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Obstetric Regional Anesthesia

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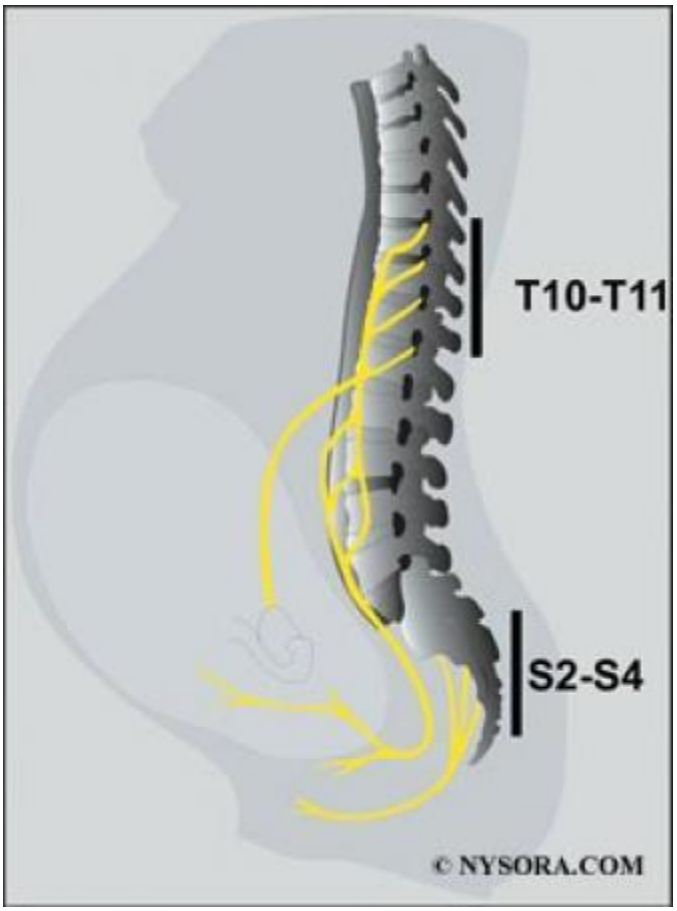

Most women experience moderate to severe pain during labor and delivery, often requiring some form of pharmacologic analgesia.1 The lack of proper psychological preparation combined with fear and anxiety can greatly enhance the patient's sensitivity to pain and further add to the discomfort during labor and delivery. However, skillfully conducted obstetric analgesia, in addition to relieving pain and anxiety,may benefit the mother in many other ways. This chapter focuses on management of an obstetric patient with primary focus on regional anesthesia techniques.

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Introduction

Most women experience moderate to severe pain during labor and delivery, often requiring some form of pharmacologic analgesia.1 The lack of proper psychological preparation combined with fear and anxiety can greatly enhance the patient's sensitivity to pain and further add to the discomfort during labor and delivery. However, skillfully conducted obstetric analgesia, in addition to relieving pain and anxiety,may benefit the mother in many other ways. This chapter focuses on management of an obstetric patient with primary focus on regional anesthesia techniques.

Physiologic Changes of Pregnancy

Pregnancy results in significant changes affecting most maternal organ systems (**Table 1**). These changes are initiated by hormones secreted by the corpus luteum and the placenta. Such changes have important implications for the anesthesiologist caring for the pregnant patient. This chapter reviews the most relevant physiologic changes of pregnancy and discusses the approach to obstetric management using regional anesthesia.

Table 1: *Summary of Physiologic Changes of Pregnancy at Term*

Variable	Change	Amount
Total blood volume	Increase	25–40%
Plasma volume	Increase	40–50%
Fibrinogen	Increase	50%

Serum cholinesterase activity	Decrease	20–30%
Cardiac output	Increase	30–50%
Minute ventilation	Increase	50%
Alveolar ventilation	Increase	70%
Functional residual capacity	Decrease	20%
Oxygen consumption	Increase	20%
Arterial carbon dioxide tension	Decrease	10 mm Hg
Arterial oxygen tension	Increase	10 mm Hg
Minimum alveolar concentration	Decrease	32–40%

Changes in the Cardiovascular System

Oxygen consumption increases during pregnancy, requiring the maternal cardiovascular system to meet the increasing metabolic demands of a growing fetus. The end result of these changes is an increase in heart rate (15–25%) and cardiac output (up to 50%) compared with values before pregnancy. In addition, lower vascular resistance is found in the uterine, renal, and other vascular beds. These changes result in a lower arterial blood pressure because of a decrease in peripheral resistance, which exceeds the increase in cardiac output. Decreased vascular resistance is mostly due to the secretion of estrogens, progesterone, and prostacyclin.2 Particularly significant increase in cardiac output occurs during labor and in the immediate postpartum period owing to added blood volume from the contracted uterus.

Clinical Pearls

Cardiovascular changes and pitfalls inadvanced pregnancy are:

- Increase in heart rate (15–25%) and cardiac output (up to 50%).
- Decrease in vascular resistance in the uterine, renal, and other vascular beds.
- Compression of the lower aorta in the supine position may further decrease uteroplacental perfusion and result in fetal asphyxia.
- For the above reason, significant hypotension is more likely to occur in the pregnant than in the nonpregnant woman having regional anesthesia, necessitating uterine displacement or lateral pelvic tilt maneuvers, intravascular preloading, and ready availability of vasopressors.

From the second trimester, aortocaval compression by the enlarged uterus becomes progressively more important, reaching its maximum effect at 36–38 weeks, after which it may decrease as the fetal head descends into the pelvis.3 Cardiac output may decrease when patients are in the supine position but not in the lateral decubitus position. Venous occlusion by the growing fetus causes supine hypotensive syndrome in 10% of pregnant women and manifests as maternal tachycardia, arterial hypotension, faintness, and pallor.4 Compression of the lower aorta in this position may further decrease uteroplacental perfusion and result in fetal asphyxia. Uterine displacement or lateral pelvic tilt should be applied routinely during anesthetic management of the pregnant patient.

Changes in the electrocardiogram are common in late pregnancy and consist of left axis deviation (caused by the upward displacement of the heart by the gravid uterus). There is also a tendency toward premature atrial contractions, sinus tachycardia, and paroxysmal supraventricular tachycardia.

Changes in the Respiratory System

Minute ventilation increases from the beginning of pregnancy to a maximum of 50% above normal by term.5 This is mostly a result of a 40% increase in tidal volume and a small increase in respiratory rate. Dead space does not change significantly during pregnancy; thus, alveolar ventilation is increased by 70% at term. After delivery, as blood progesterone levels decline, ventilation returns to normal within 1–3 weeks.6

Elevation of the diaphragm occurs with increase in the size of the uterus. Expiratory reserve volume, residual volume, and functional residual capacity decrease by the third semester of pregnancy.5 However, because there is also an increase in inspiratory reserve volume, total lung capacity remains unchanged. A decreased functional residual capacity is typically asymptomatic in healthy parturients. Those with preexisting alterations in closing volume as a result of smoking, obesity, scoliosis, or other pulmonary disease may experience early airway closure with advancing pregnancy, leading to hypoxemia. The Trendelenburg and supine positions also exacerbate the abnormal relationship between closing volume and functional residual capacity. The residual volume and functional residual capacity return to normal shortly after delivery.

Pregnant women often have difficulty with nasal breathing. Friability of the mucous membranes during pregnancy can cause severe bleeding, especially on airway instrumentation. These changes are caused by increase in extracellular fluid and vascular engorgement. It may also be difficult to performa laryngoscopy in obese, short-necked parturients with enlarged breasts. Use of a short-handled laryngoscope has proved helpful.

Clinical Pearl

- Airway edema may be particularly severe in pregnant women and those with preeclampsia, those in the Trendelenburg position for prolonged periods, and those with concurrent use of tocolytic agents.

Metabolic Changes

Oxygen consumption increases during early pregnancy, with an overall increase of 20% by term. Regardless, increased alveolar ventilation occurring during pregnancy actually leads to a reduction in the partial pressure of carbon dioxide in arterial blood (PaCO2) to 32 mm Hg and an increase in the partial pressure of oxygen in arterial blood (PaO2) to 106 mm Hg. The plasma buffer base decreases from 47 to 42 mEq; consequently, the pH remains practically unchanged. The maternal uptake and elimination of inhalational anesthetics are enhanced because of the increased alveolar ventilation and decreased FRC. However, the decreased functional residual capacity and increased metabolic rate predispose the mother to development of hypoxemia during periods of apnea/hypoventilation.7

Changes in the Gastrointestinal System

Enhanced progesterone production causes decreased gastrointestinal motility and slower absorption of food. Gastric secretions are more acidic, lower esophageal sphincter one is decreased, and a delay in gastric emptying can be demonstrated by the end of the first trimester.8 Uterine growth leads to upward displacement and rotation of the stomach, with increased pressure and a further delay in gastric emptying. By the 34th week, evacuation of a watery meal may be prolonged by 60%.9 Pain, anxiety, and administration of opioids (systemic or neuraxial) and belladonna alkaloids may further exacerbate this delay.

The risk of regurgitation on induction of general anesthesia depends, in part, on the gradient between the lower esophageal sphincter and intragastric pressures. In parturients with “heartburn,”

the lower esophageal sphincter tone is greatly reduced.10 The efficacy of prophylactic nonparticulate antacids is diminished by inadequate mixing with gastric contents, improper timing of administration, and the tendency for antacids to increase gastric volume. Administration of histamine (H2)-receptor antagonists, such as cimetidine and ranitidine, requires careful timing. A good case can be made for the administration of IV metoclopramide before elective cesarean section delivery. This dopamine antagonist hastens gastric emptying and increases resting lower esophageal sphincter tone in both nonpregnant and pregnant women.11 However, conflicting reports have appeared on its efficacy andonthe frequency of side effects, suchas extrapyramidal reactions and transient neurologic dysfunction.12,13 No routine prophylactic regimen can be recommended with certainty.

