Anesthesia for nonobstetric surgery during pregnancy

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INTRODUCTION

The need for nonobstetric surgery can arise at any point during gestation; urgent and emergency surgeries are not based on pregnancy, while elective procedures generally can be delayed until after delivery. Anatomic and physiologic changes related to pregnancy and concerns for the fetus may require adjustment of anesthetic management.

This topic will discuss the perioperative anesthetic management of patients who undergo nonobstetric surgery during pregnancy. Timing of surgery, obstetric outcomes, and perioperative obstetric outcomes are discussed separately. (See "Nonobstetric surgery in pregnant patients: Patient counseling, surgical considerations, and obstetric management".)

Surgical management of specific disorders in pregnant women is discussed in detail in individual topic reviews for each disorder. As examples, appendectomy and cholecystectomy during pregnancy are discussed separately. (See "Acute appendicitis in pregnancy", section on 'Appendectomy' and "Gallstone diseases in pregnancy", section on 'Cholecystectomy during pregnancy'.)

Preoperative pregnancy testing is also discussed separately. (See "Preoperative evaluation for anesthesia for noncardiac surgery", section on 'Pregnancy testing'.)

PHYSIOLOGIC CHANGES OF PREGNANCY

Physiologic changes of pregnancy occur in virtually all organ systems and are caused by both hormonal and mechanical factors. Effects on major organ systems are briefly discussed here and are discussed in more detail separately.

- **Cardiovascular –** Cardiac output (CO) rises significantly during normal pregnancy. CO reaches approximately 35 percent above baseline by the end of the first trimester, and plateaus at approximately 50 percent above baseline at 30 to 32 weeks gestation when patients are maintained in the left lateral decubitus position (figure 1) (see "Maternal adaptations to pregnancy: Cardiovascular and hemodynamic changes"). At term, the supine position can reduce CO by 25 to 30 percent compared with left lateral decubitus position, due to compression of the inferior vena cava by the gravid uterus. In a subset of patients, this caval compression can produce significant maternal hypotension, labeled "supine hypotensive syndrome." The progressive effect of the supine position during pregnancy is shown in the figure (figure 2).

- **Pulmonary –** Starting in the first trimester, resting minute ventilation increases, primarily due to an increase in tidal volume, and reaches nearly 50 percent above baseline at term. As a result, pregnancy is associated with a compensated respiratory alkalosis, with pH = 7.42 to 7.44 and partial pressure of carbon dioxide ($PaCO_2$) = 28 to 32 mmHg by midpregnancy (normal range in nonpregnant state: 35 to 45 mmHg) (figure 3). Progesterone-induced stimulation of ventilation is thought to be responsible for this change as well as the common complaint of intermittent dyspnea among otherwise healthy pregnant women.

  - Beyond approximately 20 weeks of gestation, upward displacement of the diaphragm leads to a 20 percent decrease in functional residual capacity (FRC).

  - Oxygen consumption increases by approximately 20 percent during pregnancy. (See "Maternal adaptations to pregnancy: Dyspnea and other physiologic respiratory changes", section on 'Physiologic pulmonary changes in pregnancy'.)

- **Hematologic –** Healthy pregnancy is associated with a modest decrease in hemoglobin concentration, as a result of a relatively greater increase in plasma volume compared with red cell mass (figure 4). Consequently, normal hemoglobin may be as low as 11 g/dL by the end of the first trimester and approximately 10.5 g/dL in the second trimester.

  Pregnancy creates a relatively hypercoagulable state, which persists into the postpartum period primarily due to an increase in concentrations of the vitamin K-dependent clotting factors and type 1 and 2 plasminogen activator inhibitor, and decreases in levels of free protein S, the cofactor of the endogenous anticoagulant activated protein C. Return to baseline thromboembolic risk generally occurs after 12 weeks postpartum. (See "Maternal adaptations to pregnancy: Hematologic changes".)

- **Gastrointestinal** – Gastroesophageal reflux is reported by 40 to 85 percent of women during pregnancy, as a result of decreased lower esophageal sphincter tone

throughout pregnancy and an increase in intraabdominal pressure as the uterus enlarges. Gastric emptying is normal during pregnancy, though it slows during labor and after administration of opioid analgesics. Gastric acid secretion is unchanged or decreased in pregnant women [1,2]. (See "Maternal adaptations to pregnancy: Gastrointestinal tract".)

- **Sensitivity to anesthetic medications –** The physiologic changes of pregnancy alter sensitivity to many anesthetic medications and may affect drug metabolism. Minimum alveolar concentration is reduced for volatile anesthetics during pregnancy [3]. While we typically do not change the choice or doses of anesthetic medications during pregnancy, when possible we monitor and titrate to effect (eg, using a train of four peripheral nerve monitor for neuromuscular blocking agents, and often a processed electroencephalogram for general anesthetics). (See 'Induction drugs' below and 'Maintenance anesthetics' below.)

The physiologic changes of pregnancy can alter the range of normal laboratory values in pregnant women. (See "Normal reference ranges for laboratory values in pregnancy".)

EFFECTS OF ANESTHETICS ON THE FETUS AND THE PREGNANCY

There is no compelling evidence that any specific anesthetic agent is teratogenic in humans or that a specific anesthetic-related medication should be avoided during the perioperative care of a pregnant patient. The possible exception to this is sugammadex, which is administered to reverse neuromuscular blocking agents. Sugammadex encapsulates progesterone and reduces free progesterone levels in pharmacologic simulation studies [4]. This effect could be consequential, since progesterone is required for endometrial decidualization and uterine growth early in pregnancy, and myometrial quiescence and cervical structural integrity later in pregnancy (see "Progesterone supplementation to reduce the risk of spontaneous preterm labor and birth", section on 'Rationale for progesterone supplementation').

While the results of animal studies of miscarriage and teratogenicity of sugammadex are mixed [5,6], studies in humans have not reported complications. Although total numbers are insufficient to conclude that sugammadex is safe during pregnancy, there is a growing body of evidence of its efficacy and safety for nonobstetric surgery [7-9]. Thus, while the decision to use sugammadex should be individualized until more evidence on hormonal and teratogenic effects is available, the Society of Obstetric Anesthesia and Perinatology has recommended avoiding routine sugammadex use during pregnancy, and instead using other reversal agents [10]. (See "Clinical use of neuromuscular blocking agents in anesthesia", section on 'Reversal of neuromuscular block'.)

