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PHYSIOLOGICAL ADAPTATIONS OF THE FEMALE TO PREGNANCY

After conception, the corpus luteum, placenta and the developing fetus release hormones, growth factors and other substances into the maternal circulation. This leads to various physical adaptions the woman has to undergo. They include:

**Hormonal:**

Pregnant women experience numerous adjustments in their endocrine system that help support the developing fetus. The fetal-placental unit secretes steroid hormones and proteins that alter the function of various maternal endocrine glands. Sometimes, the changes in certain hormone levels and their effects on their target organs can lead to gestational diabetes and gestational hypertension.

* Fetal-placental unit

Levels of progesterone and estrogen rise continually throughout pregnancy, suppressing the hypothalamic axis and subsequently the menstrual cycle. The progesterone is first produced by the corpus luteum and then by the placenta in the second trimester. Women also experience increased human chorionic gonadotropin (β-hCG), which is produced by the placenta.

* Pancreatic Insulin

The placenta also produces human placental lactogen, which stimulates maternal lipolysis and fatty acid metabolism. As a result, this conserves blood glucose for use by the fetus. It can also decrease maternal tissue sensitivity to insulin, resulting in gestational diabetes.

* Pituitary gland

The pituitary gland grows by about one-third as a result of hyperplasia of the lactotrophs in response to the high plasma estrogen. Prolactin, which is produced by the lactotrophs increases progressively throughout pregnancy. Prolactin mediates a change in the structure of the breast mammary glands from ductal to lobular-alveolar and stimulates milk production.

* Parathyroid gland

Fetal skeletal formation and then later lactation challenges the maternal body to maintain their calcium level. The mother's body adapts by increasing parathyroid hormone, leading to an increase in calcium uptake within the gut as well as increased calcium reabsorption by the kidneys. Maternal total serum calcium decreases due to maternal hypoalbuminemia, but the ionized calcium levels are maintained.

* Adrenal glands

Total cortisol increases to three times of non-pregnant levels by the third trimester. The increased estrogen in pregnancy leads to increase corticosteroid-binding globulin production and in response the adrenal gland produces more cortisol. The net effect is an increase of free cortisol. This contributes to insulin resistance of pregnancy and possibly striae.

The adrenal gland also produces more aldosterone, leading to an eight-fold increase in aldosterone. Women do not show signs of hyperaldosteronism, such as hypokalemia, hypernatremia, or high blood pressure.

The adrenal gland also produces more androgens, such as testosterone, but this is buffered by estrogen's increase in sex-hormone binding globulin (SHBG).

* Thyroid gland

The thyroid enlarges and may be more easily felt during the first trimester. The increase in kidney clearance during pregnancy causes more iodide to be excreted and causes relative iodine deficiency and as a result an increase in thyroid size. Estrogen-stimulated increase in thyroid-binding globulin leads to an increase in total thyroxine, but free thyroxine and triiodothyronine (T3) remain normal.

**Breast size:**

A woman's breasts grow during pregnancy, usually 1 to 2 cup sizes and potentially several cup sizes. Once the baby is born up to about 50–73 hours after birth, the mother will experience her breasts filling with milk sometimes referred to as “the milk coming in”. Once lactation begins, the woman's breasts swell significantly and can feel achy, lumpy and heavy, which is referred to as engorgement. Her breasts may increase in size again, but individual breast size may vary depending on how much the infant nurses from each breast. A regular pattern of nursing is generally established after 8–12 weeks, and a woman's breasts will usually reduce in size, but may remain about 1 cup size larger than prior to her pregnancy. Changes in breast size during pregnancy may be related to the sex of the infant, as mothers of female infants have greater changes in breast size than mothers of male infants.

**Cardiovascular adaptations:**

Cardiac output increases throughout early pregnancy, and peaks in the third trimester, usually to 30-50% above baseline. Estrogen mediates this rise in cardiac output by increasing the pre-load and stroke volume, mainly via a higher overall blood volume (which increases by 40–50%). The heart rate increases, but generally not above 100 beats/ minute. Total systematic vascular resistance decreases by 20% secondary to the vasodilatory effect of progesterone. Overall, the systolic and diastolic blood pressure drops 10–15 mm Hg in the first trimester and then returns to baseline in the second half of pregnancy. All of these cardiovascular adaptations can lead to common complaints, such as palpitations, decreased exercise tolerance, and dizziness.

 Uterine Compression of IVC and Pelvic Veins. Displacement of PMI by Uterus

Uterine enlargement beyond 20 weeks size can compress the inferior vena cava, markedly decrease the return of blood into the heart or preload. As a result, healthy pregnancy patients in a supine position or prolonged standing can experience symptoms of hypotension.

**Gastrointestinal:**

Changes in the gastrointestinal system during pregnancy are caused by the enlarging uterus and hormonal changes of pregnancy. Anatomically, the intestine and stomach are pushed up from their original positions by the enlarging uterus. While there aren't any intrinsic changes in the sizes of the gastrointestinal organs, the portal vein increases in size due to the hyperdynamic state of pregnancy. Elevated levels of progesterone and estrogen mediate most of the functional changes of the gastrointestinal system during pregnancy. Progesterone causes smooth muscle relaxation which slows down gastrointestinal motility and decreases lower esophageal sphincter tone. The resulting increase in intragastric pressure combined with lower esophageal sphincter tone leads to the gastroesophageal reflux commonly experienced during pregnancy.

