Nonobstetric Surgery During Pregnancy

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An estimated 0.75%–2% of pregnant women will undergo nonobstetric surgery during their pregnancy. In the United States, approximately 75,000–80,000 parturients will be exposed to anesthesia and surgery each year, and these figures are likely to be underestimated because pregnancy may be unrecognized at the time of surgery. Positive pregnancy tests have been reported in 0.3%–1.2% of females presenting for routine surgery.

Surgery may be directly (e.g., cervical cerclage) or indirectly (e.g., ovarian cystectomy) related or unrelated (e.g., appendicectomy, cholecystectomy) to the pregnancy and may be necessary during any stage of pregnancy (Fig. 1).

Key Areas

Optimal anesthetic management of these pregnant patients and their fetuses requires an understanding of:

1. Normal alterations in *maternal physiology during pregnancy*
2. The potential *fetal effects* from anesthesia and surgery
3. Maintenance of *uteroplacental perfusion and fetal oxygenation*
4. *Practical considerations* (timing of surgery, fetal monitoring, full stomach precautions, left uterine displacement, and other anesthetic considerations)
5. The importance of maternal *counseling and reassurance*
6. *Special situations* (laparoscopy, cardiopulmonary bypass, electroconvulsive therapy, neurosurgery and trauma)

Maternal Physiology of Pregnancy

During pregnancy, increased hormonal concentrations, mechanical effects of the gravid uterus and increased metabolic demands result in significant changes in maternal physiology.

Cardiovascular System

Pregnancy results in a progressive 30%–50% increase in cardiac output above baseline by 28–32 weeks of gestation, resulting from increases in stroke volume and heart rate (in the first half and the latter half of pregnancy, respectively). The blood pressure usually falls during pregnancy because of progesterone-induced vasodilatation and the low resistance placental bed. The pulse pressure widens as a result of a greater reduction in diastolic compared with systolic blood pressure.

Supine Hypotension

During the second half of gestation, the weight of the uterus compressing the inferior vena cava decreases venous return and cardiac output by approximately 25%–30% when the mother lies supine. Although upper extremity blood pressure may be maintained by compensatory vasoconstriction and tachycardia, uteroplacental perfusion is significantly reduced. To avoid or minimize supine hypotension, it is essential to displace the uterus laterally during any operation performed after 20 weeks of pregnancy.

Hematological System

The plasma volume increases by 40%–50% from pre-pregnancy levels. This raised plasma volume exceeds the increase in red blood cells, resulting in a relative dilutional anemia. This may compromise oxygen delivery and decrease the patient's reserve if significant hemorrhage occurs. Pregnancy is associated with a benign leukocytosis, which makes the white blood cell count an unreliable indicator of infection. Pregnant patients requiring surgery are at high risk for perioperative thromboembolic complications because of pregnancy-related increases in coagulation factors (fibrinogen, factors VII, VIII, X, and XII).

Respiratory System

Alveolar ventilation increases throughout pregnancy to 45%–70% above pre-pregnancy levels by term. This results in hypocarbia ($Paco_2$ 27–32 mm Hg) and respira-

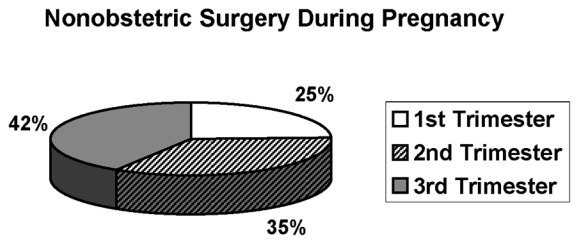

Figure 1. Trimester breakdown of nonobstetric surgery undertaken during pregnancy. Modified from Mazze RI, Kallen B. Am J Obstet Gynecol 1989;161:1178–85.

tory alkalosis (pH of 7.4–7.45). Pregnant women have a reduced oxygen reserve as a result of increased oxygen consumption and lower functional residual capacity (FRC). This results in rapid development of hypoxemia and acidosis during periods of hypoventilation or apnea. Anatomical changes and weight gain during pregnancy as well as capillary engorgement of the respiratory tract mucosa lead to more frequent difficult mask ventilation and failed endotracheal intubation.

