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Anesthesia for Cesarean Delivery

S. Datta et al., *Obstetric Anesthesia Handbook*,
DOI 10.1007/978-0-387-88602-2_12,

In recent years, the frequency of cesarean delivery has increased markedly. In 1965, the incidence was 4.5%.[1] Since then there has been a steady increase in cesarean delivery rate driven by both an increase in the percentage of all women having a first cesarean and a decline in the percentage of women delivering vaginally after a previous cesarean. As per Center for Disease Control, Atlanta, USA, the cesarean delivery rate in USA in 2005 was 30.2%. The rate of cesarean delivery varies across the world with England, 23% in 2004, Brazil 47% (some health districts with 85%), and India (Delhi 19–35%). In Sweden, Denmark, and Netherlands, the cesarean delivery rate is still close to 10% with some of the world's lowest maternal and perinatal mortality rates.[2–4]

Successful anesthesia for cesarean delivery can be accomplished in a number of ways. Common to all is the need for expert technical skills and understanding of maternal and fetal physiology, pathophysiology of associated diseases, and pharmacology. The two major anesthetic approaches are regional and general anesthesia. Discussion of regional anesthesia will include three techniques – spinal, epidural, and combined spinal epidural anesthesia – since local infiltration and field blocks are rarely used in the United States.

Regional Anesthesia

Spinal Anesthesia (Subarachnoid Block)

The advantages of spinal anesthesia for cesarean delivery are as follows:

1. Simplicity of technique
2. Speed of induction (in contrast to an epidural block)
3. Reliability
4. Minimal fetal exposure to the drug(s)

5. An awake parturient
6. Minimization of the hazards of aspiration

Disadvantages of spinal anesthesia for cesarean delivery include the following:

1. High incidence of hypotension
2. Intrapartum nausea and vomiting
3. Possibility of headaches after dural puncture
4. Limited duration of action (unless a continuous technique is used)

Problems Associated with Spinal Anesthesia

Hypotension. Following induction of spinal anesthesia for cesarean delivery, the incidence of maternal hypotension, usually defined as a decrease in systolic blood pressure to below 100 mmHg or a decrease of more than 30 mmHg from the preanesthetic value, can be as high as 80%. These hemodynamic changes result from a blockade of sympathetic vasomotor activity that is accentuated by compression of the aorta and inferior vena cava by the gravid uterus when the patient is in the supine position.

The higher the segmental sympathetic blockade (especially greater than T4), the greater the risk of hypotension and associated emetic symptoms.[5] The supine position significantly increases the incidence of hypotension. Ueland and colleagues observed an average decrease in blood pressure from 124/72 mmHg to 67/38 mmHg in mothers who were placed in the supine position following the induction of spinal anesthesia, whereas the blood pressure averaged 100/60 mmHg for mothers in the lateral position (Fig. 12-1).[6]

The significance of maternal hypotension lies in the threat to the well-being of both mother and fetus if the decreases in the blood pressure and cardiac output are not promptly recognized and corrected. Brief episodes of maternal hypotension can lower Apgar scores, prolong the time to sustained respiration, and produce fetal acidosis.[7,8] Short periods of hypotension (not more than 2 min) result in minimal fetal acidosis but no effect on newborn neurobehavioral findings between 2 h and 4 h of age. With prolonged periods of hypotension Hollmen and associates have shown neurological changes for at least

48 h in infants born to mothers who had epidural anesthesia for cesarean delivery.[9] Since spinal anesthesia offers major clinical advantages for cesarean delivery, efforts have been directed at preventing maternal hypotension. Prehydration or acute volume expansion (15–30 min prior to cesarean delivery) with 1,000–1,500 mL of lactated Ringer's solution has been suggested.[10] This dictum was challenged and a group from South Africa found no beneficial effect of a predetermined amount of volume expansion before the induction of spinal anesthesia for cesarean section.[11] In a double-blind study, Park et al.[12] randomized 55 parturients randomized to receive one of 10 mL/kg, 20 mL/kg, or 30 mL/kg of crystalloid volumes prior to induction of spinal anesthesia. Measurements included mean arterial blood pressure (MAP), cardiac index (CI), and systemic vascular resistance index (SVRI) recorded using noninvasive thoracic impedance monitoring until delivery. Maternal and neonatal colloid oncotic pressures were measured. All groups showed declines in MAP and SVRI from baseline at 5 min after spinal anesthesia, but the amount of decline did not differ among groups. Total ephedrine and additional intravenous (i.v.) fluid administered did not differ among groups.

Similar findings were also observed by Jackson et al.[13] Hence a predetermined amount of volume expansion may not be necessary before initiation of spinal block for cesarean section. On the other hand, colloid administration (1,000 ml Dextran 60, 500 ml Hydroxyethyl Starch 10%) prior to initiation of spinal anesthesia has a protective effect in minimizing the degree of hypotension.[14,15]

Several authors have observed fetal hyperglycemia, acidosis, and, ultimately, neonatal hypoglycemia when a dextrose-containing solution was used for acute volume expansion.[16,17] This has led to not recommending the use of dextrose-containing solutions for cesarean delivery unless there is an indication.

Vasopressors. The value of the administration of a prophylactic vasopressor is still controversial. From a systematic meta-analysis review of available studies to determine the dose–response characteristics of prophylactic i.v. ephedrine for the prevention of hypotension during spinal anesthesia for cesarean delivery, the authors concluded that the efficacy is

poor at smaller doses, whereas at larger doses the likelihood of causing hypertension is actually more than that of preventing hypotension.[18] On the contrary, phenylephrine (10 μgm/min) added to prophylactic ephedrine infusion (2 mg/min) halved the incidence of hypotension following the induction of spinal anesthesia as compared to ephedrine-alone group.[19] The authors do not routinely use prophylactic ephedrine because it might not be necessary in all cases and hypertension can develop in some cases. However, if there is a trend towards decreasing blood pressure, prophylactic ephedrine is used by some anesthesiologists to decrease chances of further hypotension. There is general agreement that if hypotension should develop, it should be promptly treated by a combination of a bolus infusion of intravenous crystalloid, further uterine displacement if possible, and the administration of intravenous doses of ephedrine, beginning with 5–10-mg increments to normalize the blood pressure. Although ephedrine has been the drug of choice to treat hypotension for decades in this institution, recent literature favors the rejuvenation of the use of phenylephrine to treat hypotension following spinal anesthesia

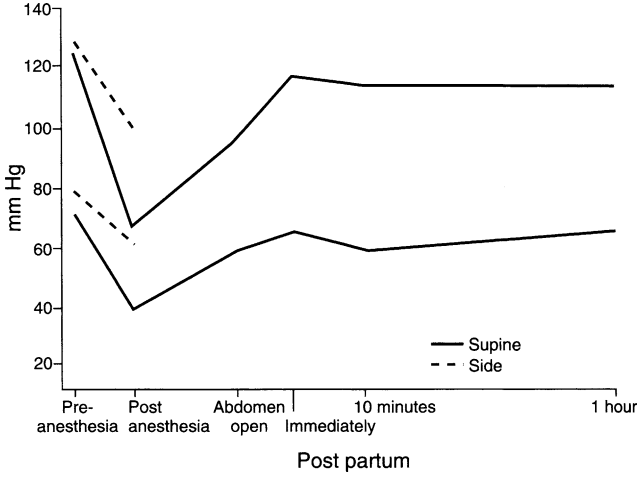

Figure 12–1. Effect of maternal blood pressure during cesarean section under spinal anesthesia. (Adapted from Ueland et al.[6])

induction. This has changed practice among some anesthesiologists. The studies claiming superiority of phenylephrine over ephedrine state the following advantages: higher mean umbilical artery pH, less nausea and vomiting, and avoidance of excessive tachycardia.[20,21] However, a recent study found no significant difference among these factors between the phenylephrine and ephedrine group even in nonelective cesarean deliveries.[22] Furthermore, no differences were found in the incidence of hypotension when a combination of phenylephrine and ephedrine was used versus using either one of them alone.[21,23]

In conclusion, there is a choice of vasopressors that can be used. It does not matter what is used as long as the hypotension is corrected. However, in some situations, tachycardia followed by ephedrine administration may be contraindicated (cardiac problems) and under these circumstances phenylephrine is a good alternative choice. A final controversy yet to be addressed is how phenylephrine affects the uteroplacental blood flow when there is a prior uteroplacental insufficiency.

