Pediatric anatomical and physiological changes

Several anatomical and physiological changes impact the effects and techniques of anesthesia administration. Pediatric patients can be divided **into four** groups based on age:

- ***Newborn**: from birth to the first 24 hours.*
- ***Neonate**: from 1 to 30 days of life.*
- ***Infant:** from 1 month to 12 months of age.*
- ***Child**: from 1 year to the onset of puberty.*

Cardiovascular Physiology

Cardiac output for a neonate is 30-60% greater than an adult. This helps meet the increased oxygen consumption requirements. Cardiac output in the pediatric patient is dependent on **heart rate**. Monitoring of the pediatric patient's heart rate can be accomplished with a **precordial stethoscope, ECG, and pulse oximetry**. Prompt recognition and treatment of bradycardia are critical.
Bradycardia is less than **80 in children (1-8 years)**, less than **100 beats per minute in infants aged (1-12 months),** and less **than 120 beats per minute in neonates**.
It is the most common rhythm before cardiac arrest in the pediatric patient.

- ***The most common cause of bradycardia in pediatrics is:***

1. Hypoxia.
2. Vagal stimulation (suctioning, surgical traction, etc.).
3. An overdose of anesthetic medications.
4. Hypothermia.
5. Increased intracranial pressure.

The ***blood volume*** of the pediatric patient is **highest as a neonate and declines with age.**
Knowledge of the approximate blood volume is important when calculating total blood volume and estimated blood loss. e.g., **a 4 kg neonate's total blood volume would be calculated as follows:**
4(kg) X 85 (ml/kg) = **340 ml** total blood volume.

Age	Blood volume
Preterm neonate	90 ml/kg
Full term neonate - 3 months	80-90 ml/kg
Above 3 months	70-80 ml/kg
Above 2 years	70 ml/kg

Pulmonary Physiology and Airway Anatomy

The ***functional reserve capacity*** is much **smaller i**n infants and neonates, during anesthesia, airway obstruction can result in hypoxia very quickly. For this reason, pulse oximetry **is essential**. Induction and emergence are especially critical periods to monitor for these complications.
Oxygen consumption for a neonate is **two times greater than that of an adult.**

➢ The anatomy of the pediatric airway is different compared to an adult:

- The pediatric patient is prone to airway obstruction related to a proportionally **larger head, short neck, and large tongue.** Positioning of the patient's airway is an important consideration. **Overextension** can result in airway obstruction in the neonate.
- Infants and neonates exchange air primarily through their nasal airways. The **larynx is higher** in the infant and child **(cervical vertebrae 3-4) than in the adult (cervical vertebrae 5-6).**
- **The epiglottis is large, stiff, and U-shaped**. **The trachea is short, and the right main bronchus is less angled.** This increases the risk of a right mainstem intubation.
- **Choosing the correct-size endotracheal tube and approximate length of insertion is important.** This can also be accomplished by a **simple calculation**.

The equation that can be used (age/4+ 4) will approximate the correct size of the endotracheal tube. Regardless of the calculations, an endotracheal tube should slide easily into the trachea, and never be pushed or forced.
The calculation for the correct endotracheal tube depth insertion is to multiply the diameter of the endotracheal tube by 3. For example, an endotracheal tube that is a size of 3.0 would be multiplied by 3 to equal a depth insertion of 9 cm. Auscultation of equal, bilateral lung sounds (including the axilla) after endotracheal tube placement should always be performed.

Renal System and Extracellular Fluid Volume

At birth, the kidneys have a **decreased glomerular filtration rate**, decreased sodium excretion, and decreased concentrating ability. The glomerular filtration rate will increase and reach adult levels by 12-24 months of age.

Neonates and infants up to **24 months are not able to compensate for alterations in fluid balance** as well as adults. This makes fluid replacement **very important**.

The extracellular fluid volume in an infant is **twice that of an adult**. Approximately **40% of the body weight in Infant is extracellular fluid compared to 20% of adults'** body weight.
Neonates, infants, and children fasting for anesthesia can become dehydrated more quickly than an adult. Careful fluid calculation includes NPO deficit, maintenance fluids, 3rd space fluid loss, and estimated blood loss replacement. For a pediatric patient that is dehydrated, it is important to correct pre-existing deficits before anesthesia to avoid hypotension.

Temperature Regulation

Neonates and infants can **rapidly lose heat,** even in warm environments. They are at greater risk for hypothermia than adults **due to:**

a) Relatively high surface-to-volume ratio.
b) High metabolic rate.
c) Insufficient body fat for insulation.