- **Fetal brain development –** Laboratory and animal studies, including studies in nonhuman primates, have reported histologic changes of the brain and adverse neurodevelopmental effects after exposure to most anesthetics during periods of rapid brain development. Human clinical studies involving young children have reported mixed results, although the most robust studies are reassuring that a single anesthetic exposure does not adversely affect neurodevelopment [11-13].

  In 2016, the US Food and Drug Administration (FDA) announced warnings about potential risks of negative effects on the developing brain from administration of anesthetics and sedative drugs to third trimester pregnant women and children under age three, especially for repeated exposures or procedures lasting more than three hours [14]. The FDA recommends that health care providers discuss with pregnant patients the benefits, risks, and appropriate timing of surgery requiring anesthesia that will take longer than three hours. However, the degree of risk remains unclear.

  Data on the effects of in utero exposure to anesthesia are limited. Two studies specifically warrant discussion and should be used for hypothesis generation. These studies are small and potential confounders may be present. Further clinical study is required to determine the effects of prolonged or repeated exposure to anesthesia and patient factors that may increase risk of neurotoxicity.

  - One observational study reported an association between prenatal exposure to anesthesia and subsequent abnormal behavior scores at 10 years of age [15]. However, conclusions from this study are limited by the small number of exposed fetuses (22) and the fact that effects of anesthesia could not be differentiated from any other potential stressors of maternal surgery or illness on the fetus.

  - In the largest study to date, a retrospective cohort study of 582 children (129 of whom were exposed to anesthesia while in utero), prenatal exposure to anesthesia was not associated with changes in executive function, behavioral problems, or psychiatric disorders at age 2 to 18 years [16]. However, worse neurodevelopmental scores were found in the subgroup of fetuses exposed to general anesthesia, which made up 111 of the 129 exposed children. Most of the children were exposed to a single anesthetic lasting approximately 90 minutes during the mother's pregnancy.

  Both the FDA and the American College of Obstetricians and Gynecologists (ACOG) advise that necessary surgery should not be avoided or delayed during pregnancy [17-19]. Neurotoxic effects of anesthetics on the developing brain are discussed in detail separately. (See "Neurotoxic effects of anesthetics on the developing brain".)

- **Teratogenicity –** Theoretically, any medication could be teratogenic if given in a high enough dose, for a long enough duration of time, and at precisely the right time of

development. Although many drugs used in anesthesia have been associated with teratogenic effects in animal studies, such findings are extremely difficult to extrapolate to humans due to interspecies variation and the high dose of agents used in the animal studies. No anesthetic agents have been shown to have teratogenic effects in humans, and multiple large retrospective studies have not shown an increase in congenital anomalies in infants born to mothers who had surgery and anesthesia during pregnancy, including the 2853 pregnancies with first trimester exposures [20-26]. A systematic review of 54 studies and 12,452 patients who underwent surgery during pregnancy showed no increase in congenital anomalies compared with the general population [27]. It is important to note that cumulative dose plays a large role in the development of congenital malformations. Some medications, such as opioids, have been associated with congenital malformations when used chronically throughout pregnancy [28]. In contrast, the use of all anesthetic medications in the perioperative setting in clinically relevant doses and concentrations has not been associated with teratogenicity.

- **Benzodiazepines** – Some early reports suggested that diazepam use in early pregnancy may be associated with cleft palate. Subsequent studies have failed to demonstrate this association or a definite risk of other anomalies, although a small increase in risk could not be excluded [29-31]. Benzodiazepines that are commonly used in the perioperative setting (eg, midazolam) have never been associated with congenital malformations.

- Nitrous oxide – Nitrous oxide has been shown to be a weak teratogen in animal models. Because of its effect of inhibiting methionine synthetase and impairing DNA production, there is concern about nitrous oxide use during pregnancy, particularly in the first trimester during organogenesis. However, no human study has shown any increase in the rate of congenital malformations with nitrous oxide use. This includes a study of over 2000 women who underwent surgery in the first trimester, most with the use of nitrous oxide [20]. Despite this reassuring evidence, it is our practice to avoid nitrous oxide during the first trimester if there are reasonable alternatives.

- **Need for neonatal support after emergency delivery** – Anesthetics and opioids cross the placenta. Thus, neonates delivered urgently during nonobstetric surgery may require ventilatory support until the respiratory depressant effects of residual anesthetics and opioids subside.

  Because most muscle relaxants are highly ionized with low lipid solubility, there is minimal placental transfer. Vecuronium crosses the placenta in small amounts, but neonatal outcome does not appear to be affected [32,33].

PREANESTHESIA EVALUATION

Pregnant patients should be evaluated preoperatively in the same manner as nonpregnant patients. A medical and obstetric history and anesthesia-directed physical examination, including airway assessment, should be performed for all pregnant patients who undergo any type of anesthesia. Laboratory evaluation should be performed selectively, based on patient factors and the planned procedure (see "Preoperative evaluation for anesthesia for noncardiac surgery"). Additional testing is not indicated in an uncomplicated pregnancy.

When considering neuraxial anesthesia, the assessment should include a focus on medical conditions that may alter the physiologic response to neuraxial anesthesia or increase the risk of complications (eg, coagulopathy, systemic and local infection, spine abnormalities, neurologic disease). (See "Overview of neuraxial anesthesia", section on 'Preoperative evaluation'.)

The American College of Obstetrics and Gynecologists (ACOG) recommends that the primary obstetric care provider should be notified or, if that provider is not at the institution where surgery is performed, another obstetric care provider with privileges at the institution should be involved [18].

PREPARATION FOR ANESTHESIA

Preparation for anesthesia includes placement of an intravenous (IV) catheter and standard physiologic monitors, measures to prevent aspiration, and in some cases, premedication.

Preoperative aspiration mitigation — Based on the anatomic and hormonal changes that occur, pregnant patients may be at increased risk of aspiration during induction of (or emergence from) general anesthesia, especially in cases of difficult or failed intubation when mask ventilation may be required. The risk of aspiration may be reduced by preoperative fasting and use of pharmacologic prophylaxis. However, no specific intervention has been shown to improve clinical outcomes, and decision to administer prophylaxis should be individualized [34].

