Physiology of pregnancy and delivery

Division of Maternal Fetal Medicine
Goals

To understand an overview of the physiology of pregnancy and delivery
Body Water

- Total body water increases from 6.5L to 8.5L
- Pregnancy is a condition of chronic volume overload
- Water retention exceeds Na retention—decreased plasma osmolality (Na decreases by 3-4)
Hematology – Blood volume

- Increases progressively starting at 6 to 8 weeks’ gestation
- Maximum volume at 32 weeks - 45% increase
- Red blood cell mass increases by 250-450 cc by term
Hematologic changes

- **IMPLICATIONS**
  - The 45% increase in circulating blood volume may:
    - Protect from maternal hemodynamic instability
    - Serve to dissipate fetal heat production and provide increase renal filtration
  - *Physiologic anemia of pregnancy*
    - May function to decrease blood viscosity
    - May improve intervillous perfusion?
Cardiovascular – Cardiac output

- Maternal cardiac output (CO) increases about 30-50% during pregnancy (mean 33%)
  - Pregnancy maximum of 6 L/min
  - CO remains maximal until delivery
Cardiovascular – Cardiac output

- Distribution of CO
  - First trimester and non-pregnant state
    - Uterus receives 2-3%
  - By term
    - Uterus receives 17%
    - Breasts 2%
  - Reduction of the fraction of CO going to the splanchnic bed and skeletal muscle
  - CO to the kidneys, skin, brain and coronary arteries does not change
Cardiovascular – Arterial BP

- BP varies with position

- Peripheral vascular resistance (PVR) falls
  - Progesterone’s smooth muscle relaxing effect
  - ? Heat production by the fetus $\rightarrow$ vasodilation

- The reduction in PVR leads to a progressive fall in systemic arterial BP during the first 24 weeks of pregnancy

- Gradual rise after 24 weeks $\rightarrow$ non-pregnant levels by term
Signs and Symptoms of Normal Pregnancy

- **Symptoms**
  - Reduced exercise tolerance
  - Dyspnea

- **Signs**
  - Peripheral edema
  - Distended neck veins
  - Point of maximal impulse displaced to the left
Cardiovascular - Labor

- First stage of labor: 12-31% rise of CO due to an increase in stroke volume (SV)

- Second stage of labor: 34% increase in CO
  - Not only pain-related
  - UCs result in the transfer of 300-500 cc of blood from the uterus to the general circulation
    - Enhanced venous return to the heart
    - Increase in CO by 10-15%
Cardiovascular - Postpartum

- Immediate PP period: 10-20% rise in CO
  - Release of obstruction of venous return
  - Extracellular fluid mobilization
- Rise in CO associated with reflex bradycardia
  - SV increases → this may persist for one to two weeks after delivery
Figure 3-8. Lung volumes in nonpregnant and pregnant women. ERV, expiratory reserve; FRC, functional residual capacity; IC, inspiratory capacity; IRV, inspiratory reserve; RV, residual volume; TLC, total lung capacity; TV, tidal volume; VC, vital capacity. (From Cruickshank DP, Wigton TR, Hays PM: Maternal physiology in pregnancy. In Gabbe SG, Niebyl JR, Simpson JL [eds] Obstetrics: Normal and Problem Pregnancies, 3rd ed. New York, Churchill Livingstone, 1996, p 94, with permission.)
Respiratory system

- LUNG VOLUME AND PULMONARY FUNCTION
  - 30-40% increase in tidal volume (Amount of air I and E with each breath)
    - 30-40% increase in minute ventilation (likely P4 mediated)
  - ERV falls by 20%
  - Vital capacity and inspiratory reserve volume remain unchanged
Respiratory system

LUNG VOLUME AND PULMONARY FUNCTION

- Respiratory rate is unchanged
- Due to elevation of the diaphragm
  - Total lung volume decreases (diaphragm) by 5%
  - Residual volume decreases (RV) by 20%
  - FRC is reduced 20%
- No change in FEV1 or the ratio of FEV1 to forced vital capacity
Respiratory system

- **DYSPNEA OF PREGNANCY**
  - Common complaint
    - 60-70% of patients
    - Late first or early second trimester
  - Likely due to various factors
    - Awareness of increased tidal volume of pregnancy
    - Decreased total lung volume/elevation of diaphragm
Renal system

- **ANATOMY**
  - Kidney enlargement
    - Increased renal vascular and interstitial volume, R>L
  - Ureteral and renal pelvis dilatation by 8 weeks
    - Right > left
      - Mechanical compression by uterus and ovarian venous plexus
      - Smooth muscle relaxation by progesterone
Renal system

- **RENAL HEMODYNAMICS**
  - Effective renal plasma flow (ERPF) and GFR increase
    - Filtration fraction falls
      - Returns to normal by late third Δ
  - Endogenous creatinine clearance increases
    - Begins by 5 weeks
Gastrointestinal - Appetite

- Increase early 1st Δ

- Increase intake 200 kcal by end 1st Δ
  - RDA: 300 kcal/day during pregnancy

- Sense of taste may be blunted
Gastrointestinal - Mouth

- Unchanged pH or production of saliva
  - Saliva production is unaltered
  - Ptyalism – usually in women with hyperemesis
    - Due to inability to swallow
    - Can lose up to 1-2 L of saliva per day
    - Decreasing starchy foods might help