The incidence of hypotension during spinal anesthesia for cesarean delivery in parturients who have active labor is lower than in pregnant women not in labor.[24] Possible explanations may be (1) the *autotransfusion of approximately 300 mL of blood into the maternal systemic circulation with intermittent uterine contractions,* (2) *a decrease in the size of the uterus secondary to a loss of amniotic fluid if the membranes are ruptured,* and (3) *higher maternal catecholamine concentrations in parturients in labor.*

Nausea and Vomiting. These symptoms commonly accompany spinal anesthesia. The mechanism is unclear but probably involves (1) systemic hypotension, which decreases cerebral blood flow and produces cerebral hypoxia, and (2) traction on the peritoneum or other viscera, which produces a vagal response manifested by a decrease in the heart rate and a resultant decrease in cardiac output. Datta et al. have evaluated the effectiveness of prompt treatment of any decrease in blood pressure on the prevention of nausea and vomiting. Their conclusion was that intravenous ephedrine, when given as soon as any reduction in blood pressure is detected, prevents a further decrease in blood pressure and significantly

diminishes the incidence of nausea and vomiting. In addition, acid–base values from the umbilical vessels of newborns whose mothers were so treated were significantly better than in the newborns of mothers who developed frank hypotension.[25] As stated in the foregoing paragraphs, in one study authors observed a reduction of nausea and vomiting when phenylephrine was used in comparison to ephedrine to treat maternal hypotension.[21]

Traction of the uterus and/or peritoneum at the time of surgery may increase the incidence of emetic symptoms in the presence of inadequate regional anesthesia.[26] Visceral pain from traction of the peritoneum or abdominal viscera (e.g., exteriorization of the uterus or stretching of the lower uterine segment) will transmit afferent stimuli via the vagus nerve to stimulate the central vomiting center. Adequate sensory anesthesia can be obtained with appropriate doses of local anesthetic, and this will also decrease the incidence of discomfort in parturients. The addition of intrathecal or epidural opioids will intensify the quality of sensory anesthesia and will decrease the incidence of intraoperative nausea and vomiting.[27,28] Nausea and vomiting following delivery of the baby can be minimized with the administration of small doses of intravenous droperidol, metoclopramide, ondansetron, dexamethasone, and combination of droperidol and dexamethasone (Figs. 12-2 and 12-3).[29–33] In United States, droperidol is not being used for this purpose because of FDA directive (prolonged QT interval and torsades de pointe).

Scopolamine patch has also been shown to be effective in decreasing nausea and vomiting.[34] In addition, acupressure via wrist band for P6 point has been shown to be somewhat effective in decreasing nausea and vomiting during cesarean delivery.[35,36] Ephedrine 25–50 mg i.m. has been used for nausea and vomiting in nonpregnant patients and is also an option during cesarean delivery. The beneficial effect of ephedrine is due to sympathomimetic effect of ephedrine on vestibular apparatus as well as improving medullary blood flow to chemoreceptor triggering zone.[37] Some anesthesiologists observed the benefit of having patients smell isopropyl alcohol in the treatment of nausea and vomiting. Lastly, subhypnotic doses of either midazolam (1 mg bolus, 1 mg/h infusion)

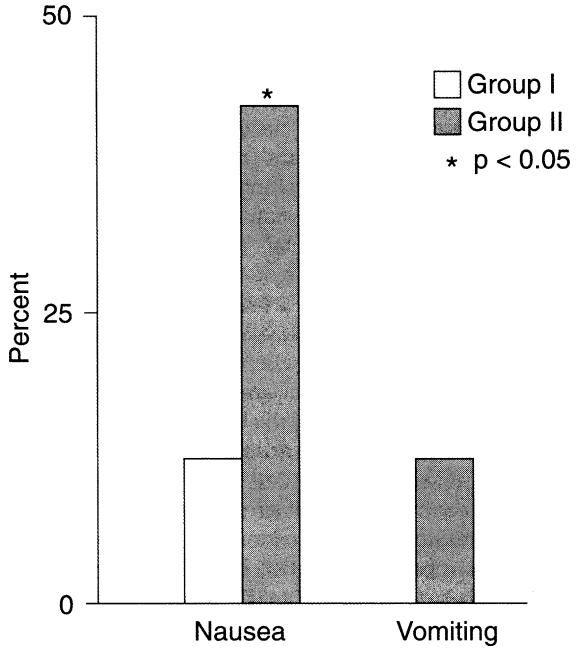

Figure 12–2. Incidence of nausea and vomiting with intravenous droperidol following delivery of the fetus during cesarean section (group 1-droperidol, group 2-saline).[29]

or propofol 20 mg bolus, 1 mg/kg infusion have also been effective in decreasing nausea and vomiting during cesarean delivery under spinal anesthesia.[38]

Headache. Headache as a result of dural puncture (PDPH) is the most troublesome complication of spinal anesthesia in obstetrics. The reported incidence of PDPH varies greatly from institution to institution (0–10%). Over the years several interesting techniques have been reported to decrease the incidence of PDPH: (1) the method of insertion of the spinal needle may be an important factor in reducing PDPH. A recent meta-analysis by Richman et al. showed a significant reduction in PDPH with parallel insertion of the spinal needle in relation to the dural fibers.[39] (2) Needles of different sizes were tried

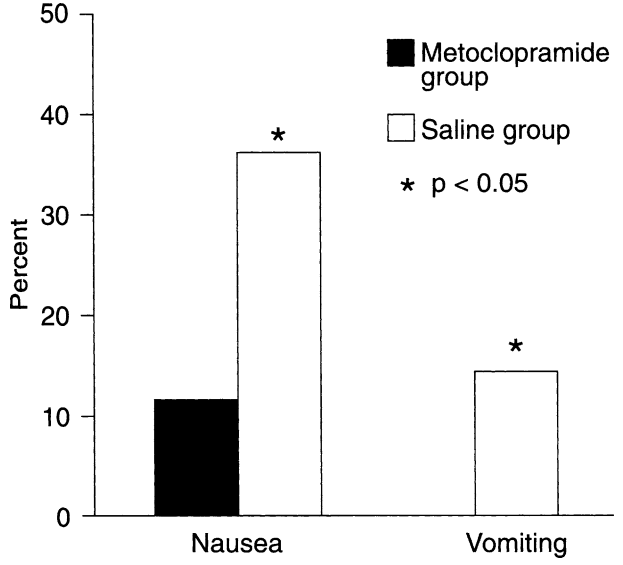

Figure 12–3. Incidence of nausea and vomiting with intravenous metoclopramide following delivery of the fetus during cesarean section. (Adapted from Chestnut.[31])

to observe the incidence of PDPH.[40] When 27-gauge Quincke needles were used, the incidence of PDPH in the author's institution remained 2–3%. (3) Configuration of the needles is also important. The long-beveled Quincke needle is associated with a higher incidence of headache than are pencil-point needles like the Greene, Whitacre, and Sprotte (Fig. 12-4).[41] This might be related to the amount of injury to the dural fibers. A meta-analysis also supports that noncutting smaller-size needles are associated with decreased PDPH.[42]

Ready and colleagues observed the effect of needle size and angle of dural puncture in relation to the rate of transdural fluid leak.[43] Quincke needles with a 30-degree approach caused a rate of leak across the dura significantly less than those following 60- and 90-degree approaches. An approach perpendicular to the dural fibers was associated with a higher incidence of PDPH. The 22-gauge Whitacre needle was also

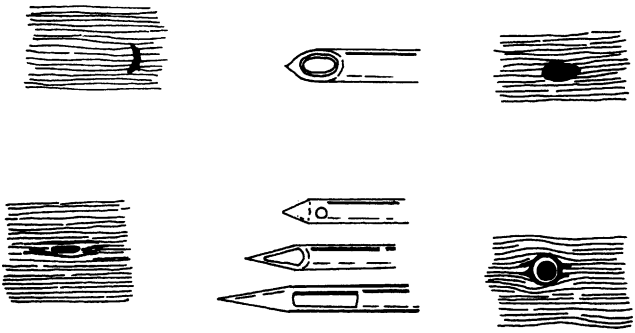

Figure 12–4. Openings made in the dura during and after insertion of pencil-point needles (Pajunk, Greene, Whitacre) and beveled needle (Quincke). Small openings are made by pencil-point needles.

associated with less leak than the 22-gauge Quincke needle. When a 25-gauge Whitacre needle was used, the incidence of headache in the author's institution was about 1%. The majorities of headaches are mild and self-limited and resolve without problems. Oral and intravenous caffeine can decrease the incidence of headaches temporarily.[40]

Technical Factors. A sensory level between the fourth and sixth thoracic dermatome is necessary for adequate anesthesia. This level is achieved in the pregnant women with doses of local anesthetic well below the required amounts in nonpregnant individuals in both spinal and epidural anesthesia (Fig. 12-5). A hyperbaric solution is preferred for cesarean section because it tends to spread to the thoracic kyphosis at approximately T5–6[44] regardless of the parturients height. Norris observed no correlation between the height or weight of parturients and the spread of spinal anesthesia when using a fixed dose (12 mg) of 0.75% hyperbaric bupivacaine in women between 4′11″ and 5′8″.[45] DeSimone and colleagues, on the other hand, compared a 12-mg with a 15-mg dose of hyperbaric bupivacaine for cesarean section and observed a significantly higher spread with 15 mg.[46] Hartwell et al. studied the correlation between vertebral length measured from

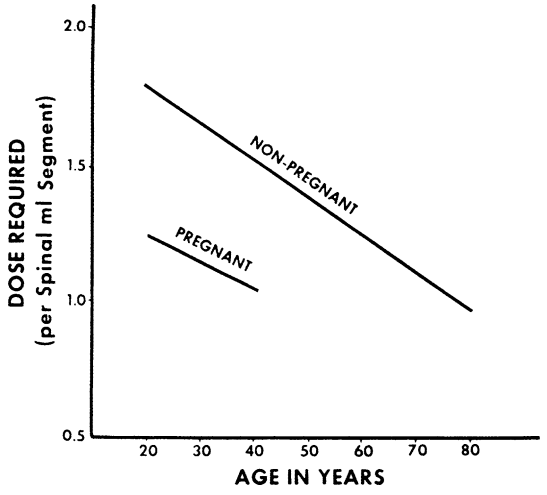

Figure 12–5. Dose required (milliliters of lidocaine per spinal segment) in parturients and nonpregnant patients. (From Bromage, p. 566.[148] Used with permission from Elsevier.)

