

# 1 Maternal Physiological Changes During Pregnancy, Labor, and the Postpartum Period



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Clinical Implications

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Clinical Implications

Parturients undergo remarkable changes during pregnancy, labor, and the immediate postpartum period that can directly affect anesthetic techniques; hence a broad knowledge of these changes is essential for proper management of these women.

### Changes in Blood Volume

Maternal blood volume increases during pregnancy, and this involves an increase in plasma volume as well as in red cell and white cell volumes.<sup>1</sup> *The plasma volume increases by 40% to 50%, whereas the red cell volume goes up by only 15% to 20%, which causes a situation that is described as “physiological anemia of pregnancy”* (normal hemoglobin, 12 g/dL; hematocrit, 35).<sup>2</sup> Because of this apparent hemodilution, blood viscosity decreases by approximately 20%. The exact mechanism of this increase in plasma volume is unknown. However, several hormones such as renin-angiotensin-aldosterone, atrial natriuretic peptide, estrogen, and progesterone may be involved in this interesting phenomenon. Two current hypothesis attribute the increase to (1) an underfill state caused by initial vasodilation, which stimulates hormones such as renin, angiotensin, and aldosterone or (2) an overfill state characterized by an early increase in sodium retention (due to an increase in mineralcorticoids) that retains fluid, causing an increase in blood volume. Levels of clotting factors I, VII, VIII, IX, X, and XII, and the fibrinogen count are elevated during pregnancy as well. *At present the majority of observers report a statistically significant fall in platelet count as pregnancy progresses.*<sup>3</sup> A recent study that observed an increase in thrombopoietin with the advancement of the gestational age also confirmed this finding.<sup>3a</sup> Systemic fibrinolysis also may increase slightly.

### Clinical Implications

The increased blood volume serves several important functions: (1) it takes care of the increased circulatory need of the enlarging uterus as well as the needs of the fetoplacental unit, (2) it fills the ever-increasing venous reservoir, (3) it protects the parturient from the bleeding at the time of delivery, and (4) parturients become hypercoagulable as the gestation progresses.

It takes about 8 weeks after delivery for the blood volume to return to normal.

## Changes in the Cardiovascular System

An increase in cardiac output is one of the most important changes of pregnancy. *Cardiac output increases by 30% to 40% during pregnancy, and the maximum increase is attained around 24 weeks' gestation.*<sup>4</sup> The increase in heart rate lags behind the increase in cardiac output initially and then ultimately rises by 10 to 15 beats per minute by 28 to 32 weeks' gestation. The increase in cardiac output initially depends mainly on the rise in stroke volume, and later the increase in heart rate also becomes an important factor. With Doppler and M-mode echocardiography technique, increases in end diastolic chamber size and total left ventricular wall thickness have been observed in recent years. Cardiac output can vary depending on the uterine size as well as on the maternal position at the time of measurement. The enlarged gravid uterus can cause aortocaval compression while the pregnant woman is in the supine position, and this will lead to reduced venous return and ultimately maternal hypotension. This effect will be exaggerated in parturients with polyhydramnios or multiple gestations.

Cardiac output increases further during labor and may show values 50% higher than prelabor values. In the immediate postpartum period, cardiac output increases maximally and can rise 80% above prelabor values and approximately 100% above nonpregnant measurements. The increase in stroke volume as well as in heart rate maintains the increased cardiac output.

## Clinical Implications

An increased cardiac output might not be well tolerated by pregnant women with valvular heart disease (e.g., aortic or mitral stenosis) or coronary arterial disease. *A severe decompensation in myocardial function can develop at 24 weeks' gestation, during labor, and especially immediately after delivery.*

Cardiac output, heart rate, and stroke volume decrease to pre-labor values 24 to 72 hours postpartum and return to nonpregnant levels within 6 to 8 weeks after delivery.<sup>5</sup>

Even with this increase in cardiac output the systolic blood pressure does not change during pregnancy; however, the dia-

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stolic blood pressure drops by 1 to 15 mm Hg. There is a decrease in mean arterial pressure because of an associated decrease in systemic vascular resistance. Pregnancy hormones like estradiol-17 $\beta$  and progesterone are probably responsible for these vascular changes.<sup>6</sup> Prostacyclin as well as nitric oxide also may play an important role.

The down regulation of  $\alpha$  and  $\beta$  receptors may also be an important factor. The heart is displaced to the left and upward during pregnancy because of the progressive elevation of the diaphragm by the gravid uterus. The electrocardiogram of normal parturients may include: (1) benign dysrhythmia, (2) reversal of ST, T, and Q waves, and (3) left axis deviation.

