Physiology of Pregnancy

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• Know how to discuss the maternal physiologic and anatomic changes associated with pregnancy

• Know how to interpret common diagnostic studies during pregnancy

• Understand the physiology of Lactation
Organ Systems Approach

- Gastrointestinal
- Genitourinary
- Hematologic
- Renal
- Cardiovascular
- Endocrinologic
- Musculoskeletal
- Respiratory
Endocrine Changes/Anatomy

- Estrogen
- Progesterone
- Human Placental Lactinogen
- Relaxin

- Space Occupation: Fetus/Uterus
Estrogen

- Renin→
  Angiotensin
  →Aldosterone →
  Sodium and Water resorption

- **Induction of Hepatic proteins**

- **Increased Cholesterol**
  Precursor for Steroid Hormones
  300 mg/dL

- **Capillary Dilation**
  Heat Dissipation
Renin - Angiotensin -> Aldosterone

- VOLUME EXPANSION

  - 50% increase in
    - Plasma Volume
    - Extracellular Fluid
    - *Cardiac Output*
    - Glomerular Filtration

Serum Sodium remains unchanged
Induction of Hepatic Proteins

- COAGULATION FACTORS
- HORMONE BINDING PROTEINS
- CYTOCHROME P450 ENZYMES*
- ALBUMIN: LOW- DILUTIONAL
- ALKALINE PHOSPHOTASE: HIGH (placenta)
Coagulation Factor Changes

Fibrinogen (Factor I): 50% INCREASE

VII-X RISE progressively until term
Prothrombin (Factor II)& Factor V-stable
Factors XI and XII decline somewhat

- Prothrombin (PT), Partial Thromboplastin (PTT) values are unchanged during normal pregnancies
Hypercoagulability of Pregnancy

Increased Incidence of
• Venous Thromboembolism VTE
  ◦ 2 x risk Pregnancy
  ◦ 5 x risk Postpartum

  • Inherited Thrombophilia
  ◦ Anticoagulation in pregnancy & for 6 weeks postpartum
Hormone Binding Proteins

- Thyroid Binding Globulin TBG
  Total Thyroxine elevated
  Free Thyroxine remains normal

- Sex Hormone Binding Globulins

- Cortisol Binding Globulin
Progesterone

- Relaxation of Smooth Muscle
- Increase in Tidal Volume
Smooth Muscle Relaxation

- Uterine Muscle can expand
- Systemic Vascular bed can expand
- All GI/GU Sphincters affected
- All Tubular structures dilate
GI & GU Sphincter Relaxation

- Esophageal Sphincter
  - GERD  GastroEsophageal Reflux Disease

- Sphincter of Oddi
  - Gallstone passage
  - Delayed Gastric Emptying

- Small Bowel- bloating

- Large Bowel- Constipation
Tubular structures dilate

- Venous Stasis
  - Risk of Thrombosis

- Uretero Vesical Junction
  - Reflux leads to PYELONEPHRITIS
  - “Hydroureter” < 1-2 cm diameter
Hydronephrosis
Obstruction?
Nausea of Pregnancy

- Proportional to HCG level
- Gastric distention can trigger nausea
- Hyperemesis Gravidarum
  - Prolonged vomiting
  - Dehydration
  - Weight Loss
  - Starvation Ketosis
Vascular Smooth Muscle Relaxation

- Allows for Volume Expansion without an increased Mean Arterial Pressure
  - Drop in MAP begins in 2nd Trimester
  - Peripheral Vascular Resistance falls 30%
  - Relative rise in pulse of 15-20 bt/min
Widened Pulse Pressure 2\textsuperscript{nd} TM

- **NonPregnant**: Diastolic: 4, Systolic: 2
- **1st TM**: Diastolic: 4, Systolic: 2
- **2nd TM**: Diastolic: 4, Systolic: 2
- **3rd TM**: Diastolic: 4, Systolic: 2