- **Incidence of aspiration** – Multiple large studies have failed to identify pregnancy as a risk factor for aspiration [35,36]. Similarly, the Serious Complications Repository (SCORE) Project found no cases of aspiration in 96,127 cesarean deliveries, of which 5332 were done under general anesthesia, many in urgent/emergency situations [37]. In a retrospective review of 51,086 first-trimester and 11,039 second-trimester pregnant patients undergoing deep sedation with propofol, there were no cases of perioperative pulmonary aspiration even though preoperative antacids or cricoid

pressure were not routinely utilized [38]. Of note, in this study pregnant patients with a body mass index greater than 40 kg/m^2, who may be at increased risk for aspiration, were not candidates for deep sedation. Taken together, these data suggest that the risk of aspiration in nonobese pregnant patients who have met fasting guidelines is extremely low and likely not different from nonpregnant patients.

- **Preoperative fasting** – Gastric emptying is not affected by pregnancy, and gastric acid secretion is unchanged or decreased in pregnant women [1,2]. Standard adult fasting guidelines apply for nonobstetric surgery in pregnant patients (table 1). Most guidelines, including those from the American Society of Anesthesiologists (ASA), recommend that patients abstain from solid food for at least six hours (eight hours for large meals and fried or fatty foods) and from clear liquids for two hours, prior to surgery. (See "Preoperative fasting in adults", section on 'Pregnant patients'.) Although gastric ultrasound has been shown to be reliable for evaluating residual stomach contents [39], it should be viewed as an additional evaluation tool rather than standard practice.

- **Pharmacologic prophylaxis** – The author does not routinely administer pharmacologic aspiration prophylaxis for pregnant patients unless it is indicated by other risk factors (eg, full stomach, emergency surgery, symptomatic gastroesophageal reflux (table 2). However, practice varies, and some experts routinely administer nonparticulate antacids, H2 receptor antagonists and/or metoclopramide for patients who are beyond 18 to 20 weeks gestation.

Sedative premedication — Most pregnant patients prefer to avoid sedatives. If anxiolysis is required, small doses of a sedative can safely be titrated to effect (eg, midazolam 1 mg IV, repeated as necessary).

MANAGEMENT OF ANESTHESIA

Positioning — Beyond 18 to 20 weeks of gestation, patients should be positioned with a 15 to 30 degree left lateral tilt when supine, to reduce aortocaval compression and cardiovascular compromise. The efficacy and need for left uterine displacement (LUD) for healthy parturients at cesarean delivery have been questioned. However, the preponderance of evidence suggests that LUD should be used for nonobstetric surgery. (See "Cesarean birth: Preoperative planning and patient preparation", section on 'Uterine displacement' and "Anesthesia for cesarean delivery", section on 'Intraoperative positioning'.)

LUD can be accomplished by tilting the operating table or by placing a wedge under the patient's right hip. Most operations can be successfully performed with LUD. If LUD compromises surgery and the supine level position is required, blood pressure may fall and

should be maintained with intravenous (IV) fluid and vasopressor therapy. (See 'Hemodynamic management' below.)

Monitoring — Standard physiologic monitors are used for all patients during anesthesia; no additional patient monitors are required because of pregnancy (see "Basic patient monitoring during anesthesia", section on 'Standards for monitoring during anesthesia'). Advanced monitoring (eg, intra-arterial continuous pressure monitoring) may be indicated based on the type of surgery or patient comorbidities.

Fetal heart rate monitoring — For all pregnant patients, the fetal heart rate (FHR) should be documented pre- and postoperatively. In some cases, intermittent or continuous FHR monitoring may be performed during surgery as well. The rationale for intraoperative FHR monitoring, when to perform FHR monitoring, and interpretation during surgery are discussed in detail separately. (See "Nonobstetric surgery in pregnant patients: Patient counseling, surgical considerations, and obstetric management", section on 'Fetal heart rate monitoring'.)

Hemodynamic management — Maternal blood pressure is the most important determinant of uteroplacental perfusion. Anesthetic agents have minimal direct effects on uterine blood flow [40,41] but can contribute to uteroplacental hypoperfusion via systemic hypotension from cardiodepressant or vasodilatory effects.

Blood pressure goals and the use of vasopressors in pregnancy have generally been studied in women undergoing cesarean delivery; the goals for physiologic parameters are also applicable for women having other types of surgery during pregnancy. While recommendations are usually to maintain systolic blood pressure at ≥100 mmHg and mean arterial pressure ≥65 mmHg or ≥80 percent of baseline, the optimal blood pressure goal has not been defined and there is likely interindividual variability. We aim to maintain the patient's baseline blood pressure and administer vasopressors to patients who drop below 20 percent of their baseline blood pressure; to awake patients who become symptomatic with nausea, vomiting, or lightheadedness; or if the fetus shows signs of distress without another readily identifiable cause.

If adequate maternal oxygenation and uterine perfusion are maintained, the fetus usually tolerates surgery and anesthesia well. Induction of anesthesia typically results in reduced FHR variability, presumably by anesthetizing the brainstem center that controls cardiac automaticity [42]. Baseline FHR may also decrease but usually remains within the normal range. If fetal bradycardia, tachycardia, or repetitive decelerations occur, adjustments to optimize uteroplacental oxygen delivery and blood flow (ie, LUD, increasing maternal blood pressure, optimal oxygenation, and maintenance of normocarbia) may be beneficial.

Both phenylephrine and ephedrine are reasonable choices to treat hypotension. The choice of vasopressor during hypotension has been studied in patients undergoing cesarean delivery. While phenylephrine is generally preferred, it can cause reflex bradycardia. Ephedrine increases maternal heart rate and has been associated with increased fetal metabolic activity and lower fetal pH values compared with phenylephrine [43]. Ephedrine crosses the placenta and can produce an increase in FHR variability and an increase in baseline FHR lasting several hours [44]. Norepinephrine has potential advantages of preserving maternal cardiac output and heart rate and has shown similar fetal outcomes when used for cesarean delivery [45]. Use of vasopressors during cesarean delivery is discussed separately. (See "Anesthesia for cesarean delivery", section on 'Vasopressors'.)

