Basics of Obstetric Anesthesia

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Outline

- Maternal physiology
- Anesthetic considerations
  - Analgesia for labor and delivery
  - The gravid airway
  - MAC requirement
- Management of common obstetric conditions
  - Postpartum hemorrhage
  - Pre-eclampsia

Maternal Physiology

Cardiovascular system

Table: Central Hemodynamic Changes at 36 to 38 Weeks Gestational Age

HR	↑ 17%
SVR	↓ 21%
PVR	↓
CO	↑ 43%
PCWP	No change
CVP	No change
MAP	No change

Clark, SL Cotton DB, Lee W, et al

Uterine Perfusion

- In an autoregulated system, flow remains constant over a range of blood pressures as a result of varying arterial resistance.

$$\text{Flow} = \text{Perfusion Pressure/Resistance} = \frac{\text{Arterial Pressure} - \text{Venous Pressure}}{\text{Arterial Resistance}}$$

- Uterine blood flow is not autoregulated because the uterine arteries are maximally vasodilated hence uterine artery resistance is at its lowest at all times
- Therefore, uterine blood flow is directly proportional to maternal blood pressure.
- Any cause of maternal hypotension, such as supine hypotension, will lead to a decrease in uterine blood flow and oxygen delivery to the fetus.

$$\text{Uterine Blood Flow} = \frac{\text{Uterine Artery Pressure} - \text{Uterine Venous Pressure}}{\text{Uterine Artery Vascular Resistance}}$$

Respiratory System - Ventilation

Table: Lung Volumes in the Pregnant and Nonpregnant Woman

	TV	IRV	ERV	RV	FRC	VC	TLC
Nonpregnant	450	2050	700	1000	1700	3200	4200
Pregnant	600	2050	550	800	1350	3200	4000

Alan C. Santos, Jonathan N. Epstein, Kallol Chaudhuri

- There is a marked increase in TV up to 40% and a significant decrease in ERV of 25%, but no significant change in IRV.
- Vital capacity (VC), the sum of the tidal volume (TV), inspiratory reserve volume (IRV), and expiratory reserve volume (ERV), is unchanged during gestation.
- Residual volume (RV) is also decreased by 15%. This leads to a marked decrease in the functional residual capacity (FRC)
- Although there is an upward displacement of the diaphragm by the gravid uterus, there is no significant change in total lung capacity (TLC) due to a widening of the anteroposterior and transverse diameter of the chest during pregnancy.

Respiratory System - Blood Gases

Table: Arterial Blood Gas Measured During Each Trimester and at Term

Gestational Age	12 Weeks	24 Weeks	32 Weeks	38 Weeks
pH	7.46	7.44	7.44	7.43
P_aCO_2 (mm Hg)	29.4	29.5	30.3	30.4
Base excess	–2.1	–2.8	–2.7	–3.1
HCO_3^-				21.7

Adapted from Templeton A, Kelman GR.

- Progesterone initially stimulates increase in minute ventilation which is further stimulated by fetal CO_2 passage across the placenta into the maternal circulation.
- Chronic hyperventilation leads to a chronic respiratory alkalosis. The increase in minute ventilation is primarily secondary to a 45% increase in tidal volume.
- The degree of respiratory alkalosis remains stable throughout pregnancy and is accompanied by a mild compensatory metabolic acidosis, via renal excretion of bicarbonate

Gastrointestinal system

Gastric anatomy

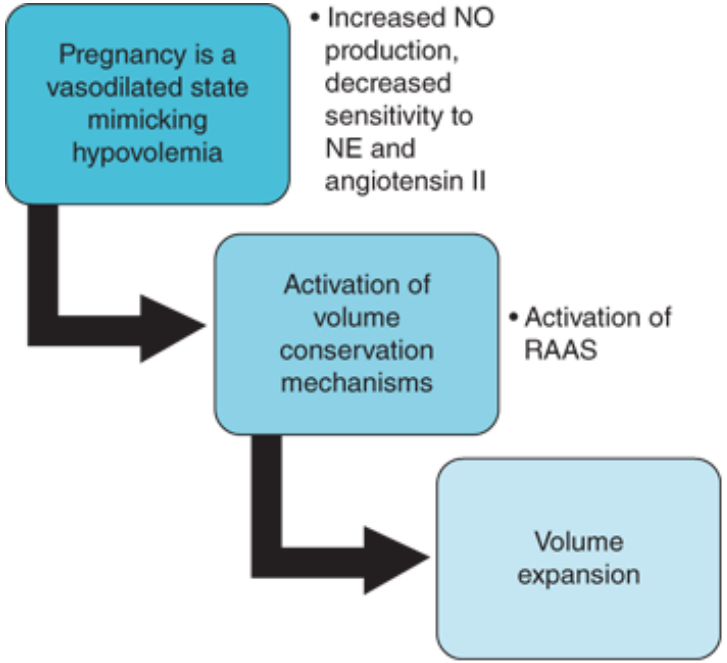
- Lower esophageal sphincter is incompetent due to the smooth muscle relaxant effect of progesterone (Richter 2005)
- Elevated GE junction and increased gastric pressure increases during pregnancy (Ngwingtin 1987)
- Gastric pH does not change during pregnancy (Ngwingtin 1987)