C7 to the level of the iliac crest and to the sacral hiatus and the sensory anesthetic level after the subarachnoid administration of 12 mg of hyperbaric bupivacaine for cesarean section. There was no correlation between patient height, weight, or body mass index and the sensory anesthesia level; however, interestingly, there was a correlation between vertebral length and sensory anesthesia level.[47] Twelve milligrams should be adequate for the majority of parturients.

Sprague showed that in order to avoid placing the patient in the supine position for even spread of the local anesthetic, spinal anesthesia should be induced with the patient in the *right* lateral position. Subsequent placement in the left semilateral position with a wedge under the right hip allows for immediate left uterine displacement and for more even distribution of the hyperbaric local anesthetic through the subarachnoid space.[48]

Medications for Spinal Anesthesia

Table 12-1lists current medications as well as their durations of action.

Table 12–1. Medications for Spinal Anesthesia

Drugs in Current Use	Duration of Surgical Anesthesia
0.5% tetracaine in 5% dextrose	90–120 min
5% lidocaine in 7.5% dextrose in water	45–60 min
0.75% bupivacaine in 8.5% dextrose in water	90–120 min
0.5% bupivacaine in 8.0% dextrose in water	90–120 min but not yet approved by FDA
5% meperidine in 10% dextrose, same volume to make it hyperbaric	45–50 min

Hyperbaric bupivacaine, 0.75%, has become a popular local anesthetic for cesarean section in our hospital (Brigham and Women's). The addition of 0.2 mg of epinephrine will improve the quality of analgesia.[49,50] Sensory and motor block is prolonged by about 30 min. [49,50] However, the onset of sensory block to T4 is delayed by about 2–6.5 min.[51] Intrathecal narcotics have been administered together with local anesthetics at the time of administration of spinal anesthesia. A combination of local anesthetic and narcotic has been shown to intensify the sensory anesthesia; visceral nociceptive afferents have also been found to be blunted. Fentanyl (6.25–12.5 μg) mixed with 0.75% bupivacaine is associated with excellent intraoperative analgesia as well as a few hours of postoperative pain relief.[27] Courtney and colleagues observed longer postoperative pain relief with 10 μg of sufentanil as compared with 6.25 μg of fentanyl.[52]

Subarachnoid morphine, 0.1–0.5 mg, mixed with 0.75% hyperbaric bupivacaine has also been used,[53] with postoperative pain relief lasting between 17 h and 27 h. However, one should be aware of the possibility of delayed respiratory depression with the use of subarachnoid morphine. Addition

of small doses of clonidine (30–60 μg) mixed with fentanyl and morphine will improve postoperative pain relief. Using the dose–response effect of intrathecal morphine, 0.1 mg was observed to be optimal with fewer side effects.[54] Butorphanol 0.4 mg mixed with 0.75% hyperbaric bupivacaine has been used in the subarachnoid space. Postoperative analgesia lasted as long as 8.2 h, but this has not become popular at this time.[55]

Interestingly, intrathecal meperidine (1 mg/kg) without local anesthetics has been used for cesarean section with success. One study compared 5% hyperbaric lidocaine to 1 mg/kg hyperbaric meperidine for cesarean section. The duration of sensory anesthesia was longer with hyperbaric meperidine.[56] Meperidine 10 mg added to intrathecal bupivacaine for cesarean section was associated with prolonged postoperative analgesia but with greater intraoperative nausea and vomiting in one study. [57] The newer anesthetics levobupivacaine and ropivacaine do not seem to add any great advantage. One study compared bupivacaine, levobupivacaine, and ropivacaine for cesarean section anesthesia and concluded that the racemic mixture of bupivacaine combined with sufentanil provided significantly superior anesthesia, and remains an appropriate choice when performing cesarean section. [58] The anesthesiologists at Brigham and Women's Hospital use 12–13 mg of hyperbaric 0.75% bupivacaine, 10–20 μg of fentanyl, and 200 μg of preservative-free morphine for spinal anesthesia.

Summary of Spinal Anesthesia for Cesarean Section

1. Bicitra, 30 mL, and metoclopramide, 10 mg, intravenously (unless contraindicated)
2. Good intravenous access and use of Ringer's lactate, unless contraindicated
3. Monitoring of pulse, blood pressure, electrocardiogram (ECG), and oxygen saturation
4. Hyperbaric bupivacaine, 0.75% (12–13 mg), except in extremes of height, mixed with 10–20 μg of fentanyl and 100–200 μg of morphine, depending upon the institution.

At Brigham and Women's, we typically use 200 μg of morphine.
5. Use of 27-gauge Quincke or 25-gauge Whitacre needles
6. Right lateral position for induction of spinal anesthesia
7. Routine left uterine displacement during surgery until delivery of the baby
8. Treatment of decreases in maternal blood pressure with phenylephrine, 40 μg, in incremental doses or ephedrine in 5–10 mg increments.
9. Oxygen by face mask
10. Postoperative monitoring for delayed respiratory depression if subarachnoid morphine is used

Continuous spinal anesthesia can be used in patients with short stature and morbidly obese parturients because one can use small doses to gradually attain a desired level of sensory anesthesia to decrease the incidence of hypotension and avoid an overly high block.

Contraindications for Spinal Anesthesia for Cesarean Section

1. Severe maternal bleeding
2. Severe maternal hypotension
3. Coagulation disorders
4. Some forms of neurological disorders
5. Patient refusal
6. Technical problems
7. Short stature and morbidly obese parturients due to the fear of high spinal block
8. Sepsis, infection in the area of needle insertion or generalized

Continuous spinal anesthesia may be used if there is an accidental dural tap while performing the epidural anesthesia, or where intentional dural puncture is made by an epidural needle, e.g., in obese parturients. Small increments of local anesthetic, 6 mg of bupivacaine mixed 10 μg of fentanyl and 0.2 mg of morphine, can be used for initiation of the block. Further local anesthetic can be given by the catheter if needed.

Epidural Anesthesia

Advantages of epidural anesthesia for cesarean section include the following:

1. Lesser incidence and severity of maternal hypotension
2. Avoidance of dural puncture, which may diminish the incidence of headaches. At this time this is controversial.
3. With a catheter technique, anesthesia can be provided for longer operations. In addition, postoperative pain relief can be also achieved with local anesthetics and epidural narcotics

Disadvantages of epidural analgesia include the following:

1. Increased complexity of the technique with a greater chance of failure. Slower onset of anesthesia, so not useful in urgent situations; however, to certain extent by adding bicarbonate to the local anesthetics and the use 3-chloroprocaine can hasten the onset time.
2. Need for larger amounts of local anesthetic agent

Problems Associated with Epidural Anesthesia

Cardiovascular Effects. There are substantial differences between the cardiovascular effects of lumbar epidural anesthesia and spinal anesthesia for cesarean delivery. A reduction in arterial blood pressure is usually less in epidural anesthesia because of the slower onset of the block. Local anesthetic containing epinephrine (1:200,000), when used for cesarean section, may contain epinephrine from 100 μg to 125 μg when injected into the epidural space. Systemic absorption of epinephrine can cause a decrease in maternal blood pressure because of its β-mimetic effect.[59]

Technical Factors. Maternal position affects both the adequacy of anesthesia and fetal outcome. The investigators at Brigham and Women's Hospital found that placing the mother in the lateral position during induction of a lumbar epidural block for cesarean delivery did not affect the adequacy of the block and resulted in improved acid–base values in umbilical cord blood.[60] Higher concentrations of bupivacaine were found in the umbilical cord blood of the more acidotic fetuses delivered to mothers who had been supine. This is probably

the result of "ion trapping" of the weakly basic local anesthetic in the more highly acidic fetal blood. However, none of the newborns in this study demonstrated any untoward effects as a result of the higher level of bupivacaine. Our practice is to keep parturients in the semi-sitting position during induction of anesthesia. With this technique, one can ensure an adequate block of the sacral nerves in order to block pelvic pain during delivery and during traction of the vagina and peritoneal structures. An additional advantage of this maneuver is the observation that the cardiac output in the pregnant woman is higher in the sitting position as compared with the supine position.