Cardiopulmonary bypass during pregnancy is reviewed separately. (See "Pregnancy and valve disease", section on 'Cardiac surgery during pregnancy'.)

Choice of anesthetic technique — The anesthetic plan for a pregnant patient must take into account the type of surgery, patient factors, and effects of anesthesia on the fetus. (See "Overview of anesthesia", section on 'Selection of anesthetic technique'.)

For patients in whom either regional or general anesthesia would be appropriate, we suggest using regional anesthesia; regional anesthesia minimizes fetal drug exposure, reduces the need to manage the airway, and provides some degree of postoperative analgesia (see 'Airway management' below). The literature comparing anesthetic techniques for surgery during pregnancy is limited to observational studies. In two retrospective reviews, general anesthesia was associated with lower birth weight despite similar gestational ages at delivery [46,47]. Whether low birth weight was a result of the anesthetic technique, the severity of the underlying condition requiring surgery, or another factor could not be determined.

Monitored anesthesia care — Sedation in pregnant patients should be titrated to effect and minimized to avoid risks of aspiration (due to oversedation) and/or hypoventilation (which can cause respiratory acidosis and compromised uteroplacental perfusion) (see 'Mechanical ventilation' below). In addition, pregnant patients often request avoidance of unnecessary drugs and those that could affect the fetus.

Monitored anesthesia care is discussed in detail separately. (See "Monitored anesthesia care in adults".)

Regional anesthesia — Regional anesthesia (ie, peripheral nerve blocks or neuraxial anesthesia) is an option for some surgical procedures, particularly those involving the extremities. Sedative medications may be safely administered during regional anesthesia according to patient preference and the clinical situation.

Neuraxial anesthesia may cause hypotension and a reduction in placental perfusion. IV fluid and vasopressors should be used to keep maternal blood pressure at baseline. A prophylactic phenylephrine infusion, which is routinely administered during neuraxial anesthesia for cesarean delivery, is not usually required for patients who are not at or near term in pregnancy. (See 'Hemodynamic management' above.)

Lower doses of spinal and epidural local anesthetics may be required during pregnancy due to mechanical and hormonal factors [48-51]. The degree of increased sensitivity is unpredictable and may be more pronounced with increasing gestational age. In patients undergoing cesarean delivery, there is a higher incidence of inadequate single shot spinal block in patients less than 32 weeks gestational age compared with patients closer to term gestation [52]. When feasible, a titratable neuraxial technique (eg, combined spinal-epidural [CSE] or epidural) may be ideal in order to minimize the chance of underdosing or obtaining a high spinal. Techniques, medications, and complications associated with neuraxial anesthesia in pregnant women are discussed separately. (See "Adverse effects of neuraxial analgesia and anesthesia for obstetrics" and "Anesthesia for cesarean delivery", section on 'Neuraxial anesthesia'.)

Pregnant patients are at increased risk for local anesthetic systemic toxicity (LAST) due to increased sensitivity to local anesthetic-induced cardiotoxicity and reduced serum levels of proteins that bind local anesthetics. This is of particular concern for blocks placed in highly vascular sites and those that require high volumes of local anesthetics (eg, epidural, transversus abdominis plane block). LAST is discussed in detail separately. (See "Local anesthetic systemic toxicity", section on 'Risk factors for LAST'.)

General anesthesia — While regional anesthesia is preferred, most nonobstetric procedures are performed under general anesthesia due to the nature of the procedure and/or patient factors.

Preoxygenation and apneic oxygenation — Thorough preoxygenation prior to induction of anesthesia is critical during any stage of pregnancy, and apneic oxygenation should also be considered. Apneic oxygenation refers to administration of oxygen to achieve mass flow through the upper airways and into the alveoli in the absence of respiratory effort. Apnea during attempts at airway management leads more rapidly to significant desaturation in pregnant compared with nonpregnant women. Preoxygenation and apneic oxygenation are discussed in detail separately. (See "Preoxygenation and apneic oxygenation for airway management for anesthesia" and "Airway management for the pregnant patient", section on 'Preoxygenation and apneic oxygenation'.)

Induction — IV induction is used for general anesthesia for most patients undergoing nonobstetric surgery and is highly preferable to inhalation induction due to a more rapid

onset of optimal intubating conditions. (See "Induction of general anesthesia: Overview", section on 'Inhalation anesthetic induction'.)

The decision to perform rapid sequence induction and intubation versus routine induction during pregnancy is discussed separately. (See "Airway management for the pregnant patient", section on 'RSII versus routine intubation'.)

Induction drugs — Induction medications, including adjuncts, are discussed in detail separately (see "General anesthesia: Intravenous induction agents").

- **Induction agents –** The selection of the anesthesia induction agent (eg, propofol, ketamine, etomidate) should be based on patient factors and provider preference. None of these agents has been clearly shown to be teratogenic or to have adverse effects on human brain development (see 'Effects of anesthetics on the fetus and the pregnancy' above). Propofol is the preferred induction agent for routine induction in otherwise healthy pregnant patients.

  Although the differences in volume of distribution and sensitivity to anesthetic may alter the response to induction agents in pregnant patients, this effect is unpredictable. We typically use induction doses based on actual body weight and titrate to effect in a similar manner to nonpregnant patients.

  The effects of pregnancy on sensitivity to IV induction agents are unclear, and the pertinent literature is limited. A study using a target controlled infusion of propofol found no difference in the concentration required for loss of consciousness in patients early in pregnancy compared with nonpregnant controls [53]. In contrast, another study reported an 8 percent reduction in the propofol dose required for loss of consciousness in patients early in pregnancy compared with nonpregnant women [54].

- **Neuromuscular blocking agents –** Pregnant patients may be more sensitive to the effects of neuromuscular blocking agents (NMBAs) than nonpregnant patients. As for all patients who receive NMBAs, at a minimum, neuromuscular monitoring with peripheral nerve stimulation should be used to guide dosing and recovery from neuromuscular block in pregnant patients. Ideally a quantitative monitor (eg, acceleromyography or electromyography) is preferred. (See "Monitoring neuromuscular blockade", section on 'Qualitative versus quantitative monitoring'.) .