Gastric emptying

- Measurement of paracetamol absorption shows delayed gastric emptying by 8 weeks gestation (Levi 1994).
- Ultrasound evaluation of gastric contents show pregnant women who are not in labor have an empty stomach after an overnight fast and 4 hours after eating.
- During labor, there is marked delay in gastric emptying of solids irrespective of the time interval after eating.
- Solid food found in the stomach up to 24 hours after eating (Carp 1992)

Hematologic system

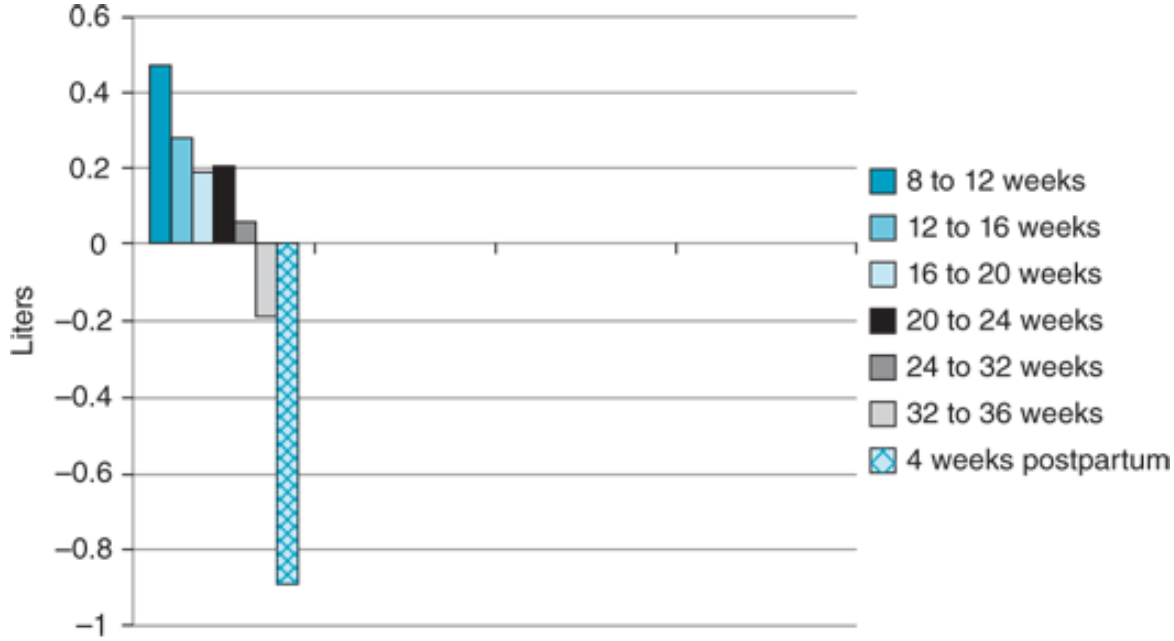
Figure: Volume regulation during pregnancy. NE, norepinephrine; NO, nitric oxide; RAAS, renin-angiotensin-aldosterone system.



Hematologic system

- A 30% increase in blood volume occurs between the 8th and 32nd weeks of pregnancy
- Approximately 1200 mL total blood volume increase

Table: Change in liters over time in maternal blood volume from 8 weeks' gestation to 4 weeks' postpartum.



Source: A. C. Santos, J. N. Epstein, K. Chaudhuri: Obstetric Anesthesia
www.accessanesthesiology.com

Table: Factor Levels and Activity During Pregnancy

	Factor Level	Factor Activity
Fibrinogen	↑↑↑	
Prothrombin	↑	
Factor VII	↑	
Factor VIII	↑	↑
Factor V		↑
Factor IX	↑	↑
Factor X	↑	↑
Factor XII	↑	↑
Factor XI	↓	↓
Factor XIII	↓↓	
Von Willibrand Factor	↑↑↑	
Platelet Count	→ or ↓ at term	

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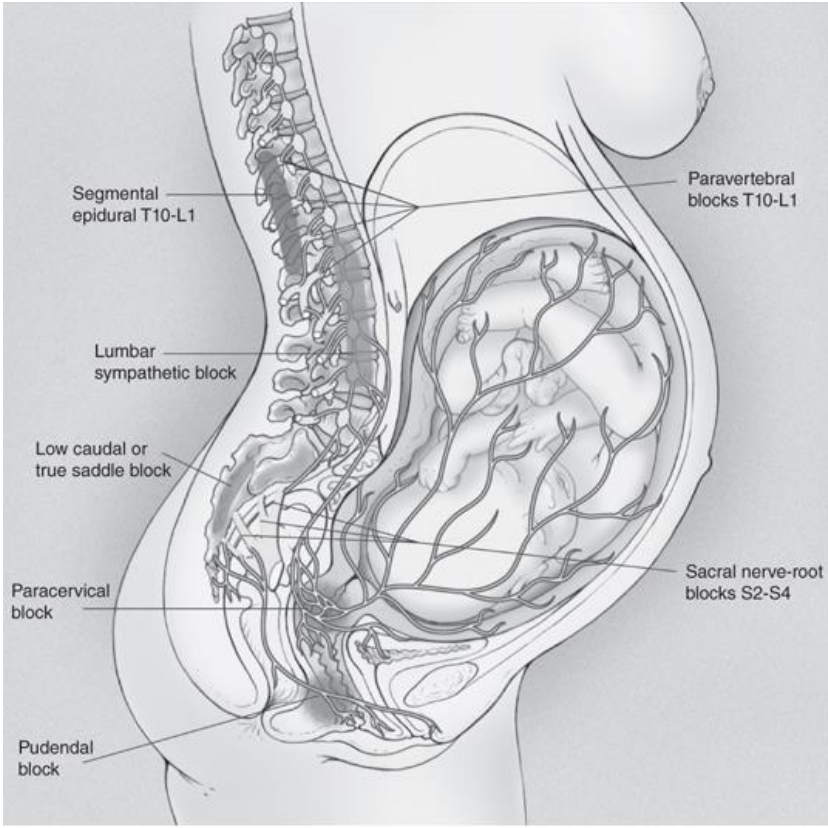
Analgesia for Labor and Delivery