The increased occurrence of gallstones during pregnancy is due to inhibition of gallbladder contraction, as result of increased smooth muscle relaxation mediated by progesterone and reduced biliary transportation of bile (mediated by estrogen) which results in cholestasis of pregnancy.

Nausea and vomiting of pregnancy, commonly known as “morning sickness”, is one of the most common gastrointestinal symptoms of pregnancy. It begins between the 4 and 8 weeks of pregnancy and usually subsides by 14 to 16 weeks. The exact cause of nausea is not fully understood but it correlates with the rise in the levels of human chorionic gonadotropin, progesterone, and the resulting relaxation of smooth muscle of the stomach. Hyperemesis gravidarum, which is a severe form of nausea and vomiting of pregnancy can lead to nutritional deficiencies, weight loss, electrolytes imbalance and is one of the leading causes of hospitalization in the first trimester of pregnancy.

Constipation is another gastrointestinal symptom that is commonly encountered during pregnancy. It is associated with the narrowing of the colon as it gets pushed by the growing uterus found adjacent it leading to mechanical blockade. Reduced motility in the entire gastrointestinal system as well as increased absorption of water during pregnancy are thought to be contributing factors.

**Immune tolerance:**

The fetus inside a pregnant woman may be viewed as an unusually successful allograft, since it genetically differs from the woman. In the same way, many cases of spontaneous abortion may be described in the same way as maternal transplant rejection.

**Musculoskeletal:**

Neuromechanical adaptations to pregnancy refers to the change in gait, postural parameters, as well as sensory feedback, due to the numerous anatomical, physiological, and hormonal changes women experience during pregnancy.

The body's posture changes as the pregnancy progresses. The pelvis tilts and the back arches to help keep balance. Poor posture occurs naturally from the stretching of the woman's abdominal muscles as the fetus grows. These muscles are less able to contract and keep the lower back in proper alignment. The pregnant woman has a different pattern of gait. The step lengthens as the pregnancy progresses, due to weight gain and changes in posture. On average, a woman's foot can grow by a half size or more during pregnancy. In addition, the increased body weight of pregnancy, fluid retention, and weight gain lowers the arches of the foot, further adding to the foot's length and width. The influences of increased hormones such as estrogen and relaxin initiate the remodeling of soft tissues, cartilage and ligaments. Certain skeletal joints such as the pubic symphysis and sacroiliac widen or have increased laxity.

The addition of mass, particularly around the torso, naturally changes a pregnant mother's center of mass. The change in center of mass requires pregnant mothers to adjust their bodies to maintain balance.

* Lumbar lordosis

To positionally compensate the additional load due to the pregnancy, pregnant women often extend their lower backs. As the fetal load increases, women tend to arch their lower backs, specifically in the lumbar region of their vertebral column to maintain postural stability and balance. The arching of the lumbar region is known as lumbar lordosis, which recovers the center of mass into a stable position by reducing hip torque. According to a study conducted by Whitcome, et al., lumbar lordosis can increase from an angle of 32 degrees at 0% fetal mass (i.e. non-pregnant women or very early in pregnancy) to 50 degrees at 100% fetal mass (very late in pregnancy). Postpartum, the angle of the lordosis declines and can reach the angle prior to pregnancy. Unfortunately, while lumbar lordosis reduces hip torque, it also exacerbates spinal shearing load, which may be the cause for the common lower back pain experienced by pregnant women.

**Respiratory:**

There are many physiologic changes that occur during pregnancy that influence respiratory status and function. Progesterone has noticeable effects on respiratory physiology, increasing minute volume (the amount of air breathed in and out of the lungs in 1 minute) by 40% in the first trimester via an increase in tidal volume alone, as the respiratory rate does not change during pregnancy. As a result, carbon dioxide levels in the blood decrease and the pH of the blood becomes more alkaline. This causes the maternal kidneys to excrete bicarbonate to compensate for this change in pH. The combined effect of the decreased serum concentrations of both carbon dioxide and bicarbonate leads to a slight overall increase in blood pH (to 7.44 compared to 7.40 in the non-pregnant state). If an arterial blood gas specimen is drawn on a pregnant woman, it would therefore reveal respiratory alkalosis (from the decrease in serum carbon dioxide mediated by the lungs) with a compensatory metabolic acidosis (from the decrease in serum bicarbonate mediated by the kidneys).

As the uterus and fetus continue to enlarge over time, the diaphragm progressively becomes more upwardly displaced. This causes less space to be available for lung expansion in the chest cavity, and leads to a decrease in expiratory reserve volume and residual volume. This culminates in a 20% decrease in functional residual capacity during the course of the pregnancy.

Oxygen consumption increases by 20% to 40% during pregnancy, as the oxygen demand of the growing fetus, placenta, and increased metabolic activity of the maternal organs all increase the pregnant person's overall oxygen requirements.s