Infants **less than 3 months do not shiver** to generate heat. It is important to take steps to minimize heat loss including **a warm operating room, warm blankets, or a heating blanket.** Monitoring the patients' temperature before, during, and after the anesthesia is important to detect abnormal drops or increases in temperature.

Pharmacology in Pediatrics

Pediatric patients respond differently to anesthetic medications when compared to adults. This is due to physiological differences that include:

a. Increase extracellular fluid.
b. Decrease skeletal mass.
c. Increase metabolic rate.
d. Decrease renal function.
e. Receptor maturity.

❖ Inhaled Anesthetics

Uptake, distribution, and potency of volatile anesthetics are different in neonates and infants than in adults.

Induction of general anesthesia occurs **faster in neonates** and infants. **Emergence also occurs faster**. The differences between adult and pediatric patients **during induction and emergence are**:

1. **Smaller functional residual capacity** (smaller lung volume).
2. **Greater blood flow to the vessel-rich tissues** such as the brain, heart, liver, and kidneys.

In infants and neonates, the vessel-rich tissues comprise **about 22% of total body weight.** In adults, the vessel rich tissues compose about 10% of the total body weight.

MAC varies according to the age of the patient.

- In general, **MAC is lower in neonates than in infants**. **MAC increases until about 2-3 months of age, peaks during infancy, and then steadily declines**.

- During puberty, there is **a brief increase** in MAC. After puberty, **MAC will continue to decline.** Lower MAC requirements for volatile anesthetics in neonates are **due to an immature central nervous system.**

❖ Intravenous Anesthetic Agents

Neonates are **sensitive to intravenous anesthetic agents**. They have an **immature blood-brain barrier and a decreased ability to metabolize medications** such as opioids and barbiturates.
In general, **lower doses of intravenous anesthetic medications are required to produce the desired effects.** There are some **generalized exceptions**. For example, to induce general anesthesia **higher doses of propofol** (on an mg/kg basis) are required when compared to an adult.
Pediatric patients less than 6 months old may be **more sensitive to respiratory depression resulting from opioid administration**. Caution should be used when administering opioids to this age group. The pediatric patient should be carefully monitored during the postoperative period.

❖ Nondepolarizing Muscle Relaxants

Neonates and infants may be more sensitive to the effects of nondepolarizing muscle relaxants. The neuromuscular junction of the infant is **immature**. The duration of action of nondepolarizing muscle relaxants may be **prolonged** due to immature renal and hepatic systems.

❖ Depolarizing Muscle Relaxants

Neonates and infants require **higher doses**, on an mg/kg basis, **of succinylcholine than the adult patient**. This is due to **an increased extracellular volume and volume of distribution.**
The dose of succinylcholine in pediatrics is 1.5-2 mg/kg IV compared to 1 mg/kg IVP in adults.
Routine use of succinylcholine in pediatric anesthesia is **not recommended**.
The use of succinylcholine in pediatrics should be reserved for emergency intubation, rapid sequence induction, and laryngospasm.

Selects the best single choice

1- Pediatric anesthesia (all true except one)
a) Pediatric patient is small adult
b) Oxygen consumption for neonate is two time greater than adult.
c) Alveolar ventilation in neonate is twice the adult rate.
d) Overextension of neonate can cause airway obstruction.
e) Neonate means 1-30 days of extra uterine life
2- Pharmacology in pediatrics (which one is true)
a) Neonates are resistant to intravenous anesthetic agents.
b) The routine use of succinylcholine is recommended.
c) MAC of inhalational agents is lower in infants than neonates.
d) Duration of action of non-depolarizing agents may be shorter.
e) Neonates and infants may be more sensitive to nondepolarizing relaxants.
3- Temperature regulation in infant and neonate (all true except one)
a) Neonates and infants can rapidly lose heat.
b) They are at greater risk for hypothermia.
c) Infants less than 3 months do not shiver to generate heat.
d) Monitoring the patients' temperature before anesthesia only.
e) Hypothermia is treated by warm operating room or warm blanket.

4- The most common cause of bradycardia in pediatrics is:
a) Vagal stimulation.
b) Hypothermia.
c) Hypoxia.
d) Traction.
e) Atropine.
5- The total blood volume for 4 kg. neonate is approximately
a) 100ml.
b) 120ml.
c) 220ml.
d) 340ml.
e) 440ml.