Stages of Labor

- First stage: Latent and active phases of cervical dilation; ends with full cervical dilation
  - pain caused primarily by uterine contraction and cervical dilation transmitted via visceral afferent fibers to **T10- L1**
  - pain tend to be diffuse in nature.
  - **bilateral paracervical block can provide relief**
- Second stage: fetus descends in the birth canal; ends with delivery of the fetus
  - pain is caused by vaginal and perineal distension transmitted via somatic afferent fibers of the pudendal nerve to **S2 to S4**
  - pain is somatic and localized
  - **bilateral pudendal nerve block transvaginal or transperineal route can produce vaginal, vulvar, and perineal anesthesia**
- Third stage: ends with delivery of the placenta
  - placenta separates and uterus contracts to establish hemostasis
- Fourth stage: period of significant physiologic changes
  - immediate 2 hours postpartum



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Analgesia for Labor

- 1st stage – T10-L1
- 2nd and 3rd stages – T10-L1, S2-S4
- Options include:
  - Nothing
  - Nonpharmacologic interventions
  - IV or inhalational agents
  - **Regional techniques**

Parenteral Agents

Name	Class	Dosage	Duration
Morphine	Opioid	2-4 mg IV	3-4 h
Hydromorphone	Opioid	0.5-2 mg IV	1-2 h
Meperidine	Opioid	25-50 mg IV	2-3 h
Fentanyl	Opioid	25-50 mcg IV	30-60 min
Nalbuphine	Agonist/antagonist	5-10 mg IV/IM	3-6 h
Butorphanol	Agonist/antagonist	1-2 mg IV	3-4 h
Midazolam	Benzodiazepine	1-2 mg IV	1-2 h
Ketamine	NMDA	10-15 mg IV	0.5-1 h

Nalbuphine

- Mu-receptor agonist/antagonist
- Commonly used systemic analgesic during labor
- For mild to moderate pain, potency similar to morphine
- Lower incidence of pruritus, nausea/vomiting and respiratory depression than morphine
- Placental transfer to fetus (fetomaternal ratio 0.74)

Zeng et al. Sci Rep: A comparison of nalbuphine with morphine for analgesic effects and safety: meta-analysis of randomized controlled trials

Fentanyl PCA

- Substitute for regional anesthesia
- Not as effective as regional for analgesia, but comparable patient satisfaction
- Ideal dosing is variable
- Side effects of opioids for mother (nausea, dizziness, sedation) and respiratory depression in baby
- Both mom and baby require careful monitoring during and after delivery

Fortescue C et al. Analgesia in labour: nonregional techniques. *C*ontin Educ Anaesth Crit Care Pain (2005) 5 (1): 9-13 doi:10.1093/bjaceaccp/mki002

Remifentanil PCA

- Potent synthetic opioid with short context-sensitive half life (3-4 minutes)
- More rapid onset and offset than Fentanyl
- Minimal accumulation of maternal plasma remifentanil
- Placental transfer occurs but rapidly metabolized and redistributed by fetus
- Possibly lower incidence of neonatal respiratory depression
- Higher patient satisfaction compared to Fentanyl but more sedation and desaturations in RCT of remifentanil vs fentanyl PCA

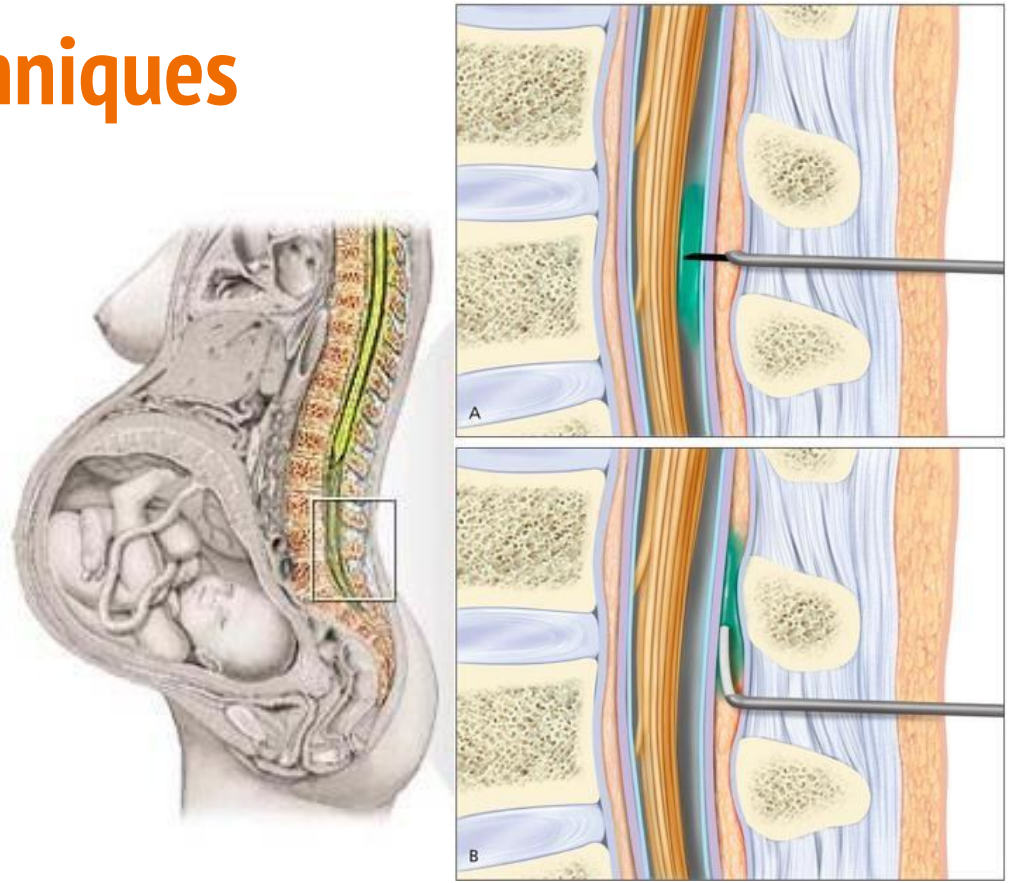
Douma et al. Obstetric analgesia: a comparison of patient-controlled meperidine, remifentanil and fentanyl in labour. Br J Anesth 2010; 104(2): 209-15

