Maternal Physiological Changes During Pregnancy and Birth and Fetal Circulation

The process of reproduction is an essential characteristic of all living organisms. While other animals lay eggs, mammals give birth to a newborn. The anatomy and physiology of the newborn baby are similar to that of an adult where all the body systems are in a functioning state. The process of embryogenesis is very complex and critical. The developing embryo gets all the nutrients required for its growth and development from the mother; therefore, certain physiological changes occur in the maternal body to be able to support the embryo. Any nutritional or hormonal deficiency at this stage, may not only result in under-weighed babies with birth defects but also affects the quality of life of the mother after delivery.

The Maternal Body’s Response to Pregnancy

Once a woman conceives and becomes pregnant, several physiological changes begin to occur in her body. This is not only to provide nourishment to the developing embryo but is also advanced preparation for parturition. The following major physiological maternal changes occur during pregnancy:

The uterine size increases from 50g in non-pregnant females to about 1 kg. The vagina enlarges and the introitus opens more widely.

The breasts also become almost double in size with a two-pound increase in weight.
The average **weight gain** in pregnancy is 24 pounds; of which 7 pounds is of the fetus, 4 pounds of extra-embryonic structures, 2 pounds each of the uterus and the breasts, 6 pounds of the accumulated fluid, and the remaining 3 pounds are fat deposits.

As the developing fetus removes substrates from the maternal blood, the **desire for food** is greatly increased. The **basal metabolic rate** (BMR) also increases by 15% during the latter half of pregnancy. **Hormones**, such as thyroxin, adrenocortical, and sex hormones also contribute to the increased BMR.

The maternal body stores **nutrients** the fetus requires during the last trimester. The weight of the fetus almost doubles in the last trimester, so it requires large quantities of nutrients. A pregnant woman, in addition to having other nutrients, must take sufficient **iron**, **calcium**, and **vitamin D**. In the later stage of pregnancy, she may also require **vitamin K** to prevent the newborn from **hemorrhaging during childbirth**.

**Cardiac changes in pregnancy include**

The **cardiac output** of the mother increases by 40% because the heart must supply additional blood to the placenta. Cardiac output, however, falls to a little above the normal value during the last eight weeks of pregnancy, with the maximum effect at 20-28 weeks of pregnancy. Vasodilatation also necessitates increased cardiac output.

There is an increase in stroke volume by about 90% that leads to an increase in left ventricular muscle mass and the end-diastolic volume but not the end-diastolic pressure.

There is a 10-20% increase in the maternal heart rate. Blood pressure decreases during the first and second trimester and returns to normal levels during the third trimester.

**Hematological changes in pregnancy**

The **maternal blood volume** increases to 30% above normal during pregnancy. This is associated with a constant level of red blood cells hence a fall in the level of hemoglobin and **hematocrit** and red blood cell count. However, there is a normal level of mean corpuscular volume and mean corpuscular hemoglobin concentration. There is an associated fall in the level of thrombocytes; as such, maternal pathological thrombocytopenia is below 100,000. The **blood viscosity** also decreases.

Due to the above changes, pregnancy is associated with a two-three-fold increase in iron requirement for hemoglobin synthesis and fetal development. Similarly, there is a need for increased folate, up to 10-20 times, and a two-fold increased need for vitamin B12.

Pregnancy is referred to as a **hypercoagulable or pro-thrombotic state**. This is thought to prevent **blood loss** during parturition. It begins in the first trimester all the way to 12 weeks post-partum.

The prothrombin time (PT) and activated partial thromboplastin time (APTT) decrease, while procoagulant factors, such as VIII, IX, and X, increase. Fibrinogen levels increase up to 50% and fibrinolytic activity is decreased.

Venous stasis in the lower limbs is associated with vasodilation and decreased flow, which is more marked on the left due to compression of the left iliac vein by the left iliac artery and the ovarian artery.

**Respiratory changes in pregnancy**

There is a 20% increase in oxygen demand during pregnancy that occurs due to a 15% increase in BMR. Due to increased BMR during pregnancy, **minute ventilation** also
increases. Some of it is attributed to an increased level of **progesterone**, which is a direct respiratory stimulant. The **PCO2 level in the blood** decreases. As the growing uterus presses upon the abdominal structures, the change in the shape of the diaphragm is limited. So, to maintain adequate ventilation, the **respiratory rate** increases.