  - Succinylcholine **–** The duration of action of succinylcholine is unpredictable in pregnant patients, though this is usually of no clinical significance. Whereas the level of pseudocholinesterase, which metabolizes succinylcholine, is reduced during pregnancy, the volume of distribution of succinylcholine increases gradually during pregnancy, such that the plasma level for a given dose may decrease [55-60]. The

end result of these competing effects is unpredictable. (See "Clinical use of neuromuscular blocking agents in anesthesia", section on 'Butyrylcholinesterase (pseudocholinesterase) deficiency'.)

We normally administer 1.5 mg/kg (typically we do not exceed 150 mg) succinylcholine for pregnant patients based on actual body weight. Although decreased pseudocholinesterase levels during pregnancy could prolong neuromuscular block after succinylcholine, levels of succinylcholine during pregnancy may be lower due to increased volume of distribution. In one small study, the duration of action of succinylcholine dosed at actual body weight was similar in pregnant patients at term compared with nonpregnant patients [60].

Fasciculations after succinylcholine administration tend to be less prominent during pregnancy, with a corresponding reduction in postoperative myalgia [61].

- **Nondepolarizing NMBAs –** We base the initial dose of nondepolarizing NMBA on ideal body weight and administer further doses based on neuromuscular monitoring (eg train-of-four peripheral nerve stimulator). There are limited data on the effects of NMBAs in pregnancy, and the available data are conflicting. Small studies have reported a more rapid onset of neuromuscular block with actual weight-based administration of vecuronium [56] and rocuronium [57] in patients at time of cesarean delivery, and prolonged duration of action of vecuronium compared with nonpregnant controls. However, these effects may have been the result of relative overdose with doses of NMBA based on actual body weight at term. In one study, onset and duration of rocuronium blockade was compared in 47 second-trimester pregnant patients who underwent transabdominal cerclage, with 47 nonpregnant patients who underwent gynecologic surgery [62]. All women received rocuronium 0.6 mg/kg IV during sevoflurane anesthesia, and mean body weights were similar between groups. The onset of rocuronium-induced blockade was similar in the two groups, and the duration of action (time to 25 percent recovery) was modestly longer in the pregnant patients (45.7 ± 12.9 minutes versus 40.6 ± 10.4 minutes).

  NMBAs have no direct effect on the fetus since they do not cross the placenta in clinically significant concentrations [32]. (See "Clinical use of neuromuscular blocking agents in anesthesia", section on 'Endotracheal intubation' and 'Effects of anesthetics on the fetus and the pregnancy' above.)

Airway management — For general anesthesia, the plan for airway management must consider the surgical procedure and patient factors, including the stage of pregnancy and risk factors for difficulty with airway management. (See "Management of the difficult airway for general anesthesia in adults".)

The appropriate strategy for airway management may depend on the gestational age at the time of the procedure, with increasing risk of passive regurgitation (and aspiration during anesthesia) as pregnancy progresses. Many experts will use a supraglottic airway for appropriate general anesthetics prior to 18 to 20 weeks of gestation and perform endotracheal intubation later in pregnancy to minimize the risk of aspiration. However, practice varies. When there are no other risk factors for aspiration present, the author has used supraglottic airways for short procedures up to 32 weeks gestation. (See "Airway management for induction of general anesthesia", section on 'Choice of airway device' and "Airway management for the pregnant patient", section on 'Choice of airway devices'.)

Maintenance of anesthesia

Maintenance anesthetics — Choice of maintenance anesthetic agents should be based on the considerations that apply to nonpregnant patients, as none of the standard anesthetic agents have been proven teratogenic or to have relatively increased adverse effects on human brain development. (See "Maintenance of general anesthesia: Overview", section on 'Selection of maintenance techniques' and 'Effects of anesthetics on the fetus and the pregnancy' above.)

Although not necessary for the safe administration of intraoperative anesthesia, we often use processed electroencephalography (eg, bispectral index [BIS]) to help determine maintenance dosing of anesthetics in pregnant patients and prevent relative overdosing and subsequent hypotension from anesthetic agents. (See "Accidental awareness during general anesthesia", section on 'Monitoring'.)

It appears likely that pregnant patients have increased sensitivity to potent inhaled anesthetics, although the degree of this effect is uncertain. Several studies have reported up to a 30 percent reduction in the minimum alveolar concentration for isoflurane starting in early pregnancy [3], and continuing into the immediate postpartum period [63,64], compared with nonpregnant patients. In contrast, a small study found no difference in the electroencephalographic measures of anesthetic effect between pregnant patients during cesarean delivery and gynecologic patients [55].

Sensitivity to propofol and to neuromuscular blocking agents is similarly unclear and is discussed above. (See 'Induction drugs' above.)

Potent inhalation agents decrease uterine tone during the operative procedure [65,66]. This is overall advantageous, particularly for abdominal procedures in the second and third trimester, as it may reduce the incidence of pre-term contractions and pre-term labor. However, in the event of emergency delivery, higher doses of uterotonic agents may be required (eg, oxytocin, methylergonovine, carboprost tromethamine) for patients who are

receiving these inhalation agents than patients who have neuraxial anesthesia. (See "Anesthesia for cesarean delivery", section on 'Administration of uterotonics'.)

Inhaled nitrous oxide (either alone or as a 50 percent mixture with oxygen) has no effect on uterine tone, maternal hemodynamic status, or FHR variability [67,68].

Mechanical ventilation — Mechanical ventilation should be adjusted to maintain the normal physiologic chronic respiratory alkalosis of pregnancy (see 'Physiologic changes of pregnancy' above). End-tidal carbon dioxide (E_TCO_2) more accurately reflects arterial carbon dioxide (P_aCO_2) in pregnant patients than in nonpregnant patients due to improved ventilation/perfusion matching [69]. Therefore, the goal for E_TCO_2 during mechanical ventilation should be approximately 30 to 32 mmHg in the last half of pregnancy. Carbon dioxide crosses the placenta relatively easily; maternal hypercarbia can cause acidosis and myocardial depression in the fetus. Hyperventilation with very low maternal carbon dioxide and severe respiratory alkalosis (P_aCO_2 <23 mmHg and pH higher than 7.5) [70] can compromise uterine blood flow and fetal oxygenation [71-73].