Complications of Epidural Anesthesia

1. Unintentional intravascular injection of local anesthetic through the epidural catheter occurs in approximately 2.3% of patients.
2. The incidence of dural puncture varies between 0.2% and 20%, depending on the experience of the anesthesiologist. The incidence of PDPH with a 17-gauge needle may be as high as 76%.
3. The incidence of shivering after induction of epidural anesthesia has been observed to vary from 14% to 68%. The peak onset of shivering usually takes place 10 min after induction of epidural anesthesia.[61] The mechanism of shivering is not known; however, the incidence can be decreased by epidural fentanyl[62] or sufentanil[63] or by intravenous meperidine.

Contraindications for Epidural Anesthesia

1. Severe maternal hypotension
2. Coagulation disorders
3. Some forms of neurological disorders
4. Patient refusal
5. Technical problems
6. Sepsis, local infection in the area of needle insertion or generalized

Local Anesthetics for Epidural Anesthesia

Table 12-2 lists current medications as well as their durations of action.

Table 12–2. Local Anesthetics for Cesarean Delivery

Drugs in Current Use	Duration of Surgical Anesthesia
Bupivacaine 0.5%	75–90 min
Ropivacaine 0.5%	75–90 min
Levobupivacaine 0.5%	75–90 min
Lidocaine with epinephrine 2%	75–90 min
2-chloroprocaine 3%	25–35 min

Unless contraindicated, 2% lidocaine with epinephrine is our drug of choice because of its excellent sensory and motor anesthesia and its sufficiently long duration of action. The lower concentration of bupivacaine (0.5%) provides a slower onset of action; hence, there is a lesser incidence of hypotension. Both 0.5% ropivacaine and 0.5% levobupivacaine have been compared with 0.5% bupivacaine for cesarean section.[64–66] No significant clinical outcome differences were observed between levobupivacaine and bupivacaine to change our practice.[64] Similarly, no significant differences were found between ropivacaine and bupivacaine, except one study that found prolonged motor block with 0.75% ropivacaine.[65,67,68] The addition of 50–100 μg of fentanyl to local anesthetic agents can improve the intensity of sensory anesthesia[69] and thus can reduce the requirements of added analgesics and tranquilizers during the operation. *2-Chloroprocaine is an ideal local anesthetic in the presence of fetal distress. Its short maternal half-life as well as fetal plasma half-life will be beneficial in such a situation.* The onset of the block can be hastened by adding sodium bicarbonate to the local anesthetic (1 ml to 9–10 ml of local anesthetic). This will not only make the block faster but also improve the quality of the block. One of the disadvantages of chloroprocaine for cesarean section is the poor quality and shorter duration of analgesia when epidural μ-agonist narcotics are used following the use of this local anesthetic. The

mechanism of this is not known at the present time. However, 2-chloroprocaine or its metabolite chloroaminobenzoic acid can act as a μ-antagonist. When the κ-agonist butorphanol, 2 mg, was used epidurally, we observed effective pain relief following the use of 2-chloroprocaine.[70]

Morphine, 3–5 mg, has been used for postoperative pain relief following epidural anesthesia, and its effect can last between 12 h and 24 h.[53] Several anesthesiologists use smaller amounts of epidural morphine (3 mg).[54,64,71] Our practice is to use 3 mg preservative free morphine epidurally for postoperative pain relief.

Summary of Epidural Anesthesia for Cesarean Section

1. Bicitra and metoclopramide, 10 mg intravenously (unless contraindicated)
2. Ringer's lactate intravenous infusion as deemed necessary
3. Monitoring of pulse and blood pressure, ECG, oxygen saturation, and fetal heart rate tracing during induction of anesthesia
4. Two percent lidocaine with epinephrine, 0.5% bupivacaine, 0.5% ropivacaine, 0.5% levobupivacaine, or 3% 2-chloroprocaine. Fractionated doses of local anesthetic agent injected epidurally until T4-level sensory analgesia is achieved. Approximately 20 ml may be required to achieve this level. If prior labor analgesia is being provided via epidural route, surgical level can be obtained with about 15 ml given in fractionated quantities (3–5 ml boluses).
5. Routine left uterine displacement
6. Treatment of decreases in maternal blood pressure with ephedrine (5–10 mg at a time) and volume expansion. Phenylephrine (40 μg) may be used in incremental doses if ephedrine is contraindicated.
7. Oxygen by face mask (6–8 L/min) to maintain better maternal and fetal acid–base values (Fig. 12-6)
8. Postoperative monitoring for delayed respiratory depression if epidural morphine is used

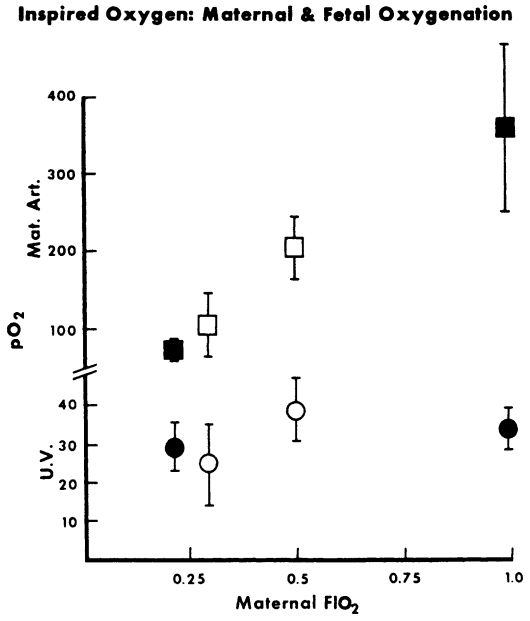

Figure 12–6. Influence of maternal inspired oxygen on maternal and fetal oxygenation at birth during cesarean section under epidural and general anesthesia. *Filled circles* (fetal) and *filled squares* (maternal) indicate epidural analgesia, whereas *open circles* and *squares* indicate a light general anesthesia plus relaxant. (From Bromage, p. 578.[148] Used with permission from Elsevier.)

Cardiovascular Complications of Bupivacaine and Neurological Complications of 2-Chloroprocaine

Albright in a 1979 editorial in *Anesthesiology* pointed out the higher incidence of cardiac arrest associated with highly lipid-soluble and protein-bound drugs like etidocaine and mainly bupivacaine.[72] The incidence of cardiac arrhythmias and cardiac arrest was higher in parturients receiving 0.75%

bupivacaine; in 1980, the FDA banned the use of 0.75% bupivacaine in obstetric patients. Numerous animal studies were performed following Albright's report regarding the central nervous system (CNS) and cardiovascular system toxicity of different clinically used local anesthetics, and these can be summarized as follows:

1. The CC/CNS ratio (CC toxicity, cardiovascular collapse; CNS toxicity, convulsion) was lower for bupivacaine and etidocaine when compared with lidocaine.
2. Ventricular arrhythmias, fatal ventricular fibrillation, and cardiac arrest occurred after the rapid intravenous injection of bupivacaine.
3. *Pregnant animals were found to be more sensitive than nonpregnant animals to the cardiotoxic effects of bupivacaine.*
4. *Cardiac resuscitation following bupivacaine toxicity was much more difficult than in the case of lidocaine*. Hypoxia and acidosis were important factors contributing to this problem.

As a rule, the cardiovascular system is more resistant than the CNS to local anesthetic. The CC/CNS ratio of lidocaine in adult sheep was 7.1 ± 1.1, whereas with bupivacaine and etidocaine it was 3.7 ± 0.5 and 4.4 ± 0.9, respectively.[73–75] The same group of observers also noticed a higher sensitivity of the myocardium to bupivacaine in pregnant animals than in nonpregnant animals. The CC/CNS ratio for nonpregnant animals was 3.7 ± 0.5 as compared with 2.7 ± 0.4 in pregnant animals.[75,76] In a subsequent study, the authors did not observe any enhancement of systemic toxicity of ropivacaine or bupivacaine during pregnancy. The exact mechanism for this difference in sensitivity in pregnant animals is not known; however, the authors speculated that the lower protein binding in pregnancy may be responsible for this increased sensitivity. Using an in vitro model, Moller and colleagues observed a significantly higher depression of V_{max} of ventricular muscles obtained from progesterone-treated animals as compared with controls.[76] It is possible that progesterone and its metabolites can interfere with sodium, potassium, or calcium channels. A study using B-estradiol in a rabbit ventricular muscle and Purkinjee fibers model showed higher

degree of depression of V_{max} with bupivacaine.[77] Clarkson and Hondeghem, observing the sodium channel blocking effect of bupivacaine, suggested that in high concentrations lidocaine blocked sodium channels in a fast-in–fast-out manner, bupivacaine in low concentrations blocked sodium channels in a slow-in–slow-out manner, whereas in high concentrations the block was of the fast-in–slow-out type.[78] The practical implication of this phenomenon is important: this might be one of the reasons for the longer resuscitation time required for bupivacaine cardiotoxicity. Kasten and Martin showed successful cardiovascular resuscitation after a massive intravenous bupivacaine overdosage in dogs by (1) ventilation with 100% O_2, (2) open heart massage, (3) bretylium for ventricular tachycardia; if circulation is present, cardioversion will be also necessary, and (4) epinephrine and atropine for electromechanical dissociation and bradycardia[79] Recently, intravenous lipid emulsion (bolus 1.2–2 ml/kg, infusion 0.25–0.5 ml/kg/min) has been the most favored method of treating bupivacaine and ropivacaine cardiac toxicity. It reverses local anesthetic toxicity by extracting lipophilic local anesthetics from aqueous plasma or tissues or by counteracting local anesthetic inhibition of myocardial fatty acid oxygenation.[80,81]

