Fetal Circulation

James Tucker
University of Utah MD/PhD Program
james.tucker@hsc.utah.edu
Fetal Circulation: Key Topics

- Placenta (blood contact with mother)
- Fetal Hemoglobin (HbF)
- Anatomic differences from adult
- Congenital abnormalities
Adult Circulation

- Heart
- Lungs
- Arteries
  - Carry blood *away from the heart*
  - Usually oxygenated
  - Exception: Pulmonary arteries
- Veins
  - Carry blood *towards the heart*
  - Usually deoxygenated
  - Exception: Pulmonary veins
Fetal Circulation

- 2 Umbilical arteries
  - carry deoxygenated blood & waste to the placenta
- 1 Umbilical vein
  - carries oxygenated blood and nutrients from the placenta
The Placenta

- Facilitates gas, nutrient, and waste exchange between maternal and fetal blood.
- Maternal and fetal blood do not mix, though certain cells pass (i.e. T-cells).
- Small molecules (drugs, poisons, etc.) can pass from mother to fetus
  - FAS: Fetal Alcohol Syndrome
  - CO from smoking
  - Meth Amphetamines can lead to brain damage
- Pharmaceutical Safety
  - (class A, B, C, D, X)
Fetal Hemoglobin (HbF)

- Higher O2 affinity than adult Hemoglobin allows HbF to “suck” oxygen across the placenta into fetal circulation.
- After birth, RBCs are killed off and replaced with RBCs containing normal adult Hb.
- Rapid death of RBCs in first weeks of life leads to neonatal jaundice
  - Normal up to 1-2 weeks
  - Jaundice after 2 weeks is a problem…
Cardiovascular Shunts

- Shunt: allows blood to flow from one place to another
- Protection of developing organs
  - Blood pressure exerts forces on capillaries
  - Some developing organs can’t take the pressure yet
    - Liver, Lungs
- Right → Left shunts protect the lungs
  - In the adult:
    - Right side of heart holds deoxygenated blood
    - Blood goes to lungs, gets oxygenated
    - Oxygenated blood returns to left side of heart
  - With a R→L shunt:
    - Blood passes from right side of heart to left without passing through the lungs
Ductus Venosus (Protects Liver)

- Some blood from the umbilical vein enters the portal circulation allowing the liver to process nutrients.
- The majority of the blood enters the ductus venosus, a shunt which bypasses the liver and puts blood into the hepatic veins.
Foramen Ovale (R ⇒ L Shunt)

- Fetal lung capillaries are fragile and can’t handle full blood load during development.
- Some blood is shunted from right atrium to left atrium (foramen ovale) skipping the lungs.
- More than one-third of blood takes this route.
- Valve-like flaps prevent back-flow.
Ductus Arteriosus (R → L Shunt)

- Protects the fetal lungs
- In the adult:
  - Right Ventricle
  - Pulmonary Trunk / Arteries
  - Lungs
  - Pulmonary Veins
  - Left Atrium
  - Aorta
- In the fetus:
  - Right Ventricle
  - Pulmonary Trunk
  - Most blood goes through DA
  - Aorta
What happens at birth?

- The change from fetal to postnatal circulation happens very quickly.
- Changes are initiated by baby’s first breath.

Fetal and Neonatal Circulation

\[
\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}
\]

Before birth, \(R_1\) is high. Thus, most of blood bypasses the lung.

After birth, \(R1\) decreases and blood is directed through the lungs.
What happens at birth?

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foramen ovale</td>
<td>Closes shortly after birth, fuses completely in first year.</td>
</tr>
<tr>
<td>Ductus arteriosus</td>
<td>Closes soon after birth, becomes ligamentum arteriosum in about 3 months.</td>
</tr>
<tr>
<td>Ductus venosus</td>
<td>Ligamentum venosum</td>
</tr>
<tr>
<td>Umbilical arteries</td>
<td>Medial umbilical ligaments</td>
</tr>
<tr>
<td>Umbilical vein</td>
<td>Ligamentum teres</td>
</tr>
</tbody>
</table>
Pathologic persistence of R→L shunts

- PFO: Patent Foramen Ovale
- PDA: Patent Ductus Arteriosus
- Each characterize about 8% of congenital heart defects.
Pathologic persistence of R→L shunts

- First problem: Blood Oxygenation
  - Any blood that bypasses the lungs fails to be oxygenated
  - The larger the R→L shunt, the less the blood gets oxygenated
  - Low blood O2 saturation leads to cyanosis (blue baby)

- Caveat: Terology of Fallot
  - Alfred Blalock, Vivien Thomas
  - Moral: Black guy made it work, white guy got the credit
  - Movie: “Something the Lord Made”
Pathologic persistence of R→L shunts

- Second Problem: Blood Clots
  - Most blood clots form in veins (lower pressure) and must pass through the heart and lungs before going back to the body
- Clot caught in the lung: Pulmonary Embolism
- PFO can allow a clot to bypass the lungs
  - Brain Infarct = Stroke
  - Bowel Infarct = Awful nasty mess
    - Don’t be a general surgeon
  - Muscle Infarct = Dr. House
    - Makes you a great doctor but kind of an ass…