Fetal oxygenation is critically dependent on the maintenance of normal maternal arterial oxygen tension, carrying capacity, and uteroplacental perfusion. Therefore, we administer a fraction of inspired oxygen (FiO_2) of at least 50 percent during anesthesia. Although high inspired FiO_2 has not been shown to improve outcomes, there is unlikely to be a downside to administration of 50 percent oxygen, as no cases of fetal retinopathy (the chief concern with high neonatal FiO_2) have been reported after nonobstetric surgery.

Postoperative care

- **Maternal monitoring** – Recovery from anesthesia requires close monitoring, particularly of the airway and respiratory system, because severe anesthetic complications may occur during emergence or in the immediate postoperative period. (See "Airway management for the pregnant patient", section on 'Maternal mortality'.)

  Complications that occur in the postanesthesia care unit are discussed in detail elsewhere. (See "Overview of post-anesthetic care for adult patients".)

- **Fetal assessment** – The FHR should be monitored in the recovery room, intermittently for previable fetuses, and continuously for the viable fetus. Uterine activity should also be monitored in cases in which the fetus is viable, as contractions are most likely to occur proximate to the procedure and as any tocolytic effect of general anesthetics wears off [20,74].

- **LUD** – Left lateral position or uterine displacement should be maintained until the patient is fully awake, alert, and able to adjust her own position.

- **Postoperative pain control** – Multimodal analgesia should be used for postoperative pain control for all patients (see "Approach to the management of acute pain in adults", section on 'Use multimodal analgesia'). Such a strategy may include nonpharmacologic methods of pain control, acetaminophen, regional anesthesia techniques, and local anesthetic infiltration with opioids used on an as-needed basis. Nonsteroidal antiinflammatory drugs (NSAIDs) should not be used routinely during pregnancy (particularly in the early first and late third trimesters) because of potential fetal effects [75], although a single dose for refractory postoperative pain in midgestation is likely safe. (See "Safety of rheumatic disease medication use during pregnancy and lactation", section on 'NSAIDs'.)

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Obstetric anesthesia".)

SUMMARY AND RECOMMENDATIONS

- **Preoperative fasting and aspiration prophylaxis**
  - Pregnancy has not been identified as an independent risk factor for aspiration. Standard adult preoperative fasting guidelines are applicable to pregnant patients at any stage of pregnancy.
  - Practice varies with respect to pharmacologic aspiration prophylaxis. The author does not routinely administer pharmacologic prophylaxis for pregnant patients unless there are other risk factors for aspiration (eg, full stomach, emergency surgery, symptomatic gastroesophageal reflux disease) (table 2). Some experts routinely administer prophylaxis for patients beyond 18 to 20 weeks gestation. (See 'Preoperative aspiration mitigation' above.)
- **Fetal effects of anesthetics** – Anesthetic agents are not known teratogens when used at standard doses in the perioperative period. Similarly, although animal models have shown that anesthetics can affect neurodevelopmental processes, they have not been proven to have adverse effects on the fetal brain. However, due to the inability to conclusively rule out adverse effects, exposure to medications should be minimized during pregnancy. (See 'Effects of anesthetics on the fetus and the pregnancy' above.)
- **Choice of anesthetic technique** – We suggest using regional anesthesia when appropriate rather than general anesthesia (**Grade 2C**) to minimize fetal drug

exposure, avoid the need to manage the airway, and provide a degree of postoperative analgesia. (See 'Choice of anesthetic technique' above.)

- **Anesthetic management**

  - All pregnant patients should be preoxygenated prior to induction of anesthesia, and apneic oxygenation should be considered, especially later in pregnancy. (See 'Preoxygenation and apneic oxygenation' above and 'Airway management' above.)

  - Pregnant patients after 18 to 20 weeks gestation should be positioned for surgery with left uterine displacement (LUD) when possible, to avoid aortocaval compression. (See 'Positioning' above.)

  - Fetal well-being can be maintained by optimizing uteroplacental perfusion, including avoiding hypotension, hypoxia, hypocarbia, and acidosis. Mechanical ventilation should be adjusted to maintain the normal physiologic chronic respiratory alkalosis of pregnancy, aiming for an end tidal carbon dioxide of 30 to 32mm Hg in the last half of pregnancy. (See 'Hemodynamic management' above and 'Mechanical ventilation' above.)

  - Pregnant patients may be more sensitive to anesthetic medications (eg, induction agents, neuromuscular blocking agents, local anesthetics) than nonpregnant patients. When appropriate, anesthetics should be titrated to effect. (See 'Physiologic changes of pregnancy' above.)

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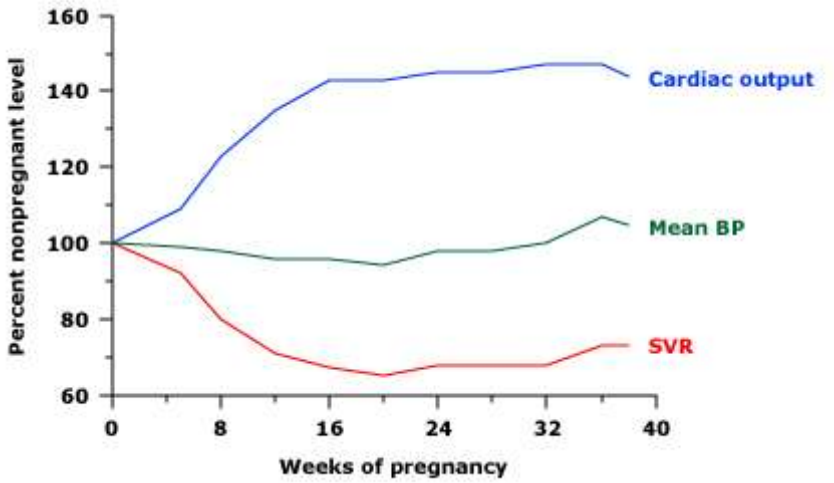
Topic 6775 Version 65.0