Endocrine Changes Influencing Plasma Volume, Blood Composition, & Glucose Metabolism

Plasma volume and total blood volume begin to increase in early gestation, resulting in an increase of 40–50% and 25–40% respectively, at term. These changes are due to an increased mineralocorticoid activity during pregnancy, which results in sodium retention and increased body water content.14 The relatively smaller increase in red blood cell volume (20%) accounts for a relative reduction in hemoglobin (to 11–12 g/L and hematocrit (to 35%); the platelet count, however, remains unchanged. Plasma fibrinogen concentrations increase during normal pregnancy by approximately 50%, whereas clotting factor activity is variable.15 Serum cholinesterase activity declines to a level of 20% below normal by term and reaches a nadir in the puerperium. The net effects of these changes in the serum cholinesterase is of negligible relevance to the metabolism of clinically used doses of succinylcholine or ester-type local anesthetics (2-choloroprocaine).16,17 The albumin–globulin ratio declines because of the relatively greater reduction in albumin concentration. A decrease in serum protein concentration may be clinically significant in that the free fractions of protein-bound drugs can be expected to increase.

Human placental lactogen and cortisol increase the tendency to hyperglycemia and ketosis, which may exacerbate preexisting diabetes mellitus. The patient’s ability to handle a glucose load is decreased, and the transplacental passage of glucose may stimulate fetal secretion of insulin, leading in turn to neonatal hypoglycemia in the immediate postpartum.

Altered Drug Responses in Pregnancy

Pregnancy results in a progesterone-mediated increase in neural sensitivity to local anesthetics.19 Lower doses of local anesthetic are needed per dermatomal segment of epidural or spinal block. This has been attributed to an increased spread of local anesthetic in the epidural and subarachnoid spaces as a result of epidural venous engorgement and enhanced sensitivity to local anesthetic block due to progesterone. The minimum alveolar concentration for inhalational agents is decreased by 8–12 weeks of gestation and may be related to an increase in progesterone levels.20

Clinical Pearls

- During pregnancy, there is a progesterone-mediated increase in neural sensitivity to local anesthetics.
- Doses of local anesthetic need to be lowered per dermatomal segment of epidural or spinal block.

Placental Transfer of Local Anesthetics

Local anesthetics readily cross the placenta by simple diffusion. Several factors influence the placental transfer of drugs, including the physicochemical characteristics of the drug itself, maternal drug concentrations in the plasma, properties of the placenta, and hemodynamic events within the fetomaternal unit.

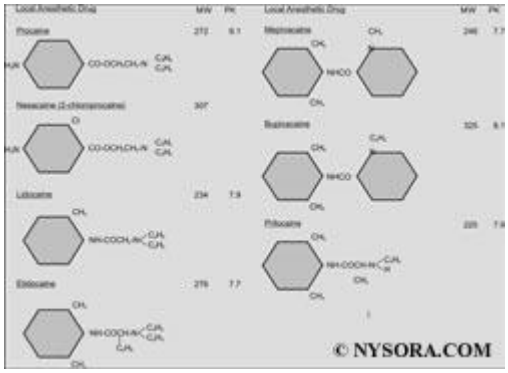

Figure 1: *Chemical structures of local anesthetics.*

Highly lipid-soluble drugs, such as local anesthetics, cross biologic membranes more readily, and the degree of ionization is important because the nonionized moiety of a drug is more lipophilic than the ionized drug. Local anesthetics are weak bases, with a relatively low degree of ionization and considerable lipid solubility. The relative concentrations of drug existing in the nonionized and ionized forms can be estimated from the Henderson-Hasselbalch equation:

pH = pKa + log (base)/(cation)

The ratio of base to cation becomes particularly important with local anesthetics because the nonionized form penetrates tissue barriers, whereas the ionized form is pharmacologically active in blocking nerve conduction. The pKa is the pH at which the concentrations of free base and cation are equal. For the amide local anesthetics, the pKa values (7.7–8.1) are sufficiently close to physiologic pH so that changes in maternal or fetal biochemical status may significantly alter the proportion of ionized and nonionized drug (**Figure 1**). At steady state, the concentrations of nonionized local anesthetics in the fetal and maternal plasma are equal. With fetal acidosis, there is a greater tendency for drug to exist in the ionized form, which cannot diffuse back across the placenta. This causes a larger total amount of local anesthetic to accumulate in the fetal plasma and tissues. This is called ion trapping.21

Clinical Pearl

- Prolonged administration of highlyprotein-bound drugs (e.g., bupivacaine) may lead to substantial fetal accumulation of the drugs.

The effects of maternal plasma protein binding on the rate and amount of local anesthetic accumulating in the fetus are inadequately understood. Animal studies have shown that the transfer rate is slower for drugs that are extensively bound to maternal plasma proteins such as bupivacaine.22,23 However, with prolonged administration of highly protein-bound drugs such as bupivacaine, substantial accumulation drug of can occur in the fetus.24

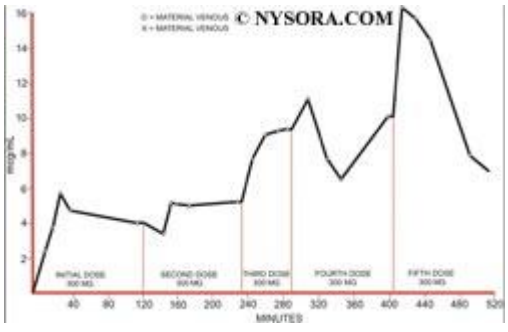

Figure 2: *Increased maternal blood concentration after repeated doses of mepivacaine.*

The concentration gradient of free drug between the maternal and fetal blood is a significant factor. On the maternal side, the dose administered, the mode and site of administration, and the use of vasoconstrictors can influence fetal exposure. The rates of distribution, metabolism, and excretion of the drug, which may vary, are equally important. Higher doses result in higher maternal blood concentrations. The absorption rate can vary with the site of injection. For instance, an IV bolus results in the highest blood concentrations. It was believed that intrathecal administration resulted in negligible plasma

concentrations of local anesthetics. However, we now know that spinal anesthesia induced with 75 mg lidocaine results in maternal plasma concentrations that are similar to those reported by others after epidural anesthesia.25 Furthermore, significant levels of the drug can be found in the umbilical vein at birth.

Repeated administration can result in high maternal blood concentrations, depending on the dose and frequency of reinjection, in addition to the kinetic characteristics of the drug. The half-life of amide local anesthetic agents is relatively long, so that repeated injection may lead to accumulation in the maternal plasma[26] (**Figure 2**). In contrast, 2-chloroprocaine, an ester local anesthetic, undergoes rapid enzymatic hydrolysis in the presence of pseudocholinesterase. After epidural injection, the mean half-life in the mother is approximately 3 minutes; after reinjection, 2-chloroprocaine can be detected in the maternal plasma for only 5–10 minutes, and no accumulation of this drug has occurred.27

Pregnancy is associated with physiologic changes, which also may influence maternal pharmacokinetics and the action of anesthetic drugs. These changes may be progressive during the course of gestation and are often difficult to predict. Nonetheless, the elimination half-life of bupivacaine after epidural injection has been shown to be similar in pregnant and nonpregnant women.28

Fetal regional blood flow changes can also affect the amount of drug taken up by individual organs. For example, during asphyxia and acidosis, a greater proportion of the fetal cardiac output perfuses the fetal brain, heart, and placenta. Infusion of lidocaine resulted in increased drug uptake in the heart, brain, and liver of asphyxiated baboon fetuses compared with nonasphyxiated control fetuses.29

Risk of Drug Exposure: Fetus versus Newborn

The fetus can excrete local anesthetics back into the maternal circulation after the concentration gradient of the free drug across the placenta has been reversed. This may occur even if the total plasma drug concentration in the mother exceeds that in the fetus, because there is lower protein binding in fetal plasma.23 2-Chloroprocaine is the only drug that is metabolized in the fetal blood so quickly that even with acidosis, substantial exposure in the fetus is avoided.27 Term as well as preterm infants have the hepatic enzymes necessary for the biotransformation of amide local anesthetics. In a comparative study, pharmacokinetics of lidocaine among adult ewes and fetal/neonatal lambs indicated that the metabolic clearance in the newborn was similar to, and renal clearance greater than, that in the adult.30 However, the half-life was longer in the newborn related to a greater volumeof distribution and tissue uptake, so that at any givenmoment the neonate's liver and kidneys are exposed to a smaller fraction of lidocaine accumulated in the body. Similar results have been reported in another study involving lidocaine administration to human infants in a neonatal intensive care unit.31

Neonatal depression occurs at blood concentrations of mepivacaine or lidocaine that are approximately 50% less than those producing systemic toxicity in the adult. However, infants accidentally injected in utero with mepivacaine (intended for maternal caudal anesthesia) stopped convulsing when the mepivacaine level decreased belowthe threshold for convulsions in the adult.32 The relative central nervous toxicity and cardiorespiratory toxicity of local anesthetics have been studied in sheep.33 The doses required to produce toxicity in the fetus and newborn lamb were greater than those required in the ewe. In the fetus, this difference was attributed to placental clearance of drug into the mother and better maintenance of blood gas tensions during convulsions, whereas in the newborn lamb, a larger volume of distribution was probably responsible for the higher doses needed to induce toxic effects.

