

# Episode 43: Maternal Physiology with Mike Hofkamp

On this episode: Dr. Jed Wolpaw and Dr. Mike Hofkamp

In this episode, episode 43, I welcome Dr. Mike Hofkamp to the show. Dr. Hofkamp is Director of OB Anesthesia at Baylor Scott & White Memorial Hospital and Clinical Associate Professor of Anesthesiology at Texas A&M Health Science Center College of Medicine. We discuss the changes to women's physiology when they become pregnant and the implications of those changes for anesthetic management.

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## Cardiovascular System

- “fetus is parasite” → mother is trying to physiologically support parasite
- Goal of cardiac system is to deliver more O<sub>2</sub> to fetus
- 50% ↑ in CO → SV ↑ by 25%, HR ↑ by 25%
  - 10 to 12kg ↑ in body weight; mostly plasma → RBC trying to catch up, but not able to resulting in **physiological anemia of pregnancy**
- LV end diastolic volume ↑, but no change in LV end systolic volume → ↑EF
- No change in LV stroke work index, pulmonary capillary wedge pressure, pulmonary artery diastolic pressure and central venous pressure
- Uterus is low resistance circuit; CO that goes there increases throughout pregnancy → ↓ in systemic vascular resistance in ~2<sup>nd</sup> trimester
- Heart sounds:
  - Exaggerated splitting of mitral and tricuspid components
  - Grade 2 systolic murmur heard at left sternal border
  - S3 could be normal because of larger circulatory volume
  - S4 always abnormal
- EKG changes:
  - Increased HR
  - Shortening PR interval and uncorrected QT interval
  - QRS shift right at beginning of pregnancy and shift left at end of pregnancy due to displacement of diaphragm
- ECHO changes:
  - LV hypertrophy occurs by 12 weeks gestation reaching 50% ↑ by term → ↑ in size, not #, of myocytes
  - 94% of patients will have pulmonic and tricuspid regurgitation at term
  - 27% of patients will have mitral regurgitation at term
- During labour:
  - First stage: 10% ↑ CO because increase SV due to sympathetic activation
  - Late first stage: 25% ↑ CO
  - Second stage: 40% ↑ CO
  - Immediately after delivery: 75% ↑ in CO because offload pressure from fetus on IVC → increase venous return

## Respiratory System

- Anatomy:
  - Thoracic cage ↑ 5-7cm due to ↑ relaxin hormone → structural changes of ribcage
  - Capillary engorgement of nasal, oropharyngeal and larynx structures that occurs early in first trimester → contributes to dyspnea feeling
  - ↑ diaphragmatic excursion, ↓ chest wall excursion and pulmonary resistance
- Lung volumes:

No Change	Increased	Decreased
- FEV <sub>1</sub>	- Inspiratory reserve volume ↑ 5%	- Expiratory reserve volume ↓ 45%
- FEV <sub>1</sub> /FVC	- Tidal volume ↑ 45%	- Residual volume ↓ 15%
- Flow volume loop		
- Closing capacity		

<ul style="list-style-type: none"> <li>- Vital capacity</li> <li>- Respiratory rate</li> </ul>	<ul style="list-style-type: none"> <li>- Inspiratory capacity ↑ 15%</li> <li>- Dead space ↑ 45%</li> <li>- Minute ventilation ↑ 45%</li> <li>- Alveolar ventilation ↑ 45%</li> </ul>	<ul style="list-style-type: none"> <li>- Functional residual capacity ↓ 20% (↓30% when supine)</li> <li>- Total lung capacity ↓ 5%</li> </ul>
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- FRC reflects worst gas exchange in pulmonary cycle → FRC is decreased so pregnant people desaturate quickly

- Blood gas:

- Progesterone is respiratory stimulant → ↑ MV → left shift in CO<sub>2</sub> response curve

	Normal	1 <sup>st</sup> trimester	2 <sup>nd</sup> trimester	3 <sup>rd</sup> trimester
PaCO <sub>2</sub> (mmHg)	40	30	30	30
PaO <sub>2</sub> (mmHg)	100	107	105	103
pH	7.4	7.44	7.44	7.44
HCO <sub>3</sub> <sup>-</sup>	--	21	--	20

- Progesterone and estrogen ↑ hypoxic ventilatory response
- Metabolism and respiration during labour

	First stage	Second stage	After delivery
Minute Ventilation	↑ 70 to 140%	↑ 120 to 200%	Remain ↑ until ~6 to 8 weeks after
O <sub>2</sub> consumption	↑ 45%	↑ 75%	Remain ↑ until ~6 to 8 weeks after

- O<sub>2</sub> supply not meet demand during labour → accumulation of lactic acid
  - Neuraxial anesthesia attenuate O<sub>2</sub> demand and ↓ lactic acid build-up
- After delivery, FRC increase

## Other Pregnancy-Related Conditions

- Pregnancy Associated Sleep Disorder is diagnosed condition caused by mechanical and hormonal changes → progesterone has sedating effect
  - Sleep quality worst in 1<sup>st</sup> and 3<sup>rd</sup> trimesters
- Pregnancy associated with transient restless leg syndrome