Inhalational analgesia

- Nitrous oxide is most common agent
- Minimal effects on uterine blood flow or contractions
- Further research needed to assess effectiveness and risk profile
    - Increases nausea and vomitting
    - Oxidizes Vitamin B12 -> inhibition of methionine synthetase -> folate deficiency -> megaloblastic anemia

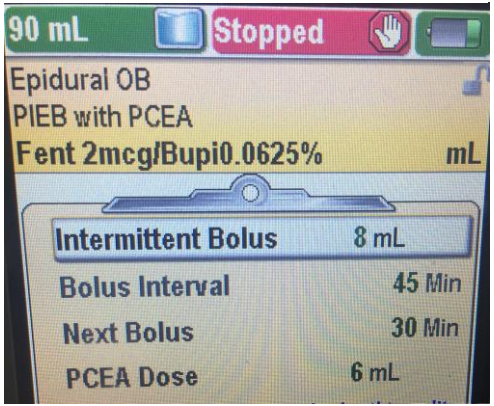
Regional anesthetic techniques

- Epidural
- Spinal
- Combined spinal-epidural (CSE)



Epidural analgesia

- Most commonly used technique
- Highly effective analgesia for labor and can be used to provide anesthesia for cesarean delivery
- Usually placed once active labor is achieved, although there are potential advantages to placing early
- Patient-controlled (PCEA)
- Minimal effect on progress of labor, need for oxytocin augmentation, operative delivery, or cesarean delivery



Spinal and CSE for labor

- Spinal
  - Last-minute anesthetic for advanced labor
  - Rapid and dense analgesia lasting 1.5-2 hours
  - Motor-blockade
  - Prior spine surgery – serial spinals
- Combined Spinal Epidural
  - Great option for rapid progression
  - Rapid pain relief with minimal motor blockade
  - Lower probability of failed epidural

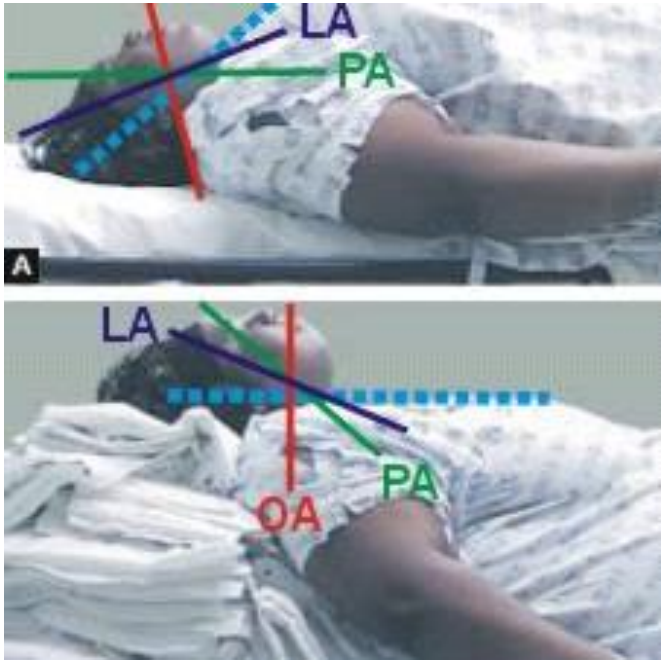
Post-Dural Puncture Headache

- Differential Dx: Tension or migraine headache, cortical vein thrombosis, SDH, SAH, meningitis
- Positional headache
- Onset 1-2 days after dural puncture
- Duration usually 7-14 days
- Conservative management includes fluid and caffeine intake, oral analgesics
- Gold standard is epidural blood patch

The Gravid Airway

Why are we so concerned?

