Review of Placental Structure and Transport

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Disclosure

• Dr Burchfield has nothing to disclose
Placentation

https://www.youtube.com/watch?v=bped-RVWsLk
ARS Question 1

In the placenta

1. Maternal blood mixes with fetal blood
2. Fetal blood bathes maternal vessels and pulls oxygen out from maternal blood
3. Maternal blood bathes fetal vessels and gives up oxygen to fetal blood
4. Maternal blood and fetal blood stay
Mature Villi

Note that the syncytiotrophoblast is adherent to the uterine wall.
Blood Flow Through the Villous Space
Human approximates concurrent flow
Transfer Across the Placenta

● Hemochorial Placenta
  ● Maternal blood in direct contact with trophoblastic tissue (Human, monkey, rat, rabbit)

● Epitheliochorial Placenta
  ● Maternal epithelium maintained

● Functionally, wide differences in these two.
Types of Placenta

a. Epitheliochorial
   - Cow, pig, horse

b. Endotheliochorial
   - Dog, cat

c. Hemochorial
   - Human, rodent
Hemochorial Placenta

- More permeable to lipid-soluble (water insoluble) molecules in which no transporters exist through pore mechanism
- Hydrophilic drugs (water soluble vitamins) more readily cross by a carrier protein or a pore mechanism
ARS Question 2

The following is true about transport across the placenta

1. Water soluble materials pass easily across the syncytiotrophoblast
2. Transport of lipid soluble materials is primarily through transtrophoblastic channels
3. Glucose is transferred by simple diffusion
4. Permeability of the trophoblastic tissue favors lipid soluble transfer
Transfer from Mother to Fetus

- All must pass under control of the syncytiotrophoblast
  - Transcellular Transport
  - Paracellular Transport (extracellular, water-filled pathway)
- Syncytiotrophoblast is NOT continuous
  - 7% replaced by fibrin
  - May serve as paratrophoblastic routes
Transtrophoblastic Channels

- 20 nm tubules passing through the trophoblast
- Functionally, carry water-soluble, lipid insoluble with diameter <1.5 nm
- Sites for fetal-maternal fluid shifts
  - colloid and osmotic forces
- Channels can dilate and close
  - control mechanism for water balance
Transtrophoblastic Channels

Fetal Circulation

Maternal Circulation
Mechanisms of Transfer

- Diffusion
  - Rate of diffusion = Perm x Surf Area x (Cm-Cf)
  - Lipid insoluble, unless transporter present, crosses through paratrophoblastic routes and are size dependent. These pathways are small and limit the rate of transfer.
  - Lipid soluble diffuse across the entire trophoblast surface and Perm is large. Primarily dependent on Cm and Cf.
  - Gases through simple diffusion
Mechanisms of Transfer

- Water soluble—Surface area small
- Lipid soluble—Surface area large

Rate of diffusion = Perm x Surf Area x (Cm - Cf)
# Placental Characteristics Affecting Transport

<table>
<thead>
<tr>
<th>Factor</th>
<th>First</th>
<th>Third</th>
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<tbody>
<tr>
<td>Surface area (m²)</td>
<td>1.5</td>
<td>12–14</td>
</tr>
<tr>
<td>Villus diameter (µm)</td>
<td>170</td>
<td>40</td>
</tr>
<tr>
<td>Syncytiotrophoblast thickness (µm)</td>
<td>10</td>
<td>1.7</td>
</tr>
<tr>
<td>Number of microvilli × 10^6/cm²</td>
<td>600</td>
<td>1200</td>
</tr>
<tr>
<td>Uteroplacental blood flow (mL/min)</td>
<td>50</td>
<td>600</td>
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</table>
Human approximates concurrent flow
Oxygen—a bit complicated

Content bound to Hb
20 mL/100 mL

“Dissolved gas” or partial pressure of maternal oxygen
0.3 mL/100 mL
Oxygen—a bit complicated

Fetus warms maternal blood, so unloads easier.

Fetus unloads CO₂ which changes maternal Hb pH.