Aortocaval compression is one of the most important events during pregnancy, especially when the parturient lies supine. Hence left uterine displacement must always be maintained. This becomes more important following regional (spinal or epidural) analgesia or anesthesia. Volume expansion is always important. Recently, however, the importance of infusion of predeterminant volume has been challenged.<sup>6a</sup> Engorgement of the epidural venous plexus increases the risk of intravascular catheter placement in pregnant women; direct connection of the azygos system to the heart as well as brain also increases the risks of local anesthetic cardiovascular and central nervous system toxicity.

### Changes in the Respiratory System

Changes in the respiratory parameters start as early as the fourth week of gestation. Minute ventilation is increased at term by about 50% above nonpregnant values. The increase in minute ventilation is mainly due to an increase in tidal volume (40%) and, to a lesser extent, to an increase in the respiratory rate (15%).<sup>7</sup> Alveolar ventilation is greatly increased as the tidal volume increases without any change in the anatomic dead space. At term the PCO<sub>2</sub> value is decreased (32 to 35 mm Hg). Increased progesterone concentrations during pregnancy decrease the threshold of the medullary respiratory center to carbon dioxide.<sup>8</sup>

Functional residual capacity, expiratory reserve volume, and residual volume are decreased at term. These changes are related to the cephalad displacement of the diaphragm by the large gravid uterus. Inspiratory capacity increases because of increase in tidal volume and inspiratory reserve volume. Vital capacity is unchanged. Even with the presence of elevation of the diaphragm the total lung capacity is slightly reduced because of the presence of an increase in chest circumference.

Besides these changes in respiratory parameters, there are some structural changes. The respiratory mucous membrane becomes vascular, edematous, and friable.

## Clinical Implications

A decreased functional residual capacity as well as increased oxygen consumption can cause a rapid development of maternal hypoxemia. *Decreased functional residual capacity, increased minute ventilation, as well as a decreased minimal alveolar concentration (MAC) will make parturients more susceptible to inhalational anesthetics as compared with their nonpregnant counterparts.*

*Because of the increased edema, vascularity, and friability of the mucous membrane, one should try to avoid nasal intubation in pregnant women, and smaller endotracheal tubes should be used for oral intubation.*

During the first stage of labor, in the absence of pain relief, hyperventilation can decrease the maternal  $\text{PaCO}_2$  to values as low as 18 mm Hg and, subsequently, produce fetal acidosis. In the second stage of labor,  $\text{PaCO}_2$  increases to a certain extent and may stay around 25 mm Hg.<sup>9</sup> Maternal alkalosis associated with decreased  $\text{PaCO}_2$  values due to hyperventilation as a result of labor pain causes fetal acidosis because of (1) decreased uteroplacental perfusion (with significant drop of maternal  $\text{PaCO}_2$ ) and (2) shifting of the maternal oxygen dissociation curve to the left. Decreased FRC decreases the time for denitrogenation. However, because of decreased FRC and increased oxygen demand the parturients rapidly become hypoxic when apneic. All respiratory parameters return to nonpregnant values within 6 to 12 weeks postpartum.

**Table 1-1.** Changes in the Renal System

|                    | Nonpregnant | Pregnant    |
|--------------------|-------------|-------------|
| BUN (mg/dl)        | 13 ± 3      | 8.7 ± 1.5   |
| Creatinine (mg/dl) | 0.67 ± 0.14 | 0.46 ± 0.13 |

## Changes in the Renal System

The glomerular filtration rate is increased during pregnancy because of increased renal plasma flow.<sup>10</sup> A rise in the filtration rate decreases plasma blood urea nitrogen (BUN) and creatinine concentrations by about 40% to 50% (Table 1-1). Tubular reabsorption of sodium is increased. However, glucose and amino acids might not be absorbed as efficiently; hence glycosuria and aminoaciduria may develop in normal gestation.<sup>11,12</sup> The renal pelvis and ureters are dilated, and peristalsis is decreased.

### Clinical Implications

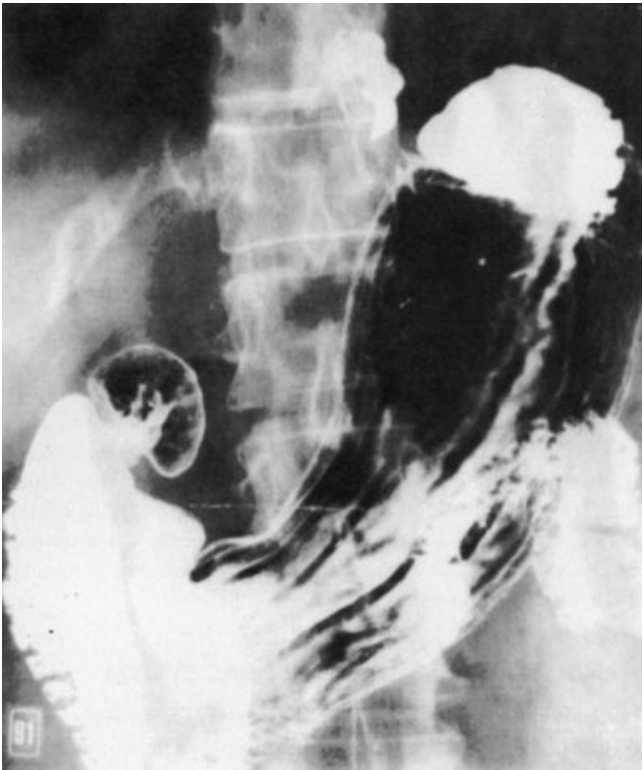
*Normal parturients' BUN (8 to 9 mg/dl) and creatinine (0.4 mg/dl) values are 40% less than in nonpregnant women. So nonpregnant values in parturients will suggest abnormal kidney function.* Physiological diuresis during the postpartum period occurs between the second and fifth days. The glomerular filtration rate and BUN concentration slowly return to nonpregnant values by the sixth postpartum week.

