ANATOMI FISIOLOGI SIRKULASI
FETUS, BAYI & DEWASA

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Fetal Circulation

Differs from the postnatal (after birth) circulation, because

- Lungs, kidneys, and gastrointestinal tract are nonfunctional
- O2 and nutrients are derived from maternal blood
- CO2 and wastes are eliminated into maternal blood
Placenta

Is the “fetal lung”

However cellular layers covering the villi are thicker and less permeable than the alveolar membranes in the lungs and exchange is much less efficient.

Is also the route by which all nutritive materials enter the fetus and wastes are discharged to the maternal blood.
Arrangement of Fetal Circulation

- 55% of fetal COP goes through placenta
- Blood in umbilical vein (UV) ± 80% saturated with O2 (in arterial circulation of adult: ± 98%)
- Ductus venosus (DV) diverts some of the blood directly to Inferior Vena Cava (IVC) and remainders mixes with portal blood
  - IVC blood is ± 67% saturated with O2
  - Portal and systemic venous blood is only ± 26% saturated with O2
Arrangement of Fetal Circulation

- Most of the blood entering heart through IVC is diverted directly to left atrium (LA) via foramen ovale → left ventricle (LV)
- Most of blood from SVC enters right ventricle (RV) and is expelled into pulmonary artery (PA)
- Resistance of collapsed lungs is very high
- Pressure in PA > aorta
- Most of the blood from PA passes into aorta via ductus arteriosus
In this fashion:

- Relatively unsaturated blood from RV is diverted into trunk and lower body.
- The head of fetus receives the better-oxygenated blood from the LV.
- From aorta, some of blood is pumped into the umbilical arteries (UA) and back to placenta.
- O2 saturation of the blood in lower aorta and UA is ± 60 % saturated with O2.
Tissues of fetal and newborn mammals have a remarkable but poorly understood resistance to hypoxia.

O2 saturation of maternal blood in placenta is so low that the fetus might suffer hypoxic damage if fetal red cells did not have a greater O2 affinity than adult.

Fetal red cells contain fetal Hb (Hb F) while adult red cells contain adult Hb (Hb A).
The fetal oxyhemoglobin dissociation curve is shifted to the left → at equal pressure of O2, fetal blood carries significantly more O2 than does maternal.

In early fetal life, the high cardiac glycogen levels that prevail may protect the heart from acute periods of hypoxia.

The glycogen levels decrease in the late fetal life and reach adult levels by term.
Umbilical Vessels

- Umbilical vessels have thick muscular walls with a muscular sphincter.
- Hemorrhage of the newborn is prevented by constriction of the umbilical vessels, because they are very reactive to trauma, sympathomimetic amines, bradykinin, angiotensin, and changes in PO2.
- Closure of the umbilical vessels increases the total peripheral resistance and the blood pressure.
- When blood flow ceases through the umbilical vessels, the ductus venosus closes (the event that closes of DV is still unknown).
Changes in Fetal Circulation & Respiration at Birth

- At birth, placental circulation is cut off and peripheral resistance suddenly rises.
- Pressure in aorta rises until > in PA.
- Because of placental circulation has been cut off, the infant becomes increasingly asphyxial and cooling of the body → activates respiratory center.
- Finally, infant gasps several times and the lungs expand → vascular resistance decrease to ± 1/10.
- Markedly negative intrapleural pressure (-30 to -50 mmHg) during the gasps contributes to the expansion of the lungs.
The sucking action of the first breath plus constriction umbilical veins (UV) squeezes 100 ml of blood from placenta (the “placental transfusion”).

Once the lungs are expanded, the pulmonary vascular resistance falls to < 20% of utero value and pulmonary blood flow increases markedly.

Blood returning from the lungs raises the pressure in the LA, closing foramen ovale by pushing the valve that guards it against the interatrial septum.
The LA pressure is raised > IVC and RA by:

1. The decrease in pulmonary resistance → large flow of blood through the lungs to the LA
2. The reduction of flow to the RA ← occlusion of the UV
3. The increased resistance to LV output ← occlusion of the UA

 Abruptly closes the valve over the foramen ovale
The septal leaflets fuse over several days
The decrease in pulmonary vascular resistance → the pressure in the PA fall to ± ½ (to ± 35 mmHg)

The slight increase in aortic pressure → reverses the blood flow through the ductus arteriosus (DA)

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The large ductus arteriosus begin to constrict

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Manifested as a murmur in the newborn, because of turbulent flow
DA constricts within a few hours after birth, producing functional closure, and permanent anatomic closure follows in the next 24-48 hours due to extensive intimal thickening.

Mechanism producing the initial constriction is not completely understood, but the increase in arterial O2 tension plays an important role as follows:
1. The high O2 tension of the arterial blood that passes through the DA
2. The pulmonary ventilation with O2 that closes the DA. Ventilation with air low in O2 opens this shunt vessel

Whether O2 acts directly on the DA, or through the release of a vasoconstrictor substance is not known.
Relatively high concentrations of vasodilators (especially prostaglandin) are present in the DA. Synthesis of the prostaglandin is facilitated by cyclooxygenase at birth. In many premature infants the ductus fails to close spontaneously, but closure can be produced by infusion of drugs that inhibit cyclooxygenase.
(a) Fetal circulation

- Right atrium
- Superior vena cava
- Arch of aorta
- Pulmonary artery
- Pulmonary veins
- Heart
- Right ventricle
- Liver
- Ductus arteriosus becomes Ligamentum arteriosum
- Ductus venosus becomes Ligamentum venosum
- Umbilical vein becomes Ligamentum teres
- Umbilicus
- Inferior vena cava
- Abdominal aorta
- Common iliac artery
- Umbilical arteries become Medial umbilical ligaments

(b) Circulation at birth

- Uterine artery
- Urethra
- Umbilical cord
- Placenta

Legend:
- Red: High oxygenation
- Dark purple: Moderate oxygenation
- Purple: Low oxygenation
- Light purple: Very low oxygenation
The Walls of Cardiovascular System

At birth:
- The walls of the two ventricles are approximately of the same thickness, with a possibly slight preponderance of the RV
- The muscle layer of the PA is thick, which is partly responsible for the high pulmonary vascular resistance of the fetus

After birth:
- The thickness of the RV and PA walls diminishes
- The LV walls become thicker
These changes are progressive over a period of weeks after birth
Thank You