**Renal changes in pregnancy** include a 40% fall in systemic vascular resistance that also affects the kidneys, leading to increased renal blood flow. Thus, the **glomerular filtration rate (GFR)** increases by 50% to excrete out excessive water and salts retained in the body due to hormonal changes occurring during pregnancy. This increase in blood flow causes the kidneys to enlarge by 1-1.5 cm. This may be accompanied by a dilatation of the pelvicalyceal system.

Relaxin secreted from the corpus luteum and the placenta peaks in the first trimester to stimulate the formation of endothelin and vasodilatation of the renal arteries.

**Changes in the alimentary canal**

Pregnancy is associated with increased nausea and vomiting, which is thought to be due to hormonal imbalances. It is also thought to be a protective mechanism against consuming any teratogenic substances. This phenomenon resolves by the 20th week of gestation in most cases.

**Endocrine changes**

There is an increased level of all thyroid hormones; thus, pregnancy is considered a hyperthyroid state.

Reduced vascular resistance activates the RAAS system, causing a three-fold increase in aldosterone in the first trimester and a 10-fold increase in the third trimester.

The pituitary gland enlarges during pregnancy due to the proliferation of prolactin-producing cells in the anterior lobe.

Pregnancy is a diabetogenic state associated with an increase in maternal glucose to supply the fetus and accompanying insulin resistance.

**Skeletal and bone changes**

Pregnancy is associated with reversible bone loss because of increased bone turnover to supply the fetus with calcium.

**Summary of maternal changes**

The heart rate and stroke volume **increase to maintain cardiac output** and arterial pressure when systemic vascular resistance falls.

If red blood cell production cannot keep pace with increasing plasma volume, **hematocrit falls** during pregnancy, leading to physiological anemia.
Maternal Changes During Parturition

Parturition refers to the birth of the baby as a result of forceful uterine contractions. Two main effects that initiate such contractions are hormonal changes and mechanical factors.

Hormonal factors

During pregnancy, the placenta produces estrogen and progesterone in excessive amounts. Estrogen promotes uterine contractility, while progesterone inhibits it. It has been hypothesized that, at the time of delivery, the ratio of estrogen to progesterone increases significantly, initiating uterine contractions.

The pituitary gland of the fetus produces oxytocin, while the adrenal glands produce cortisol. Both stimulate uterine contractions.

At the time of labor, the fetal membranes secrete prostaglandins, which also stimulate the cervix and the uterus.

Mechanical factors

When the smooth muscles of the uterus are stretched, their contractile power increases. The movements of the fetus cause intermittent stretch of the uterine wall. In a twin pregnancy, the average time of delivery is 19 days earlier than in a single pregnancy, emphasizing the importance of mechanical forces produced by the fetus.

When the fetal membranes are ruptured, the baby’s head is pushed further downwards, causing stretching and irritation of the cervix. This results in the transmission of signals from the cervix to the uterus, either by the nerve reflexes or through the direct myogenic transmission of signals.

Initiation of Labor

The weak and rhythmic contractions of the uterus that occur throughout the pregnancy are called Braxton-Hicks contractions. However, at the end of pregnancy, these uterine contractions become stronger in amplitude and frequency. The result is dilatation of the cervix, which forces the baby out of the birth canal.

This process is known as labor. The normal duration of labor in a primary gravida is up to 24 hours and, when exceeded, the woman is said to be in obstructed labor, which
requires urgent intervention. The duration of labor significantly decreases with each successive pregnancy.

The process of labor has been explained based on a positive feedback mechanism. As the **fetal head descends down into the pelvis**, it **stretches the cervix**. This stretch response causes **uterine contractions**. These uterine contractions begin from the **fundus of the uterus** above and then propagate downwards, causing a further **stretch of the cervical wall**. This re-sends the signals to the uterus to produce another forceful contraction, stronger than the previous one. The cervix is stretched and dilated further. Finally, the baby emerges from the birth canal.

Another important event occurring during the cervical stretching process is the **signal transmission from the cervix to the hypothalamus**, which results in the production of **oxytocin hormone**. This hormone causes a **stronger uterine contraction** than the previous one, so every succeeding uterine contraction is stronger than the preceding one.

