physiology of normal pregnancy [created by Paul Young 02/10/07]

cardiac changes

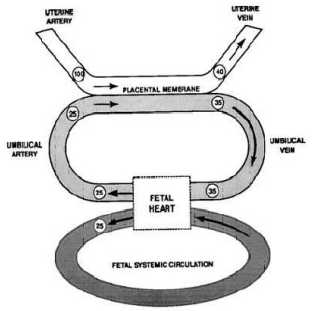
Central hemodynamic changes in normal pregnancy

Measurement	Nonpregnant state	Pregnant state
Cardiac output (L/min)	4.3 ± 0.9	6.2 ± 1.0
Heart rate (beat/min)	71 ± 10	83 ± 10
Systemic vascular resistance (dyne × cm × s^{-5})	1530 ± 520	1210 ± 266
Mean arterial pressure (mm Hg)	86.4 ± 7.5	90.3 ± 5.8
Pulmonary capillary wedge pressure (mm Hg)	6.3 ± 2.1	7.5 ± 1.8
Central venous pressure (mm Hg)	3.7 ± 2.6	3.6 ± 2.5
Colloid oncotic pressure (mm Hg)	14.5 ± 2.5	10.5 ± 2.7

Adapted from Clark SL, Cotton DB, Lee W, Bishop C, Hill T, Southwick J, et al. Central hemodynamic assessment of normal term pregnancy. Am J Obstet Gynecol 1989;161:1441.

- Maternal blood volume increases progressively during pregnancy by about 2 L, or 30% to 50% more than the volume during the nongravid state. Maternal red cell mass increases only 20% to 30%, which results in hemodilution and the relative anemia of pregnancy.
- As the uterus enlarges by about 20 weeks' gestation, the supine position may result in significant compression of the inferior vena cava, or supine hypotension syndrome. This uterine compression effectively may decrease venous return, resulting in a 20% to 30% decrease in ejection fraction. Lateral repositioning of can displace the uterus to the left, restoring cardiac output.
- Blood pressure, especially the diastolic component, tends to be lower in pregnancy.
- Physical examination often reveals a systolic ejection murmur and a third heart sound.
- Echocardiography of normal pregnant patients demonstrates the following:
(1) increases in all cardiac chamber dimensions,
(2) increased left ventricular wall thickness,
(3) small pericardial effusions,
(4) mild tricuspid and pulmonic regurgitation in 90% of patients, and
(5) mild mitral regurgitation in 30%

fetal physiology



- The placenta serves the following three main functions:
(1) respiratory and gas exchange,
(2) nutrition for the fetus, and
(3) waste elimination.
- Maternal oxygen delivery to the placenta is affected by uterine artery blood flow, oxygen content of the uterine artery blood, and hemoglobin concentration and saturation.
- Uterine blood flow at term is about 10% of cardiac output (600-700 mL/min), compared with 50 mL/min in the nonpregnant state.
- Hypotension, uterine contractions, and vasoconstriction can decrease uterine blood flow. Vasoconstriction can be seen in preeclampsia and with administration of the many inotropic support agents that commonly are used in the ICU. Ephedrine, which has predominantly b-adrenergic activity, is the vasopressor of choice for the treatment of hypotension in pregnancy.
- In the setting of trauma-induced blood loss, the uterine artery vasoconstricts, which can precipitate fetal hypoxia despite relatively normal vital signs. Maternal blood flow is maintained at the expense of the fetus.
- The fetus has many protective mechanisms to ensure its O2 extraction capacity:
(i) The fetus has a higher hemoglobin concentration.
(ii)Fetal hemoglobin is 80% to 90% saturated at a Po2 of 30 to 35 mm Hg, whereas the major form of adult hemoglobin is only 30% saturated at this Po2. This difference is a result of the leftward shift of the fetal oxygen dissociation curve.
(iii) The fetus has the ductus arteriosus, which provides the fetus with two ventricles to supply circulation.
- The fetus has about 42 mL of oxygen reserves, and its oxygen consumption is 20 mL/min. In the face of complete hypoxia to the fetus, only 2 minutes of oxygen reserve would be expected; however, a fetus with this condition can survive at least 10 minutes by shunting blood flow to vital organs and decreasing oxygen consumption.
- A fetus is considered viable when the gestational age is 24 to 25 weeks and the weight is estimated to be greater than 750 g

