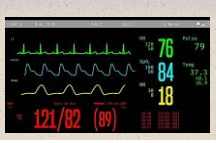
Intraoperative Monitoring

Athanasios Chalkias MD, PhD
Asst. Professor of Anesthesiology

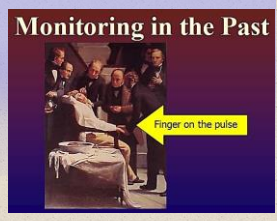
Objectives

- To understand the value of clinical monitoring
- Basic monitoring
- Advanced monitoring
- To appreciate that modern monitoring is an essential component of anesthesia care



Many years ago…

The most primitive method of monitoring the patient 50 years ago were continuous palpation of the radial pulsations throughout the operation or wake up test!!



Intraoperative Monitoring

- An essential component of anesthesia care
- Anesthesia and surgery can cause rapid changes in vital functions
- Anesthesia clinicians must monitor patient physiologic variables and anesthesia equipment during all types of anesthesia
- Patient and equipment monitoring is used to:
  - Titrate administration of anesthetic medication
  - To detect physiologic perturbations and allow intervention before the patient suffers harm
  - To detect and correct equipment malfunction

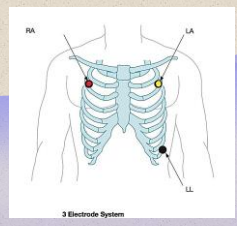
Basic monitoring

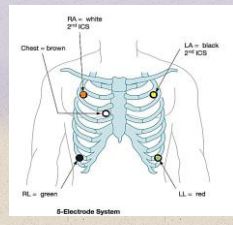
- We are NOT authorized to start a surgery in the absence of any of these monitors
  - ECG
  - Peripheral capillary oxygen saturation (SpO_2)
  - Blood pressure: NIBP (non-invasive), IBP (invasive)
  - Capnography
- During the most critical times during anesthesia
  - E.g. induction – recovery

Electrocardiogram

Electrocardiogram

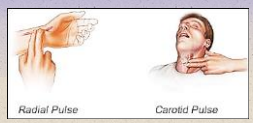
- Value
  - Heart rate
  - Rhythm (arrhythmias) usually best identified from lead II
  - Ischemic changes & ST segment analysis
  - Capnography
- Timing of ECG monitoring
  - Throughout the surgery: before induction until after extubation & recovery
- Types & connections of ECG cables
  - 3-leads or 5-leads



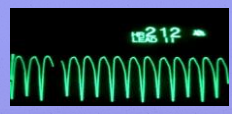


Electrocardiogram

- RULES
  - QRS beep ON must be heard at all times – NO silent monitors
  - Remember that your clinical judgement is much more superior to the monitor – Check radial (peripheral) pulsations
  - Cautery → artefacts & fallacies in ECG (noise/electrical interference) → check peripheral pulsations
  - Arrhythmias → check carotid (central) and radial (peripheral) pulsations
  - No pulse??



Electrocardiogram



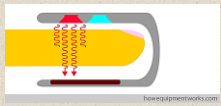
Pulse oximetry

Pulse oximetry

- Maybe the most important monitor
  - Gives a LOT of information about the patient
- Waveform of pulse oximeter = plethysmography (arterial waveform)
  - Indicates that the pulse oximeter is reading the arterial O_2 saturation
  - Without the waveform pulse oximeter readings are unreliable/incorrect
- Finger, Toe, Ear lobe, Nose
  - The red light is applied to the nail. Nail polish and stains should be removed → false readings and artefacts
  - In infants and children can be applied to 2 fingers or to the hand
  - Usually attached to the limb with the IV line (opposite the limb with the blood pressure cuff)

Pulse oximetry

- Definition: % of oxy-Hb / oxy + deoxy-Hb
- The principle of pulse oximetry
  - Based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin
  - Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through
  - Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through



Pulse oximetry

- Timing of SpO_2 monitoring
  - Before induction till after extubation & recovery
  - The LAST monitor to be removed off the patient before transport to recovery room
  - Should be continued in recovery room
  - Throughout the surgery: before induction until after extubation and recovery

