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QUESTION

ELUCIDATE THE PHYSIOLOGICAL ADAPTATIONS OF THE FEMALE TO PREGNANCY

ANSWERS

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 cholithiasis 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 organs 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 sign

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.

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.

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.

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 CO₂ 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 CO₂ in the blood facilitates removal of CO₂ from fetal cells and produces a CO₂ 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

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

Functional Changes Of all functional renal changes that accompany pregnancy, the most striking is that of glomerular filtration rate (GFR), which increases by approximately 50 percent. Renal plasma flow on the other hand increases by approximately 25 percent. Both begin to change early in the second trimester of pregnancy and in lateral recumbency are maintained at these elevated levels to term. The factors responsible for these changes remain conjectural, but the following have been suggested; 1) The growth hormone-like effect of the hormone human placental lactogen, 2) The increased production and plasma concentration of free cortisol, 3) The increase in blood volume, 4) The hemodilution and hydremia resulting in decreased colloid osmotic pressure. Regardless of etiology, these functional alterations force us to redefine normal values of renal function during pregnancy. The normal serum creatinine in pregnancy drops to 0.46 mg.% as compared with the nonpregnant value of 0.67 mg.%. The BUN decreases to 8.2 mg.% from a nonpregnant value of 13 mg.%. Uric acid also declines to a value of 3.1 mg.% from approximately 4.5 mg.%. The upper-normal uric acid level in pregnancy is 5 mg.% and

levels higher than that should raise suspicion of preeclampsia. Creatinine clearance values increase to 150 - 200 ml/min as compared with values of 65 to 145 ml/min in the nonpregnant patient. Although a glomerular tubular balance exists for sodium during pregnancy, this is not the case for glucose or amino acids.

Posture and Renal Function in Pregnancy In non-pregnant individuals the up-right posture causes extra cellular fluid to shift to the legs, resulting in a relative decrease in central blood volume. This response is exaggerated during pregnancy and a similar response also occurs when the supine position is assumed. The extent of the change is a 50 to 60 percent decrease in urine flow and sodium excretion in supine recumbency versus lateral recumbency, accompanied by 20 percent decrease in renal plasma flow and glomerular filtration. The underlying patho-physiology is likely to be inferior vena caval obstruction, resulting in pulling of blood in the dilated veins of the lower extremities, dependent edema, decreased venous return, decreased central blood volume, increased aldosterone production, and ultimately decreased urinary excretion of sodium and water. In summary, one has to remember that the normal values of renal function are altered appreciably and that values normal to the non-pregnant could indicate substantial renal impairment in the pregnant patient.

CHANGES IN THE REPRODUCTIVE SYSTEM Rhythmic tightenings of the uterus occur as part of preparatory changes for labor. These are called Braxton-Hicks contractions and since the advent of ultrasound, can be seen as early as eight to nine weeks. As the pregnancy advances these contractions become more frequent and they are more likely to be felt by the patient.

MUSCULAR SKELETAL AND NEUROLOGIC SYMPTOMS A number of women may experience backache in the upper back, which is secondary to muscle tension from increasing breast size and discomfort. Most women, however, experience low back pain secondary to muscular fatigue and strain that is caused by the changes in body balance from the growing uterus. Several patients also may experience pressure on nerve roots that in turn may lead to muscular spasms and pelvic joint pains secondary to bone ligament relaxation from the sex hormones. The changes that happen on the ligaments and the cartilage of the pelvic bones secondary to the sex hormones may also lead some women to present with gait alterations. Finally, a number of women may experience paresthesias (numbness and tingling of fingers and toes). A number of theories are suggested for the explanation of these symptoms. The fingers and upper extremities are affected if lordotic posture is extreme; the head and neck are flexed, putting strain on the brachial nerves and causing tingling of hands and arms. Toes and lower extremities are affected if gravid uterus presses on femoral veins and nerves supplying lower extremities, thus interfering with circulation and causing paresthesias. Edema may cause pressure and tingling of hands or feet, especially in hands when rising in the morning. Sometimes excessive edema of the hands may lead to carpal tunnel syndrome. Finally, Vitamin B deficiency, hypoglycemia and hyperventilation have been suggested as causes of these symptoms

Cardiovascular system:

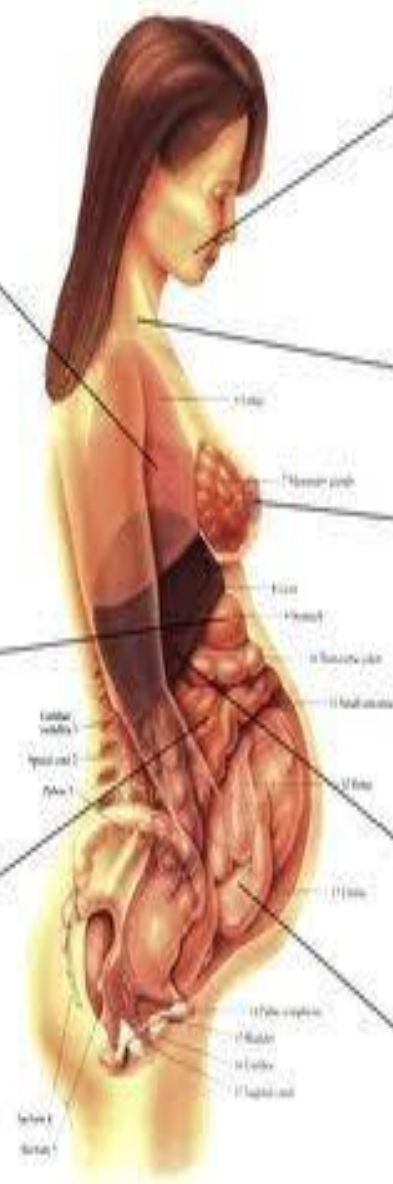
- Progressive vasodilatation
- Higher blood flow to the uterus, gut and breast
- Higher angiogenesis (breast, gut)
- Higher pressure on mesenteric vessels and lymph nodes
- Higher leukocytes' concentration

Stomach:

- Decreased motility
- Higher emptying time
- Reduced gastric secretion
- Higher gastric pH

Gut:

- Decreased motility
- Decreased peristalsis
- Higher emptying time
- Constipation
- Changes in the immune system
- Modification of the gut microbiota



Oral cavity:

- Alteration of the oral pH
- Modification of the oral microbiota
- Hyperemic, edematous, bleeding gums
- Trend to gingivitis

Esophagus:

- Gastric reflux
- Esophagitis
- Heartburn

Mammary glands:

- Ducts/alveoli hyperplasia
- Ducts/alveoli hypertrophy
- Increase of immune cells
- Increased lymph/blood supply
- Production of pre-colostrum

Gall bladder:

- Decreased motility
- Modification of bile's composition

Uterus:

- Increased size
- Increased pressure on surrounding organs, blood and lymph vessels