Fetal Hb binds tighter.
Maternal Oxygen Administration

a. Raise maternal pO2 to 535 torr
b. Increases content by 1.3 vol, or 5%
c. Increases maternal venous content by 1.3 vol
d. Increases maternal venous pO2 by 11 torr
e. Increases fetal umbilical vein pO2 by 11 torr
f. Increases fetal O2 content by 2 vol, or 25%
Fetal CO2 Elimination

- Carbon dioxide is very lipid soluble and is rapidly transferred across the placenta.
- The concentration gradient is due to a high fetal production of carbon dioxide as a byproduct of oxidation, and a low maternal PCO₂ due to increased minute ventilation during pregnancy.
- A low fetal PCO₂ occurs only when maternal carbon dioxide concentration decreases (maternal and fetal respiratory alkalosis).
- Increased fetal PCO₂ may occur with poor gas exchange between fetal and maternal blood (e.g., abruption or severe placental infarcts) or when the PCO₂ in the maternal blood greatly increases.
Carbohydrate Transport

- Requires GLUT receptors on maternal and fetal surfaces, uses **facilitated diffusion**
  - Passive via transmembrane proteins
- Still follows a concentration gradient across 3 compartments
  - Maternal
  - Placental
  - Fetal
- Placenta consumes glucose to maintain gradient
  - If fetal high, placenta consumes more
Amino Acids

- Active transport
- Fetal concentrations > maternal
- Not specific transporters, but families of transporters
  - Dependent on a.a. polarity and branching
Lipids

- Little knowledge of lipid transport in human placenta
  - Sheep, 3% fat. Humans 18% fat.
  - Fetal serum lipid composition approximates mother
    - Fatter babies born to mothers with higher lipids
- Thus, likely that lipid content is dependent on transplacental concentration gradient
**Water and Electrolytes**

<table>
<thead>
<tr>
<th>Ion</th>
<th>Maternal Plasma (mM)</th>
<th>Fetal Plasma (mM)</th>
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</thead>
<tbody>
<tr>
<td>Sodium (Na⁺)</td>
<td>138 ± 2</td>
<td>139 ± 4</td>
</tr>
<tr>
<td>Potassium (K⁺)</td>
<td>4.6 ± 0.5</td>
<td>6.4 ± 0.2</td>
</tr>
<tr>
<td>Calcium (Ca²⁺)</td>
<td>2.23 ± 0.12</td>
<td>2.81 ± 0.17</td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>107 ± 2</td>
<td>108 ± 2</td>
</tr>
<tr>
<td>Phosphate (PO₄³⁻)</td>
<td>0.46 ± 0.20</td>
<td>0.62 ± 0.10</td>
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Simple diffusion
Tightly regulated through K⁺ pumps
Simple diffusion
**Ca++**

Step 1: Facilitated diffusion

Step 2: Protein binding that decreases iCa++

Step 3: Active transport to the fetus
Ca, PO₃, Mg

- Active transport
  - Ca++ channels on maternal side
  - Bound in the placenta, leading to a gradient for iCa++
  - Pumped to fetus by Ca-ATPase
Vitamins/Iron

- Fat soluble, mainly by simple diffusion
  - A, D, E, K
  - Deficiencies rare, toxicity possible
- Water soluble, mainly by active transport
  - Less storage, more likely to have deficiencies
- Iron
  - Complex; active transport through transferrin
Nutrient Transport Summary
Immunoglobulin transfer

- IgG—Endocytosis
  - Receptor binding
  - Vesicle
    - protect from proteolysis
  - Active process
- IgM—No passage
Timing of IgG Transfer

![Graph showing the relationship between IgG concentration (g/L) and gestational age (weeks). The graph indicates a positive correlation with an R^2 value of 0.87 and a significance level of P<0.04.]

B: Fetal

IgG (g/L) vs Gestational age (weeks)
Match the molecule with the transfer mechanism!