Pulse oximetry

- Value
  - SpO_2: arterial O_2 saturation (oxygenation of the patient)
  - Heart rate
  - ***Peripheral perfusion status***
    - Loss of waveform in hypoperfusion states: hypotension/cold extremities
  - Gives an idea about the rhythm from the plethysmography wave
    - Cannot identify the type of arrhythmia but can recognize if irregularity is present
- Pulse oximeter tone changes with desaturation
  - From high pitched to low pitched (deep sound)
- By listening to the monitor you can recognize
  - Heart rate and O_2 saturation

Pulse oximetry

- Readings
  - Normal person on room air (FiO_2: 21%) > 96%
  - Patient under general anesthesia (FiO_2: 100%) = 98-100%
  - < 90% = hypoxemia / < 85% = severe hypoxemia
  - It is not accepted for O_2 saturation to ↓ below 96% with 100% O_2 under general anesthesia → Poor perfusion? → Must search for a cause
    - Cold extremities → Poor tissue perfusion → warm the patient, put a glove filled with warm water in the patient's hand (always avoid hypothermia)
    - Hypotension & shock → Poor tissue perfusion
    - Sometimes by electrical interference from cautery in some monitors
    - Misplaced on the patient's finger, slipped
    - Patient movement, shivering
    - Cardiac arrest

Pulse oximetry

- RULES
  - Keep the sound of the pulse oximeter ON at ALL times
  - Pay attention to the sound of the pulse oximeter – NO silent monitors
  - ALWAYS Remember that your clinical judgement is much more superior to the monitor
  - Check patient colour for cyanosis: lips, nails
  - If hypoxemia occurs immediately check the correct position of the probe on the patient and check his/her colour: nails & lips, then manage accordingly and CALL FOR HELP

Blood pressure

Blood pressure

- Non-invasive arterial blood pressure monitoring (NIBP)
  - Automated
  - Gives readings for systolic, diastolic, and mean arterial blood pressure
- Value
  - Maintain individualized hemodynamic stability
  - Avoid and manage extremes changes (hypo- and hypertension)
- Avoid
  - ↓ MAP < 60 mmHg (for cerebral & renal perfusion)
  - ↓ DAP < 50 mmHg (for coronary perfusion)

Blood pressure

- Risks of hypertensive episodes
  - CVS: myocardial ischemia, pulmonary edema
  - CNS: hemorrhagic stoke, hypertensive encephalopathy
- Risk of hypotensive episodes
  - CVS: myocardial ischemia, cardiac arrest
  - CNS: ischemic stroke, delayed recovery
  - Renal injury
  - Global ischemia

Blood pressure

- Timing of monitoring
  - Throughout the surgery: before induction till after extubation & recovery
- Frequency of measurement
  - By default every 3-5 minutes
    - Every 3 minutes: e.g. immediately after spinal anesthesia, in conditions of hemodynamic instability, during hypotensive anesthesia
    - Every 10 minutes: e.g. in awake patients under local anesthesia
- Reading error/failure
  - Pressure line is disconnected
  - Leakage from damaged cuff / small cuff – large cuff
  - Line is compressed (under someone's foot or under a weal)
  - Line contains water from washing!

Blood pressure

- RULE
  - YOUR clinical judgement is always superior to the monitor
  - Check peripheral pulse volume from time to time (e.g. radial artery)
    - i.e. if radial artery pulsations are lost = SAP is < 90 mmHg
    - i.e. if dorsalis pedis and superficial temporal pulsations are lost = SAP is < 80 mmHg
  - Check patient colour for pallor: lips, tongue, nails, conjunctiva

Blood pressure

- Invasive arterial blood pressure monitoring (IBP)
  - It is beat to beat monitoring of via an arterial cannula
  - CO, CI, SVV,SVR, SV, DO_2, etc.
  - Indications
    - Major surgeries
    - Cardiac surgery, in surgeries involving extreme hemodynamic changes or instability e.g. pheochromocytoma
    - During deliberate hypotensive anesthesia
    - During the use of inotropes
    - Critically ill patients
    - Repeated ABG sampling