Gastrointestinal and Renal System

Pregnant women are at risk for esophageal reflux, regurgitation of gastric contents, and aspiration pneumonitis from lower esophageal sphincter incompetence, distortion of gastric and pyloric anatomy, and increased gastric pressure from the gravid uterus. Although it is unclear at what stage during pregnancy this risk becomes significant, gastric aspiration prophylaxis should be considered after 16–20 weeks gestation. Renal blood flow and glomerular filtration rates increase significantly during pregnancy. This causes creatinine and blood urea nitrogen levels to decrease and normal laboratory values should be adjusted accordingly for pregnant patients.

Central Nervous System and Response to Anesthesia

General Anesthesia. Induction of anesthesia occurs more rapidly during pregnancy because alveolar hyperventilation and decreased FRC allow faster equilibration of inhaled agents. Minimum alveolar concentration for volatile anesthetic agents decreases by approximately 30%–40% in pregnancy, and subanesthetic concentrations of anesthetic agents can induce unconsciousness.

Regional Anesthesia. More extensive neural blockade is usually obtained after neuraxial anesthesia, possibly as a result of a decreased epidural space capacity and an enhanced response to neural blockade as a result of hormonal changes in pregnancy.

Fetal Concerns

Risk of Teratogenicity

Despite theoretical concerns, no anesthetic agents have been conclusively shown to be tetratogenic in humans. However, because of the rarity of congenital defects and ethical issues, definitive prospective clinical studies investigating possible teratogenic effects of anesthetic agents are impractical. Extrapolation of findings from animal studies to drug effects during anesthesia in humans (single dose, limited exposure) are limited because of potential species-specific effects, experimental design issues (e.g., poor control of blood pressure and oxygenation during anesthesia), and the use of higher doses for prolonged periods. Epidemiologic surveys of operating room personnel chronically exposed to subanesthetic concentrations of inhalation agents and outcome studies of pregnant women who have undergone surgery have not definitively demonstrated increases in teratogenicity. Although there are no anesthetic agents proven to be teratogens, ideally, pregnant patients should be exposed to the fewest drugs possible and at the lowest concentration clinically indicated. Organs have different periods of sensitivity and vulnerability. Drug exposure during the period of organogenesis (approximately Days 15–70 after the first day of the last menstrual period) is best avoided if possible. In addition, other factors during anesthesia and surgery (hypoxia, hypercapnia, stress, temperature, ionizing radiation >5–10 rads) may be teratogenic themselves or enhance the teratogenicity of other agents.

Anesthetic Agents and Perioperative Medication. Teratogenesis has not been associated with the use of any commonly used induction agents, including barbiturates, ketamine, and propofol. Despite concerns about potential teratogenic effects from chronic diazepam therapy during pregnancy, there is no evidence to suggest that a single dose of a benzodiazepine (e.g., midazolam) during the course of anesthesia would be harmful to the fetus. Similarly, no evidence supports the teratogenicity of opioids and muscle relaxants in humans. Muscle relaxants appear to have a wide margin of safety because of limited placental transfer. There is also no evidence to support teratogenicity of local anesthetic in humans. Under well-controlled conditions, no teratogenic effects have been associated with any volatile agents in clinical concentrations.

Nitrous Oxide. Under certain conditions, nitrous oxide is a weak teratogen in rodents (e.g., at >50% concentrations for >24 h). Proposed etiologies for nitrous oxide teratogenicity include methionine synthase inhibition, which alters DNA synthesis, or induced sympathetic and/or α_1-adrenergic receptor

stimulation. However, epidemiologic and outcome data in humans do not support an increased risk of congenital anomalies with nitrous oxide exposure.

Preterm Labor

Most epidemiologic studies of nonobstetric surgery during pregnancy have reported an increased incidence of preterm delivery. It is unclear whether surgery, manipulation of the uterus, or the underlying surgical pathology is responsible. Second trimester procedures and those that do not involve uterine manipulation carry the lowest risk for preterm labor. Surgical strategies to minimize handling of the uterus should be considered. Volatile anesthetic agents depress myometrial irritability and are potentially advantageous for abdominal or high-risk procedures. Beta-2 agonists (e.g., terbutaline) and magnesium are effective tocolytics, although their routine prophylactic use is controversial because of their potential risks and limited benefits on preterm labor prevention. Selective tocolytic administration to patients at greatest risk (e.g., cervical cerclage) can be considered. Indomethacin is used to prevent premature onset of labor; however, the potential risks (e.g., premature closure of ductus arteriosus and development of oligohydramnios) should be considered. Nitroglycerin can be used for uterine relaxation during short procedures or to manage refractory uterine activity. When technically feasible, external tocodynamometer monitoring for uterine contractions should be performed intraoperatively. Patients who receive potent analgesics and who may be unaware of mild uterine contractions should receive fetal monitoring during the postoperative period.