- Higher incidence of difficult intubation
- Airway edema
- Friable tissues
- Enlarged breasts, difficult positioning
- Increased aspiration risk
    - Progesterone relaxes LES
    - Uterus alters angle of GE junction
    - Labor halts gastric emptying
    - ?NPO status
    - Not just with GA
- Rapid desaturation
    - Decreased FRC
    - Higher oxygen consumption



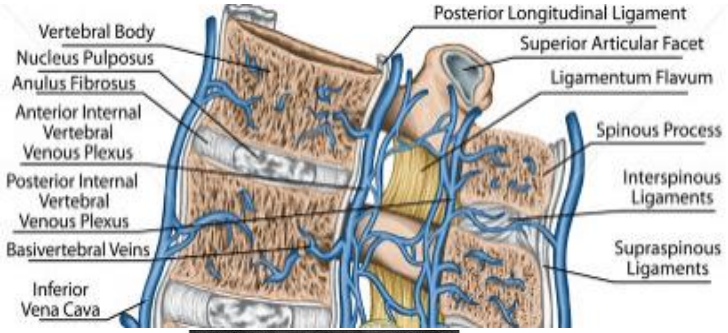

STORZ

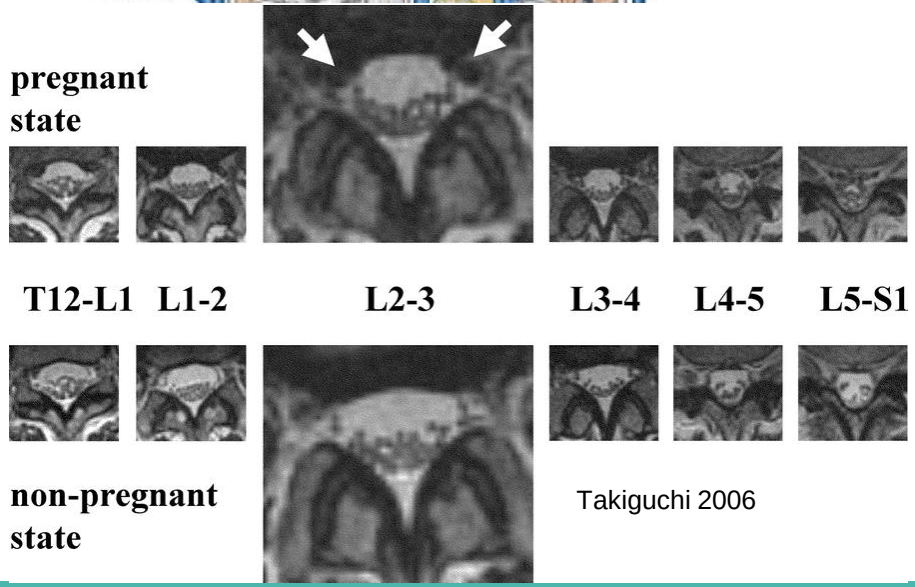

GlideScope

Anesthetic Requirement

Effects of Pregnancy on Local Anesthetic Requirements

- Gravid uterus causes decreased venous return and distension of epidural veins resulting in decreased intrathecal volume (Takiguchi 2006)
- Progesterone cause increased susceptibility to Na-channel blockade caused by local anesthetics
- CSF in pregnant patient has higher pH and lower PCO2 increasing diffusion of nonionized local anesthetic across nerve cell membrane (Hirabayashi 1996).
- Patients have non-pregnant local anesthetic requirements within 24-48 hours after delivery (Abouleish 1986).





Takiguchi 2006

Maternal Complications

INCIDENCE OF SERIOUS COMPLICATIONS

307,000 deliveries, 157 (0.05%) total complications, 85 (0.02%) were anesthesia related

Serious Complication	Totals	Incidence	95% CI	Anesthesia Related	Incidence	95% CI
Maternal death	30	1:10,250	1:7,180, 1:15,192	0		
Cardiac arrest	43†	1:7,151	1:5,319, 1:9,615	2	1:128,398	1:35,544, 1:1,060,218
Myocardial infarction	2	1:153,748	1:42,562, 1:1,269,541	2	1:128,398	1:35,544, 1:1,060,218
Epidural abscess/meningitis	4			4	1:62,866	1:25,074, 1:235,620
Epidural hematoma	1			1	1:251,463	1:46,090, 1:10,142,861
Serious neurologic injury	27	1:11,389	1:7,828, 1:17,281	7	1:35,923	1:17,805, 1:91,244
Aspiration	0			0		
Failed intubation	10			10	1:533	1:290, 1:971
High neuraxial block	58			58‡	1:4,336	1:3,356, 1:5,587
Anaphylaxis	5§	1:61,499	1:26,353, 1:189,403	0		
Respiratory arrest in labor suite	25	1:8,455	1:5,714, 1:12,500	16	1:10,042	1:6,172, 1:16,131
Unrecognized spinal catheter	14			14	1:15,435	1:9,176, 1:25,634
Total	157‖	1:1,959	1:1,675, 1:2,294	85#	1:3,021	1:2,443, 1:3,782

* The incidence and 95% CI are listed only once when solely related to anesthesia. † Fourteen cardiac arrests did not result in maternal death. ‡ Also includes high blocks on labor and delivery that resulted in respiratory arrests from local anesthetic administration. § The medications associated with anaphylaxis were administered by anesthesia personnel but were not anesthesia medications. ‖ There were 157 total serious complications; however, some complications are listed in more than one category. # There were 85 anesthesia-related serious complications; however, some complications are listed in more than one category.