Blood pressure

- Pulmonary artery catheter

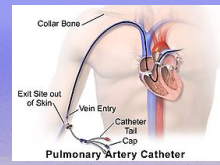
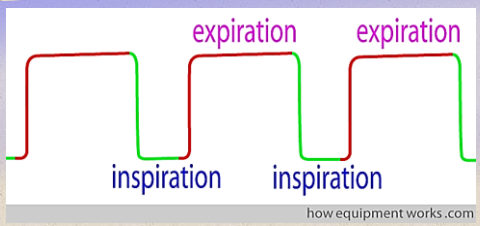


Table 1. Hemodynamic monitoring with a pulmonary artery catheter: Normal pressures and resistance values.*

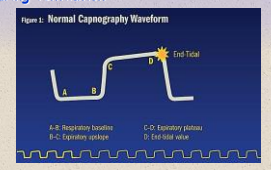
	Mean	Range
Right atrium	3 mm Hg	1–5 mm Hg
Right ventricle		
Peak systolic	25 mm Hg	15–30 mm Hg
End-diastolic	5 mm Hg	4–12 mm Hg
Pulmonary capillary wedge pressure	9 mm Hg	6–12 mm Hg
Systemic vascular resistance	1100 dyne-sec-cm^{-5}	700–1600 dyne-sec-cm^{-5}
Pulmonary vascular resistance	70 dyne-sec-cm^{-5}	20–130 dyne-sec-cm^{-5}

Capnography



Capnography

- Continuous CO_2 measurement displayed as a waveform sampled from the patient's airway during ventilation
- A point on the capnogram
  - The final measurement at the endpoint of the patient's expiration before inspiration begins again
  - The highest CO_2 measurement during ventilation
- Phases of the capnogram
  - Baseline: A-B
  - Upstroke: B-C
  - Plateau: C-D
  - End-tidal: point D
  - Downstroke



Capnography

- Normal range: 30-35 mmHg
  - Usually lower than arterial $PaCO_2$ by 5-6 mmHg due to dilution by dead space ventilation
- Value (data gained from capnography & $ETCO_2$)
  - ETT: esophageal intubation
  - Ventilation: hypo- and hyperventilation, curare cleft (spontaneous breathing trials)
  - Pulmonary perfusion: pulmonary embolism
  - Breathing circuit: disconnection, kink, leakage, obstruction, unidirectional valve dysfunction, rebreathing, exhausted soda lime
  - Cardiac arrest: adequacy of resuscitation during cardiac arrest, ROSC

Capnography

- Factors affecting $ETCO_2$

↑ ETCO2	↓ ETCO2
Changes in CO2 Elimination	
• Hypoventilation. • Rebreathing. • Partial airway obstruction. • Laparoscopy→CO_2 absorption.	• Hyperventilation. • Hypoperfusion. • Pulmonary embolism.
Changes in CO2 Production	
• Fever. • Thyroid storm. • Malignant Hyperthermia	• Hypothermia.

Other techniques

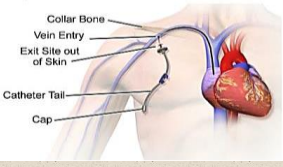
Nerve stimulator

- Peripheral nerve stimulator (train-of-four monitor)
- Is used to assess neuromuscular transmission when neuromuscular blocking agents (NMBAs) are given to block musculoskeletal activity
- Can ensure proper medication dosing and thus decrease the incidence of side effects

Central venous pressure

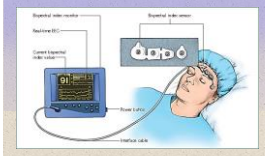
Central Venous Pressure (CVP)

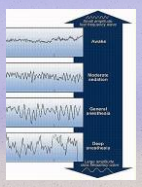
- Blood pressure in thoracic *vena cava*, near *right atrium*
  - Amount of blood returning to the heart
  - Ability of the heart to pump the blood into the arterial system
  - CVP for monitoring hemodynamics
    - Preload
    - Volume overload
    - Cardiac failure
    - Sepsis
    - …

