Neonate

First month of life. Neonates have various anatomical / physiological / pharmacological differences compared to older children and especially adults which should be considered and managed appropriately

ANESTHETIC CONSIDERATIONS:

- Unique airway anatomy
  - More cephalad larynx, slanting v.cords, prominent occiput, large tongue, long epiglottis, short neck and trachea, narrowest at cricoid ring, narrow nares (obligate nasal breathers)
- Altered physiology
  - Rapid desaturation and risk of postoperative apnea (compliant chest wall, □ closing volume, □ minute ventilation to FRC ratio, □ O2 consumption, ↓ lung compliance, low proportion Type 1 (slow twitch) fibers (diaphragm & intercostals)
  - HR / preload dependant CO (vagolytics for bradycardia), resting CO □ relative to BW, immature baroreceptors (sens to depressant effects anesthetics), persistent / reversion to fetal circulation, risk of paradoxical emboli (eliminate air bubbles in IV)
  - Inability to effectively thermoregulate
  - Inability to effectively regulate glucose metabolism
  - Renal Na^+ loss (IV must contain Na^+)
- Altered pharmacokinetics / pharmacodynamics
  - Larger volume of distribution
  - Less protein binding
  - Decreased renal and hepatic elimination
  - Altered anesthetic requirements (lower MAC, faster uptake inhalational agents)
  - NMJ more sens to non-depol NMB (larger Vd but decr elimination)
- Potentially difficult IV access and monitoring

ANESTHETIC GOALS:

1. Avoid hypoxemia (rapid desaturation)
2. Lung protective ventilation (minimize Paw)
3. Anticipate bradycardia (hypoxemia, atropine 20 mcg/kg)
4. Maintain adequate body temperature (avoid hypothermia)
5. Manage glucose regulation
6. Maintain volume status (avoid volume overload)
7. Avoid respiratory depressants

HISTORY

- Obstetric history (DM, PIH, U/S result, labor and delivery, APGARs…)
- Neonatal condition (admissions, seizures, feeding, activity, weight gain, colour)

Maternal History	Anticipated neonatal sequelae
Rh-ABO incompatibility	Hemolytic anemia, hyperbilirubinemia, kernicterus
Toxemia	Small BW associated problem
HTN	SBW
Infection	Sepsis, decreased PLTs, viral infection
Hemorrhage	Shock, anemia
Diabetes	Hypoglycemia, birth trauma, macrosomia, SBW
Polyhydramnios	TEF, anencephaly, multiple anomalies
Oligohydramnios	Renal hypoplasia, pulmonary hypoplasia
Cephalopelvic disproportion	Birth trauma, hyperbilirubinemia, fractures
Alcoholism	Hypoglycemia, FAS, SBW, malformations

Neonatal History	Sequelae
Respiratory	RDS, BPD, apnea / bradycardia, congenital malformation, meconium aspiration
CVS	Cardiac anomalies, PDA, PPHTN
Neurologic	Infections, hemorrhage, encephalopathy, seizures
Metabolic / endocrine	Inborn errors of metabolism, hypoglycemia, hyperbilirubinemia
Hematologic	Rh-ABO incompatibility, anemia
Infections	Syphilis, Toxoplasmosis, RSV, CMV, Herpes (STORCH)
GI	NEC, hernias, jaundice
Other	ROP

PHYSICAL

- **GENERAL** – vitals, color
- **CNS** – twitches, seizures (can indicate ↓ Ca^{++})
- **HEENT** – airway (tongue, tonsils, palate) and facial dysmorphic features
- **RESP** – respiratory distress, grunting, indrawing, accessory muscle use, deviation of trachea
- **CVS** – PDA (3-5th day of life develops L to R shunt bounding pulses wide pulse pressure, gallop rhythm, tachycardia), CHF (retractions, decreased a/e, crackles, decreased perfusion / capillary refill, edema, hepatomegaly, new onset apneas)
- **GU** - hydration (fontanel, sunken eyes, mucous membranes, cap refill, sensorium, U/O)

INVESTIGATIONS

- **Labs**
  - Hb / HCT (commonly anemic), bilirubin, crossmatch
  - Blood glucose
  - Blood C&S (if evidence of sepsis)

OPTIMIZATION

- Breast milk up to 4 hours preoperatively
- Glucose containing IV solutions when fasting
- Warm room
- Organize postoperative monitoring for apnea (e.g. NICU bed)

ANESTHETIC OPTIONS

- Local, regional, GA

ANESTHETIC SETUP

- **Drugs**
  - Atropine, SCh
- **Equipment**
  - Standard CAS monitors including temperature
  - Consider pre- and post-ductus SpO_2 monitors (i.e. hand and foot)
  - Glucose monitoring
  - Neonatal circuit and equipment
    - Straight blade laryngoscope (Windsor / Oxford), shoulder roll, microcuff vs. uncuffed ETT
  - Heat lamps, heating blanket, warm OR, skin temperature probe
  - IV infusion pump, separate volume and glucose lines, low dead-space IV tubing