D'Angelo R et al. Serious Complications Related to Obstetric Anesthesia: The Serious Complication Repository Project of the Society for Obstetric Anesthesia and Perinatology. Anesthesiology 2014; 120:1505-12

CAUSES OF MATERNAL MORTALITY

Causes*	Number
Hemorrhage	10
Preexisting cardiac disease	5
Hypertension	3
Amniotic fluid embolism	3
Pulmonary embolism	2
Anaphylaxis	2
Cocaine	2
Infection/sepsis	2
Unreported cause	1
Total	30

* Each patient is listed in only one category although many can easily be listed in multiple categories; for example, depending on the clinical presentation, an amniotic fluid embolism can also be categorized into cardiac arrest and hemorrhage categories.

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Postpartum hemorrhage

Definition
- > 500 ml EBL after vaginal delivery or > 1L after C-section
- Often underestimated due to concealed bleeding ie. uterus, peritoneal cavity and retroperitoneal space

Causes
- Uterine tone
- Retained products (placental tissue or clots)
- Trauma (genital tract lacerations)
- Coagulopathy

Risk factors
- Uterine atony: multiple gestation, prolonged induction, birth weight > 4500g
- Abnormal placentation: accreta, increta, percreta
- Inherited bleeding disorders

Treatment
- Uterotonics
- Invasive measures: intrauterine balloon tamponade, uterine compression sutures, angiographic arterial embolization, uterine artery ligation, hysterectomy

Uterotonics

Medication	Route of Administration	Dose	Side Effects
Oxytocin (Pitocin)	Infusion	20-80 μ/L	Hypotension with bolus or rapid infusion, nausea, emesis, water intoxication
Methylergonovine (Methergine)	Intramuscular	0.2 mg IM q2-4h, up to 1 mg	Hypertension, vasoconstriction, nausea, emesis
15-Methyl prostaglandin $F_{2\alpha}$ (Hemabate)	Intramuscular, intrauterine	250 mg q15–90 min; repeat to total of 1 mg	Bronchospasm, systemic and pulmonary hypertension, nausea, emesis, diarrhea, flushing
Misoprostol (Cytotec)	Rectal, sublingual, oral	600-1000 mg; single dose	Tachycardia, fever

Preeclampsia

- 2013 ACOG eliminated diagnostic criteria of proteinuria > 300 mg in 24 hr collection
- Diagnosed as hypertension (>140/90) in association with thrombocytopenia, impaired liver function, renal insufficiency, pulmonary edema, or cerebral or visual disturbances
- Classified as severe if any of following present:
  - Systolic blood pressure greater than or equal to 160 mm Hg, or diastolic blood pressure greater than or equal to 110 mm Hg
  - Thrombocytopenia (platelet count less than or equal to 100,000/mm^3)
  - Impaired liver function as indicated by elevated liver enzymes (to twice normal levels) and/or severe persistent right upper quadrant pain
  - Renal insufficiency as indicated by serum creatinine concentration greater than 1.1 mg/dL or a doubling of the serum creatinine
  - Pulmonary edema
  - New-onset cerebral or visual disturbances

Magnesium Sulfate

- Used to be used as a tocolytic agent for preterm labor
  - Competes with Ca2+ for entry into myometrium, reducing intracellular Ca2+ levels, inhibiting muscle contraction in both skeletal and smooth muscle
  - Given as loading dose (4-6 g over 30 minutes, then infusion 1-2 g/hr)
- Primary indication is seizure prophylaxis for patients with severe preeclampsia
- New data show benefit for fetal neuroprotection when administered during preterm labor as young as 23 weeks with improved developmental outcomes (ACOG 2010)
  - Crosses blood-brain barrier and decreases CNS irritability and decrease N-methyl-D-aspartate activity.
- Therapeutic levels (4 - 9 mEq/L)
  - Flushing, nausea, blurry vision, headache, lethargy, generalized muscle weakness
  - Decreased systemic vascular resistance and pronounced hypotension with neuraxial and general anesthesia
  - Increased risk of postpartum hemorrhage during vaginal or cesarean delivery
  - Reduction in minimum alveolar concentration of volatile anesthetics
  - Increased sensitivity of nondepolarizing neuromuscular blockers
  - Increased risk of pulmonary edema
- 8-12 mEq/L
  - Loss of deep tendon reflexes
- 15-20 mEq/L
  - Respiratory arrest
- >25 mEq/L
  - Cardiac arrest -> Rescue: Calcium gluconate 1g over 10 minutes IV

Questions

Which of the following lung volumes and capacities change the LEAST during pregnancy?

A. Tidal volume
B. Functional residual capacity
C. Expiratory reserve volume
D. Residual volume
E. Vital capacity

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d. A and B

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Somatic pain associated with the second stage of labor can be controlled by any of the following regional nerve blocks except

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True statements regarding inclusion of intrathecal opioids in obstetric anesthesia practice include each of the following except

a. Their chief site of action is the substantia gelatinosa of the dorsal horn of the spinal column
b. There is no motor blockade
c. There is no sympathetic blockade
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1. Creatinine
2. MAC for volatile anesthetics
3. Pseudocholinesterase
4. Amount of local anesthetics required for neuroaxial anesthesia

Select A if options 1, 2 and 3 are correct
Select B if options 1 and 3 are correct
Select C if options 2 and 4 are correct
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Drugs useful in the treatment of uterine atony in an asthmatic patient with preeclampsia include

