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**PHYSIOLOGICAL ADAPTATIONS TO PREGNANCY**

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

anatomic, physiologic, biochemical and psychological changes take

place. 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.

Vascular spider nevi and palmar erythema happen also during

pregnancy. There is no clear explanation for these changes, but

they most likely represent the result of vasodilatation that

happens in the skin during pregnancy. Chloasma and other

pigmented lesions can happen as a result of increased melanocyte-

stimulating hormone activity which in turn is a result of

increased estrogen and progesterone levels. These lesions

usually begin at about five to six months gestation. One way

that these lesions may be prevented is by the use of screening

agents and avoidance of direct sunlight. Skin pruritus affects a

number of women and it may be related to increased retention of

bile salts in the skin secondary to estrogen effects. Scratching

of the skin can then lead to infected excoriations.

* **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 left-

lateral 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 pre-

pregnancy 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 mediating

changes 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 findings

were 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.

* 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 PGE and PGI 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.

* **PHYSIOLOGICAL RESPIRATORY CHANGES**
* Anatomic Changes

Mucosal edema and hyperemia secondary to capillary engorgement

are common findings in the nasopharynx and the tracheal bronchial

tract. In fact the majority of pregnant women have redness and

swelling of the lungs that at times can produce changes in the

voice. Changes also occur in chest circumference (6 to 7 cm.),

vertical diameter (4 to 5 cm.), and the substernal angle (from 70

to 105 degrees). The increase in chest circumference compensates

for the elevation of the diaphragm, so that essentially there is

no change in the overall volume of the thoracic cavity.

* Pulmonary Ventilation

During normal pregnancy the patients are in a state of

hyperventilation. The arterial CO declines and the maternal

arterial blood pH remains unchanged by compensatory increase in

renal excretion of bicarbonate, which decreases to 21 mEq/L from

27 mEq/L. This hyperventilation of pregnancy seems to be related

to the direct action of progesterone on the respiratory center.

This effect with the lowering of the CO

in the blood facilitates removal of CO from fetal cells and produces a CO

tension in the fetus similar to what will be found in the newborn. During the

labor process the hyperventilation process is augmented and the

patients ventilation peak values can reach as high as 40 liters

per minute as compared to the 12 liters per minute prior to

labor. This is most likely attributable to the painful uterine

contractions that lead to a spontaneous hyperventilation.

The oxygen consumption increases as pregnancy advances. The

increase in oxygen consumption relates to the additional energy

requirements of the fetus as well as the other metabolic

alterations that happen to the body of the pregnant woman. The

total increment in basal oxygen consumption has been estimated at

approximately 50 ml per minute. During labor, oxygen consumption

rises during each uterine contraction from about 250 ml per

minute to 750 ml per minute. The average oxygen consumption,

which includes that during and between contractions, increases

progressively and in the second stage approaches twice that of

the term pregnant woman before the onset of labor.

During pregnancy the functional residual capacity of the lungs is

decreased. The reduction has been attributed to the elevation of

the diaphragm from the enlarging uterus. This effect is

counterbalanced by a proportional increase in inspiratory

capacity that results in an unchanged vital capacity.

* **RENAL PHYSIOLOGICAL CHANGES**

The changes in renal function during pregnancy are profound and

are surpassed only by those of the cardiovascular system. Major

anatomic as well as functional changes are apparent as shown in

the following paragraphs.

* Anatomic Changes

The kidney size increases only slightly during normal pregnancy.

However, the more striking in structural changes are those of

the ureters, calyces, and renal pelvis. These changes are

readily seen as early as the third month of gestation and remain

until approximately the fourth month postpartum. Since these

changes appear long before the gravid uterus is large enough to

cause mechanical compression of the ureters, a hormonal effect is

postulated. Progesterone, a smooth muscle relaxant, is produced

in large concentrations even early in pregnancy, and is most

likely the cause of the dilatation and decrease in peristaltic

activity. Later in pregnancy, mechanical compression must

certainly play a role. Interestingly, the dilatation of the

upper urinary tract is greater on the right than on the left.

The explanation given by some for this phenomenon is that the

colon acts as a cushion to protect the left ureter, where as the

right ureter is more exposed.