It has been suggested that bupivacaine may be implicated as a possible cause of neonatal jaundice

because its high affinity for fetal erythrocyte membranes resulting in a decrease in filterability and deformability renders subjectsmore prone to hemolysis.However, amore recent study has failed to show demonstrable bilirubin production in newborns whose mothers were given bupivacaine for epidural anesthesia during labor and delivery.34

Neurobehavioral studies have revealed subtle changes in newborn neurologic and adaptive function with regional anesthesia. Inthe case of most anesthetic agents, these changes are minor and transient, lasting for only 24–48 hours.35

Anesthesia For Labor and Vaginal Delivery

In the first stage of labor, pain is caused by uterine contractions related to dilation of the cervix and distention of the lower uterine segment. Pain impulses are carried in visceral afferent type C fibers, which accompany the sympathetic nerves. In early labor, only the lower thoracic dermatomes (T11-12) are affected. However, with progressive cervical dilation during the transition phase, adjacent dermatomes may be involved and pain referred from T10 to LI. During the second stage, additional pain impulses due to distention of the vaginal vault and perineum are carried in the pudendal nerve, which is composed of lower sacral fibers (S2-4).

Regional analgesia may benefit the mother in other ways beyond relieving pain and anxiety. In animal studies, pain may cause maternal hypertension and reduced uterine blood flow.36 Epidural analgesia blunts the increases in maternal cardiac output, heart rate, and blood pressure that occur with painful uterine contractions and "bearing-down" efforts.37 By reducing maternal secretion of catecholamines, epidural analgesia may convert a previously dysfunctional labor pattern to a normal one.38 Regional analgesia can benefit the fetus by eliminating maternal hyperventilation with pain, which often leads to a reduced fetal arterial oxygen tension owing to a leftward shift of the maternal oxygen–hemoglobin dissociation curve.39

The most frequently chosen methods for relieving the pain of parturition are psychoprophylaxis, systemic medication, and regional analgesia. Inhalational analgesia, conventional spinal analgesia, and paracervical blockade are less commonly used. General anesthesia is rarely necessary but may be indicated for uterine relaxation in some complicated deliveries.

Systemic Analgesia

The advantages of systemic analgesics include ease of administration and patient acceptability. However, the drug, dose, time, and method of administrationmust be chosen carefully to avoid maternal or neonatal depression. Drugs used for systemic analgesia are opioids, tranquilizers, and occasionally ketamine.

Systemic Opioids

In the past, meperidine was the most commonly used systemic analgesic to ameliorate pain during the first stage of labor. It can be administered by IV injection (effective analgesia in 5–10 minutes) or intramuscularly (peak effect in 40–50 minutes). It was also commonly used for postoperative pain in the general population. But with the popularity of its administration, disturbing side effects began to emerge. One of the most serious side effects was the occurrence of seizures both from the primary drug effect and from its metabolite, normeperidine. In the pregnant patient at risk for seizures—that is, with pregnancy-induced hypertension or preeclampsia—confusing the picture by the administration of a drug known to cause seizures complicates patient care.40,41 Other side effects are nausea and vomiting, doserelated depression of ventilation, orthostatic hypotension, the

potential for neonatal depression, and euphoria out of proportion to the analgesic effect, leading to misuse of the drug.42 Meperidine may also cause transient alterations of the fetal heart rate, such as decreased beat-to-beat variability and tachycardia. Among other factors, the risk of neonatal depression is related to the interval from the last drug injection to delivery.43 The placental transfer of an active metabolite, normeperidine, which has a long elimination half-life in the neonate (62 hours), has also been implicated in contributing to neonatal depression and subtle neonatal neurobehavioral dysfunction. Consequently, the use of meperidine has fallen out of favor as an analgesic for labor.

Experience with the newer synthetic opioids, such as fentanyl and alfentanil, has been limited. Although they are potent, their use during labor is restricted by their short duration of action. For example, a single IV injection of fentanyl, up to 1 mcg/kg, results in prompt pain relief without severe neonatal depression.44 These drugs offer an advantage when analgesia of rapid onset but short duration is necessary (e.g., with forceps application). For more prolonged analgesia, fentanyl can be administered with patient-controlled delivery devices.45 More commonly, fentanyl (15–25 mcg) and sufentanil (5–10 mcg) have been used with local anesthetics in an initial spinal dosewith a local anesthetic during the placement of a continuous spinal–epidural for labor with excellent relief of pain.46,47

Remifentanil is an opioid that is rapidly metabolized by serum and tissue cholinesterases, and consequently, has a short (3-minute), context-sensitive half-time.48 When used in bolus dosing (0.3–0.8 mcg/kg per bolus), remifentanil has been found to have an acceptable level of maternal side effects and minimal effect on the neonate. Remifentanil crosses the placenta and appears to be either rapidly metabolized or redistributed in the neonate.49 In one study, Apgar and neurobehavioral scores were good in neonates whose mothers were given an intravenous infusion of remifentanil, 0.1 mcgkg/ min during cesarean section delivery under epidural anesthesia.50 When administered by patient-controlled analgesia, remifentanil has been found to provide better pain relief, equivalent hemodynamic stability, less sedation, and a lesser degree of oxygen desaturation when compared with meperidine.49,51 In countries outside the United States, intermittent nitrous oxide has been used for labor analgesia. When comparing remifentanil with nitrous oxide, remifentanil was found to provide better pain relief with fewer side effects.52

Opioid agonists–antagonists, such as butorphanol and nalbuphine, have also been used for obstetric analgesia. These drugs have the proposed benefits of a lower incidence of nause, vomiting, and dysphoria, as well as a "ceiling effect" on depression of ventilation.53 Butorphanol is probably the most popular; unlike meperidine, it is biotransformed into inactive metabolites and has a ceiling effect on depression of ventilation in doses exceeding 2 mg. A potential disadvantage is a high incidence of maternal sedation. The recommended dose is 1–2 mg by IV or IM injection. Nalbuphine 10 mg IV or IM is an alternative to butorphanol.

Naloxone, a pure opioid antagonist, should not be administered to the mother shortly before delivery to prevent neonatal ventilatory depression because it reverses maternal analgesia at a time when it is most needed. In some instances, naloxone has been reported to cause maternal pulmonary edema and even cardiac arrest. If necessary, the drug should be given directly to the newborn IM (0.1 mg/kg.

Ketamine

Ketamine is a potent analgesic. However, it may also induce unacceptable amnesia that may interfere with the mother's recollection of the birth. Nonetheless, ketamine is a useful adjuvant to incomplete regional analgesia during vaginal delivery or for obstetric manipulations. In low doses (0.2–0.4 mg/kg), ketamine provides adequate analgesia without causing neonatal depression.

Regional Analgesia Techniques

Regional techniques provide excellent analgesia with minimal depressant effects in mother and fetus. The techniques most commonly used for labor anesthesia include central neuraxial blocks (spinal, epidural, and combined spinal/epidural), paracervical, and pudendal blocks, and, less frequently, lumbar sympathetic blocks. Hypotension resulting from sympathectomy is the most common complication that occurs with central neuraxial blockade. Therefore, maternal blood pressuremust be monitored at regular intervals, typically a very 2–5 minutes for approximately 15–20 minutes after the initiation of the block and at routine intervals thereafter. Regional analgesia may be contraindicated in the presence of severe coagulopathy, acute hypovolemia, or infection at the site of needle insertion. Chorioamnionitis without sepsis, is not a contraindication to central neuraxial blockade.

Epidural Analgesia

Effective analgesia for the first stage of labor is achieved by blocking the T10-Ll dermatomes with a low concentrations of local anesthetic, often in combination with a lipid-soluble opioid. For the second stage of labor and delivery, because of pain due to vaginal distention and perineal pressure, the block should be extended to include the pudendal segments, S2-4 (**Figures 3 and 4**).

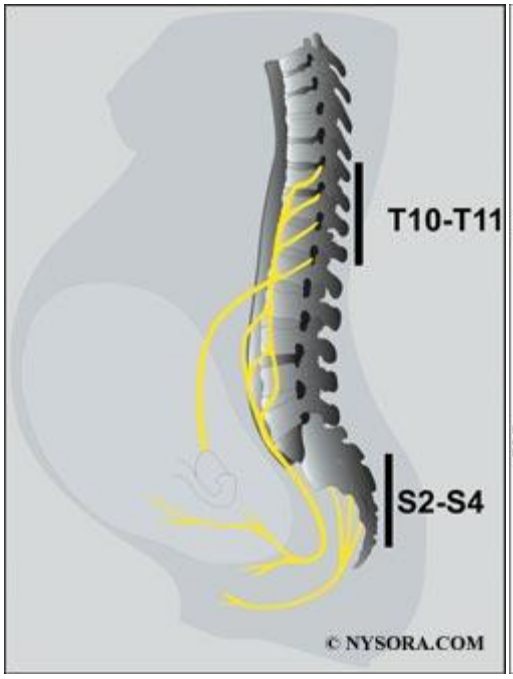

Figure 3: *Pain pathways in a parturient.*

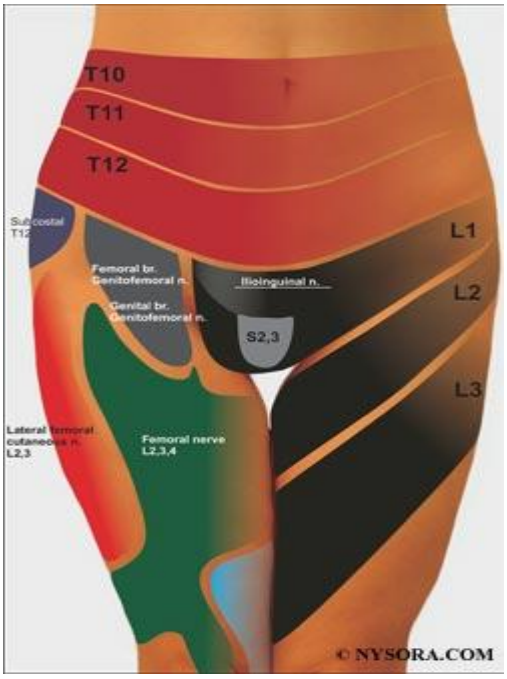

Figure 4: *Dermatomal level of the lower abdomen, perineal area, hip, and thighs.*