The pain signals from the uterus and the birth canal travel through the **spinal cord** to give signals to the **abdominal muscles**. These muscles contract forcefully, further aiding the passage of the fetus through the birth canal. The combined force of the contraction of the abdominal muscles and the uterus pushing the baby through the birth canal is around 25 pounds.

In the early part of labor, the frequency of uterine contractions is low, occurring after every 30 minutes, but, as the labor progresses, these contractions become stronger and may recur after every five minutes. These **intermittent, rhythmic contractions of the uterus** are of utmost importance as they **prevent the blockage of blood flow to the fetus**, which may result in fetal death. **Abusive use of oxytocin** may cause uterine **spasm**, resulting in **fetal death**.

![Image: "The Positive Feedback Mechanism of Labor." by OpenStax – https://cnx.org/contents/FPTk1zmh@8.25:fEi3C8ot@10/Preface. License: CC BY 4.0](Image: "The Positive Feedback Mechanism of Labor." by OpenStax – https://cnx.org/contents/FPTk1zmh@8.25:fEi3C8ot@10/Preface. License: CC BY 4.0)

The process of labor is divided into three stages:
1. The first stage is the **start of labor until full dilatation of the cervix** (10cm), which is approximately equal to the size of the fetal head. This is the longest stage of labor and can last up to 24 hours.

2. The second stage is from the **dilatation of the cervix until the expulsion of the fetus**. This is the shortest phase of labor and is sometimes as short as one minute.

3. The third stage is when the **placenta is separated from the uterus and is expelled through the birth canal**. This may take up to 45 minutes. The positive feedback mechanism is illustrated in the diagram beside.

**Fetal Circulation**

During fetal development, the **lungs are non-functional**. Therefore, the fetus cannot oxygenate its blood. It gets the oxygen and other nutrients directly from the mother via **placental circulation**. Therefore, the fetal circulatory system is different from an adult circulatory system. There are **several bypass mechanisms** discussed below:

Oxygenated blood and other nutrients travel through the placenta into the **umbilical vein**. The exchange of gasses occurs at this level.

**Ductus venosus** shunts the oxygenated blood away from the **liver** into the **inferior vena cava**. The blood then enters the **right atrium** through the **inferior vena cava**.

Some of the blood goes directly to the **left atrium via foramen ovale**, which is a window-like opening between the two atria. The remaining blood, which enters the **pulmonary artery**, re-enters the **aorta** through a connection between the two called **ductus arteriosus**. It shunts blood away from the **lungs**.

After supplying the head and the body, the mixed blood travels **back to the placenta via umbilical arteries**. It then enters the maternal circulation.

**Changes at birth**

The **first cry of the baby** lets the airflow into the lungs. As a result, the lungs expand and blood starts flowing in the pulmonary arteries. The increase in pressure in the right side of the heart, and in the pulmonary artery, causes the **closure of foramen ovale and ductus arteriosus**. **Prostaglandin inhibition** also plays an important role in their closure.

The **functional closure of ductus venosus** occurs at birth. However, its anatomical closure may take a week. The remnant of ductus venosus is called **ligamentum venosum**.
Adult circulation

In an adult, two circulatory systems flow simultaneously. The deoxygenated blood from different parts of the body enters the right atrium via superior and inferior vena cava. From the right atrium, the blood flows into the right ventricle and is finally pumped into the pulmonary artery. The pulmonary artery takes the blood to the lungs, where it gets oxygenated. This is pulmonary circulation.

The oxygenated blood leaves the lungs and enters the left atrium via pulmonary veins. It then flows into the left ventricle and is then pumped into the aorta and to all parts of the body. This is called systemic circulation.

Comparison of fetal and adult circulation

In fetal circulation, the exchange of gasses occurs at the placental level, while in an adult circulation, it occurs in the lungs.

In a fetal heart, there is higher pressure on the right side of the heart while, in adult circulation, the left side of the heart bears more pressure of the blood.

In fetal circulation, the lungs are bypassed by the foramen ovale and ductus arteriosus. In an adult, there are two circuits of blood.

In the fetus, the blood flowing is oxygenated, deoxygenated, or mixed. Under normal physiological conditions, adult blood is either oxygenated or deoxygenated.

References