Other Potential Fetal Risks

Some outcome studies show an increased risk of spontaneous abortions and low birth weight (LBW) infants in patients who underwent surgery during pregnancy. LBW results from both preterm delivery and intrauterine growth restriction. Relative risk of spontaneous abortion among women who had general anesthesia for surgery during pregnancy for nongynecological and gynecological surgery is 1.6 and 2.0, respectively. Although anesthesia and surgery are associated with an increased incidence of spontaneous abortion, IUGR, and perinatal mortality, these can be attributed to the procedure, surgical site, and/or the underlying maternal condition not necessarily exposure to anesthesia.

Behavioral Effects

Recent evidence suggests that some anesthetic, analgesic, and psychoactive drugs may induce widespread neuronal apoptosis in the developing rat brain when administered for prolonged periods during the period of synaptogenesis or brain growth spurt. These changes may produce behavioral deficits and persist into adolescence and adulthood, affecting behavior and function. However, behavioral teratology has not been demonstrated in humans and its significance is yet to be determined.

Uteroplacental Perfusion and Fetal Oxygenation

Fetal oxygenation depends on maternal oxygen delivery (arterial oxygen tension and oxygen-carrying capacity) and uteroplacental perfusion. Transient and moderate decreases in maternal Pao_2 are well tolerated by the fetus because fetal hemoglobin is present in high concentration and has a high affinity for oxygen. However severe prolonged maternal hypoxemia may cause fetal hypoxia and fetal death. Any complication that causes profound maternal hypoxemia (e.g., difficult intubation, pulmonary aspiration, high spinal) is a potential threat to the fetus. In contrast, moderate hyperoxia improves fetal oxygenation and is not associated with intrauterine retrolental fibroplasia and premature ductus arteriosus closure because of the large maternal-fetal oxygen tension gradient. $Paco_2$ should be kept in the normal range for pregnancy. Maternal hypercapnia can cause fetal acidosis that may result in fetal myocardial depression and hypotension. Maternal hyperventilation and hypocarbia can compromise maternal-fetal oxygen transfer by causing umbilical artery constriction and shifting the maternal oxyhemoglobin dissociation curve to the left. Maternal hypotension from any cause can jeopardize uteroplacental perfusion and cause fetal asphyxia. Provided that hypotension is prevented, maternal administration of volatile agents in moderate concentrations (1–1.5 MAC) has minimal effect on uteroplacental blood flow. Uteroplacental perfusion may be reduced by uterine vasoconstriction from drugs such as high dose α-adrenergics or increased circulating catecholamines (e.g., preoperative anxiety and light anesthesia). Drugs that cause uterine hypertonus (e.g., ketamine in early pregnancy in doses >2 mg/kg or α-adrenergics) may also compromise uteroplacental perfusion.

Practical Anesthetic Considerations

Timing of Surgery

As a general rule, elective surgery should not be performed during pregnancy. If surgery is necessary (cardiac, neurosurgery, abdominal emergencies, or malignancies), choice of timing is essentially a balance between maternal and fetal risks and the urgency of surgery (Fig. 2).

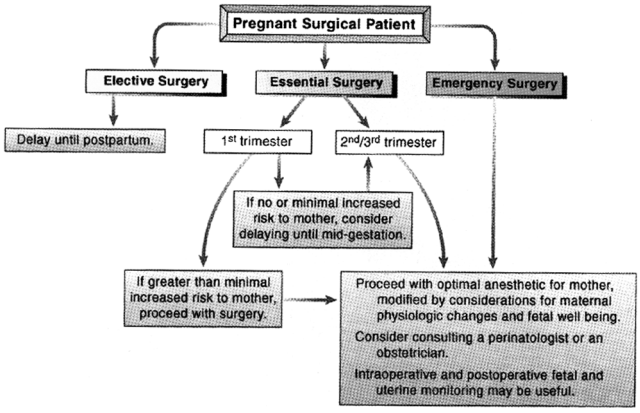

Figure 2. Timing of nonobstetric surgery in a pregnant surgical patient. Adapted from Rosen MA. Anesthesiology 1999;91:1159–63.