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Magnesium sulfate is used as an anticonvulsant in patients with preeclampsia and may produce any of the following effects EXCEPT

a. Sedation
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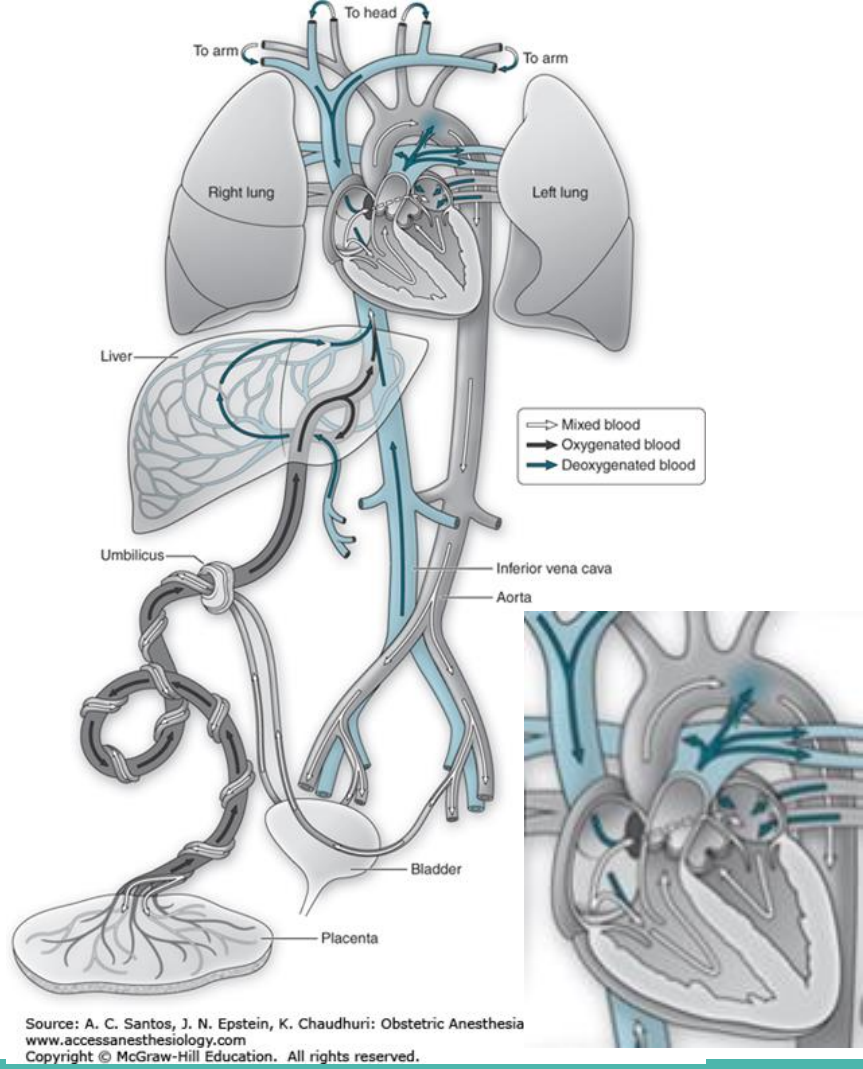
Placenta and Fetal Circulation

- Blood leaving the placenta enters the fetus via the umbilical vein, approximately 40% to 60% of this blood bypasses the liver via the ductus venosus.
- On entering the right atrium, 30% of this blood will preferentially flow across the foramen ovale to the left atrium because of deflection by the crista dividens. This blood will then pass through the left ventricle and exit to the ascending aorta supplying the cerebral and coronary circulations, thereby providing essential organs with the greatest amount of oxygen.
- Approximately 90% of the blood exiting the right ventricle will be shunted across the ductus arteriosus due to high fetal pulmonary vascular resistance, while the remaining 10% of the blood will enter the pulmonary circulation providing nutrients for pulmonary growth.
- Blood shunted across the DA enters the aorta just before the left subclavian artery and provides nutrients to the lower body of the fetus.
- From the descending aorta, blood flows to the internal iliac arteries and then umbilical arteries to the placenta.



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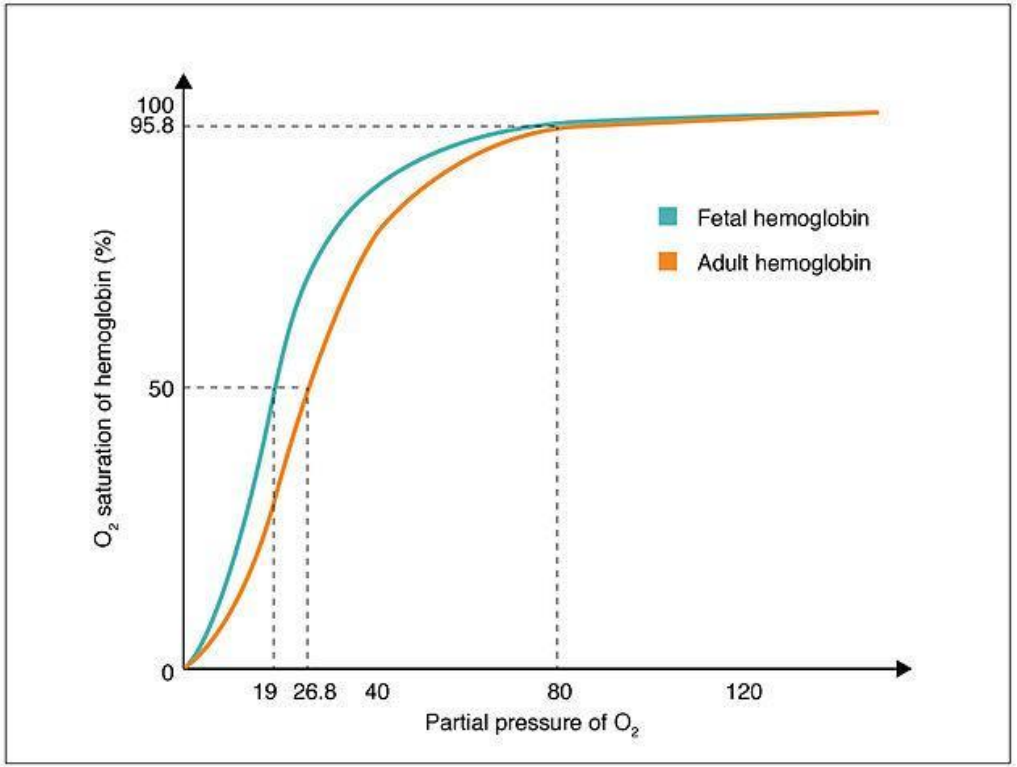
Fetal vs Adult Hemoglobin