There has been concern that early initiation of epidural analgesia during the latent phase of labor (2–4 cm cervical dilation) may result in prolongation of the first stage of labor and a higher incidence of dystocia and cesarean section delivery, particularly in nulliparous women.54–57 Generally speaking, the first stage of labor is not prolonged by epidural analgesia, provided that aortocaval compression is avoided.54–56,58,59 Chestnut et al.[58,59] demonstrated that the incidence of cesarean section delivery was no different in nulliparous women having epidural analgesia initiated during the latent phase (at 4 cm dilation) compared with women whose analgesia was initiated during the active phase. Others have shown that epidural analgesia is not associated with an increased incidence of cesarean section delivery compared with IV patient-controlled analgesia in nulliparous women.55,56 However, a prolongation of the second stage of labor has been reported in nulliparous women, possibly owing to a decrease in expulsive forces or malposition of the vertex.54,59 Thus, with use of epidural analgesia, the American College of

Obstetricians and Gynecologists (ACOG) has defined an abnormally prolonged second stage of labor as longer than 3 hours in nulliparous and 2 hours in multiparous women.60 Alonger second stage of labor may be minimized by the use of an ultra-dilute local anesthetic solution in combination with opioid.61 Long-acting amides such as bupivacaine, ropivacaine, and levobupivacaine are most frequently used because they produce excellent sensory analgesia while sparing motor function, particularly at the low concentrations used for epidural analgesia.

Clinical Pearls

- Analgesia during the first stage of labor is achieved by blocking the T10-Ll dermatomes anesthetic (see **Figure 3**).
- Analgesia for the second stage of labor and delivery requires the block of the S2-4 segments because of pain due to vaginal distention and perineal pressure.

Analgesia for the first stage of labor may be achieved with 5–10 mL of bupivacaine, ropivacaine, or levobupivacaine (0.125–0.25%) followed by a continuous infusion (8–12 mL/h) of 0.0625% bupivacaine or levobupivacaine, or 0.1% ropivacaine. Fentanyl 1–2 mcg/mL or sufentanil 0.3–0.5 mcg/mL may be added. During the actual delivery, the perineum may be blocked with 10 mL of 0.5% bupivacaine, 1% lidocaine, or, if a rapid effect is required, 2% chloroprocaine in the semirecumbent position.

There is controversy regarding the need for a test dose when using a dilute solution of local anesthetic.62,63 Catheter aspiration alone is not always diagnostic. For that reason, some authors believe that a test dose should be administered to improve detection of an intrathecally or intravascularly placed epidural catheter. If injected into a blood vessel, 15 mcg epinephrine results in a change in heart rate of 20–30 bpm with a slight increase in blood pressure within 30 seconds of administration. The duration is approximately 30 seconds. The anesthesiologist should observe the tachometer during the first minute after injection to determine whether an accidently intravascular injection has occurred. Other subtle signs of intravascular injection may include a feeling of apprehension, unease, or palpitations. It is important to fractionate the total dose of local anesthetic and observe the patient at 1-minute intervals.

Patient-controlled epidural analgesia is a safe and effective alternative to conventional bolus or infusion techniques.64 Maternal acceptance is excellent, and demands on anesthesia manpower may be reduced. Initial analgesia is achieved with bolus doses of local anesthetic. Once the mother is comfortable, patient-controlled epidural analgesia may then be started with a maintenance infusion (4–8 mL/h) of local anesthetic (bupivacaine, levobupivacaine, ropivacaine 0.0625–0.125%) with or without opioid (fentanyl 1–2 mcg/mL) sufentanil 0.3–0.5 mcg/mL). The machine may be programmed to administer an epidural demand bolus of 4 mL with a lockout period of 10 minutes between doses.64 The caudal rather than the lumbar approach may result in a faster onset of perineal analgesia and therefore may be preferable to the lumbar epidural approach when an imminent vaginal delivery is anticipated. However, caudal analgesia is no longer popular because of occasionally painful needle placement, a high failure rate, potential contamination at the injection site, and risks of accidental fetal injection. Before caudal injection, a digital rectal examination must be performed to exclude needle placement in the fetal presenting part. Low spinal “saddle block” has virtually eliminated the need for caudal anesthesia in modern practice.

Spinal Analgesia

A single intrathecal injection for labor analgesia has the benefits of a reliable and rapid onset of neural blockade. However, repeated intrathecal injections may be required for a long labor, thus

increasing the risk of postdural puncture headache. In addition, motor block may be uncomfortable for some women and may prolong the second stage of labor.

Microcatheters were introduced for continuous spinal anesthesia in the 1980s. They were subsequently withdrawn when found to be associated with neurologic deficits, possibly related to maldistribution of local anesthetic in the cauda equina region.65 Fortunately, in a recent multi-institutional study, no cases of neurologic symptoms occurred after the use of 28-gauge microcatheters for continuous spinal analgesia in laboring women.66 Spinal anesthesia is also a safe and effective alternative to general anesthesia for instrumental delivery.

Combined Spinal Epidural Analgesia

Combined spinal–epidural analgesia is an ideal analgesic technique for use during labor. It combines the rapid, reliable onset of profound analgesia resulting from spinal injection with the flexibility and longer duration of epidural techniques.

Technique

After identification of the epidural space using a conventional (or specialized) epidural needle, a longer (127-mm), pencil-point spinal needle is advanced into the subarachnoid space through the epidural needle (more detail on this technique can be found in Chapter 16). After intrathecal injection, the spinal needle is removed and an epidural catheter inserted. Intrathecal injection of fentanyl 10–25 mcg or sufentanil 2.5–5 mcg, alone or in combination with 1 mL of isobaric bupivacaine 0.25%, produces profound analgesia lasting for 60–120 minutes with minimal motor block.67 Opioid alone may provide sufficient relief for the early latent phase, but almost always the addition of bupivacaine is necessary for satisfactory analgesia during advanced labor. An epidural infusion of bupivacaine 0.03–0.0625% with opioid may be started within 10 minutes of spinal injection. Alternatively, the epidural component may be activated when necessary. Women with hemodynamic stability and preserved motor function who do not require continuous fetal monitoring may ambulate with assistance.68,69 Before ambulation, women should be observed for 30 minutes after intrathecal or epidural drug administration to assess maternal and fetal well-being. A recent study indicated that early administration of combined spinal–epidural analgesia to nulliparous women did not increase the cesarean section delivery rate.70

Clinical Pearl

- Intrathecal injection of fentanyl 10–25 mcg or sufentanil 5–10 mcg alone or more commonly in combination with 1 mL isobaric bupivacaine 0.25% produces profound analgesia lasting for 90–120 minutes with minimal motor block.

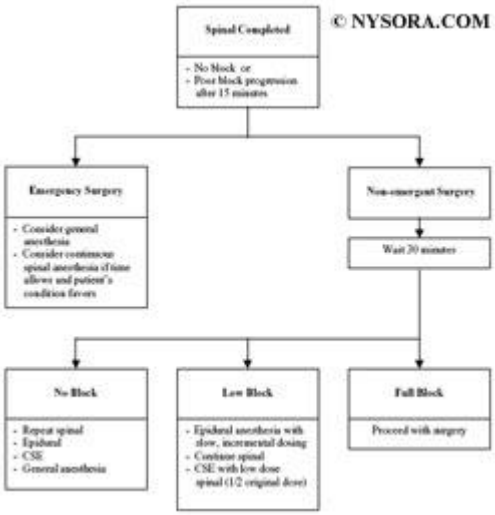

Figure 5: *Management algorithm for an obstetric patient with inadequate neuraxial anesthesia. CSE, combined spinal–epidural.*

The most common side effects of intrathecal opioids are pruritus, nausea, vomiting, and urinary retention. Rostral spread resulting in delayed respiratory depression is rare with fentanyl and sufentanil and usually occurs within 30 minutes of injection.71 Transient nonreassuring fetal heart rate patterns may occur because of uterine hyperstimulation, presumably as a result of a rapid decrease in maternal catecholamines or because of hypotension after sympatholysis.72 A preliminary study by O'Gorman et al.[73] suggests that fetal bradycardia may occur in the absence of uterine hyperstimulation or hypotension and is unrelated to uteroplacental insufficiency. The incidence of fetal heart rate abnormalities may be greater in multiparous woman with a rapidly progressing, painful labor.74 Most studies have demonstrated that the incidence of emergency cesarean section delivery is no greater with combined spinal–epidural analgesia than after conventional epidural analgesia.75,76 Postdural puncture headache is always a risk after intrathecal injection. However, the incidence of headache is no greater with combined spinal–epidural analgesia compared with standard epidural analgesia.77