For the fetus, the second trimester is the optimal time to perform surgery. The theoretical risk of teratogenicity is increased during the period of organogenesis in the first trimester and the risk of preterm labor is higher during the third trimester. Maternal risk is greatest during the third trimester because of physiological changes of pregnancy. However, the primary goal is to preserve the mother's life, and remote fetal risks associated with anesthesia and surgery are of secondary importance in the event of a serious maternal illness. When planning surgery, it is important to ensure that her obstetrician is informed and that contingency plans have been discussed in the event of complications. The decision to perform simultaneous cesarean delivery depends on a number of factors e.g., gestational age and maternal condition. Cesarean delivery may be performed immediately before the surgical procedure to avoid fetal risks associated with prolonged anesthesia and intraoperative cardiopulmonary changes and blood loss.

Diagnosis

Because of diagnostic difficulties, the disease (especially intra-abdominal pathology such as appendicitis) may be advanced at the time of surgery. Nausea, vomiting, constipation, and distention are common symptoms of both normal pregnancy and abdominal pathology. Further diagnostic uncertainty is introduced by the increased white blood cell count, which can reach 15,000/mm^3 in normal pregnancy. Further delay may result from the reluctance to perform necessary studies involving radiation on pregnant patients.

Fetal Monitoring During Surgery

Intermittent or continuous fetal heart rate (FHR) monitoring should be considered for the viable-age fetus and for major surgical procedures. It should be considered a tool to monitor intrauterine well-being, not to avoid medicolegal claims. Continuous transabdominal FHR monitoring is feasible from 18–22 weeks gestation. Transabdominal monitoring may not be possible during abdominal procedures or when the mother is very obese. A vaginal Doppler probe may be considered in selected cases. Fetal well-being, as indicated by FHR variability, is present by 25–27 weeks gestation. Loss of beat-to-beat variability and decreased baseline FHR are common after administration of anesthetic agents but decelerations suggest fetal hypoxemia. An unexplained change in FHR mandates the evaluation of maternal position, blood pressure, oxygenation, acid-base status, and inspection of the surgical site to ensure that neither surgeons nor retractors are impairing uterine perfusion. Maternal hypothermia during surgery may result in slowing of the fetal heart rate. Monitoring maternal temperature perioperatively and the use of warming devices to maintain normothermia are important. Intraoperative FHR monitoring requires the presence of a trained practitioner to monitor and interpret the tracing. A multidisciplinary plan is necessary in the event of persistent fetal distress, e.g., performing an emergency cesarean delivery.

Anesthetic Management

Preoperative Care. Gastric aspiration prophylaxis (H_2-receptor antagonist and 30 mL of a nonparticulate antacid before the induction) should be considered after 16–20 weeks gestation. Premedication anxiolysis (e.g., midazolam 1 mg) may be necessary for the anxious parturient, as elevated catecholamines may decrease uterine blood flow.

Prevention of Aortocaval Compression. After 20 weeks gestation, the pregnant patient should be transported in the lateral position, and left uterine displacement instituted when positioned on the operating table. The effectiveness of left uterine displacement can be assessed by measuring the blood pressure on the right leg or observing the pulse oximeter waveform on the right foot. For surgery in the prone position, the abdomen should hang unobstructed and any external compression should be avoided.

Anesthetic Technique

No study has correlated improved fetal outcome with any anesthetic technique and the choice of anesthesia should be guided by maternal indications as well as the site and nature of the surgery. When possible, a local or regional anesthetic technique may be preferable. Regional techniques minimize fetal drug exposure and maternal perioperative complications. However, laparoscopy and most upper abdomen operations usually require general anesthesia. Regardless of the technique used, avoidance of hypoxemia, hypotension, hypovolemia, acidosis, and hypercarbia/

hypocarbia are the most critical elements of the anesthetic management. Blood glucose levels should be checked, especially during prolonged surgery or in patients with gestational diabetes or glucose intolerance.