The following is a summary of the cardiovascular complications of bupivacaine:

1. Bupivacaine is more cardiotoxic than is lidocaine.
2. Parturients may be more susceptible than nonpregnant patients to bupivacaine cardiotoxicity, but the mechanism is unknown.
3. *The resuscitation time following bupivacaine administration may be longer, and one must remember to relieve aortocaval compression by proper left uterine displacement.*
4. *Intravenous intralipid emulsions should be considered*
5. Epinephrine and atropine may be necessary in high doses.
6. Amiodarone should be the drug of choice for the treatment of ventricular tachyarrhythmias.
7. Amrinone may be the drug of choice to treat bupivacaine-induced myocardial depression.
8. If necessary, extracorporeal circulatory assistance is to be considered.

Differences Between Spinal and Epidural Anesthesia for Cesarean Delivery

Table 12-3 lists the differences between spinal and epidural anesthesia for cesarean delivery.

Table 12–3. Differences Between the Spinal and Epidural Anesthesia for Cesarean Delivery

Spinal Anesthesia	Epidural Anesthesia
Advantages	
Simple, rapid, reliable	Lesser incidence of hypotension
Minimal drug exposure	Avoidance of dural puncture
	Provide anesthesia for longer duration
	Use for postoperative analgesia
Disadvantages	
Hypotension	More complex procedure
Nausea and vomiting	Longer onset of time
Limited duration of action unless a continuous catheter technique is utilized	Large amount of local anesthetic required
Combined spinal and epidural anesthesia Advantages: Shortened recovery room stays if small amount of local anesthetic used for spinal block and less hypotension for the same reason	

Combined Spinal Epidural (CSE) Technique

The CSE technique has been popularized by a group from Sweden.[82] The authors suggested the following advantages of CSE technique: (1) speed of onset; (2) superior surgical analgesia and muscular relaxation; (3) lesser need for supplementary analgesics, sedatives, and antiemetics; (4) lower incidences of hypotension; (5) lower dose of local anesthetics in the mother and fetus; (6) blocking of sacral nerve roots due to use of

hyperbaric local anesthetic; (7) CSE block appears to combine the reliability of spinal block and the versatility of epidural block. If the CSE block is properly performed, this technique may be associated with all of the advantages mentioned by the author. Davies et al., conducted a randomized blind study comparing CSE technique with the epidural procedure. Their conclusions were both epidural anesthesia and CSE were associated with lower failure rates, with good operative conditions. However, CSE conferred high levels of maternal satisfaction. In addition, maternal advantages also included greater satisfaction after block placement before surgery, and reduced pain during delivery of the fetus in CSE group.[83] Some studies showed that spinal part of CSE technique was associated with a higher block compared to single-shot spinal technique for cesarean delivery. However, this was not proven in a more recent study where cerebrospinal fluid pressure was also monitored.[84] One of the distinct advantages of CSE technique is that it facilitates administering smaller amounts of local anesthetic agent (7–8 mg bupivacaine) and the epidural catheter can be used to augment the block further if indicated. This sequential combined spinal epidural anesthesia has been shown to decrease the degree of hypotension, and also associated with shorter recovery room stay.[85,86] This method has been used successfully for cesarean delivery in parturients with cardiac disease.[87,88]

General Anesthesia

The *advantages* of general anesthesia are as follows:

1. Speed of induction
2. Reliability
3. Reproducibility
4. Controllability
5. Avoidance of hypotension

The following are *disadvantages* of general anesthesia:

1. Possibility of maternal aspiration
2. Problems of airway management
3. Narcotization of the newborn
4. Maternal awareness during light general anesthesia

Complications of General Anesthesia

Maternal Aspiration

Since Mendelson recognized the importance of gastric pH in maternal aspiration, the necessity of neutralizing this acid has become apparent.[89] Roberts and Shirley reported the aspiration of gastric contents during anesthesia for cesarean delivery despite the previous administration of particulate antacids.[90] Another disturbing factor is the demonstration, in animals, that particulate antacids, if aspirated, may cause physiological and structural alterations in the lung. *Nonparticulate antacids* (0.3 M *sodium citrate or Bicitra*) *avoids this problem.*[91] Dewan and colleagues demonstrated the effectiveness of 30 mL of 0.3 M sodium citrate administered within an hour of induction of cesarean section. None of the parturients given sodium citrate had gastric aspirates at risk (pH < 2.5) of acid aspiration.[92]

Anticholinergics. Glycopyrrolate, an anticholinergic, has been advocated because of its ability to decrease gastric secretions. However, it can relax the gastroesophageal sphincter, and hypothetically increase the risk of regurgitation and aspiration.

Other Pharmacological Agents. The histamine (H_2) receptor antagonists cimetidine and ranitidine have been used to inhibit basal gastric acid secretion in order to increase the gastric pH and decrease gastric volume.[93] Metoclopramide, which increases gastric motility as well as esophageal sphincter tone, is a commonly used medication, especially for parturients undergoing cesarean section under general anesthesia[94] Metoclopramide also has a central antiemetic property related to its antidopaminergic action on the chemoreceptor trigger zone (CTZ).[95]

Airway Management

Parturients decrease arterial oxygen saturation faster than nonpregnant women (Table 12-4), and this is related to increased oxygen consumption and decreased functional residual capacity. Preoxygenation with 100% oxygen is absolutely essential before the induction of anesthesia. *Norris and Dewan compared two methods of preoxygenation: 100% oxygen for*

Table 12–4. Maternal Oxygen Tension in Pregnant and Nonpregnant Patients Following Apnea

	Parturient Women		Gynecological Patients	
Parameter	Before Apnea	After Apnea (1 min)	Before Apnea	After Apnea (1 min)
PaO_2 (mmHg)	473 ± 34*†	334 ± 43*†	507 ± 38	449 ± 40
$PaCO_2$ (mmHg)	31.4 ± 2.4	40.4 ± 2.7	35.6 ± 1.8	44.3 ± 1.1
pH	7.41 ± 0.02	7.33 ± 0.01	7.45 ± 0.02	7.35 ± 0.01

†$P < 0.05$.
From Archer et al.[151]

3 min vs. four maximal deep breaths in 30 s. The mean PaO_2 was not different between the groups.[96,97] Hence in a situation of acute fetal distress, four deep breaths of 100% oxygen may suffice. Pregnant women denitrogenate faster during preoxygenation; however, they also desaturate faster during apnea as compared to nonpregnant subjects.[97,98] Rapid sequence induction utilizing cricoid pressure (Sellick's maneuver) followed by endotracheal intubation is the routine induction procedure. American Society of Anesthesiologists monitoring standards should be followed in every case including capnography.