## Changes in the Gastrointestinal System

Gastrointestinal motility, food absorption, and lower esophageal sphincter pressure are decreased during pregnancy, probably due to an increased level of plasma progesterone.<sup>13</sup> Lower esophageal sphincter pressure is decreased during pregnancy, on the other hand intragastric pressure is increased during the last trimester. Heartburn during pregnancy is the result of reduced barrier pressure. The gastric emptying time of solid as well as liquid material is not changed during pregnancy. Because of decreased plasma gastrin concentration during

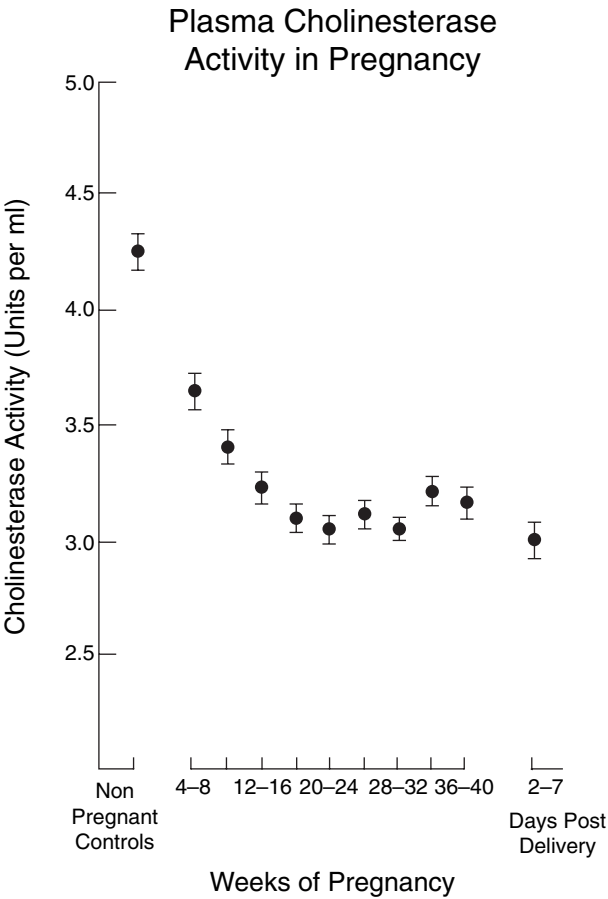
pregnancy, there is reduction in the total acid content of the stomach. Gastric emptying time is significantly slower during labor and hence gastric volume is increased. Analgesic drugs will further increase the gastric emptying time. The enlarged gravid uterus divides the stomach into fundal and antral parts and also increases gastric pressure (Fig. 1-1).

Serum glutamic oxaloacetic transaminase, lactic dehydrogenase, and alkaline phosphatase levels are elevated



**Figure 1-1.** Fundal and antral sacs in parturients following a Barium meal. (From Holdsworth JD, et al. Fundal and antral sacs in parturients following a barium meal. *Anaesthesia* 1970; 35s641. Used with permission from Blackwell Publishing.)

during pregnancy and labor, and the sodium Bromsulphalein excretion test is also often abnormal in the majority of par-turients. *Serum cholinesterase activity is reduced 24% before delivery and becomes lowest (33%) on the third postpartum day*<sup>14</sup> (Fig 1-2). Even with this lower activity, normal dosing



**Figure 1-2.** Plasma cholinesterase activity in pregnancy. (From Cohen SE: *Semin Anesthesia* 1982; 1:73. Used with permission from Elsevier.)



*of succinylcholine for intubation (1 to 1.5 mg/kg) is not associated with prolonged neuromuscular blockade during pregnancy.*

Gallbladder function and emptying are impaired during pregnancy, and there is evidence that parturients may be more prone to gallstone problems.

## **Clinical Implications**

Pregnant women in labor should always be considered to have a full stomach irrespective of the time of their last meal. General anesthesia should be avoided when possible. The routine use of nonparticulate antacid is important before cesarean section and before induction of regional anesthesia, and one should allow for proper mixing of the antacid and stomach contents.