General Anesthesia

Induction. General anesthesia mandates endotracheal intubation beginning at approximately 16–20 weeks gestation. Preoxygenation with 100% oxygen administration for 3–4 min (or 4 vital capacity breaths if time is restricted) before a rapid sequence induction with cricoid pressure should be performed. Fasciculation after the administration of succinylcholine does not occur consistently. The use of a smaller endotracheal tube (6.0–7.0 mm) is recommended because of respiratory tract mucosa edema and engorgement associated with pregnancy. Avoid nasal intubations that may precipitate bleeding because of increased mucosal vascularity. Use drugs with a history of safe use during pregnancy including thiopental, morphine, fentanyl, succinylcholine, and most nondepolarizing muscle relaxants. Although not similarly "time-tested," many consider propofol safe during pregnancy.

Maintenance. A moderate concentration of a volatile agent (<1.5–2.0 MAC) with a high concentration of oxygen (Fio_2 = 0.5) is recommended. Although scientific evidence does not support avoidance of nitrous oxide during pregnancy, using concentrations of <50% and limiting its use in the first trimester and during extremely long operations is suggested. If nitrous oxide is avoided, adequate analgesia should be administered to minimize the need for higher doses of a volatile agent that may cause maternal hypotension. Opioids and induction agents decrease FHR variability to a greater extent than do the inhalation agents. Opioid-induced fetal respiratory depression is relevant only if cesarean delivery is to be performed at the same time as the surgical procedure.

Positive-pressure ventilation may reduce uterine blood flow and decrease uteroplacental perfusion as a result of increased intrathoracic pressure and decreased venous return. Hyperventilation should be avoided and end-tidal CO_2 should be maintained in the normal range for pregnancy. Plasma cholinesterase levels decrease by approximately 25% in pregnancy; however, prolonged neuromuscular blockade with succinylcholine is uncommon because concomitant larger volumes of distribution associated with pregnancy offsets the impact of decreased drug hydrolysis. The pharmacokinetic and pharmacodynamic profiles of many drug administered to pregnant patients may differ from nonpregnant patients. Patients on magnesium for tocolysis may have prolonged muscle paralysis after the administration of muscle relaxants; therefore, reducing the dose of muscle relaxant is recommended.

The effects of reversal agents are unpredictable. Because of theoretical concerns of anticholinesterase agents increasing uterine tone and precipitating preterm labor, slow administration after a preceding dose of atropine is recommended. Glycopyrrolate is often recommended because it crosses the placenta less readily than does atropine. Atropine rapidly crosses the placenta and in large doses may cause fetal tachycardia and loss of FHR variability. However, transplacental passage of atropine may be preferable to counteract the fetal effects of neostigmine. Although limited anticholinesterase transplacental transfer is predicted because of its molecular size and structure, neostigmine can have significant transplacental passage and fetal effects without concomitant atropine administration.

Regional Anesthesia

Maternal hypotension associated with spinal or epidural anesthesia should be prevented or minimized by fluid preloading and leg compression devices. Appropriate vasopressors should be available to treat hypotension if it occurs. Phenylephrine has been shown to be the preferred vasopressor for the treatment of hypotension after neuraxial anesthesia for cesarean delivery, as the use of ephedrine causes greater fetal acidosis. Patients receiving magnesium are more prone to hypotension, which is often more resistant to treatment with vasopressors. Pregnant patients may have reduced requirements for local anesthetics and appropriate dose reduction is necessary to prevent a high block. Patients are at higher risk for systemic local anesthetic toxicity because decreased protein binding during pregnancy results in a greater fraction of unbound drug.

Postoperative Care

The FHR and uterine activity should be monitored during recovery from anesthesia. If the fetus is viable and premature labor occurs, early pediatric consultation is advised and, if necessary, the patient should be transferred to a hospital with a neonatal intensive care unit. Adequate analgesia should be obtained with systemic or spinal opioids. Regional anesthesia may be preferable because systemic opioids may reduce FHR variability. The routine and prolonged use of nonsteroidal antiinflammatory drugs is best avoided because of potential fetal effects (e.g., premature closure of