An additional hazard of general anesthesia could be a difficulty or impossibility of endotracheal intubation following the intravenous induction of anesthesia. This remains the major contributing factor to anesthesia-related maternal complications.[99,100] The incidence of failed tracheal intubation in the pregnant population is perhaps eight times higher than in the nonpregnant population.[101] The first national study of anesthesia-related maternal mortality in the United States revealed that 52% of the deaths resulted from complications of general anesthesia predominantly related to airway management problems.[102] Despite decreases in the number of obstetric general anesthetics and better awareness of obstetric airway difficulties, a recent survey study has shown that

the incidence of difficult intubation and subsequent complications have not diminished with time.[103] Furthermore, a critical evaluation of anesthesia-related maternal deaths in Michigan, 1985–2003, showed that airway obstruction or hypoventilation during emergence and extubation were the cause of five maternal deaths.[104] Obvious factors such as enlarged breasts have been implicated, but simple maneuvers for dealing with these problems did not seem to decrease the incidence of difficult intubation.[103,105,106]

Pilkington et al. demonstrated that the airway edema can increase during the course of pregnancy and result in increases in Mallampati score.[106] Furthermore, Kodali et al. have shown recently that the two components of upper airway (Samsoon's modification of Mallampati class, and pharyngeal volume) decrease during the course of labor.[107] Oral volume changes were observed by photographing the upper airway pre- and post-labor using a special camera (fig. 12-7a, b). The pharyngeal airway changes were demonstrated using acoustic reflectometry (Fig. 12-8). The relationship between increasing airway classification and relative ease or difficulty at intubation in term pregnant women undergoing cesarean delivery under general anesthesia were studied by Rocke et al.[108] The relative risk of encountering difficult intubation in pregnant women with a class 3 airway was 7.58 times more compared to parturients with class 1 airways during general anesthesia. This relative risk increased to 11.3 in pregnant women with a class 4 airway. This suggests that a change in airway class from 2 to 4 in parturients is associated with enhanced relative risk of encountering difficult intubation from 3.23 to 11.3. Therefore, women undergoing labor may be at increased risk of difficult intubation, particularly if labor is associated with airway changes. Hence, it is prudent to reevaluate the airway in women in labor presenting for cesarean delivery just prior to commencement of the anesthetic, rather than obtaining the information from the pre-labor evaluation data sheet. However, it must be remembered that the concealed portion of the upper airway, namely the pharyngeal volume, can also narrow during labor.[107]

If difficult intubation is encountered following induction of general anesthesia, it is essential that oxygenation should

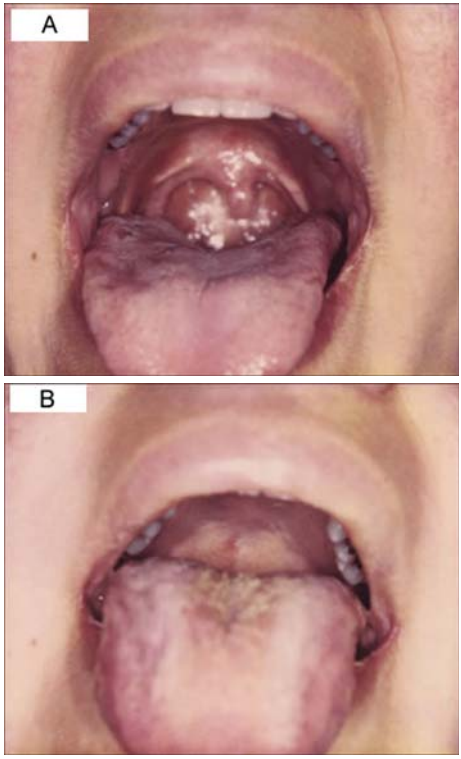

Figure 12–7. Airway pictures (**a**) pre-labor (Samsoon's modification of Mallampati class 1 airway), and (**b**) post-labor (Samsoon's modification of Mallampati class 3 airway). From Kodali [107] with permission.

be maintained by ventilating via mask. If there is no urgency such as continued fetal distress or antepartum hemorrhage, anesthesia may be discontinued and the woman may be allowed to wake up while the situation is assessed and an alternative anesthetic strategy is adopted. On the other hand, if it is deemed essential to continue anesthesia, laryngeal mask can be inserted to facilitate anesthesia.[109–111] Depending on

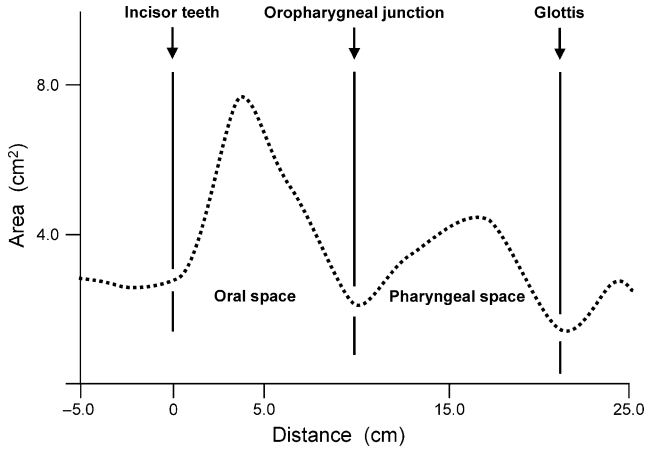

Figure 12–8. Acoustic reflectometry tracing showing various components of upper airway beginning from incisor teeth to glottis. (From Kodali et al.[107] Used with permission.)

the circumstances and available expertise/equipment, endotracheal tube can be inserted via fiber optic bronchoscope through the laryngeal mask airway under vision to minimize trauma to the airway. Laryngeal mask airway has also been successfully used in the instances of difficult intubation–difficult ventilation scenario. Laryngeal mask airway has also been placed under local anesthesia to act as a conduit for awake endotracheal intubation before induction of general anesthesia.[112] A means of instituting transtracheal ventilation should be immediately available in every obstetric suite if laryngeal mask airway does not restore access to airway. Patel described a system for delivering transtracheal ventilation. It consists of a 12- or 14-gauge intravenous catheter that will connect easily to the adapter of a 3-mm endotracheal tube. The end of this system can be attached easily to conventional anesthesia system.[113]

A difficult or failed intubation drill is extremely important, and every institution should have a plan before the situation

arises (Fig. 12-9). When a difficult intubation is suspected, close communication with the obstetrician and the woman is absolutely vital to make the final decision.

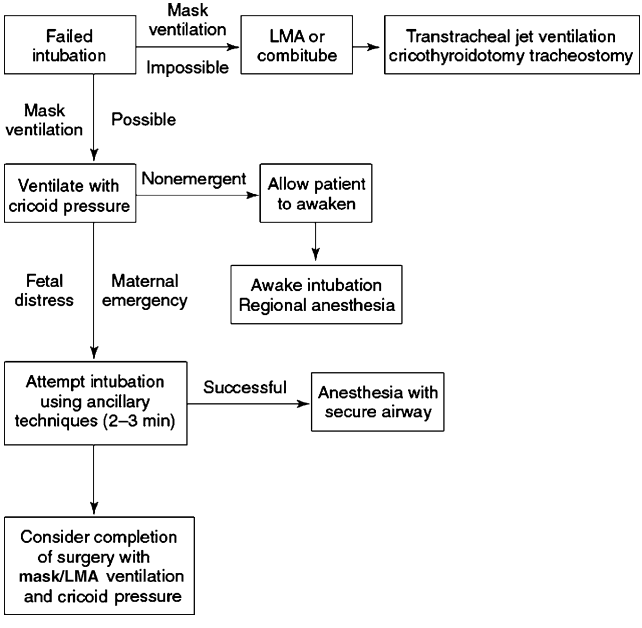

Figure 12–9. Steps in a drill when intubation is difficult during cesarean section. (Adapted from Malan and Johnson.[149])

Choice Between Regional and General Anesthesia when Difficult Airway Is Anticipated

Regional Anesthesia

Many anesthesiologists prefer either epidural or a continuous spinal technique when a difficult airway is anticipated. The technique should be instituted, if possible, before the onset of active labor.

The *advantages* of regional anesthesia include the following:

1. It can be used for an acute fetal distress situation without facing difficult intubation and thus promoting further fetal compromise.
2. The woman is awake, and thus there is less chance of gastric aspiration.
3. The continuous spinal technique can be induced in a very short time and can be used in situations where there is fetal distress.

Disadvantages of regional anesthesia include the following:

1. *Accidental intravascular injection with a possibility of convulsion, cardiovascular collapse, and aspiration.*
2. *Accidental subarachnoid injection causing total spinal anesthesia with the possibility of severe hypotension, unconsciousness, and aspiration. Obviously, in both these situations, ventilation with 100% oxygen will be absolutely essential and airway may have to be secured.*

General Anesthesia

The *advantages* of general anesthesia include the following:

1. *Airway is secured electively: Awake intubation by using either a laryngoscope or fiber-optic technique after anesthetizing the oral cavity with local anesthetic is the method of choice. Awake laryngeal mask insertion and endotracheal intubation is an alternative.*
2. *One can avoid the complications of regional anesthesia* (*accidental intravascular or subarachnoid injection*).

The following are *disadvantages* of general anesthesia:

1. It might take a longer time; hence, it may not be ideal in acute fetal distress situations.
2. Maternal discomfort while airway is being secured before general anesthesia.