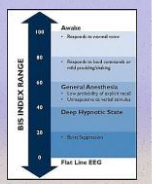


Transesophageal echocardiography

Bispectral Index

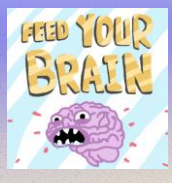






Intra-cranial pressure

- The pressure inside the lateral ventricles/lumbar subarachnoid space in supine position
- The normal value of ICP is 10-15 mmHg in adults
- Indications for ICP monitoring
  - Head Injury
  - Brain Tumors
  - Hemorrhage
  - Hydrocephalus
  - Neuromedical conditions



Intra-cranial pressure

- Techniques of ICP monitoring

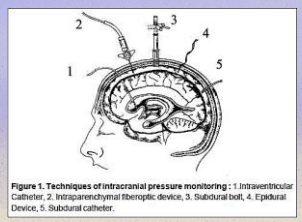
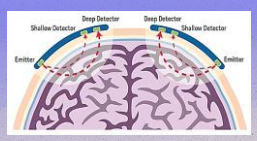


Figure 1. Techniques of intracranial pressure monitoring : 1.Intraventricular Catheter, 2. Intraparenchymal fiberoptic device, 3. Subdural bolt, 4. Epidural Device, 5. Subdural catheter.

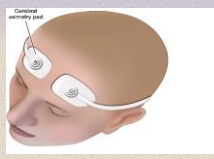
Cerebral oxygenation/metabolism

- Near Infrared Spectroscopy (NIRS)
- Jugular bulb venous oximetry monitoring
- Brain tissue oxygenation
- Microdialysis catheter



Cerebral oxygenation/metabolism

- **Near Infrared Spectroscopy (NIRS)**
  - The principle of absorption of near-infrared light by chromophores (e.g. oxyhemoglobin)
  - Light in the near-infrared region (70-1000 nm) is very minimally absorbed by body tissues. It can penetrate tissues up to 8 cm
  - Measure regional cerebral blood flow, cerebral blood volume, cerebral oxygen saturation and cerebral metabolism

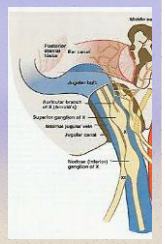


Cerebral oxygenation/metabolism

- **Near Infrared Spectroscopy (NIRS) – Limitations**
  - Inability to assess the contribution of extracranial tissue to the signal changes
  - Presence of intracranial blood in the form of hematomas and contusions can interfere with the measurements
  - Measures small portion of frontal cortex, contributions from non-brain sources
  - Temperature changes affect near infrared absorption water spectrum
  - Degree of contamination of the signal by chromophores in the skin can be appreciable and are variable
  - Not validated – threshold for regional oxygen saturation not known (20% reduction from baseline?)

Cerebral oxygenation/metabolism

- **Jugular bulb venous oximetry monitoring**
  - $(A-V)DO_2$ x CBF = cerebral metabolic rate of oxygen ($CMRO_2$)
  - When $CMRO_2$ is constant, any change in cerebral blood flow is associated with a reciprocal change in the cerebral arteriovenous oxygen difference
  - Based on the principle of reflectance oximetry
  - Continuous monitoring of jugular venous oxygen saturation ($SjVO_2$) is carried out by a catheter placed retrograde through the internal jugular vein into the jugular bulb
  - For accurate measurement, the tip of the catheter must be within 1 cm of the jugular bulb



Cerebral oxygenation/metabolism

- **Indices obtained from $SjVO_2$**
  - Jugular venous oxygen saturation ($SjVO_2$)
  - Cerebral arteriovenous oxygen difference ($A-VDO_2$)
    - The difference between arterial and jugular venous oxygen content
  - Cerebral oxygen extraction (CEO_2)
    - The difference between SaO_2 and $SjVO_2$

Table 2 : Indices of adequacy of cerebral blood flow derived from $SjVO_2$ monitoring