Table 1. Laparoscopy During Pregnancy

- Use an open technique to enter the abdomen to avoid potential uterine or fetal trauma
- Monitor maternal end-tidal CO_2 (30–35 mmHg range) ± arterial blood gas (if the procedure is prolonged) to avoid fetal hypercarbia and acidosis
- Maintain low pneumoperitoneum pressures (8–12 mm Hg, not >15 mm Hg) and minimize insufflation time or use a gasless technique to avoid decreases in uteroplacental perfusion
- Protect the uterus with lead shielding during periods of radiation
- Limit the extent of Trendelenburg and reverse Trendelenburg positions and initiate any position changes slowly
- Monitor fetal heart rate and uterine tone when feasible

ductus arteriosus and development of oligohydramnios). Acetaminophen is safe to prescribe in this setting. Early mobilization and venous thrombosis prophylaxis should be considered as patients are at risk for thromboembolism.

Counseling and Reassurance

A pregnant patient requiring surgery will naturally be extremely nervous and anxious. In addition to the stress of having to undergo a surgical procedure, she will have many justifiable concerns about the potential effects of anesthesia on her unborn child. There is a lot of misinformation about the potential risks that may compound her anxiety. Concerns regarding congenital malformations, fetal loss, and the risk of premature onset of labor should all be addressed. The patient should be reassured about the safety of anesthesia and the lack of documented associated teratogenicity. Patients should be warned about the increased risk of first trimester miscarriages and premature delivery (approximately 5% without surgery to 6%–8% with surgery). It is important to document details of the risks discussed in the patient's records. In addition, it is advisable to educate the patient about symptoms of premature labor and to reinforce the need for left uterine displacement in the perioperative and postoperative periods. If the patient is awake during the procedure, FHR monitoring during surgery is reassuring and can be offered.

Special Situations

Laparoscopy

Laparoscopy may be performed during pregnancy for both diagnostic and therapeutic surgery (e.g., cholecystectomy, appendectomy, ovarian torsion). Once regarded as contraindicated in pregnancy, in recent years laparoscopy is being performed with increasing frequency because of its many benefits (e.g., shorter hospitalization, less postoperative pain) over conventional surgery. Studies comparing laparotomy with laparoscopy report no differences in fetal outcome. To ensure laparoscopy during pregnancy is undertaken safely, it is important to consider key differences compared to nonpregnant patients (Table 1).

General anesthesia has been used for the majority of laparoscopy procedures, although there are several reports describing the use of epidural anesthesia. The pneumoperitoneum and Trendelenburg position may reduce lung compliance and FRC, increase airway pressures, and predispose to hypoxemia, especially with advanced gestation. The combination of pneumoperitoneum, aortocaval compression, and the reverse Trendelenburg position can result in significant decreases in venous return and hypotension. Limiting the insufflation pressure, left uterine displacement and limited reverse Trendelenburg initiated slowly will minimize decreases in blood pressure. Vasopressors (e.g., ephedrine, phenylephrine) may be needed to treat hypotension and maintain maternal blood pressure during laparoscopy. Fetal well-being is best preserved by maintaining maternal oxygenation, acid-base status, and hemodynamic measurements within normal pregnant limits. FHR and uterine tone monitoring may not be possible during peritoneal insufflation except by the transvaginal route. The prothrombotic pregnancy state and lower extremity venous stasis from the pneumoperitoneum increase the risk of thromboembolism. Intermittent pneumatic compression devices and thromboembolic prophylaxis are important.

Cardiopulmonary Bypass During Pregnancy

Cardiopulmonary bypass (CPB) may be necessary during pregnancy for open valve surgery and to manage aortic dissection, massive pulmonary or amniotic fluid embolus, and coronary artery dissection. If possible, surgery requiring CPB should be delayed until the second trimester or later. Most cardiac operations with CPB during pregnancy can be performed with reasonable safety in the mother, but there is increased risk for the fetus. If the parturient tolerates pregnancy, a primary cesarean delivery with concomitant or staged CPB with surgical repair can be performed. Patients requiring CPB should be managed in a tertiary center with multidisciplinary team involvement. Important considerations in the pregnant patient undergoing CPB are outlined in Table 2.