- In the fetus, gas exchange occurs in the placenta.
- pO2 of maternal blood in the placenta is 30 to 35 mm Hg (oxygen saturation 65%) much like mixed venous blood
- Once this blood passes into the fetus through the placenta the oxygen saturation increases to 80% due to the presence of HbF which has a higher affinity for oxygen than does HbA.



<table>
<tr><td rowspan="3">Stage 1</td><td rowspan="2">Latent</td><td>Starts at regular uterine contractions</td><td rowspan="2">1-6 hrs</td><td rowspan="2">Highly variable duration, cervix effaces and slowly dilates</td><td rowspan="3">Continous FHR monitoring
doppler
fetal scalp electrode (FSE)
Monitor uterine activity
tocodynamometer
internal uterine pressure catheter
Analgesic
epidural
meperidine</td></tr>
<tr><td>Ends at cervix dilation to 4 cm</td></tr>
<tr><td>Active</td><td>Starts cervix dilation to 4 cm</td><td>4-6 hrs</td><td>Regular and intense contractions. Cervix effaces and dilates quickly. Fetal head progressively descends into the pelvis.</td></tr>
<tr><td colspan="2"></td><td>Ends at full cervix dilation to 10 cm</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Stage 2</td><td>Starts at complete cervical dilation</td><td rowspan="2">1-2 hrs</td><td rowspan="2">Baby undergoes all stages of cardinal movements:

1) Descent
2) Flexion
3) Internal rotation
4) Extension
5) External rotation</td><td rowspan="2">Maternal effort accelerated delivery
Perineum control
Episiotomies
Once head delivered
suction nose and mouth
evaluate nuchal cord
Deliver shoulders
gentle downward pressure on head
deliver anterior shoulder
easy upward force
deliver posterior shoulder
Deliver body
Clamp and cut cord
Give infant to mother in warmer
Send umbilical cord blood for
ABO & Rh testing
blood gases</td></tr>
<tr><td colspan="2"></td><td>Ends at delivery of baby</td></tr>
<tr><td colspan="2">Stage 3</td><td>Starts after baby is delivered</td><td rowspan="2">0-1/2hrs</td><td rowspan="2">Placenta separates and uterus contracts to establish hemostasis</td><td rowspan="2">Wait for signs of placental separation
uterus firms/rises in abdomen
gush of blood
lengthening of cord
Apply gentle / constant traction
may take 30 minutes</td></tr>
<tr><td colspan="2"></td><td>Ends at delivery of placenta</td></tr>
</table>

Pattern	Definition
Baseline	The mean FHR rounded to increments of 5 bpm during a 10-minute segment, excluding: ● Periodic or episodic changes ● Periods of marked FHR variability ● Segments of baseline that differ by more than 25 bpm The baseline must be for a minimum of 2 minutes in any 10-minute segment, or the baseline for that time period is indeterminate. In this case, one may refer to the prior 10-minute window for determination of baseline. Normal FHR baseline: 110-160 bpm Tachycardia: FHR baseline ≥ 160 bpm Bradycardia: FHR baseline < 110 bpm
Baseline variability	Fluctuations in the baseline FHR that are irregular in amplitude and frequency Variability is visually quantitated as the amplitude of peak-to-trough in bpm ● Absent: amplitude range undetectable ● Minimal: amplitude range detectable but ≤ 5 bpm ● Moderate (normal): amplitude range 6-25 bpm ● Marked: amplitude range > 25 bpm
Acceleration	A visually apparent abrupt increase (onset to peak in < 30 seconds) in the FHR At 32 weeks of gestation and beyond, acceleration has a peak of 15 bpm or more above baseline, with duration of 15 seconds or more but less than 2 minutes from onset to return. Before 32 weeks of gestation, an acceleration has a peak of 10 bpm or more above baseline, with a duration of 10 seconds or more but less than 2 minutes from onset to return. Prolonged acceleration lasts 2 minutes or more but less than 10 minutes in duration. If an acceleration lasts 10 minutes or longer, it is a baseline change.
Early deceleration	Visually apparent usually symmetrical gradual decrease and return of the FHR associated with a uterine contraction A gradual FHR decrease is defined as from the onset to the FHR nadir of 30 seconds or more. The decrease in FHR is calculated from the onset to the nadir of the deceleration. The nadir of the deceleration occurs at the same time as the peak of the contraction. In most cases the onset, nadir, and recovery of the deceleration are coincident with the beginning, peak, and ending of the contraction, respectively.