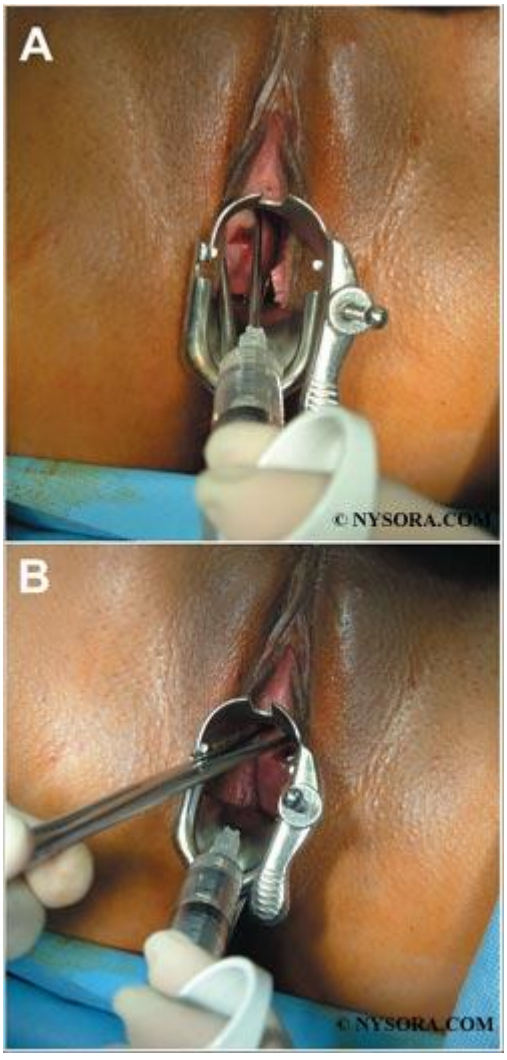

Figure 6. A and B: Paracervical block is a useful technique to provide

Unintentional intrathecal catheter placement through the dural puncture site is also rare after use of a 26-gauge needle for combined spinal–epidural analgesia. The potential exists for epidurally administered drug to leak intrathecally through the dural puncture, particularly if large volumes of drug are rapidly injected. In fact, epidural drug requirements are approximately 30% less with combined spinal–epidural analgesia than with standard lumbar epidural techniques for cesarean section delivery.78 Some clinicians do not advocate the combined spinal–epidural analgesia technique for labor because of the concern for an "unproven" epidural catheter that may need to be used emergently for cesarean section delivery. The patient may have a partial block insufficient for surgery with an epidural that may or may not work. An algorithm for patient management in the event of an incomplete spinal can be found in **Figure 5**.

Paracervical Block

Although paracervical block effectively relieves pain during the first stage of labor, it is now rarely used in the United States because of its association with a high incidence of fetal asphyxia and poor neonatal outcome, particularly with the use of bupivacaine. This may be related to uterine artery constriction or increased uterine tone.79 Paracervical block is a useful technique to provide analgesia for uterine curettage. The technique is very simple and involves a submucosal injection of local anesthetic at the vaginal fornix near the neural fibers innervating the uterus (**Figure 6**).

Paravertebral Lumbar Sympathetic Block

Paravertebral lumbar sympathetic block is a reasonable alternative when contraindications exist to central neuraxial techniques. Lumbar sympathetic block interrupts the painful transmission of cervical and uterine impulses during the first stage of labor.80 Although there is less risk of fetal bradycardia with lumbar sympathetic block comparedwith paracervical blockade, technical difficulties associated with the performance of the block and risks of intravascular injection have hampered its routine use. Hypotension may also occur with lumbar sympathetic blocks.

Pudendal Nerve Block

The pudendal nerves are derived from the lower sacral nerve roots (S2-4) and supply the vaginal vault, perineum, rectum, and sections of the bladder. The nerves are easily blocked transvaginally where they loop around the ischial spines. Local anesthetic, 10 mL, deposited behind each sacrospinous ligament can provide adequate anesthesia for outlet forceps delivery and episiotomy repair.

Anesthesia for Cesarean Section Delivery

The most common indications for cesarean section delivery include failure to progress, nonreassuring fetal status, cephalopelvic disproportion, malpresentation, prematurity, and prior uterine surgery involving the corpus. The choice of anesthesia should depend on the urgency of the procedure in addition to the condition of the mother and fetus. After a comprehensive discussion of the risks and benefits of all anesthesia options, the mother's desires should be considered. Before the initiation of any anesthetic technique, resuscitation equipment for mother and neonate should be available (**Table 2**).

Table 2. Resuscitation Equipment in the Delivery Room

- Radiant warmer
- Suction with manometer and suction trap
- Suction catheters
- Wall oxygen with flow meter
- Resuscitation bag (≤750 mL)
- Infant face masks
- Infant oropharyngeal airways
- Endotracheal tubes 2.5, 3.0, 3.5, and 4.0 mm
- Endotracheal tube stylets
- Laryngoscope(s) and blade(s)
- Sterile umbilical artery catheterization tray
- Needles, syringes, three-way stopcocks
- Medications and solutions
    - 1:10,000 epinephrine
    - Naloxone hydrochloride
    - Sodium bicarbonate
    - Volume expanders

Advantages of Regional Anesthesia in the Obstetric Patient

A 1992 survey of obstetric anesthesia practices in the United States demonstrated that most patients undergoing cesarean section delivery do so under spinal or epidural anesthesia.81 Regional techniques have several advantages: They reduce the risk of gastric aspiration, avoid depressant anesthetic drugs, and allow the mother to remain awake during delivery. Operative blood loss may also be reduced with regional compared with general anesthesia. Generally speaking, with regional techniques the duration of antepartum anesthesia does not affect neonatal outcome, provided that there is no protracted aortocaval compression or hypotension.82 The risk of hypotension may be greater than during vaginal delivery because the sensory block must extend to at least the T4 dermatome. Proper positioning and prehydration with at least 10–15 mL/kg of dextrose crystalloid solution is recommended, particularly if a volume deficit exists.83 If hypotension occursdespite these measures, left uterine displacement should be increased, the rate of IV infusion augmented, and IV ephedrine 5–15 mg (or phenylephrine 25–50 mcg) administered incrementally. Note, however, that routine aggressive prehydration has become controversial because of reports of ineffectiveness and pulmonary edema, especially in patients with preeclampsia.

Spinal Anesthesia

Subarachnoid block is probably the most commonly administered regional anesthetic for cesarean section delivery because of its speed of onset and reliability. It has become an alternative to general anesthesia for emergency cesarean section.84 Hyperbaric solutions of lidocaine 5%, tetracaine 1.0%, or bupivacaine 0.75% have been used. However, bupivacaine has now become the most widely used drug for spinal anesthesia for cesarean delivery. Using 0.75% hyperbaric bupivacaine, Norris[85] has shown that it is not necessary to adjust the dose of drug based on the patient's height. Hemodynamic monitoring during cesarean section should be similar to that used for other surgical procedures with the exception that blood pressure should be monitored at a minimum of every 3 minutes before the birth of the baby. Before delivery, oxygen should be routinely administered to optimize fetal oxygenation. Reports of transient neurologic syndrome and/or cauda equina syndrome have been associatedwith lidocaine in doses greater than 60 mg, whether it is in a 5% or a 2% preparation.

This has led some clinicians to avoid the use of lidocaine for intrathecal administration (see Local Anesthetic Toxicity). See **Table 3** for local anesthetics and their dosages that are commonly used for cesarean section delivery with subarachnoid block.

Table 3. *Local Anesthetics Commonly Used for Cesarean Section Delivery with Subarachnoid Block*

Dosage per height of patient (cm)	Bupivacaine 0.75% in8.25% Dextrose (mL)	Bupivacaine 0.5% (isobaric) (mL)
150–160 cm	8	8
160–180 cm	10	10–12.5
>180 cm	12	12.5–15
Onset of action	2–4 min	5–10 min

Clinical Pearls

- Even with an adequate dermatomal level for surgery, women may experience visceral discomfort, particularly during exteriorization of the uterus and traction on abdominal viscera.
- Perioperative analgesia can be provided more favorably by the addition of fentanyl 6.25 mcg or 0.1 mg of preservative-free morphine to the local anesthetic solution.

Despite an adequate dermatomal level, women may experience varying degrees of visceral discomfort, particularly during exteriorization of the uterus and traction on abdominal viscera. Improved perioperative analgesia can be provided by the addition of fentanyl 10 mcg or 0.1 mg of preservative free morphine to the local anesthetic solution.86 Nausea and vomiting may be alleviated by the administration of droperidol ormetoclopramide. Maternal sedation should be avoided, if possible. If the initial block is not adequate, concern exists regarding a repeat spinal injection and the potential for inadvertent high spinal anesthesia. **Figure 5** presents a range of options that are available in situations in which spinal anesthesia fails to prove adequate for surgery.

Lumbar Epidural Anesthesia

Epidural anesthesia has a slower onset of action and a larger drug requirement to establish an adequate sensory block compared with spinal anesthesia. The advantages are a perceived reduced risk of postdural puncture headache and the ability to titrate the local anesthetic through the epidural catheter. However, correct placement of the epidural catheter and avoidance of inadvertent intrathecal or intravascular injection are essential.

Clinical Pearls

- Aspiration of the epidural catheter for blood or cerebrospinal fluid is not absolutely reliable for detection of catheter misplacement.
- A “test dose” is often used to rule out inadvertent intravascular or intrathecal catheter placement.
- A small dose of local anesthetic, lidocaine 45 mg or bupivacaine 5mg, produces a readily identifiable sensory and motor block if injected intrathecally.
- Addition of epinephrine (15 mcg) with careful hemodynamic monitoring may signal intravascular injection when followed by a

transient increase in heart rate and blood pressure.