Effect of General Anesthesia on the Baby

Causes of neonatal depression under general anesthesia can be classified as follows:

I. Physiological causes
   A. Maternal hypoventilation

B. Maternal hyperventilation
C. Reduced uteroplacental perfusion due to aortocaval compression

II. Pharmacological causes
A. Induction agents
B. Neuromuscular blockers
C. Low oxygen concentration
D. Nitrous oxide and other inhalational agents
E. Effect of prolonged induction-delivery and uterine incision-delivery intervals

Underlying Physiology

The physiological changes of pregnancy render the parturient more susceptible to rapid changes in blood gas tension. Hypoventilation will reduce the oxygen tension in the mother and in turn will cause neonatal acid–base alterations or biochemical depression. *Maternal hyperventilation may also impose potential harm to the fetus during general anesthesia by decreasing fetal oxygen tension. Mechanisms (Fig. 12-10)*

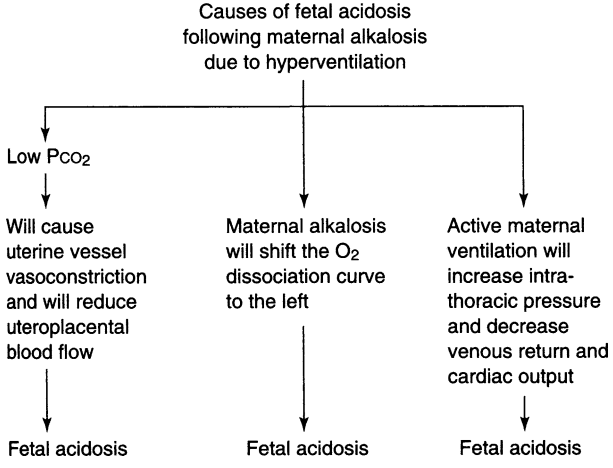

Figure 12–10. Causes of fetal acidosis following maternal alkalosis due to hyperventilation.

that have been invoked to explain this phenomenon[114] *include (1) vasoconstriction of umbilical vessels secondary to maternal hypocarbia, (2) altered maternal hemodynamics secondary to increased intrathoracic pressure during hyperventilation that causes a decrease in aortic and uterine blood flow, and (3) a shift of the maternal oxyhemoglobin dissociation curve to the left* (Fig. 12-11). Capnography is vital in preventing hypo- or hyperventilation. The arterial to end-tidal carbon dioxide gradient is decreased from the usual 4–5 mmHg in nonpregnant individuals to almost to zero in pregnancy, and hence

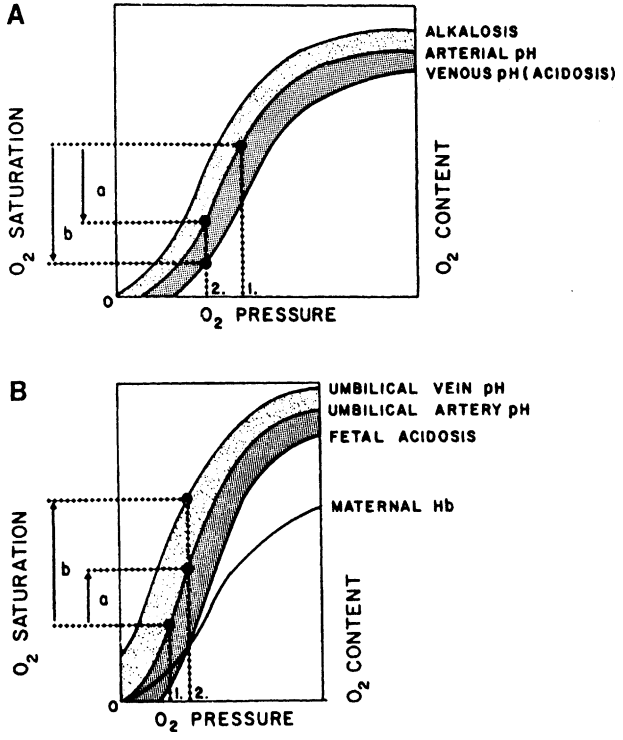

Figure 12–11. Hemoglobin dissociation curves of mother and fetus at the intervillous space and the importance of maternal PCO_2. A lower maternal PCO_2 will shift the curve to the *left*. (From Abouleish.[150] Used with permission.)

during cesarean section under general anesthesia end-tidal carbon dioxide reflects arterial carbon dioxide.[115] Maintaining end-tidal carbon dioxide around 32 mmHg is a reasonable approach in guiding ventilation during cesarean section under general anesthesia.

Aortocaval compression becomes more important when abdominal delivery is undertaken for suspected or documented fetal asphyxia. Increased asphyxia by permitting the patient to be supine will be highly detrimental to the fetus. Better fetal outcomes result from avoiding aortocaval compression. A left uterine tilt must be assured all the time.

Pharmacological Effects

Induction Agents. Standard practice is induction of anesthesia with an intravenous injection of thiobarbiturate, usually thiopental. The recommended dose is 4 mg/kg pregnant body weight. Thiobarbiturates cross the placenta rapidly and are detected in fetal blood within seconds of their administration to the mother (Fig. 12-12). *The concentration of umbilical vein blood remains lower than that of maternal vein blood;*

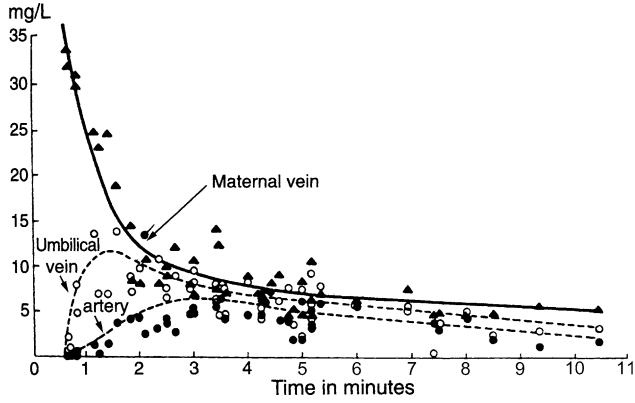

Figure 12–12. Thiamylal concentrations in the maternal vein, umbilical vein, and umbilical artery. (From Kosaka et al.[116] Used with permission.)

the concentration of umbilical artery blood is lower than that of umbilical vein blood.[116] *These gradients result from (1) a rapid decline in concentration of thiobarbiturate in maternal blood secondary to rapid redistribution, (2) nonhomogeneous distribution in the intervillous space, (3) extraction of thiobarbiturate from umbilical vein blood by the fetal liver, and (4) progressive dilution through shunting in the fetal circulation*. Ketamine (1–1.5 mg/kg) may be the induction agent of choice in the presence of hemorrhage. The nonbarbiturate induction agent propofol (2–2.5 mg/kg) did not show any significant advantage for cesarean section.[117–119] A combination of remifentanyl and propofol has also been used in selective cases such as Marfan's syndrome.[119] Etomidate (0.3 mg/kg) has been associated with less myocardial depression and greater hemodynamic stability and is the drug of choice in patients with cardiovascular compromise..[120,121]

Neuromuscular Blockers. Neuromuscular blockers are highly ionizable, and except in unusual circumstances, there is little observable effect on the newborn that can be attributed to muscle relaxants. Studies of *d*-tubocurarine, pancuronium, metocurine, and succinylcholine suggest that after a volume injection small quantities of these drugs may cross the placenta but maternal paralyzing doses do not affect the fetus. However, prolonged maternal and newborn neuromuscular blockade has been reported after the administration of succinylcholine to the mother.[122] This was due to the presence of atypical pseudocholinesterase in both the mother and newborn. Some authors recommend the administration of a small dosage of a nondepolarizing muscle relaxant *before the use of succinylcholine to prevent fasciculations and an associated increase in intragastric pressure*.[123] This concept is not agreed upon universally; opponents will not use any nondepolarizing muscle relaxants prior to the use of succinylcholine because (1) *parturients rarely exhibit fasciculations after succinylcholine;*[124] (2) *succinylcholine produces inconsistent and unpredictable elevations in intragastric pressure;*[125] (3) *succinylcholine tends to increase lower esophageal sphincter pressure in association with increased intragastric pressure, and thus the barrier pressure remains essentially unchanged;*[126]

(4) *intubation conditions may not be ideal if a nondepolarizing muscle relaxant is used prior to succinylcholine due to decreased efficacy of succinylcholine;* and (5) muscle pain after succinylcholine administration is far less following cesarean section than in nonpregnant subjects. Laudanosine, a metabolite of atracurium crosses the placenta and the mean placental transfer is 14% of maternal levels. Laudanosine levels are much lower with the cisatracurium and therefore should not affect the baby.[127]

Oxygenation. Fetal oxygenation is also affected by maternal inspired oxygen concentrations. A higher maternal inspired oxygen concentration will increase both maternal and fetal oxygen tensions and will improve the fetal condition at birth. For elective cesarean deliveries with no fetal distress, inspired oxygen concentration of 33–50% seems appropriate as there was no difference between the fetal oxygenations within this range of inspired oxygen concentrations.[128] Inspiratory oxygen concentration of 100% was associated with increased fetal oxygenation during elective cesarean delivery under general anesthesia. [129] Hence it may be prudent to use 100% inspiratory oxygen concentration for emergency cesarean delivery for fetal distress. Contrary to earlier reports, maternal hyperoxygenation does not result in fetal acidosis.

