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**PHYSIOLOGICAL ADAPTATIONS OF FEMALES TO PREGNANCY**

**INTRODUCTION**

Pregnancy is a unique period in a woman's lifetime. A number of

anatomic, physiologic, biochemical and psychological changes take

place. These changes may easily be misinterpreted by physicians

who lack experience in regards to pregnancy effects on a woman's

body. It is important that physicians caring for women

understand the implications of these physiological changes in

order to avoid any diagnostic errors and errors of management.

One has to remember that nature does not waste energy or effort.

 In that respect all the physiological changes that happen during

pregnancy, happen for a purpose. As it will be appreciated later

on in this chapter, almost every organ system of a female body is

affected to some degree.

An attempt was made to present the information by organ systems

although there may be some overlap since most of the organ

systems interact with each other and affect each other. Some

organ systems will be discussed in detail more than others. This

distinction will be solely based on the significance of the

particular organ system changes.

**SKIN CHANGES**

A number of changes take place in the skin of pregnant women.

Mechanical stretching of the skin over the abdomen and breasts

can lead to striae. The increased levels of estrogen and

progesterone have also been implicated. Usually striae remain

permanently with some change in color. Prevention may be

achieved with moisturizing creams, especially those containing

lanolin and other oily substances. It should be realized,

however, that striae may develop despite any preventative measures.

**CHANGES IN THE GASTROINTESTINAL SYSTEM**

Nausea and vomiting are the most frequent complaints involving

the gastrointestinal system and usually happen in early pregnancy

while heartburn happen primarily in late pregnancy. The gums

become hyperemic and edematous during pregnancy and tend to

bleed. The muscular wall of the esophagus is relaxed and this

may cause reflux, which in turn can lead to esophagitis and

heartburn. The stomach and the intestines have decreased

motility presumably due to the effect of progesterone on smooth

muscle contractility. This causes an increase in the time that

it takes for the stomach to empty. Reduced gastric secretion has

also been documented and it could account for the improvement of

peptic ulcers sometimes observed in pregnancy. Decreased

motility of the large intestine may lead to constipation.

The liver is affected significantly by pregnancy. Cholestatic

jaundice is considered to be the result of estrogen effect on

elimination of bilirubin by the liver. The effect of estrogens

also, is to increase protein synthesis in the liver, which leads

to increased production of fibrinogen and binding proteins. The

liver enzymes are usually unaffected with the exception of

alkaline phosphatase, which is increased at approximately two

fold to four fold that is a result of a placental production.

Pregnancy increases the size and decreases the motility of the

gall bladder. The decreasing motility and increase in volume,

combined with changes in the bile's composition, explain the

correlation between the incidence of cholelithiasis and pregnancy.

**CARDIOVASCULAR CHANGES**

Of all changes that happen in pregnancy, the single most

important is the one involving the cardiovascular system.

Adequate cardiovascular adaptation secures good placental

development and thus appropriate fetal growth.

In brief, the cardiovascular changes involve a substantial change

in the blood volume, cardiac output, heart rate, systemic

arterial blood pressure, systemic vascular resistance, oxygen

consumption and alterations in regional blood flow of various

organ systems.

**Blood Volume**

Significant increases in the blood volume start taking place in

the first trimester and continue until the mid third trimester,

at approximately the 32nd to the 34th week. Beyond this point in

gestation, the blood volume plateaus. This pattern was

established with studies that kept the patients in the leftlateral position to avoid vena cava compression. However,

studies that kept the patient in the supine position had

controversial results indicating a decline in the blood volume

after 34 to 36 weeks. The average absolute increase in blood

volume during pregnancy is about 1600 ml and in terms of percent

change one should expect a 40 to 50 percent increase above prepregnancy levels. The increase in the blood volume is achieved

by a combination of increases in the plasma volume and the RBC

mass. The calculated plasma volume expansion is approximately

1300 ml and the volume of the RBC increases about 400 ml. This

discordance in the change between the cellular elements of the

blood and the liquid portion leads to the so called "physiologic

anemia of pregnancy". The mechanisms leading to hypervolemia in

pregnancy are still not entirely understood and seem to be

multifactorial. Increased estrogen levels in pregnancy cause

increased production of renin from the kidneys, the uterus and

the liver and thus cause elevated renin plasma levels. The

increase in renin, which stimulates aldosterone secretion, is

associated with sodium retention and an increase in total body

water. The roll of atrial natriuretic factor (ANF) in mediatingchanges in fluid balance during gestation is still not clearly

understood. On the other hand increased levels of human

chorionic somatomammotropin and prolactin increase the amount of

erythropoiesis and thus causes the necessary increase in the red

blood cell mass.