*Diastolic* vs *Systolic*
Vascular Smooth Muscle Relaxation

Pregnant women have reduced sensitivity to catecholamines and angiotensin

- Preeclamptic women do not
  - Diffuse arterial vasospasm
  - Intermittant -> Sustained
  - Progression exacerbated by Catecholamines
Preeclampsia

- After 20 weeks of pregnancy
- Hypertension >140/90
- Proteinuria 300mg/24 hours
- Eclampsia = Grand Mal Seizure
Etiology of Preeclampsia

- UNKNOWN
- Immunologic factors
- Abnormal Terminal Villi / Ut Vasculature
- Soluble Proteins    VEGF, sFLT
- Systemic Inflammatory state

- ObGyn Basic science research:
  - Dr. Virginia Winn’s lab looking at placental pathology
Trophoblastic invasion of Endometrium
Spiral Arteries
Chorionic Villi

Normal pregnancy
A
Myometrium
Decidua

Spiral arteries

Preeclampsia
B

Villus (containing fetal arteriole and venule)
Intervillous space (maternal blood)

Umbilical artery
Umbilical vein
Pulmonary Function Changes

- Increased Minute Ventilation
  no change in Respiratory Rate

- Reduced Functional Residual Capacity
  due to Diaphragm Elevation in 3\textsuperscript{rd} TM
Pulmonary Function Changes

**NONPREGNANT**

- Inspiratory Reserve
  - **TIDAL VOLUME**
  - Expiratory Reserve Reserve
  - Residual Volume

**PREGNANT**

- Inspiratory Reserve
  - **TIDAL VOLUME**
  - Expiratory Reserve Reserve
  - Residual Volume
ICU Patient: 36 wk Pregnant

- ↓ Functional Residual Capacity
- ↑ Oxygen consumption
- ↓ Oxygen reserve
- Rapid decrease in oxygen saturation if alveolar hypoventilation occurs
  - IV Sedation
  - High Spinal block
  - Pulmonary pathology
Arterial Blood Gas changes

- Reduced maternal pCO2 facilitates the excretion of Fetal CO2 at the villi
- Maternal pH remains unchanged
- Renal excretion of HCO3 increased
- Problem: loss of buffering capacity
Placental Physiology

• Chorionic Villi
  INTERVILLOUS SPACE = MATERNAL BLOOD

• Gas exchange
  ◦ Fetal hemoglobin dissociation curve

• Adaptive responses (high altitude)

• Maladaptive Responses
  ◦ Smoking -> Intrauterine Growth Restriction
Chorionic Villi

Normal pregnancy:
- Myometrium
- Decidua
- Villus (containing fetal arteriole and venule)
- Intervillus space (maternal blood)

Preeclampsia:
- Spiral arteries
- Umbilical artery
- Umbilical vein
Human Placental Lactinogen

- Insulin Antagonist
- Increase in Insulin Resistance
Maternal Hyperglycemia

*Facilitated Diffusion* of Glucose -> Placenta
Fetal Hyperglycemia  ->  Macrosomia
Fetal Hyperinsulinemia ->
Neonatal Hypoglycemia
Relaxin

peptide hormone in the insulin family
produced in placenta and decidua

- Increase in Joint Mobility
  - Sacroiliac joints
  - Symphysis Pubis
  - Lumbar vertebrae
    - paraspinus muscle spasm
    - nerve root compression -> paresthesias
Sacroiliac Joints
Symphysis Pubis Separation
Fetus/Uterus

- Space Occupation -> Compression of Vena Cava, Bladder, Bowel Nerve Roots, Peripheral Nerves

Repositioning of intraabdominal organs - Appendix
Appendicitis in 20 week pregnancy
Pregnancy Weight Gain

- *Where does it all go?*
  
  *Approximate breakdown of a weight gain of 30 pounds*

- Blood 3 lb
- Breasts 2 lb
- Uterus 2 lb
- Fetus 7.5 lb
- Placenta 1.5 lb
- Amniotic fluid 2 lb
- Fat, protein & other nutrients 8 lb
- Retained water 4 lb
VOLUME EXPANSION