- Water  •  Active transport
- Amino acids  •  Pinocytosis
- Glucose  •  Simple diffusion
- Immunoglobulins  •  Active transport
- Iron  •  Facilitated diffusion
- Alcohol  •  Simple diffusion

- Which immunoglobulin crosses the placenta?
- IgG  \( \rightarrow \) think the placenta is gross
- Which immunoglobulin is found in breast milk?
- IgA  \( \rightarrow \) breast milk, areolar
Normal and Abnormal Placentas
ARS Question 3

- Vasoprevia is most likely to happen with
  1. Circumvallate placenta
  2. Villamentous insertion
  3. Abruptio placenta
  4. Placenta increta and percreta but not accreta
Placental Structures

- Placentome
  - One villous tree and corresponding intervillous space. 40-60 per placenta

- Cotyledon
  - Lobes in the placenta, each containing at least one placentome.
Cotyledon
Abnormal Placements

A. Normal
B. Previa
C. Acreta
D. Abruption
Abruption

- Maternal hemorrhage
- Fetal asphyxia or death
Placental abruption

In a placental abruption, part of the placenta separates from the uterine wall before birth. A revealed abruption causes vaginal bleeding; in a concealed abruption blood collects behind the placenta.

Placenta
Blood

Concealed abruption
Revealed abruption
Previa

- Maternal hemorrhage
- Premature labor
Previa

Marginal  Complete  Low-lying
Acreta
Acreta

- Prior section with placentation over the scar
- Massive maternal hemorrhage
- May be delivered prematurely because of bleeding or for optimal timing of delivery for mother’s health
Abnormal Development—Circumvallate

- Bleeding (usually painless) in up to 50% of cases
- Hydorrhea (27%)
- Severe intermittent uterine contractions (20%)

A thickened, greyish-white ring on the fetal surface, created by a double fold of amnion and chorion with degenerated decidua and fibrin in between.
Succenturate Lobe

Its antenatal recognition is important as vessels connecting the main placenta with the succenturiate placenta may rupture during labor causing fetal death. In addition, there is an increased postpartum risk of postpartum hemorrhage from retention of placental material.
Villamentous Insertion (velamentous)

- Increased risk for intrauterine growth retardation
- Preterm birth
- Fetal bleeding
- Fetal mortality rate 75%
Vasa previa

- Umbilical Cord
- Placenta
- Fetal Blood Vessels
- Cervix
Management of Vasa Previa

1. Low lying placenta requires evaluation of cord insertion
2. Transvaginal US with color doppler for succenturiate lobe or velamentous insertion
3. C-Section before labor
4. Increased risk of premature labor, so steroids 28-32 weeks and hospitalization at 30-32 weeks

Prenatal diagnosed: survival 97% and transfusion 3%

Undiagnosed: survival 44% and transfusion 58%
AMNIOTIC BANDS SYNDROME

IN THIS DETAIL, AMNIOTIC BANDS CONSTRICT THE BLOOD SUPPLY TO THE FINGERS

AMNION IS SEPARATED FROM THE UTERUS
AMNIOTIC BANDS
WALL OF THE UTERUS
AMNION (INNER MEMBRANE)

FETUS AT 16 MONTHS
AMNIOTIC CONSTRUCTION BANDS ARE CAUSED BY DAMAGE TO THE PLACENTA CALLED THE AMNION. DAMAGE TO AMNION PRODUCES FIBER-LIKE BANDS THAT CAN TRAP PARTS OF THE DEVELOPING BABY.
Amniotic Band Syndrome

- Typically constriction and/or amputation of digits or limbs
- A strong relationship between ABS and talipes exists.
  - A 31% with associated clubfoot deformity with 20% occurring bilaterally
- Other abnormalities found with ABS include: club hands, cleft lip/palate
Amniotic Band Syndrome--Pathophysiology

- The **amniotic band** theory: ABS occurs due to partial rupture of the amniotic sac.
  - This rupture involves only the amnion; the chorion remains intact.
- Fibrous bands of the ruptured amnion float in amniotic fluid and encircle and trap some part of the fetus.
- As the fetus grows but the bands do not, the bands become constricting.
Amniotic Band Syndrome--Pathophysiology

- The **vascular disruption** theory: Because the constricting mechanism of the amniotic band theory does not explain the high incidence of cleft palate and other forms of cleft defects occurring together with ABS, this co-occurrence suggests an "intrinsic" defect of the blood circulation.
Amniotic Band Syndrome
Amniotic Band Syndrome
Amniotic Band Syndrome
Amniotic Band Syndrome
Pulmonary Circulation
Foramen Ovale
I know this may sound dumb but is placenta considered a gluten? Was thinking of making that with chicken.

For when you are here.

Placenta?!!! Like from a human?!!!! Wtf?!

OMG! Stupid spell check. Polenta.