GRAPHICS

Hemodynamic changes in normal pregnancy

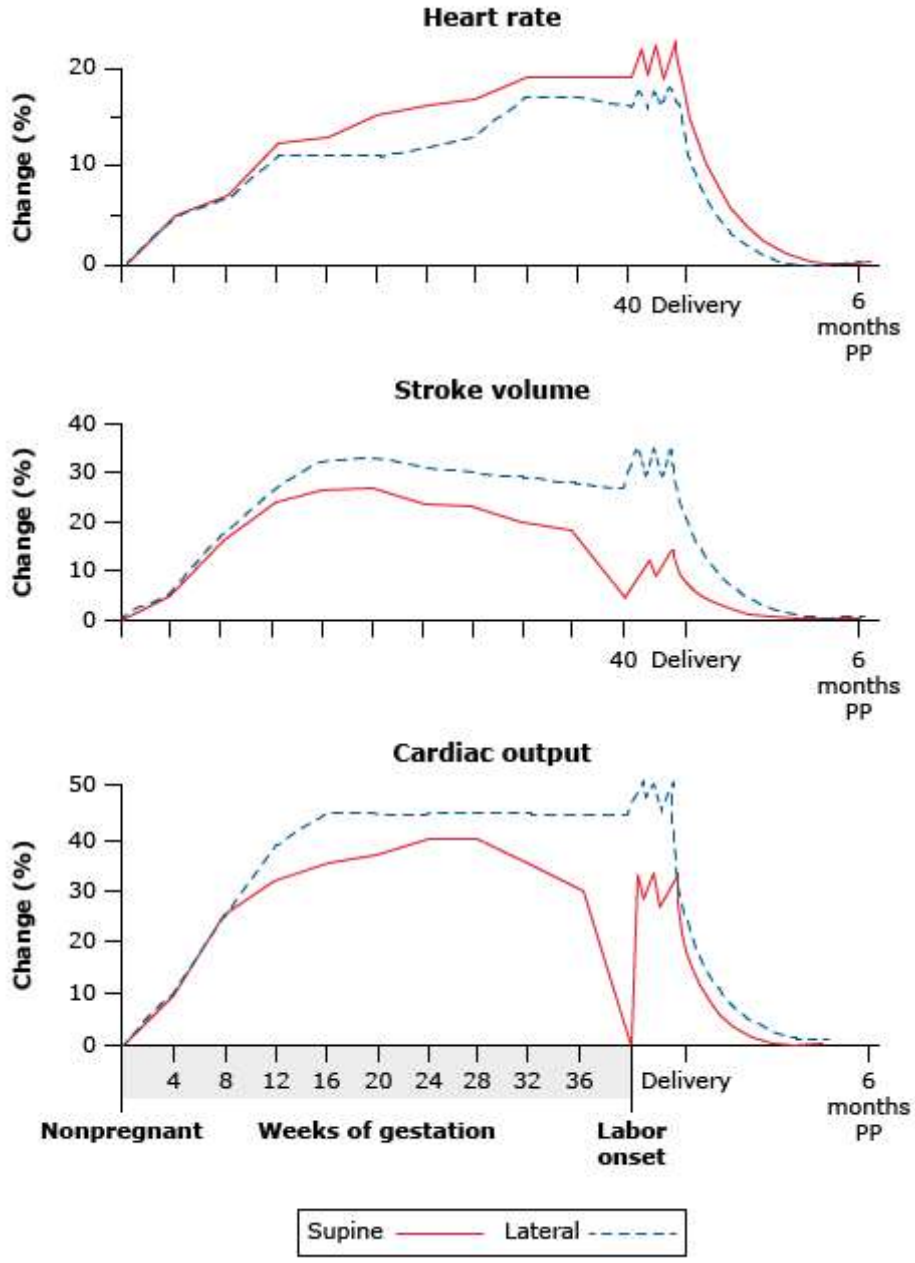


Normal pregnancy is characterized by an increase in cardiac output, a reduction in systemic vascular resistance, and minimal change in mean blood pressure. These changes are associated with a 10 to 15 beat/minute increase in heart rate.

BP: blood pressure; SVR: systemic vascular resistance.

Graphic 54685 Version 8.0

Supine and lateral systemic hemodynamics during normal pregnancy



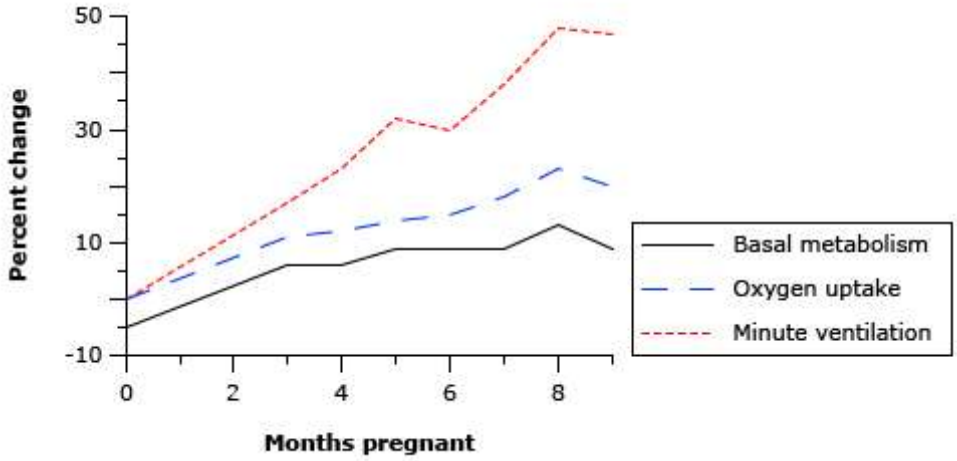
Systemic hemodynamics across a normal pregnancy can vary in the second and third trimesters depending on whether the patient is in a supine or lateral position.

PP: post-pregnancy.

Data from: Bonica JJ, McDonald JS. Principles and Practice of Obstetric Analgesia and Anesthesia, 2nd ed, Williams & Wilkins, Baltimore 1994. p.60.

