 Decreases with:

- Hyperventilation
- Hypothermia
- Low cardiac output
- Pulmonary embolism
- Circuit disconnect
- Cardiac arrest

Clinical Uses of Capnography:

- Detection of untoward events
- Maintenance of normocarbia
- Weaning from mechanical ventilation
- Evaluating effectiveness of CPR
Describe Wave Forms representing the following:

- Normal wave form
- COPD
- Inadequate neuromuscular relaxation
- Unequal lung emptying Restrictive lung disease
- Esophageal intubation
- Malignant hyperthermia
- Cardiac arrest
- Pulmonary embolism

Mass Spectrometry:

- Gas enters high vacuum area
- Bombarded by electron beam
- Charged particles passed over strong magnet
- Different components are deflected according to their chemical composition
- Specific collectors measure composition
Obstruction in Airway or Breathing Circuit

Possible Causes:
- Partially kinked or occluded artificial airway
- Presence of foreign body in the airway
- Obstruction in expiratory limb of breathing circuit
- Bronchospasm

Low CO\(_2\)

Malignant hyperthermia, first sign

The effect of muscle relaxant start to decrease

Reabsorption of CO\(_2\)
Peripheral Nerve Stimulation:

- Neuromuscular blockade is monitored during surgery to guide repeated doses of muscle relaxants and to differentiate between the types of block.
- All techniques for assessing neuromuscular blockade use a peripheral nerve stimulator (PNS) to stimulate a motor nerve electrically.
- A peripheral nerve stimulator delivers a current of variable frequency and amplitude 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.
- Ulnar nerve stimulation of the adductor pollicis muscle and facial nerve stimulation of the orbicularis oculi are most commonly monitored.
Neurological monitoring:

Depth of Anesthesia:
- Clinical Signs:
  - eye signs
  - respiratory signs: tachypnea
  - cardiovascular signs: tachycardia
- CNS signs
- EEG monitoring
- Facial EMG monitoring (experimental)
- Esophageal contractility (obsolete)

CNS Monitoring:
- Clinical: sensorium, reflexes, “wake up test”
- Electroencephalography, BIS
- Evoked potentials (esp. somatosensory EPs)
- Monitoring for venous air emboli
- Intracranial pressure (ICP) monitoring
- Transcranial doppler studies
Bispectral index:
- A new two channeled EEG
- Bispectral data takes the data generated EEG, through number of steps calculate single number correlate with depth of anesthesia
- BIS value 65-85 advocated a measure of sedation
- BIS value 40-65 recommended for general anesthesia
- Measure: depth of anesthesia

Temperature Monitoring:
Rationale for use
- detect/prevent hypothermia
- monitor deliberate hypothermia
- adjunct to diagnosing MH
- monitoring CPB cooling/rewarming
Sites:
- Esophageal
- Nasopharyngeal
- Axillary
- Rectal
- Bladder

Wake-up Test:
- Test neurologic function following reversible surgical manipulation
- Movement must not cause damage
- Patient is allowed to awaken
- Amnesia must be maintained
- After awakening, patient follows verbal commands
  - Evaluates corticospinal tracts (thoracic)
- Response to painful stimuli
  - Lumbar cord function
- Measuring ICP:
  - Ventricular catheter
  - Subdural bolt
  - Lumbar CSF catheter
  - Scanning techniques
Electrolyte / Metabolic Axis:
- Fluid balance
- Sugar
- Electrolytes
- Acid-base balance
- Nutritional status

Coagulation Monitoring:
- Clinical signs
- PT / PTT / INR
- ACT
- Platelet counts
- Factor assays
- TEG

Detecting Mishaps Using Monitors:
1. Disconnection
2. Hypoventilation
3. Esophageal intubation
4. Bronchial intubation
5. Circuit hypoxia
6. Halocarbon overdose
7. Hypovolemia
8. Pneumothorax
9. Air Embolism
10. Hyperthermia
11. Aspiration
12. Acid-base imbalance
13. Cardiac dysrhythmias
14. IV drug overdose
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Color reference:
Black-slids
Green-Notes
Blue-Book
Red-important

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