Although the mechanical effects of a gravid uterus on the stomach are resolved in a few days, the other gastrointestinal changes revert back to nonpregnant states within 6 weeks postpartum.

## **Changes in the Central and Peripheral Nervous Systems**

The central and peripheral nervous systems undergo significant changes during pregnancy. The MAC is decreased by 25% to 40% (different inhalational anesthetics) during pregnancy.<sup>15</sup> Increased progesterone and endorphin concentrations during pregnancy have been implicated as a cause of this change. However, a few studies have shown that endorphin concentrations do not increase during pregnancy until the parturient is in active labor,<sup>16</sup> so endorphin might not be involved in the difference in MAC values. By injecting exogenous progesterone in oophorectomized rabbits, a decrease in MAC was observed when compared with control animals.<sup>17</sup>

A wider dermatomal spread of sensory anesthesia was observed in parturients following the use of epidural anesthesia as compared with their nonpregnant counterparts of the same age group.<sup>18</sup> This difference was explained on the

**Table 1-2.** Increased Sensitivity in Nerves  
From Pregnant Animals as Compared  
With Nonpregnant Ones\*

| Nerve Fibers<br>(N = 6) | Pregnant Animals | Nonpregnant<br>Animals <sup>†</sup> | P     |
|-------------------------|------------------|-------------------------------------|-------|
| A                       | 11.2 ± 0.4       | 19.4 + 3.7                          | 0.001 |
| B                       | 6.7 ± 2.8        | 17.9 <sup>‡</sup>                   | 0.03  |
| C                       | 12.1 ± 5.2       | 31.6 <sup>‡</sup>                   | 0.001 |

\*From Datta S. Lambert H, Gregus J. et al. *Anesth Analg* 1983; 62:1070-1072.

<sup>†</sup>Time in minutes for a 50% block with 0.35 mM bupivacaine HCl in HEPEs Liley's solution.

<sup>‡</sup>The statistical method employed does not yield a standard deviation here.

basis of a reduced epidural space volume caused by an engorged epidural venous plexus because of aortocaval compression by the large gravid uterus. However, a more recent report showed that this difference exists even during early pregnancy (8 to 12 weeks) when one might not expect any mechanical obstruction by the small gravid uterus and thus that other factors may be involved in this difference<sup>19</sup> The factors suggested are (1) compensated respiratory alkalosis of pregnancy, (2) reduced plasma and cerebrospinal fluid (CSF) protein levels during pregnancy, and (3) pregnancy hormones. An increased sensitivity of the pregnant nerve fiber to bupivacaine was observed in recent studies<sup>20</sup> (Table 1-2). This increased sensitivity was also observed in nerves from oophorectomized rabbits treated chronically with exogenous progesterone.<sup>21</sup> Interestingly, this phenomenon was not observed following acute exposure to progesterone.<sup>22</sup> More recently, enhanced sensitivity of the peripheral nerve to local anesthetic has been documented in humans.<sup>23</sup> It is possible that progesterone or one of its active metabolites is responsible for the observed increased sensitivity of the peripheral nervous system to anesthetics in parturients.

## Clinical Implications

Even though the exact mechanism of the increased sensitivity of the central nervous system and peripheral nervous

system to general and local anesthetics is not known, one must reduce the doses of anesthetics in pregnant women.

There is controversy regarding the time needed for these changes to revert back to their prepregnant state because of a lack of studies in this area. However, there is evidence that increased sensitivity to the local anesthetic used for epidural or spinal anesthesia can exist up to 36 hours postpartum.

## **Changes in the Musculoskeletal System**

The hormone relaxin is responsible for both the generalized ligamentous relaxation and the softening of collagenous tissues.

## **Changes in the Dermatological System**

Hyperpigmentation of certain parts of the body such as the face, neck, and midline of the abdomen is not uncommon during pregnancy. Melanocyte-stimulating hormone is responsible for this change.

## **Changes in Mammary Tissue**

Enlargement of the breasts is an integral part of the physiological changes of pregnancy.

## **Changes in the Ocular System**

Intraocular pressure has been shown to decrease during pregnancy; this is related to (1) increased progesterone levels, (2) the presence of relaxin, and (3) decreased production of aqueous humor due to increased secretion of human chorionic gonadotropin.<sup>24</sup>

## **Clinical Implications**

Relaxation of ligaments and collagen tissue of the vertebral column is the main cause of lordosis during pregnancy.

Enlarged breasts, especially in parturients with short necks, may make intubation extremely difficult. A short-handled laryngoscope as described by Datta and Briwa may be helpful in such cases.<sup>25</sup> Changes in intraocular pressure in parturients may produce visual disturbances as well as contact lens intolerance.

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