Graphic 55985 Version 6.0

Changes in ventilation during pregnancy

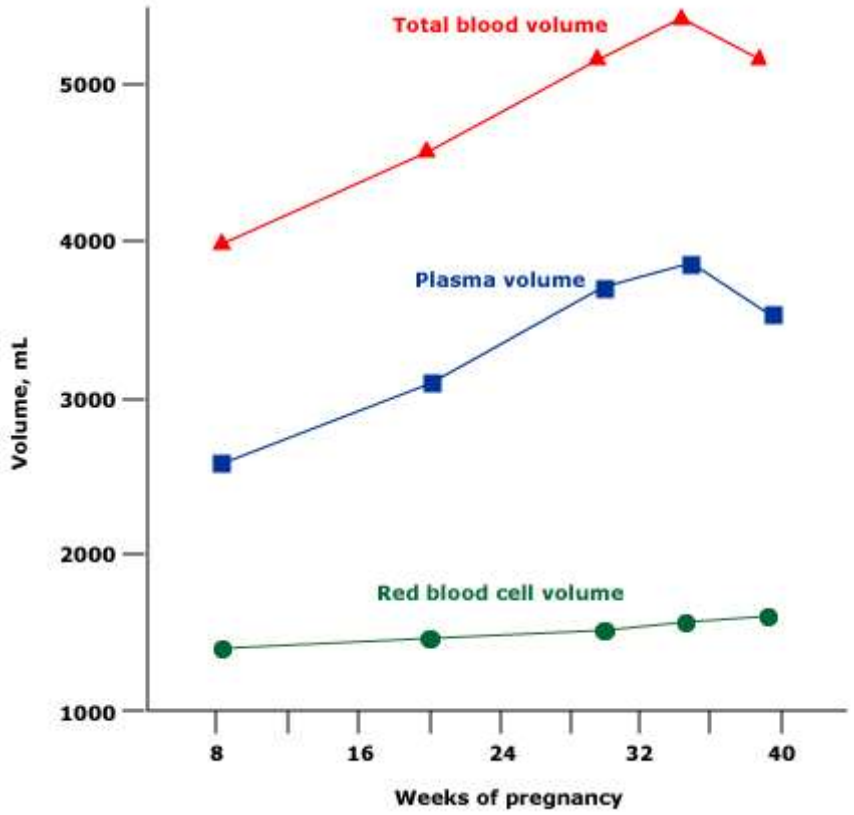


Time course of % increases in minute ventilation, oxygen uptake, and basal metabolism during pregnancy.

Modified from: Prowse CM, Gaensler EA. Respiratory and acid-base changes during pregnancy. Anesthesiology 1965; 26:381.

Graphic 59101 Version 4.0

Total blood volume, plasma volume, and red cell volume in normal pregnancy



Data from: Shnider SM, Levinson G. Anesthesia for Obstetrics, 3rd ed, Williams & Wilkins, Baltimore 1993. p.8.

Graphic 61948 Version 5.0

Fasting guidelines of international anesthesia societies

Anesthesia society	Fasting requirements at time of induction	Comments
American Society of Anesthesiologists, 2017[1,2]	▪ 2 hours clear liquids, excluding alcohol ▪ 4 hours breast milk ▪ 6 hours nonhuman milk, formula, light meal ▪ 8 hours or more for fatty meal, fried food, meat ▪ Chewing gum allowed up until induction	▪ Healthy patients, not in labor, elective surgery ▪ Light meal defined as toast or cereal with clear liquid ▪ Healthy adults should drink carbohydrate containing clear liquids up to 2 hours prior to surgery
European Society of Anesthesiology and Intensive Care[3,4]	▪ Adults: • 2 hours clear liquids • 6 hours milk, solid food • Chewing gum and sucking hard candy allowed up until induction	▪ Encourage oral fluid up to 2 hours
	▪ Children: • 1 hour clear liquids • 3 hours breast milk • 4 hours formula or nonhuman milk, light breakfast (weak recommendations) • 6 hours other solid food	▪ Encourage oral fluid up until fasting time
Australian and New Zealand College of Anaesthetists[5]	▪ Adults: • 2 hours clear liquids • 6 hours limited solid food	▪ Guidelines may not apply to patients who are at increased risk of perioperative regurgitation or vomiting ▪ Up to 400 mL of clear liquid up to 2 hours prior to induction for adults is likely safe
	▪ Children >6 months of age: • 1 hour clear liquids (≤3 mL/kg) • 4 hours breast milk • 6 hours formula and limited solid food	
	▪ Children <6 months of age: • 1 hour clear liquids (≤3 mL/kg)	

	• 3 hours breast milk • 4 hours formula	
Association of Anaesthetists in Great Britain and Ireland[6]	▪ 2 hours clear liquids ▪ 4 hours breast milk ▪ 6 hours solid food, formula and cow's milk	▪ Gum chewing treated as clear
Canadian Anesthesiologists' Society[7]	▪ 1 hour clear liquids for children ▪ 2 hours clear liquids for adults ▪ 4 hours breast milk ▪ 6 hours for solid food, infant formula, nonhuman milk, expressed breast milk fortified with additions	▪ Encourage oral clear liquids up until fasting time
Scandinavian Society of Anaesthesiology and Intensive Care Medicine[8]	▪ 2 hours clear liquids ▪ 4 hours breast milk and infant formula ▪ 6 hours solid food and cows milk ▪ 2 hours chewing gum and any tobacco product ▪ Up to 1 hour prior to induction, 150 mL of water	▪ 2 hours for preoperative carbohydrate drinks intended for preoperative nutrition
German Society of Anesthesiology and Intensive Care[9]	▪ 2 hours clear liquids ▪ 4 hours breast milk and infant formula ▪ 6 hours meal	
Pediatric societies		
Joint statement from Association of Paediatric Anaesthetists of Great Britain and Ireland, European Society for Paediatric Anaesthesiology, L'Association Des Anesthésistes-Réanimateurs Pédiatriques d'Expression Française[10]	▪ 1 hour clear liquids for children up to 16 years of age	▪ Encourage intake of clear liquids
Canadian Pediatric Anesthesia Society[11]	▪ 1 hour clear liquids for children	▪ Encourage intake of clear liquids

The Society for Paediatric Anaesthesia of New Zealand and Australia[12]	▪ 1 hour clear liquids for children	▪ Encourage intake of clear liquids

GERD: gastroesophageal reflux disease.

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Graphic 94641 Version 19.0

Conditions that increase risk of aspiration during induction of anesthesia

Full stomach – nonfasted, emergency surgery or trauma
Pregnancy after 12 to 20 weeks gestation (gestational age for increased risk is controversial)
Symptomatic gastroesophageal reflux
Diabetic or other gastroparesis
Hiatal hernia

Gastric outlet obstruction
Esophageal pathology
Bowel obstruction
Increased intra-abdominal pressure – ascites, abdominal mass

Graphic 98506 Version 8.0

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