- High GFR
- Dilutional Anemia
- Decreased Colloid Osmotic Pressure
High GFR

- Change in renal function parameters
  - Cr Cl – 150 ml/min
  - Plasma Cr - <=0.7mg/dL

- More rapid excretion of drugs
  - Antibiotics: penicillins, aminoglycosides
Dilutional Anemia

- **Plasma Volume** increases by 50%
  - starts at 10 wk
  - increases until 30 wk when it plateaus
Rise in Plasma volume and RBC mass

without Fe supplement
Dilutional Anemia

- **RBC mass** begins increasing at 10 wk
- at a slower rate & does not plateau

Without Fe supplement: 18% rise

- With Fe supplement: 30% rise
Dilutional Anemia

- Reduced Viscosity
- reduced resistance to flow
- facilitating placental perfusion
- lowering cardiac work
Decreased Colloid Osmotic Pressure

- Dependent Edema is the norm
- Lower threshold for Pulmonary Edema/ARDS
- Airway Edema in acute illness
  - Anesthesia issues
Cardiac Parameters

- Stroke volume x HR = Cardiac Output
- Rise in Stroke Volume peaks at 20-24 wk
- Gradual Rise in Heart Rate plateaus 28wk
  - Stroke Volume returns to near normal level
  - Sustained rise in Cardiac output
  - No change in MAP, CVP, PA pressure
Supine Caval Compression

- <24 wk  no effect
- 24-28 wk  10% decline cardiac output
- 28-32 wk  15%
- 32-38 wk  20%
- 38-40 wk  25-30%

- Standing  36-38 wk  20%  do we notice this?
Supine Hypotension Syndrome

- < 10% of pregnant women
  - Lightheaded, nausea, occ. Syncope
  - May arise after only 20-30 seconds supine

- Symptoms absent in 90% due to paravertebral collateral circulation

- Rerouting venous blood to R heart
- Reduced placental perfusion still possible
Placental Perfusion

- 10% of Maternal CO delivered to uterus
  - Nonpregnant 2%
  - 700-800 ml/min at term
Uteroplacental Insufficiency

- Heat, Exercise, Anxiety, Excitement, Decreased Venous return can reduce flow

- Healthy Placenta can tolerate 50% reduction in flow without fetal impact

- Hypovolemic fetus => Oligohydramnios
- Hypoxic fetus => Metabolic Acidosis
Lactation Physiology

- **Estrogen** stimulates the proliferation and differentiation of the ductal system

- **Progesterone** promotes an increase in the size of the lobes, lobules and alveoli

- ACTH and Growth Hormone also have trophic effects
Pregnancy

- Secretory activity begins gradually around 16 wks of gestation

- In late pregnancy there is a differentiation of alveolar cells from secretory cells and initiation of milk synthesis
Prolactin

- Anterior Pituitary: Lactotrophs hypertrophy in pregnancy
  - acute enlargement postpartum

- Gradual rise in prolactin until 3rd trimester then steeper rise

- Wide variation in prolactin levels at term
Range of Prolactin levels
Postpartum

- Gradual switch from only endocrine to autocrine control (in response to suckling)
- Oxytocin --->let down (milk ejection reflex)
Lactation Maintenance

- Prolactin levels gradually drop about 50%. This level is sustained by 8 feedings per 24 hours.

- Lack of feeding leads to build up of intraluminal pressure and a peptide “Feedback Inhibitor of Lactation” (FIL) that acts on alveolar cells to decrease milk production.
Summary

- **ESTROGEN**
  - Renin -> Volume Expansion
  - Hepatic Proteins -> Coagulation

- **PROGESTERONE**
  - Smooth Muscle Relaxation -> accommodation
  - Increased Minute Ventilation -> CO2 clearance

- **BOTH**: Trophic effects on Breast
95-99% of Pregnancies are normal