- However, the use of an epinephrine test dose is controversial because false-positive results do occur in the presence of uterine contractions.

Aspiration of the epidural catheter for blood or cerebrospinal fluid is not 100% reliable for detection of catheter misplacement. For this reason, a "test dose" is often used to rule out inadvertent intravascular or intrathecal cathether placement. A small dose of local anesthetic, lidocaine 45mg or bupivacaine 5mg, produces a readily identifiable sensory and motor block if injected intrathecally. Addition of epinephrine (15 mcg) with careful heart rate and blood pressure monitoring may signal intravascular injection with transient increase in heart rate and blood pressure. However, an epinephrine test dose is controversial because false-positive results do occur in the presence of uterine contractions. In addition, epinephrine may reduce uteroplacental perfusion. Electrocardiography and application of a peak-to-peak heart rate criterion may improve detection (10 beats over maximum heart rate preceding epinephrine injection). Rapid injection of 1 mL of air with simultaneous precordial Doppler monitoring appears to be a reliable indicator of intravascular catheter placement.87 A negative test, although reassuring, does not eliminate the need for fractional administration of local anesthetic.

Local Anesthetic Choices

The most commonly used agents are 2-chloroprocaine 3%, bupivacaine 0.5%, and lidocaine 2% with epinephrine 1:200,000.

Adequate anesthesia can be usually achieved with 15–25 mL of local anesthetic given in divided doses. The patient should be monitored as with spinal anesthesia. Because of its extremely high rate of metabolism in maternal and fetal plasma, 2-chloroprocaine provides a rapid-onset, reliable blockwith minimal risk of systemic toxicity.27 It is the local anesthetic of choice in the presence of fetal acidosis and when a preexisting epidural block is to be rapidly extended for an urgent cesarean section delivery.84 Neurologic deficits after massive inadvertent intrathecal administration of the drug have occurred with the formulation containing a relatively high concentration of sodium bisulfite, at a low pH.88 In a new formulation of 2-chloroprocaine (Nesacaine-MPF), ethylene diaminetetraacetic acid (EDTA) has been substituted for sodium bisulfite.However, severe spasmodic back pain has been described after epidural injection of large volumes of Nesacaine-MPF in surgical patients, but not in parturients.89 This has been attributed to EDTA-induced leaching of calcium from paravertebral muscles. The most recent formulation of 2-chloroprocaine contains no additives and is packaged in an amber vial to prevent oxidation.

Bupivacaine 0.5% provides profound anesthesia of slower onset for cesarean section delivery but of longer duration of action. Considerable attention has been focused on the drug because it was reported that unintentional intravascular injection could result not only in convulsions but also in almost simultaneous cardiac arrest, with patients often refractory to resuscitation.90 The greater cardiotoxicity of bupivacaine (and etidocaine) compared with other amide local anesthetics has been well established.

When using potent long-acting amide local anesthetics, fractioning the induction dose is critical. Lidocaine has an onset and duration intermediate to those of 2-chloroprocaine and bupivacaine. The need to include epinephrine in the local anesthetic solution to ensure adequate lumbosacral anesthesia limits the use of lidocaine in women with maternal hypertension and uteroplacental insufficiency.

Prolonged postoperative pain relief can be provided by epidural administration of an opioid, such as morphine 4mg or using patient-controlled epidural anesthesia. Delayed respiratory depression may

occur with the use of morphine; hence the patient must be monitored carefully in the postoperative period. Recently, a lipid-encapsulated preparation of morphine (Depo Dur) has been approved for postcesarean section delivery analgesia. It can only be used epidurally and can last up to 48 hours, and the patient must be monitored for delayed respiratory depression.

Anesthetic Complications

Maternal Mortality

A study of anesthesia-related deaths in the United States between 1979 and 1990 showed that the case fatality rate with general anesthesia was 16.7 times greater than that with regional anesthesia. Most anesthesia-related deathswere a result of cardiac arrest due to hypoxemia when difficulties securing the airway were encountered.81 Pregnancy-induced anatomic and physiologic changes, such as reduced functional residual capacity, increased oxygen consumption, and oropharyngeal edema, may expose the patient to serious risks of desaturation during periods of apnea and hypoventilation.

Pulmonary Aspiration

The risk of inhalation of gastric contents is increased in pregnant women, particularly if difficulty is encountered establishing an airway or if airway reflexes are obtunded. Measures to decrease the risks of aspiration include comprehensive airway evaluation, prophylactic administration of nonparticulate antacids, and preferred use of regional anesthesia.

Hypotension

Regional anesthesia may be associated with hypotension, which is related to the degree and rapidity of local anesthetic induced sympatholysis. Thus, greater hemodynamic stability may be observed with epidural anesthesia, where gradual titration of local anesthetic allows for better control of the block level as well as for adequate time for administration of vasopressors in anticipation of blood pressure reduction.

The risk of hypotension is lower in women who are in labor compared with nonlaboring women.91 Maternal prehydration with 15 mL/kg of lactated Ringer's solution before initiation of regional anesthesia and avoidance of aortocaval compression may decrease the incidence of hypotension. It has been demonstrated that for effective prevention of hypotension, the blood volume increase from preloading must be sufficient to result in a significant increase in cardiac output.92 This was possible only with the administration of hetastarch, 0.5–1 liter.92 Nonetheless, controversy exists regarding the efficacy of volume loading in the prevention of hypotension.81,93 If hypotension does occur despite prehydration, therapeutic measures should include increasing displacement of the uterus, rapid infusion of IV fluids, titration of IV ephedrine (5–10 mg), and oxygen administration. In the presence of maternal tachycardia, phenylephrine 25–50 mcg may be substituted for ephedrine in women with normal uteroplacental function. Continued vigilance and active management of hypotension can prevent serious sequelae in both mother or neonate.91,94

Total Spinal Anesthesia

High or total spinal anesthesia is a rare complication of intrathecal injection in modern day practice. It occurs with excessive cephalad spreadof local anesthetic inthe subarachnoid space. Unintentional intrathecal administration of epidural medication as a result of dural puncture or catheter migration may also result in this complication. Left uterine displacement and continued fluid and vasopressor

administration may be necessary to achieve hemodynamic stability. Reverse Trendelenburg position does not prevent cephalad spread and may cause cardiovascular collapse because of venous pooling related to sympathectomy. Rapid control of the airway is essential, and endotracheal intubation may be necessary to ensure oxygenation without aspiration.

Clinical Pearls

- Obstetric patients often complain of difficulty breathing during cesarean section delivery under neuraxial anesthesia.
- Although most common reasons are inability to feel "breathing" as the abdominal and thoracic segments are anesthetized (including the stretch receptors), practitioners must rule out an impending "high spinal" anesthesia by repetitive examinations.
- The following maneuvers are useful to rule out the possibility of high neuraxial anesthesia:
    1. Ability of the patient to phonate
    2. Ability to squeeze the practitioner's hand (indicates that the block level is below the level of the brachial plexus (C6-T1)

Systemic Toxicity of Local Anesthetics

Unintended intravascular injection or drug accumulation after repeated epidural injection can result in high serum levels of local anesthetic. Rapid absorption of local anesthetic from highly vascular sites of injection may also occur after paracervical and pudendal blocks.

Resuscitation equipment should always be available when any major nerve block is undertaken. Intravenous access, airway equipment, emergency drugs, and suction equipment should be immediately accessible. To avoid systemic toxicity of local anesthetic agents, strict adherence to recommended dosages and avoidance of unintentional intravascular injection are essential.

Despite these precautions, life-threatening convulsions and, more rarely, cardiovascular collapse may occur. Seizure activity has been treated with IV thiopental 25–50 mg or diazepam 5–10 mg. In current clinical practice, propofol 20–50 mg or midazolam 2–4 mg are more commonly used. The airway should be evaluated and oxygenation maintained. If cardiovascular collapse does occur, the Advanced Cardiac Life Support (ACLS) algorithm should be followed. Cesarean delivery may be required to relieve aortocaval compression and to ensure the efficiency of cardiac massage.95

Postdural Puncture Headache

Pregnant women have a higher risk for developing postdural puncture headache. The reduced epidural pressure also increases the risk of cerebrospinal fluid leakage through the dural opening.

Neurologic Complications

Neurologic sequelae of central neuraxial blockade, although rare, have been reported. Pressure exerted by a needle or catheter on spinal nerve roots produces immediate pain and necessitates repositioning. Infections such as epidural abscess and meningitis are very rare and may be a manifestation of systemic sepsis. Epidural hematoma can also occur, usually in association with coagulation defects. Nerve root irritation may have a protracted recovery, lasting weeks or months. Peripheral nerve injury as a result of instrumentation, lithotomy position, or compression by the fetal head may occur even in the absence of neuraxial technique.

Regional Anesthesia in Complicated Pregnancy

Pregnancy and parturition are considered "high risk" when accompanied by conditions unfavorable to the well-being of the mother or fetus, or both. Maternal problems may be related to the pregnancy, that is, preeclampsia-eclampsia, hypertensive disorders of pregnancy, or antepartum hemorrhage resulting from placenta previa or abruptio placentae. Diabetes mellitus; cardiac, chronic renal, and neurologic problems; sickle cell disease; asthma; obesity; and drug abuse are not related to pregnancy but often are affected by it. Prematurity (gestation of less than 37 weeks), postmaturity (42 weeks or longer), intrauterine growth retardation, and multiple gestation are fetal conditions associated with risk. During labor and delivery, fetal malpresentation (e.g., breech, transverse lie), placental abruption, compression of the umbilical cord (e.g., prolapse, nuchal cord), precipitous labor, or intrauterine infection (e.g., prolonged rupture ofmembranes) may increase the risk to the mother or fetus.