general

- Pregnancy is characterized by progesterone-mediated hyperemia and edema of mucosal surfaces. This change is evident in the nasopharynx and oropharynx. Pregnant women tend to have more nasal congestion. Accordingly, endotracheal and nasogastric tube size should be downsized.
- The diaphragm is displaced cephalad about 4 cm, and the lower chest wall widens about 5 to 7 cm. These changes peak at 37 weeks' gestation which is important if the patient requires a chest drain
- When the diaphragm is pushed upward, the heart is rotated slightly to the left, which results in electrocardiographic changes of Q waves inferiorly along with T-wave inversion.
- At 12 weeks, the bladder becomes an abdominal structure and is susceptible to blunt trauma.
- At 20 weeks, the fundus of the uterus is at the level of the umbilicus and can be injured directly in blunt or penetrating trauma

renal changes

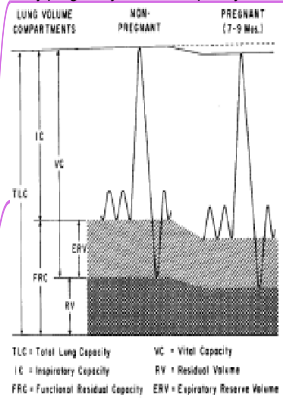
- By 16 weeks' gestation, the glomerular filtration rate increases by 50% and remains elevated throughout pregnancy resulting in lower levels of serum creatinine, blood urea nitrogen, and uric acid.
- Plasma levels of creatinine and that exceed 70 may indicate renal impairment

GI changes

- Gastroesophageal reflux is a common symptom in most pregnant women. Progesterone causes smooth muscle relaxation and results in a decrease in lower esophageal sphincter pressure, beginning in the first trimester. As abdominal girth increases, the stomach is displaced, causing a further decrease in the effectiveness of the sphincter. Pregnant women always should be considered at high risk for aspiration.
- Increased plasma volume leads to hypoalbuminema.
- Serum alkaline phosphatase concentrations (from placenta) increase above the normal range during the fifth month of gestation and continue to increase to two to four times the normal values.
- Appendicitis is the most common nonobstetric condition of pregnancy that requires surgery, followed by cholecystitis.

respiratory changes

- Spirometry remains normal throughout pregnancy. Flow volume loops, and peak flows remain unchanged.
- Total lung capacity decreases by about 4% to 5%. This change mostly is caused by the upward displacement of the diaphragm.
- Functional residual capacity (FRC) decreases by 20% because of decreases in expiratory reserve volume and residual volume.
- Diffusion capacity may remain the same or increase slightly in early pregnancy and subsequently return to normal values.



- Minute ventilation increases by about 50% during pregnancy
- The increase in minute ventilation is caused by an increase in tidal volume with little to no change in respiratory rate. This increase begins before the end of the first trimester and remains fairly constant during the remainder of the pregnancy.
- The increase in minute ventilation leads to a normal hyperventilation of pregnancy, which in turns leads to a mild chronic respiratory alkalosis with a compensatory metabolic acidosis. A normal arterial blood gas in a gravid woman is a pH of 7.40 to 7.47, with a Paco2 of 30 to 32 mm Hg and a normal to slightly elevated Pao2. The kidneys compensate partially for the alkalosis by increasing renal bicarbonate excretion, which keeps serum HCO3 levels between 18 and 21 mEq/L (base deficit, 3-4 mEq/L). Arterial blood gas values of 7.47 for pH, 32 mm Hg for Paco2, and 90 mEq/L for HCO3 do not necessarily indicate a pathologic situation that requires further evaluation.
- Oxygen consumption increases by about 20%.
- The combination of the decrease in FRC and the increase in oxygen consumption lowers maternal oxygen reserve.