The increase in blood volume with pregnancy appears to serve the

essential physiologic needs of both the mother and fetus. It

ensures adequate supplies required for normal fetal growth and

oxygenation even under circumstances that affect the maternal

cardiac output (inferior vena cava compression). This increased

blood volume also helps normal pregnant women to withstand

hemorrhage equal to the volume of blood added to the circulation

during the course of the normal pregnancy without any signs of

decompensation.

**Cardiac Output**

It has been well established since the beginning of this century

that the cardiac output increases an average of 50 percent during

pregnancy. It is generally accepted that cardiac output begins

to rise during the first trimester, probably around the tenth

week of pregnancy and continues to rise up until the 24th week of

gestation. Once it reaches the peak it stays rather stable.

That was the case in most if not all of the studies that

evaluated women in a left-lateral tilt while studies that placed

women in the supine position have shown a rather false reduction

in cardiac output which was primarily mediated by inferior vena

cava compression.

Cardiac output is a product of stroke volume and pulse rate. The

rise in cardiac output early in pregnancy is disproportionately

greater than the increase in heart rate, and therefore is

attributable to augmentation in stroke volume. As pregnancy

advances, heart rate increases and becomes a more predominant

factor in increasing cardiac output. At the late stages of

pregnancy, the stroke volume declines to normal, non-pregnant

values.

The effect of maternal posture on cardiac output was demonstrated

by a number of studies. A significant decrease (25 to 30

percent) in cardiac output, measured by dye dilution technique,

was demonstrated in the supine position between the 38th and 40th

weeks of pregnancy but not before the 24th week. These findingswere confirmed recently by echocardiographic studies. Since

heart rate was not affected significantly, positional decline in

cardiac output was due to decreased stroke volume. The fall in

cardiac output was also not associated with a significant change

in blood pressure. This is probably due to an increase in

peripheral vascular resistance.

As many as 11 percent of women when placed in the supine

position, will develop symptomatic hypotension and drop in the

cardiac output which may lead to a loss of consciousness. These

symptoms are relieved promptly with left-lateral positioning. In

these particular patients who develop the symptoms, the cardiac

output is not maintained despite the fact that they develop a

significant increase in their heart rate. It is believed that

the patients who become symptomatic are those who lack sufficient

paravertebral collateral circulation to permit blood from the

legs and the pelvic organs to bypass the occluded inferior vena

cava.

**Heart Rate During Normal Pregnancy**

The baseline heart rate increases by about 10 to 20 beats per

minute. This increase starts early in pregnancy and gradually

continues to go upward with the highest values achieved at term.

 Some investigators, however, suggested that the total increase

happens early in pregnancy and remains so throughout the

remainder of gestation.

In twin gestations, the rise of the heart rate is more pronounced

and it can reach as much as 40 percent above the non-pregnant

state. A change also from the supine position to the lateral

position may cause the heart rate to drop slightly.

**The Heart**

A number of changes happen to the heart and are unique to

pregnancy. Increasing intra-abdominal contents displace the

heart upward with some forward rotation. As a result the

anterior posterior diameter and the cardiothoracic ratio are

increased. The overall dimensions of the heart are increased

during pregnancy as a result of increased diastolic heart volume

without any change in the ventricular wall thickness. Systolic ejection murmurs are common in pregnancy while diastolic

murmurs are less frequent. The systolic murmurs are usually the

result of the hyperdynamic circulation.

Electrocardiogram changes have been reported during pregnancy.

Transient ST and T changes are common in pregnancy, SRQ waves and

inverted T waves in lead III. Left access deviation of the QRS

complex has been reported also in pregnancy.

**Blood Pressure**

A slight decrease in the systolic arterial blood pressure and a

significant decrease in the diastolic pressure have been observed

to occur in normal pregnancy. This decrease becomes evident in

the late first trimester and continues throughout most of the

second trimester. The lowest values are noted in mid pregnancy

and there after the blood pressure returns toward non-pregnant

levels before term. The degree of change in the blood pressure

parameters has been found to be affected by parity, smoking,

preexisting hypertension, maternal age and ethnic background. In

the typical normal pregnancy the mean arterial pressure

(diastolic plus 1/3 of the difference between systolic and

diastolic) is less than 85 mm of mercury. Studies have found

that when the mean arterial blood pressure in the mid second

trimester is higher than 90 mm of mercury, there is increased

perinatal mortality and morbidity.