In general, the anesthetic management of the high-risk parturient is based on the same maternal and fetal considerations as for the management of healthy mothers and fetuses. However, there is less room for error because many of these functions may be compromised before the induction of anesthesia. For example, significant acidosis is prone to develop in fetuses of diabetic mothers when delivered by cesarean section with spinal anesthesia complicated by even brief maternal hypotension.

Preeclampsia-Eclampsia

Pathophysiology and Signs and Symptoms

Hypertensive disorders occur in approximately 7%of all pregnancies and are a major cause of maternal mortality. The most recent diagnostic criterion for preeclampsia is referred to as "proteinaceous increase in blood pressure."96 The presence or absence of edema is no longer considered on of the required criteria. Rather than a specific blood pressure elevation, a blood pressure that is consistently 15% above baseline is now considered diagnostic. The added appearance of convulsions is diagnostic for eclampsia.96 Preeclampsia-eclampsia is a disease unique to humans, occurring predominantly in young nulliparous women. Symptoms usually appear after the 20th week of gestation, occasionally earlier with a hydatidiform mole.

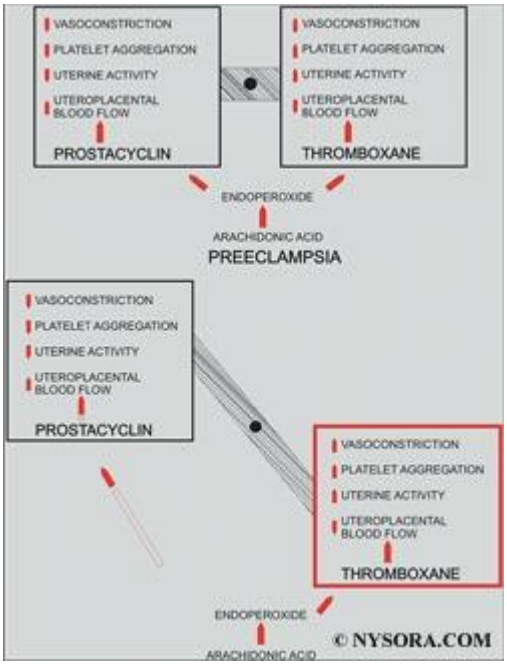

Figure 7: *Pathophysiology of preeclampsia and eclampsia.*

The origin of preeclampsia-eclampsia is unknown, but all patients manifest placental ischemia. Placental ischemia results in a release of uterine renin, an increase in a release of uterine renin, an increase in angiotensin activity, and a widespread arteriolar vasoconstriction causing hypertension, tissue hypoxia, and endothelial damage (**Figure 7**). Fixation of platelets at sites of endothelial damage results in coagulopathies, occasionally in disseminated intravascular coagulation. Enhanced angiotensin-mediated aldosterone secretion leads to an increased sodium reabsorption and edema. Proteinuria, a sign of preeclampsia, is also attributed to placental ischemia, which would lead to local tissue degeneration and a release of thromboplastin with subsequent deposition of fibrin in constricted glomerular vessels. As a result, increased permeability to albumin and other plasma

proteins occurs. Furthermore, there is a decreased production of prostaglandin E, a potent vasodilator secreted in the trophoblast, which normally balances the hypertensive effects of the rennin–angiotensin system.

Many of the symptoms associated with preeclampsia, including placental ischemia, systemic vasoconstriction, and increased platelet aggregation, may result from an imbalance between the placental production of prostacyclin and thromboxane. During normal pregnancy, the placental produces equal amounts of these two, but in a preeclamptic pregnancy, there is seven times more thromboxane than prostacyclin.97 According to the latest theory, endothelial cell injury is central to the development of preeclampsia.98 This injury occurs as a result of reduced placental perfusion, leading to a production and release of substances (possibly lipid peroxidases) causing endothelial cell injury. Abnormal endothelial cell function contributes to an increase in peripheral resistance and other abnormalities noted in preeclampsia through a release of fibronectin, endothelin, and other substances.

Clinical Pearls

Preeclampsia is classified as severe if it is associated with any of the following:

- Systolic BP consistently >15% above baseline
- Diastolic BP consistently >15% above baseline
- Proteinuria of 5 g/24 h
- Oliguria (400 mL/24 h)
- Cerebrovisual disturbances
- Pulmonary edema or cyanosis
- Epigastric pain
- Intrauterine growth retardation

In severe preeclampsia-eclampsia, all major organ systems are affected because of widespread vasospasm. Global cerebral blood flow is not diminished, but focal hypoperfusion cannot be ruled out. Postmortem examination has revealed hemorrhagic necrosis in the proximity of thrombosed precapillaries, suggesting intense vasoconstriction. Edema and small foci of degeneration have been attributed to hypoxia. Petechial hemorrhages are common after the onset of convulsions. Symptoms related to the above changes include headache, vertigo, cortical blindness, hyperreflexia, and convulsions. Cerebral hemorrhage and edema are the leading causes of death in preeclampsia-eclampsia, which together account for approximately 50% of deaths. Heart failure may occur in severe cases as a result of peripheral vasoconstriction and increased blood viscosity from hemoconcentration. Decreased blood supply to the liver may lead to periportal necrosis of variable extent and severity. Subcapsular hemorrhages account for the epigastric pain encountered in severe cases.

In the kidneys, there is swelling of glomerular endothelial cells and deposition of fibrin, leading to a constriction of the capillary lumina. Renal blood flow and glomerular filtration rate decrease, resulting in reduced uric acid clearance and, in severe cases, reduced clearance of urea and creatinine. Although preeclampsia is accompanied by exaggerated retention of water and sodium, the shift of fluid and proteins from the intravascular into the extravascular compartment may result in hypovolemia, hypoproteinemia, and hemoconcentration, which may be further aggravated by proteinuria. The risk of uteroplacental hypoperfusion and poor fetal outcome correlates with the degree of maternal plasma and protein depletion. The mean plasma volume in women with preeclampsia was found to be 9% less than normal, and in those with severe disease it was as much as 30–40% below normal.99

Adherence of platelets at sites of endothelia damage may result in consumption coagulopathy, which develops in approximately 20% of patients with preeclampsia. Mild thrombocytopenia, with platelet count of 100,000–150,000 per mm, is the most common finding. Prolongation of prothrombin and partial throboplastin times indicates consumption of procoagulants. Bleeding time, prolonged in approximately 25% of patients with normal platelet counts, is no longer considered a reliable test of clotting.100 The HELLP syndrome is a particular form of severe preeclampsia characterized by hemolysis, elevated liver enzymes, and low platelets.

The goals of the management of the patient with preeclampsia-eclampsia are to prevent or control convulsions, improve organ perfusion, normalize blood pressure, and correct clotting abnormalities. The mainstay of anticonvulsant therapy in the United States is magnesium sulfate. Its efficacy in preventing seizures has beenwell substantiated, but its mechanism of action remains controversial. The patient usually receives a loading dose of 4 g in a 20% solution, administered over 5 minutes followed by a continuous infusion of 1–2 g/h.

Antihypertensive therapy in preeclampsia is used to lessen the risk of cerebral hemorrhage in the mother while maintaining, even improving, tissue perfusion. Plasma volume expansion combined with vasodilation fulfills these goals.101 Hydralazine is the most commonly used vasodilator because it increases uteroplacental and renal blood flows. Nitroprusside is used during laryngoscopy and intubation to prevent dangerous elevations in blood pressure. Trimethaphan, a ganglion blocking agent, is useful in hypertensive emergencies when cerebral edema and increased intracranial pressure are a concern because it does not cause vasodilation in the brain. Other agents that have been used to control maternal blood pressure include α-methyldopa, nitroglycerine, and now more frequently, labetalol.102

Consumption coagulopathy may require infusion of fresh whole blood, platelet concentrates, fresh frozen plasma, and cryoprecipitate. Delivery is indicated in refractory cases or if the pregnancy is close to term. In severe cases, aggressive management should continue for at least 24–48 hours after delivery.

Anesthesia Management

There are very few contraindications for epidural anesthesia in labor and delivery. In the presence of severe clotting abnormalities or severe plasma volume deficit, the risk:benefit ratio favors other forms of anesthesia.103 In volume-depleted patients positioned with left uterine displacement, epidural anesthesia does not cause an unacceptable reduction in blood pressure and leads to a significant improvement in placental perfusion.104With the use of radioactive xenon, it was shown that the intervillous blood flow increased by approximately 75% after the induction of epidural analgesia (10 mL bupivacaine 0.25%).105 The total maternal body clearance of amide local anesthetics is prolonged in preeclampsia, and repeated administration of these drugs can lead to higher blood concentrations than in normotensive patients.106

For cesarean section delivery, the sensory level of regional anesthesia must extend to T3-4, making adequate fluid therapy and left uterine displacement even more vital. Epidural anesthesia has been preferred to spinal anesthesia in preeclamptic women because of its slower onset of action and controllability. The rapid onset of spinal anesthesia may be associated with hypotension, particularly in a volume-depleted patient. However, in two recent studies, the incidence of hypotension, perioperative fluid and ephedrine administration, and neonatal conditions were found to be similar in preeclamptic women who received either epidural or spinal anesthesia for cesarean delivery.107,108 There is an increased sensitivity to vasopressors in preeclampsia; therefore, lower doses of ephedrine are usually required to correct hypotension.