Table 2. Cardiopulmonary Bypass During Pregnancy

- Maintain high pump flows (30–50% increase over the non-pregnant state)
- Maintain mean arterial/perfusion pressures >60 mmHg for optimal uteroplacental perfusion
- Limit hypothermia (temperatures <32°C can reduce uteroplacental perfusion and cause fetal dysrhythmias and cardiac arrest)
- Monitor fetal heart rates continuously during CPB
- Optimize acid-base, glucose, Pao_2 and $Paco_2$

Table 3. ECT During Pregnancy

- Use anesthetic agents (e.g. barbiturates, succinylcholine, anticholinergics) with a long history of safe use during pregnancy
- Confirm the absence of uterine contractions using tocodynamometry before and after ECT
- Monitor the FHR immediately before and after ECT
- Consider full stomach prophylaxis and endotracheal intubation after the first trimester
- Provide left uterine displacement in patients >20 weeks' gestation

Electroconvulsive Shock Therapy

The treatment of major psychiatric disorders during pregnancy is problematic and optimal management remains controversial. Electroconvulsive shock therapy (ECT) avoids potential teratogenicity from psychotropic medications and it is often used to treat major depression and bipolar disorders during pregnancy especially when rapid control of depressive symptoms is needed. ECT does not appear to be a significant risk factor for miscarriage, stillbirths, or premature labor. Key points to consider are outlined in Table 3.

Cardioversion During Pregnancy

Maternal cardiac arrhythmias are not uncommon during pregnancy and may jeopardize the life of the mother and the fetus. The management of arrhythmias during pregnancy is similar to that for nonpregnant patients. When antiarrhythmic drug treatments fail or are not indicated because of hemodynamic instability, direct current cardioversion should be attempted. Cardioversion has been performed safely during pregnancy. Although it is a relatively low-risk procedure, FHR monitoring and plans to perform emergency cesarean delivery in the event of fetal distress should be considered. Key management points are similar to ECT and are outlined in Table 3.

Neurosurgery During Pregnancy

Neurosurgical interventions (e.g., aneurysm or arteriovenous malformation repair) may be necessary during pregnancy. Because the placental bed is unable to autoregulate and requires adequate perfusion pressures, controlled or induced hypotension will reduce uteroplacental perfusion. A 25%–30% reduction in systolic BP or a mean BP <70 mm Hg may lead to a reduction in uteroplacental blood flow. Limiting the dose ($<0.5\ mg \cdot kg^{-1} \cdot h^{-1}$) and duration of sodium nitroprusside administration is important as it can accumulate in the fetus and cause cyanide toxicity. Nitroglycerin may be a safer alternative. Excessive maternal hyperventilation and hypocarbia (<25 mm Hg) can compromise maternal-fetal oxygen transfer. FHR monitoring should be performed continuously, especially if induced hypotension and hyperventilation is planned so that necessary adjustments can be made if fetal distress occurs. Osmotically active agents (e.g., mannitol, loop diuretics) can cause significant fluid shifts in the fetus. Hypovolemia and very large doses of mannitol should be avoided as they have the potential to cause fetal dehydration. If endovascular treatments are undertaken, then uterine shielding during periods of radiation is necessary.

Table 4. Indications for an Emergency Cesarean Delivery in a Pregnant Trauma Patient

1. Traumatic uterine rupture
2. Stable mother with viable fetus that is in distress
3. A unsalvageable mother who still has a viable fetus
4. A gravid uterus that is interfering with intraoperative surgical repair

Trauma During Pregnancy

Trauma is one of the leading nonobstetric causes of morbidity and mortality. The primary management goals (airway maintenance and resuscitation) are similar to the care of nonpregnant trauma cases. Avoidance of hypoxia, hypotension, acidosis and hypothermia are important for maintenance of uteroplacental perfusion and fetal well-being. Pregnant patients are more prone to developing pulmonary edema resulting from relative hypoproteinemia and hypervolemia. In stable patients without ongoing blood loss, conservative fluid management is preferable and central venous monitoring should be consider if renal insufficiency or fluid overload occurs. Trauma may result in

placental abruption and fetal loss. The primary aim should be optimization of the mother, and the obstetric management can be planned at a later point. After initial resuscitation and trauma surveys are complete, an early ultrasound in the emergency room is recommended to determine fetal viability. Indications for an emergency or urgent cesarean delivery are outlined in Table 4. No radiological or invasive tests should be withheld because of fetal concerns. Whenever possible, the uterus should be shielded during radiation procedures. Ultrasound and magnetic resonance imaging that do not utilize ionizing radiation are preferable.

Further Reading

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