Nitrous Oxide. Nitrous oxide crosses the placenta rapidly and attains a fetal umbilical artery/umbilical vein concentration ratio of 0.8 after 15 min. The prolonged administration of nitrous oxide in high concentrations may result in low Apgar scores, possibly caused by direct CNS depression and diffusion hypoxia. Our current practice is not to exceed a nitrous oxide concentration of 50%. Mankowitz and his associates[130] have demonstrated that newborns whose mothers received nitrous oxide (50% oxygen and 50% N_2O with 0.6–1.0% enflurane) for cesarean delivery were largely unaffected at birth. However, they recommend (as do the authors) that all infants born to mothers who have received nitrous oxide before delivery receive oxygen or oxygen-enriched air, especially when the induction-to-delivery interval is prolonged, to further aid the infants in the adaptation from intrauterine to extrauterine life.

In the past, various inhalational agents have been used in combination with nitrous oxide, including halothane, methoxyflurane, trichloroethylene, enflurane (Ethrane), and isoflurane. All are reported to produce satisfactory anesthesia with few side effects. The current trend is to use isoflurane, and newer agents sevoflurane and desflurane with or without nitrous oxide (isoflurane 0.5% in 50% nitrous oxide, oxygen; sevoflurane 1% with 50% nitrous oxide, oxygen, or 1.5–2% in 100% oxygen: sevoflurane 1.5% keeps BIS score <60).[131–133] In one study, desflurane 2.5% in 50% nitrous oxide, oxygen had better neonatal condition than sevoflurane 1.5% in 50% nitrous oxide, oxygen.[134] However, in another study, general anesthesia for caesarean section with 4.5% desflurane in 50% nitrous oxide maintained BIS < 60 more often (statistically significant) than 3% of desflurane in 50% N_2O without maternal and neonatal adverse effects in healthy parturients.[135]

Effect of Induction-Delivery and Uterine Incision-Delivery Intervals. There is a difference of opinion about the optimal time for delivery of the infant when general anesthesia is used for cesarean delivery. Several authors found a better neonatal status when the induction-delivery interval was less than 10 min. Crawford et al. emphasized that if aortocaval compression is avoided, the inspired oxygen concentration is 65–70%, and there is no hypotension, then an induction-delivery interval as long as 30 min has no significant effect on the acid–base status of the newborn infants.[136] When Datta et al. used 50% nitrous oxide/50% oxygen and a small concentration of a volatile agent to produce amnesia, they found no significant effect on the acid–base values and Apgar scores when babies were delivered within 10 min.[137]

Another important factor related to the induction-delivery interval that may have considerable influence on the infant's condition is the duration of the uterine incision-delivery interval. In the absence of hypotension during spinal anesthesia, the length of the induction-delivery interval is not a factor in regard to neonatal outcome as measured by Apgar scores and neonatal acid–base values. However, uterine incision-delivery intervals longer than 180 s are associated with low Apgar scores as well as acidotic babies. During general anesthesia when

induction-delivery intervals were greater than 8 min or uterine incision-delivery intervals were greater than or equal to 180 s, lower 1-min Apgar scores (less than 7) and neonatal umbilical artery acidosis were present.[137] We also observed that prolonged uterine incision-delivery intervals during regional anesthesia resulted in elevated fetal umbilical artery norepinephrine concentrations and associated fetal acidosis.[138] An adverse outcome with prolonged uterine incision-delivery intervals may be the result of (1) the effects of uterine manipulations on uteroplacental and umbilical blood flows, (2) pressure of the uterus with accentuation of aortocaval compression, (3) compression of the fetal head during a difficult delivery, or (4) inhalation of amniotic fluid as a result of gasping respirations by the fetus in utero. The presence of increased norepinephrine concentrations in the fetus may be a sign of fetal hypoxia.

Maternal Awareness

A major problem with general anesthesia for cesarean delivery is the incidence of maternal awareness and unpleasant recall associated with the use of small doses and low concentrations of anesthetics to minimize neonatal effects. Incidences of recall have been reported to range from 17% to 36%. The use of low concentrations of potent volatile anesthetic agents will successfully prevent awareness and recall without adverse neonatal effect or excessive uterine bleeding.[139] As stated above, desflurane 4.5% or sevoflurane 1.5% in 50% nitrous oxide has been shown to assure BIS scores <60 during cesarean section general anesthesia. This can minimize the chances of awareness.

Summary of General Anesthesia for Cesarean Delivery

1. Premedication with metoclopramide, 10 mg intravenously, and nonparticulate antacid (30 mL of a 0.3 M sodium citrate solution)

2. Monitoring of blood pressure, pulse, ECG, O_2 saturation, capnography, temperature, nerve stimulator
3. Left uterine displacement
4. Preoxygenation with 100% oxygen
5. Induction with thiopental/ketamine/propofol and succinylcholine while maintaining cricoid pressure
6. Cuffed endotracheal tube
7. Fifty percent O_2, 50% N_2O with a small amount of isoflurane (0.75%), enflurane (1%), desflurane (4%), or sevoflurane (1.5%) unless contraindicated
8. Avoidance of hypoventilation or hyperventilation, maintain end-tidal carbon dioxide around 32 mmHg.
9. Muscle relaxants: either a 0.1% succinylcholine infusion or nondepolarizing muscle relaxants (vecuronium 4 mg) with the use of a neuromuscular blockade monitor.
10. Desufflation of the stomach by a gastric tube after induction and intubation
11. Minimization of the induction-delivery interval
12. Minimization of the uterine incision-delivery interval
13. Use of narcotics in the mother after delivery of the baby
14. Extubation performed when the mother is wide awake

Air Embolism During Cesarean Delivery

A mention of air embolism during cesarean delivery needs emphasis in this chapter because of its high incidence during cesarean delivery. The incidence of venous air embolism during cesarean delivery has been reported to be between 9.5% and 65%,[140,141] and this can happen during epidural, spinal, and general anesthesia. Air emboli in the pulmonary circulation may cause a ventilation/perfusion mismatch and can lower oxygen saturation.[142] Chest pain and dyspnea may be associated with venous air embolism, and ECC changes have also been observed. The majority of changes have been noted with uterine incision and delivery[140] as well as at the time of uterine exteriorization.[143] Hence, oxygen saturation, blood pressure, and pulse should be closely monitored during delivery and immediately postpartum.

Postoperative Pain Relief

Intravenous Method

Patient-controlled analgesia (PCA) has become a popular method for postoperative pain relief following general anesthesia for cesarean section. Morphine remains the drug of choice for this purpose.[144] Sinatra and colleagues compared morphine, meperidine, and oxymorphone for PCA and observed a rapid onset and less sedation, nausea, vomiting, and pruritus with meperidine.[145] However, the same group reported neonates whose mothers received meperidine for PCA scored lower in the neurobehavioral scoring system than did the morphine-treated group.[146] A significant amount of normeperidine was found in the breast milk of the mothers who received meperidine. The authors concluded that PCA with morphine for pain relief following cesarean section provided equivalent maternal analgesia and overall satisfaction to that provided by PCA with meperidine, but with significantly less neurobehavioral depression among breast-fed neonates on the third day of life. One should not expect such problems if meperidine PCA is not used for more than 24 h.

Neuraxial Narcotics

As already stated, preservative free morphine (0.2 mg spinal or 3 mg epidural) provides satisfactory pain relief for 18–24 h. Palmer et al. described the dose–response relationship of epidural morphine for postcesarean analgesia for quality of analgesia and relation to the side effects of pruritus, nausea, and vomiting in 60 term parturients undergoing nonurgent cesarean delivery. The patients received a single dose of epidural morphine after delivery (0 mg, 1.25 mg, 2.5 mg, 3.75 mg, or 5 mg). The quality of analgesia increased as the dose of epidural morphine increased to at least 3.75 mg; increasing the dose further to 5 mg did not improve analgesia. Side effects were not dose related.[54] Based on this study and others, the general practice is to use 3 mg morphine epidurally.[71] However, it is prudent to monitor respiratory rate following their use

in the postoperative period to detect a rare event of delayed respiratory depression. Kato et al. retrospectively evaluated parturients receiving 0.15 mg intrathecal morphine for cesarean delivery for bradypnea (respiratory rate $\leq$ 10 breaths/min) within 24 h after the intrathecal injection. Of 1915 patients, 5 women (0.26%) developed bradypnea (respiratory rate $\leq$ 10 breaths/min) during the 24 h period. The incidence of severe bradypnea (oxygen desaturation below 90% and 30-s apneas requiring naloxone) was 1/1915 (0.052%).[147] Therefore, our practice is to monitor hourly respiratory rate in the postoperative period for 18–24 h. We also use neuraxial narcotics in morbidly obese parturients to avoid intravenous narcotics. The patients are, however, kept under close surveillance at least for a day.

Summary

Our understanding of the physiology, pharmacology, and clinical management of anesthesia for cesarean delivery has greatly advanced in recent years. If the basic principles about various techniques described in this chapter are adhered to, one should expect an excellent maternal and fetal outcome with either general or regional anesthesia in the normal parturient.

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