- Gums – edematous and soft
  - May bleed after brushing

- Epulis gravidarum
  - Regress 1-2 months after delivery
  - Excise if persistent or excessive bleeding
Gastrointestinal - Stomach

- Decreased tone and motility
  - Progesterone
  - Possibly due to decreased levels of motility
- Conflicting info about delayed gastric emptying
- Reduced tone of the gastroesophagoeal junction sphincter
  - Increased intraabdominal pressure leads to acid reflux
Gastrointestinal - Small bowel

- Reduced motility of small bowel
  - Increased transit time in the third trimester and postpartum

- Enhanced iron absorption
  - As a response to increased iron needs
Gastrointestinal - Colon

- Constipation
  - Mechanical obstruction by the uterus
  - Reduced motility (progesterone)
  - Increased water absorption

- Portal venous pressure is increased
  - Dilation of gastroesophageal vessels
    - Issue in those with preexisting esophageal varices
  - Dilation of hemorrhoidal veins → hemorrhoids
NAUSEA AND VOMITING

- Morning sickness complicates 70% of pregnancies
- Onset 4-8 weeks up to 14-16 weeks
- Cause?
  - Relaxation of smooth muscle of stomach, elevated levels of steroids and hCG
  - Rx – supportive: reassurance, support, and avoiding triggers...

HEG

- Weight loss, ketonemia, electrolyte imbalance and dehydration
- Possible renal or hepatic damage
- IVF, antiemetics
  - NPO
  - continue IV
you can’t drink any alcohol and you still get a hangover every morning
Endocrine - Thyroid

- The normal pregnant woman is euthyroid

- Changes in thyroid morphology and lab indices
  - Estrogen-induced increase in TBG

- Serum TSH decreases early in gestation
  - Rises to pre-pregnancy levels by end of first Δ

- Total T4 and total T3 increase early in gestation
  - Role of hCG stimulating the thyroid
  - Rise in TBG leads to rise in total T4 and total T3
  - Active hormones free T4 and free T3 are unchanged

- Free T4 is the most reliable method of evaluating thyroid function in pregnancy
Endocrine - Pancreas

- Fetus primarily depends on glucose
  - Facilitated diffusion
    - Carrier-mediated but not energy dependent process

- Active transport of amino acids to the fetus

- Ketones diffuse freely across the placenta
Skin

- Spider angiomata (face, upper chest, and arm) and palmar erythema
  - Elevated estrogen levels
  - Both regress after delivery

- Striae gravidarum

- Increased eccrine sweating and sebum excretion
**Breasts**

- **Early change**
  - Tenderness, tingling and heaviness
  - Vascular engorgement leads to enlargement
    - Ductal growth due to estrogen
    - Alveolar hypertrophy due to progesterone

- **Enlargement and pigmentation of areolae**

- **Colostrum may be expressed later in pregnancy**

- **Milk production**
  - E2, p4, prolactin, hPL, cortisol and insulin
  - Lactation likely due to drop in estrogen and progesterone after delivery
Skeleton

- Lordosis
  - Keep center of gravity over the legs
  - Back pain...

- Relaxin
  - Relaxation of the pubic symphysis and sacroiliac joints
    - Facilitates vaginal delivery but may lead to discomfort

- Implications
  - Unsteadiness of gait and trauma from falls
Labor
Cervical effacement

- Collagen chains are broken down.
- Hydrophobic glycosaminoglycans are replaced by more hydrophilic hyaluronic acid.

Cervical smooth muscle contraction causes the cervical tissue to be pulled upward and be incorporated into the lower segment of the corpus.
Uterus -- Myometrium

- Smooth muscle cells
- Muscle cells spiral and are arranged in bundles.
- Thick + thin filaments
- Gap junctions
The Biochemistry of Contractions

- **Contractile proteins**
  - Actin (thin filament)
  - Myosin (thick filament)
  - Tropomyosin
  - Skeletin

- **Regulatory proteins**
  - Calmodulin
  - Cyclic adenosine monophosphate (cAMP)
  - Enzymes → (de)phosphorylation
What are the hormonal mediators of labor?

- Prostaglandins (E, F)
- Steroids
  - Progesterone
  - Estrogen
  - Cortisol
- Oxytocin
The important hormones

- **Prostaglandins (PGs)**
  - E and F are the important classes
  - Receptors are found in decidua and myometrium
  - Produced in the myometrium, decidua, and fetal membranes

- **Oxytocin (OT)**
  - Potent uterine stimulant
  - OT gene upregulated by estrogen
  - Receptors are located in
    - Myometrium
    - Fetal membranes (amnion)
    - Decidua
The important hormones -- Steroids

- **Progesterone**
  - Derivative of cholesterol – need progesterone for estrogen synthesis.
  - Reduced **uterine** levels **may** precede labor in humans.

- **Estrogen**
  - Does not directly cause myometrial contractions.
  - Upregulates gap junctions and OT receptors.
Events of term labor

- In order to have labor, the uterus has to contract and the cervix has to dilate!

- What causes uterine contractions/cervical ripening?
  - Uterine ctx
    - Prostaglandins (E2, F2α)
    - Anything that increases intracellular Ca
    - Gap junctions
    - Increase oxytocin receptors
  - Cervical ripening
    - Collagenase, elastase (i.e., metalloproteases)