Systemic Vascular Resistance

Normal pregnancy is associated with a significant fall in

systemic vascular resistance. As a result, the diastolic blood

pressure drops as well as the systolic. However, the diastolic

blood pressure drops more than the systolic leading to a widening

of the pulse pressure. The mechanism for this change is not

entirely clear. It has been speculated, however, that a

significant portion of this decline is caused by the development

of a low resistance circulation in the pregnant uterus.

Estrogens, Prolactin, circulating prostaglandins PGE2 and PGI2 may

be responsible for the vasodilatation that can cause a drop in

the peripheral resistance. In addition, the profound dilatation

of the skin vessels as a result of the increased maternal body

heat dissipation may contribute to the drop in the systemic

vascular resistance.

**Blood Flow Changes in Various Organ Systems During Pregnancy**

The most profound changes in regional blood flow occur in the

uterus with a 5 to 10 fold increase. This change starts early in

pregnancy and continues until almost term. Approximately 20% of

the maternal cardiac output perfuses the uterine vessels

(placental and nonplacental). The kidneys also demonstrate

substantial increase of the regional blood flow as much as 30 to

80 percent and at the same time a 50 percent increase in

glomerular filtration rate is noted. The regional blood flow in

the extremities also increases and more so in the hands than the

legs. As it was mentioned previously, there is a significant

dilatation in the skin vessels which leads to an increase in the

regional blood flow. These changes in the skin vessels may cause

warm skin, clammy hands, vascular spiders, and palm erythema.

The liver circulation is not affected very much and the same is

true for the brain blood flow which is autoregulated. The blood

flow to the breast is increased during pregnancy to prepare the

breast for lactation. The effect of pregnancy on coronary blood

flow is still unknown. It is safe, however, to speculate that an

increase may happen since augmentation of cardiac function is

present during pregnancy.

**Cardiocirculatory Changes During Labor and Delivery**

During labor significant hemodynamic changes take place. These

changes can in part be explained by the effect of the uterine

contractions, which may cause a significant increase of 300 to

500 ml in central blood volume, and in part by the effect of pain

and anxiety on the cardiovascular system. It is important to

note here that in the lateral position, cardiac output between

contractions is higher than in the supine position and the

increase during contractions is smaller.

The effect of uterine contractions during labor on the heart rate

is variable. Some investigators have reported an increase in the

heart rate and others have reported a decline in the heart rate.

 The differences may have to do with different position of the

patient during the labor process and certainly different

hemodynamic changes that can lead to the variability in the heart rate. Significant variations of individual heart rate responses

to uterine contractions may also play a role.

During labor (uterine contractions), both the systolic and

diastolic blood pressures increase. The elevation of the blood

pressure can be as high as 35 mm Hg in the systolic component and

as high as 25 mm Hg in the diastolic component. As the labor

process advances and the patient enters the second stage, an

increase in the diastolic blood pressure as high as 65 mm Hg

above the baseline can be observed. It is believed that since

the peripheral resistance does not change or it changes only

slightly during labor, the increase in blood pressure is

attributed to the rise in cardiac output. Redistribution of

maternal cardiac output to the upper part of the peripheral

circulation after compression of the distal aorta and the common

iliac artery has also been suggested to play a role in the

elevation of systemic pressures as measured in the arm. These

hemodynamic changes are less pronounced in lateral recumbency

than in the supine position.

The hemodynamic changes during labor are influenced to a great

extent by the form of anesthesia or analgesia employed. The

above-mentioned changes in the cardiac output and blood pressure

did not happen on patients with caudal anesthesia. The

progressive rise in the heart rate and the blood pressure that is

normally observed is abolished on these patients and the stroke

volume is also maintained throughout labor but rises rapidly

after delivery.

In patients who undergo cesarean section maternal hemodynamics

can be significantly affected by anesthesia. A patient with

heart disease may not tolerate the marked fluctuations with

subarachnoid block anesthesia. Balanced anesthesia with

thiopental, nitrous oxide, and succinyl choline, and epidural

anesthesia without epinephrine are associated with smaller

hemodynamic fluctuations and therefore should be preferred in

patients with limited cardiac reserves.

**Hemodynamic changes in the postpartum period**

In the postpartum period the blood volume decreases by about 10

percent on the patients who undergo vaginal delivery and 15 to 30

percent for those who undergo cesarean section. The cardiac

output increases by 60 to 80 percent immediately after delivery and it rapidly decreases to a level slightly above the

nonpregnant value. Complete return to normal nonpregnant values

will take sometimes a few weeks. The stroke volume increases

also significantly and the heart rate drops by 4 to 17 beats per

minute shortly after delivery. Blood pressure is usually

unchanged unless excessive blood loss has taken place in which

case the blood pressure will drop or in other medical

complications. The peripheral vascular resistance according to

some investigators is increased and according to others is

unchanged.