## Hematological System

- Blood volume ↑ by 50% by 34 weeks gestation
- Physiologic anemia of pregnancy as plasma ↑ 55% vs. RBC production ↑ 30%
  - Estrogen ↑ renin → ↑ renal Na<sup>+</sup> absorption by 900mg → 7L extra H<sub>2</sub>O resorption
- Laboratory values:
  - Hb: 11.6 g/dL
  - Hematocrit: 35.5%
  - Albumin diluted: 4.5g/dL → 3.9 g/dL in 1<sup>st</sup> trimester → 3.3g/dL at term
  - Total plasma: 7.8g/dL → 7.0g/dL
  - Maternal colloid osmotic pressure ↓ by 25%
- Hypercoagulability state in pregnancy
  - Factors ↑ are I (fibrinogen), VII, VIII, IX, X, XII
  - Factors unchanged are II, V

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- Factors ↓ are XI, XIII
  - Coagulation lab values:
    - PT and PTT ↓ 20%
    - TEG → show hypercoagulability
    - Antithrombin III ↓
    - Platelet count show no change or ↓
    - No change in bleeding time
    - ↑ in fibrin degradation products and plasminogen
  - **Gestational thrombocytopenia:** 1% of healthy patients will have platelet count <100,000/mcL
    - If see low platelet count, rule-out pre-eclampsia, eclampsia, HELLP syndrome
    - Amount of platelets required for safe neuraxial anesthesia is difficult to quantify
      - Research shows cancer patients undergoing chemotherapy are able to get lumbar puncture without resulting in hematoma with platelet < 50,000/mcL
      - Dr. Mike Hofkamp uses cut-off of 70,000/mcL for epidural and 50,000/mcL for spinal → caveat is that everything else has to be perfect (ie. has to only be dilution effects responsible for low platelets)
  - Normal blood loss:
    - Vaginal 600mL
    - C-section 1000mL
  - Blood volume:
    - Drops from 150% at term to 125% of pre-pregnancy during 1<sup>st</sup> post-partum week
    - Drops to 110% of pre-pregnancy blood volume six to nine weeks post-partum

## Immune System

- WBC 6000/mm<sup>3</sup> pre-pregnancy to 9000-11,000/mm<sup>3</sup> during pregnancy
- During labour, WBC reach 15,000/mm<sup>3</sup> → without source of infection
- Polymorphonuclear leukocyte activity ↓ during pregnancy → potentially reason for ↑ infection

## Gastrointestinal System

- Stomach displaced upward and leftward → ↑ gastroesophageal reflux
  - Gastric emptying not altered during pregnancy, but ↑ during labour
    - Progesterone slow esophageal peristalsis and intestinal transit → pregnant people are constipated with heartburn
    - Risk of aspiration because of low pH and high volume
    - Epidural analgesia does NOT delay gastric emptying vs. epidural with fentanyl will delay gastric emptying because of systemic absorption of opioid
  - Liver size, morphology and blood flow unchanged; LFTs rise to upper limit normal because of production in placenta
  - ↑ risk of gallbladder disease because of biliary stasis, ↑ secretion of bile with cholesterol
    - If patients going to have laparoscopic cholecystectomy, best during 2<sup>nd</sup> trimester because risk of anesthetic teratogenicity during organogenesis and decreased intraabdominal room in 3<sup>rd</sup> trimester
      - Rare for OB to do intra-op fetal monitoring
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## Renal System

- ↑ renal vascular volume and interstitial volume
- ↑ 50% GFR and renal plasma flow
- ↑ creatinine clearance 150 to 200mL/min; creatinine level should be lower than pre-pregnancy
- ↑ total protein excretion and urinary albumin excretion
- Renal compensation by ↑  $\text{HCO}_3^-$  secretion because of respiratory alkalosis (create lower  $\text{PaCO}_2$  to offload fetus  $\text{CO}_2$ )

## Endocrine System

- Thyroid:
  - o ↑ thyroid function 50 to 70%
  - o ↑ total T<sub>3</sub> and T<sub>4</sub> because estrogen induced ↑ in globulins
    - Free T<sub>3</sub> and T<sub>4</sub> does not change so no thyrotoxicosis during pregnancy
- Glucose metabolism:
  - o Mean glucose same
  - o ↑ glucose demand because of fetus
  - o Insulin resistance due to placenta hormones (lactogen mostly responsible)
- Adrenal function:
  - o Plasma cortisol: 100% ↑ after 1<sup>st</sup> trimester; 200% ↑ at term → result in ↑ fluid retention to support ↑ cardiac output

## Musculoskeletal System

- Back pain result of relaxin → alters collagen fibers in pelvic connective tissue → allows pelvic to expand to expel fetus
  - o 19% of patients have back pain in 1<sup>st</sup> trimester
  - o 49% of patients have back pain at term

## Nervous System

- MAC 40% lower in pregnant patients because of progesterone
- ↑ endorphins and enkephalins found in plasma and CSF
- Require less local anesthetic to achieve epidural or spinal level because adiposity of tissues surrounding epidural and spinal space put pressure on epidural and spinal space
- Dependent on sympathetic nervous system to maintain hemodynamics → spinals and epidural catheters drop BP

## Anesthetic Implications of Pregnancy

- Avoid supine position: gravid uterus compress IVC → ↓ venous return
    - o Unclear what optimal level of lateral decubitus position is, but standard of care is to not have pregnant women lie flat on back
  - 10x ↑ in failed intubations, but based on data before video laryngoscopes
    - o Emerging data show airway management with pregnancy women is safer with video
  - Consider use of smaller cuff due to airway engorgement → have 6.0, 6.5, 7.0 tube available
    - o May not be able to pass larger tube
  - ↓ FRC and ↑ O<sub>2</sub> demand → more rapid hypoxemia (usually desaturate in <1minute)
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