MANAGEMENT OF ANESTHESIA

- **Induction**
  - IV vs. Inhalation
    - Difficult IV – 24G peripheral: ACF, saphenous, lateral foot, scalp, umbilical, interosseous, cut-down
    - Rapid inhalational induction with lower MAC and possible toxicity
  - For GA consider:
    - Pre-treatment with atropine (20 mcg/kg)
    - Remifentanil for induction
    - Increased SCh dose (2 mg/kg), prolonged rocuronium effect
  - Airway: 3.5 uncuffed ETT, Miller 1, shoulder roll, suction
    - ET tube size:
      - Premature (2.5 kg) 2.5
      - Term 3.0
      - 2-8 months 3.5
      - 8-12 months 4
      - 18-24 months 4.5
      - Older than 24 months (age in years / 4 + 4)
- **Maintenance**
  - Drugs: MAC of full term infant = adult (6 m/o = increase MAC 50%, premature = decrease MAC 20–30%)
  - Maintenance fluid: 4-2-1 rule usually N/S with D5 as a separate line
  - PCV 20 cmH_2O (or less)
- **Emergence**
  - awake, warm, comfortable, reversed

DISPOSITION & MONITORING

- May require apnea monitoring

PATHOPHYSIOLOGY

Normal Blood Gas Values In The Newborn

Subject	Age	PO_2 (mm Hg)	PCO_2 (mm Hg)	pH
Fetus (term)	Before labor	20-25	40	7.37
Fetus (term)	End of labor	10-20	55	7.25
Newborn (term)	10 min	50	48	7.20
Newborn (term)	1 hr	70	35	7.35
Newborn (term)	1 wk	75	35	7.40
Newborn (preterm, 1500 g)	1 wk	60	38	7.37

Fetal Blood Gas Values

	pO2	pCO2	pH
Uterine artery	96	28	7.45
Uterine vein	33	37	7.35
Umbilical artery	15	44	7.33
Umbilical vein	28	35	7.37

- **Airway**
  - Superior larynx
    - Premature: C3
    - Term Infants: C3-4
    - Adults C4-5
  - Large head and tongue

- Narrowed, angled and long epiglottis (angled away from trachea)
- Narrowest point at the level of cricoid
  - Normal subglottic lumen = 5.5 mm in full term neonate, 3.5 mm preterm
- 70% of term infants are obligate nasal breathers (until about 5 months)

- **Tracheobronchial Tree**
  - Compliant tracheobronchial tree → susceptible to dynamic airway collapse particularly with partial airway obstruction (e.g. epiglottitis)
  - Short trachea : neonate = 5 cm, 1-2 y/o = 7.5 cm, 2-4 y/o = 8 cm
- **Respiratory**
  - Physiology
    - Chest wall and respiratory muscles
      - Ineffective accessory muscles d/t unfavorable anatomic rib configuration → ↑ work of breathing 3 x that of adults
      - Compliant chest wall, thus negative intrathoracic pressure is poorly maintained by diaphragm and results in paradoxical ventilation due to indrawing
    - Lung volumes → same as adult on per kg basis
      - Vt (6-8 cc/kg) and FRC (30 cc/kg) same for adults and infants
      - Alveolar ventilation much higher (200-250 mL/kg/min vs. 90 mL/kg/min) d/t higher RR (30-50 per minute vs. 12 per minute)
      - Thus, higher VO_2 to FRC ratio → increased propensity to desaturate
    - Oxygen consumption (VO_2) at rest
      - Neonates 7-9 mL/kg/min (c.f. adults 2-3 mL/kg/min)
    - Higher closing volumes
      - Children < 5 y/o → CC > FRC
  - Clinically: they are more prone to desaturation with apnea
    - Increased VO_2
    - Increased CC → increased shunting with apnea
    - Higher Ve (minute ventilation) to FRC → decreased physiologic reserve
  - They also have faster induction with inhalational anesthetics
    - Increased Ve to FRC ratio (5:1 neo vs 1.5:1 adult)
    - Increased CO to vessel rich group of organs
- **Cardiovascular**
  - Higher total Hb and presence of fetal Hb (HbF)
    - HbF is shifted to L resulting in less off-loading of O_2 (due to lower affinity for 2,3-DPG) → p50 HbF is 18 mmHg
    - Physiologic anemia due to change from HbF → HbB with nadir at 2-3 months
    - HbB then slowly increases to adult levels by 10 years of age
    - HbB dissociation curve shifts to R as HbF → HbB and also due to increased 2,3-DPG
  - Increased CO due to HR
    - HR at term ~120 bpm → increases to 160 bpm by one month of age
  - Poor LV compliance, particularly at higher LVEDV (only early on)
    - Starling curve is shifted down and to right, thus increase in SV for increasing preload are minimal (i.e. fixed SV)
  - Transitional circulation with potential to revert back to fetal circulation
    - May have persistent ductus arteriosus with potential for L → R or R → L shunting
    - Need to avoid conditions which allow reversion to fetal circulation (i.e. factors which increase PVR and R → L shunting)
      - Hypoxia
      - Hypercarbia
      - Acidosis
      - Ventilation above or below FRC (hyperinflation or atelectasis)
      - Sympathetic stimulation
      - High hematocrit
- **Thermoregulation**
  - Two mechanisms to produce heat
    - Major mechanism is non-shivering thermogenesis mediated by brown fat (note these are absent in extremely premature infants < 30 weeks)
    - Shivering thermogenesis
      - Minor mechanism in newborns and inhibited by anesthesia
    - Highly susceptible to radiant heat loss due to large surface area
- **Renal and Metabolic Function**
  - GFR at term is 15-30% of adult levels, 60% by 1 month, approximates adult level by 1 year
  - ↓ RBF (↓ GFR) due to low peripheral SVR (low RPP) & □ RVR, ↓ permeability/size/number glomeruli
  - Obligate Na loss due to insensitivity of neonatal distal tubule to aldosterone (Na^+ in IV)
  - Higher total body water:
    - Pre-term: 80%
    - Term 70%
    - Results in larger volume of distribution
- **Glucose homeostasis**
  - Significant glycogen and fat stores do not develop until late in gestation thus neonates have obligate glucose requirements
    - Pre-term: 8-10 mg/kg/min
    - Term 5-8 mg/kg/min
  - Risk factors for hypoglycemia
    - Pre-term, SGA, fasted infants, infants of diabetic mothers