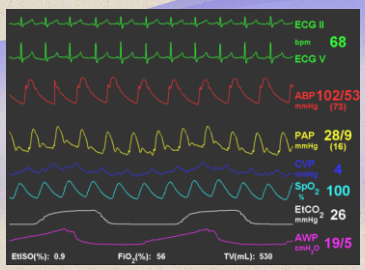
1. $SjVO_2$	: Normal : Hyperaemia : Low flow	- 60-80% > 90% < 50%
2. $(A-V)DO_2$ ($CMRO_2$/CBF)	: Normal : Hyperaemia : Low flow	- 5 - 7.5 vol % < 5 vol % > 7.5 vol %
3. CEO_2	: Normal : Hyperaemia : Low flow	- 24-40% < 24% > 40%

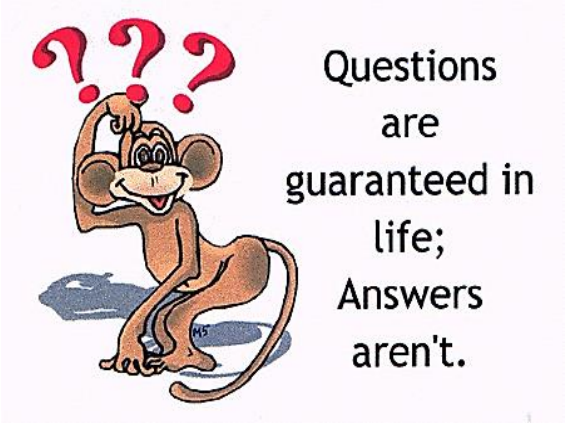
Multimodal assessment

- **Clinical monitoring**
  - Colour: cyanosis: nails, lips, palms, conjunctiva
  - Chest rise & fall (inflation)
  - Vapor in ETT (absent in ventilators with humidifiers/if filter is used)
  - Airway pressure
  - Ventilator bellows (return to full inflation during expiratory phase)
  - Ventilator sound: during respiratory cycle
  - Abnormal sounds e.g. leakage, disconnection, high airway pressure, other alarms (low expired tidal volume, apnea alarm, etc.)

Multimodal assessment

Sure signs of endotracheal intubation	**Unsure signs** of endotracheal intubation
1. Capnography. 2. Under vision.	1. Auscultation of both lungs + epigastrium (where is max intensity?). 2. Chest inflation. 3. Vapour in ETT. 4. Good compliance of bag. 5. O2 saturation.





MCQ 1

- Pulse oximetry measures which of the following:

1. Oxygen saturation of hemoglobin
2. Partial pressure of oxygen dissolved in the blood
3. End-tidal carbon dioxide
4. Oxygen perfusion

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MCQ 2

- A patient with alcoholic cirrhosis, ascites, and gastrointestinal bleeding receives 4 units of red blood cells during anesthesia with isoflurane in oxygen for emergency exploratory laparotomy. After the peritoneum is opened and the fluid is drained, blood pressure (NIBP) decreases to 65/40 mmHg and SpO_2 decreases to 96%, but he patient has palpable radial pulse in both arms. The most likely value of SAP is:

1. > 180 mmHg
2. > 90 mmHg
3. < 90 mmHg
4. 65 mmHg

MCQ 2

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2. > 90 mmHg
3. < 90 mmHg
4. 65 mmHg

MCQ 3

- $ETCO_2$ is typically how much lower than $PaCO_2$:

1. 1-2 mmHg
2. 3-5 mmHg
3. 8-10 mmHg
4. 10-15 mmHg

MCQ 3

- $ETCO_2$ is typically how much lower than $PaCO_2$:

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2. 3-5 mmHg
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MCQ 4

- Invasive monitoring consists of:

1. Blood pressure cuff
2. Arterial and/or pulmonary artery catheter
3. ECG leads
4. Mechanical ventilation

MCQ 4

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1. Blood pressure cuff
2. Arterial and/or pulmonary artery catheter
3. ECG leads
4. Mechanical ventilation

MCQ 5

- The most likely cause of this capnographic tracing obtained just after laryngoscopy and intubation is:

1. Partial obstruction of the endotracheal tube
2. Pulmonary embolus
3. Insertion of an endotracheal nasogastric tube
4. Esophageal intubation
5. Mild bronchospasm

MCQ 5

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