Antepartum Hemorrhage

Antepartum hemorrhage occurs most commonly in association with placenta previa (abnormal implantation on the lower uterine segment and partial to total occlusion of the internal cervical os) and abruptio placentae. Placenta previa occurs in 0.11% of all pregnancies, resulting in up to 0.9% incidence of maternal and a 17–26% incidence of perinatal mortality. It may be associated with abnormal fetal presentation, such as transverse lie or breech. Placenta previa should be suspected whenever a patient presents with painless, bright red vaginal bleeding, usually after the seventh month of pregnancy. The diagnosis is confirmed by ultrasonography. If the bleeding is not profuse and the fetus is immature, obstetric management is conservative to prolong the pregnancy. In severe cases or if the fetus is mature at the onset of the symptoms, prompt delivery is indicated, usually by cesarean section. An emergency hysterectomy may be required because of severe hemorrhage, even after the delivery of the placenta, because of uterine atony. In patients who have undergone prior uterine surgery, the risk of severe hemorrhage is even greater owing to a higher incidence of placenta acreta (penetration of myometrium by placental villi).

Abruptio placentae occurs in 0.2–2.4% of pregnant women, usually in the final 10 weeks of gestationandin association with hypertensive diseases. Complications include Couvelaire uterus (ie, when extravasated blood dissects between the myometrial fibers), renal failure, disseminated intravascular coagulation, and anterior pituitarynecrosis (i.e., Sheehan syndrome). The maternal mortality is high (1.8–11.0%), and the perinatal mortality rate is even higher (excess of 50%). The diagnosis of abruptio placentae is based on the presence of uterine tenderness, hypertonus, and vaginal bleeding of dark, clotted blood. Bleeding may be concealed if the placental margins have remained attached to the uterine wall. Changes in the maternal blood pressure and pulse rate, indicative of hypovolemia, may occur if the blood loss is severe. Fetal movements may increase during acute hypoxia and decrease if hypoxia is gradual. Fetal bradycardia and death may ensue.

Anesthesia Management

Establishment of invasive monitoring (arterial line, central venous catheter) and blood volume replacement via a 14- or 16-gauge stimulating needle is usually required. If clotting abnormalities exist, blood components and fresh frozen plasma, cryoprecipitate, and platelet concentrates may be required. Epidural anesthesia may be considered, but general anesthesia is indicated in the presence of uncontrolled hemorrhage and coagulation abnormalities.109

Preterm Delivery

Preterm labor and delivery present a significant challenge to the anesthesiologist because the mother and the infant may be at risk. The definition of prematurity was altered to distinguish between the preterm infant, born before the 37th week of gestation, and the small-for-gestational-age infant, who may be born at term but whose weight is more than 2 standard deviations below the mean. Although preterm deliveries occur in 8–10% of all births, they account for approximately 80% of early neonatal deaths. Severe problems, such as respiratory distress syndrome, intracranial hemorrhage, hypoglycemia, hypocalcemia, and hyperbilirubinemia, are prone to develop in preterm infants.

Obstetricians frequently try to inhibit preterm labor to enhance fetal lung maturity. Delaying delivery be even 24–48 hours may be beneficial if glucocorticoids are administered to the mother to enhance fetal lung maturity. Various agents have been used to suppress uterine activity (tocolysis) such as ethanol, magnesium sulfate, prostaglandin inhibitors, β-sympathomimetics, and calcium channel blockers. β-Adrenergic drugs, such as ritodrine and terbutaline, are the most commonly used tocolytics. Their predominant effect is β2 receptor stimulation, which results inmyometrial inhibition, vasodilation, and bronchodilation. Numerous maternal complications, that is, hypotension, hypokalemia, hyperglycemia, myocardial ischemia, pulmonary edema, and death, have been reported.

Anesthesia Management

Complications may occur because of interactions with anesthetic drugs and techniques. With the use of regional anesthesia, peripheral vasodilation caused by β-adrenergic stimulation increases the risk of hemodynamic instability in the presence of preexisting tachycardia, hypotension, and hypokalemia. The premature infant is known to be more vulnerable than the term newborn to the effects of drugs used in obstetric analgesia and anesthesia. However, there have been few systemic studies to determine the maternal and fetal pharmacokinetics and dynamics of drugs throughout gestation.

There are several postulated causes of enhanced drug sensitivity in the preterm newborn: less protein available for drug binding; higher levels of bilirubin, which may compete with the drug for protein binding; greater drug access to the central nervous system because of a poorly developed blood–brain barrier; greater total body water and lower fat content; and a decreased ability tometabolize and excrete drugs. However, most drugs used in anesthesia exhibit low to moderate degrees of binding in the fetal serum: approximately 50% for bupivacaine, 25% for lidocaine, 52% for meperidine, and 75% for thiopental.

In selection of the anesthetic drugs and techniques for delivery of a preterm infant, concerns regarding drug effects on the newborn are far less important than prevention of asphyxia and trauma to the fetus. For labor vaginal delivery, well-conducted epidural anesthesia is advantageous in providing good perineal relaxation. Before induction of epidural blockade, the anesthesiologist should ascertain that the fetus is neither hypoxic nor acidotic. Asphyxia results in a redistribution of fetal cardiac output, which increases oxygen delivery to vital organs such as the brain, heart, and adrenals. Regardless, these changes in the preterm fetus may be better preserved with bupivacaine or chloroprocaine than with lidocaine.110,111 Preterminfants with breech presentation are usually delivered by cesarean section. Regional anesthesia can be successfully used, with nitroglycerin available for uterine relaxation if needed.

Clinical Pearls

- In selecting the anesthetic drugs and techniques for delivering a preterminfant, concerns about drug effects on the newborn are far less important than prevention of asphyxia and trauma to the fetus.
- Before induction of epidural blockade, the anesthesiologist should ascertain that the fetus is neither hypoxic nor acidotic.

Regional analgesia during laborandvaginal delivery has become the preferred technique of pain relief in selected high risk patients because it prevents obtundation of the mother and depression of the fetus and reduces many of the potential adverse physiologic effects of labor, such as increased oxygen consumption and hemodynamic alterations. For cesarean section delivery, regional anesthesia has emerged as a safe and effective technique in high-risk parturients, partly because of the added ability to provide prolonged postoperative analgesia.

Nonobstetric Surgey in the Pregnant Woman

Approximately 1.6–2.2% of pregnant women undergo surgery for reasons unrelated to parturition. Apart from trauma, the most common emergencies are abdominal, intracranial aneurysms, cardiac valvular disease, and pheochromocytoma. Surgery to correct an incompetent cervix with Shirodkar or McDonald sutures is a procedure directly related to surgery.

When the necessity for surgery arises, anesthetic considerations are related to the alterations in maternal physiologic condition with advancing pregnancy, the teratogenicity of anesthetic drugs, the indirect effects of anesthesia on uterplacental blood flow, and the potential for abortion or premature delivery. The risks must be balanced to provide the most favorable outcome for mother and child. Five major studies have attempted to relate surgery and anesthesia during human pregnancy to fetal outcome as determined by anomalies, premature labor, or intrauterine death.112–115 Although they failed to correlate surgery and anesthetic exposure with congenital anomalies, all the studies demonstrated an increased incidence of fetal death, particularly after operations performed in the first trimester. A particular anesthetic agent of technique was not implicated. The condition that necessitated surgery was the most relevant factor, with fetal mortality greatest after pelvic surgery or procedures performed for obstetric indications, that is, cervical incompetence.

The cytotoxicity of anesthetic agents is closely associated with biodegradation, which, in turn, is influenced by oxygenation and hepatic blood flow. Thus, the complications associated with anesthesia—maternal hypoxia, hypotension, administration of vasopressors, hypercarbia, hypocarbia, and electrolyte disturbances—may be greater factors in teratogenesis than the use of the agents themselves.116,117

Experimental evidence on exposure to specific drugs and agents is discussed briefly, with the understanding that it is difficult to extrapolate laboratory data to the clinical situation in humans. Very large numbers of patients must be exposed to a suspected teratogen before its safety can be ascertained. Complicating factors include the frequency of maternal exposure to a multiplicity of drugs; the difficulty in separating the effects of the underlying disease process and surgical treatment from those of the drug administered; differing degrees of risk with stage of gestation; and the variety, rather than the consistency, of anomalies that appear in association with one agent. With regard to regional anesthetic agents, local anesthetics have not been shown to be teratogenic in animals or humans.

Caution has been exercised with sedatives before block placement because of several reports describing a specific relationship between diazepam and oral clefts; however, other studies have not confirmed this.118,119 When appropriate, regional techniques are a viable alternative to general anesthesia in the pregnant patient presenting for nonobstetric surgery. As maternal pain and apprehension may result in decreased uterine blood flow and deterioration of the fetus (similar to infusions of epinephrine or norepinephrine), early intervention for pain with regional techniques, i.e., peripheral nerve blocks per epidural infusions, can be substantiated especially in the compromised patient.120

Clinical Pearls

- Local anesthestics have not been shown to be teratogenic in animals or humans.

Summary

Pregnancy results in a number of significant physiologic changes that require adjustment in anesthesia and analgesia techniques for safe and effective management of the pregnant patient. It is prudent to delay surgeries, when possible, until after the birth of the fetus. Only emergency surgery should be considered during the first trimester.

Regional techniques have becomethe most accepted for pain relief during labor and vaginal

delivery. Likewise, neuraxial techniques are now the most frequently administered anesthetics for cesarean section delivery.Advances in regional anesthesia and itswidespread routine use have resulted in significantly enhanced maternal safety compared with that with general anesthesia.

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