- Signs and symptoms
  - Respiratory distress, apnea, cyanosis, seizures, tremors, high-pitched cry, irritability, limpness, lethargy, poor feeding, temperature instability, sweating
- Treatment: 0.5-1 g/kg (maximum concentration 12.5%

- **Hypocalcemia**
  - Neonates are prone to this, particularly if ill
  - Must treat concurrent hypomagnesemia
  - Treatment: 20 mg/kg of $CaCl_2$
- **GI / Hepatic Function**
  - Prolonged gastric emptying and incompetent LES
  - Immature hepatic metabolism
- **Altered Response to Anesthetics**
  - Volatiles:
    - Decreased anesthetic requirements due to immature nervous system up to three months of age
    - MAC: premature < full term < neonate < infant
  - Muscle relaxants
    - Larger Vd but decreased elimination due to immature hepatic and renal function
    - Thus, unpredictable but generally follow the same pharmacokinetics as adults
  - Spinal anesthesia
    - Increased CSF volume which accounts for increased amount of local anesthetic requirements

Comparison of various factors in premature / neonates vs. adults	
Factor	**Premature and neonate vs. adult (from Cote)**
Protein binding	Less
Total protein	Less
Alpha$_1$ acid glycoprotein	Less
Vd	Higher
Water content	Higher
CNS / CVS sensitivity	Higher (more respiratory depression)
fat and muscle content	Lower
Redistribution of drugs	Less (leading to higher peak and longer duration)
Hepatic enzyme action	Less
Hepatic blood flow	Less
$T_{1/2}$ for hepatic drugs (STP)	Increased in neonates but decreased in 4-10 y/o
Morphine clearance	Adult values at 1-6 months of age, progressively increasing
Glucuronosyltransferase activity	Adult levels by 6-18 months of age
Sulfotransferase activity	Well developed in newborn (preferred route for Tylenol)
GFR	Reduced, progressively increases to 2 y/o (adult level)
$T_{1/2}$ for renal (gent, amp)	Increased premature > term > adult
CNS myelination	Incomplete
Brain morphine concentrations	Higher d/t immature BBB (doesn't apply to fentanyl)
MAC (Iso / Halo / Des)	1-12 m/o > 0-30 d/o and 1-5 y/o > premature > adults
MAC (Sevo)	0-30 d/o > 1-6 m/o > 6-12 m/o > child > adult

Comparison Of Normal Respiratory Values In Infants And Adults		
Parameter	**Infant**	**Adult**
Respiratory frequency	30–50	12–16
Tidal volume (ml/kg)	7	7
Dead space (ml/kg)	2–2.5	2.2
Alveolar ventilation (ml/kg/min)	100–150	60
Functional residual capacity (ml/kg)	27–30	30
Oxygen consumption (ml/kg/min)	7–9	3

Apgar Score: 1 and 5 minutes → normal > 8			
	2 points	**1 point**	**Zero**
Heart rate	> 100	< 100	Absent
Colour	Pink	Extremities blue	Pale / Blue
Tone	Active	Some flexion	Limp
Respiratory effort	Good / Crying	Slow, regular	Absent
Suction response	Cough / Sneeze	Grimace	Absent

References: Barash 5th Ch 43
Miller 7th Ch 82, 84
Cote 4th Ch 2, 4, 6,12