Chapter 45

Anesthetic Management of Cesarean Section Patients

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Introduction

The ideal anesthetic protocol for cesarean section would provide ample analgesia, muscle relaxation, and sedation or narcosis for optimal operating conditions and safety without unduly endangering either mother or fetus. By their very nature, anesthetics, analgesics, tranquilizers, and sedatives cross the blood-brain barrier. Because the physicochemical properties that allow drugs to cross the blood-brain barrier also enable their placental transfer, it is not possible to selectively anesthetize the mother. Agents that affect the maternal central nervous system will also produce fetal effects, which effects are generally characterized by depression and decreased viability. In many cases, cesarean section is an emergency procedure. Due to the emergent nature of surgical fetal extraction, the physical condition of the mother and fetus is less than optimal because veterinary assistance has been delayed. Thus, the veterinarian is faced with the dilemma of having to anesthetize the mother, who may already be compromised, without adversely affecting the fetus.

Selection of an anesthetic protocol for cesarean section should be based on safety of the mother and fetus, patient comfort, and veterinarian's familiarity with the anesthetic technique. Factors in decision making regarding anesthesia protocol include considerations of the physiological alterations induced by pregnancy and labor, the pharmacology of selected drugs and their direct and indirect effects on the fetus and neonate, the benefits and risks of the techniques chosen, and the risk of procedure-related complications associated with anesthetic management. Regardless of the technique used, a major goal associated with drug selection should be to minimize fetal depression. This may be achieved by surgical expediency, which decreases maternal recumbency time and fetal drug absorption. This goal is of major importance in the larger species. With prolonged uterine isolation prior to fetal delivery, placental perfusion decreases, resulting in fetal hypoxemia, acidosis, and distress.

Physiological Alterations Induced by Pregnancy

Metabolic demands of gestation and parturition are met by altered physiological function (Table 45.1). Most of the data describing physiological alterations of pregnancy have been obtained from data collected in humans and ewes. Although little work has been done in other species, the changes should be comparable, if not greater, in magnitude. Birth weight expressed as percentage of maternal weight for people, sheep, dogs, and cats is 5.7%, 11.4%, 16.1%, and 13.2%, respectively.[1] This suggests that the physiological burden and therefore physiological alterations may actually be greater in animals than in women.

Cardiovascular

During pregnancy, maternal blood volume increases by approximately 40%; plasma volume increases more than red cell mass, resulting in decreased hemoglobin concentration and packed cell volume.[2] Increased heart rate and stroke volume cause cardiac output to increase 30% to 50% above normal.[3,4] Plasma estrogens decrease peripheral vascular resistance, resulting in an increase in cardiac output while systolic and diastolic blood pressures remain unchanged. During labor and the immediate postpartum period, cardiac output increases an additional 10% to 25% as a result of blood being extruded from the contracting uterus.[5] Cardiac output during labor is also influenced by body position, pain, and apprehension.[2] During labor, systolic pressure increases by 10 to 30 mm Hg. Although central venous pressure does not change during pregnancy, because of increased venous capacity, it increases slightly (4 to 6 cm of water) during labor and has been reported to increase by 50 cm of water during

Table 45.1. Physiological alterations induced by pregnancy.

Variable	
Heart rate	↑
Cardiac output	↑
Blood volume	↑
Plasma volume	↑
Packed cell volume, hemoglobin, and plasma protein	↓
Arterial blood pressure	o
Central venous pressure	o, ↑ During labor
Minute volume of ventilation	↑
Oxygen consumption	↑
pH_a and PaO_2	o
$PaCO_2$	↓
Total lung and vital capacity	o
Functional residual capacity	↓
Gastric emptying time and intragastric pressure	↑
Gastric motility and pH of gastric secretions	↓
Gastric chloride ion and enzyme concentration	↑
SGOT, LDH, and BSP retention time	↑
Plasma cholinesterase	↓
Renal plasma flow and glomerular filtration rate	↑
Blood urea nitrogen and creatinine	↓
Sodium ion and water balance	o

o, no change. BSP, sulfobromophthalein sodium; LDH, lactate dehydrogenase; PaO_2, arterial oxygen partial pressure; $PaCO_2$, arterial carbon dioxide partial pressure; pH_a, arterial pH; SGOT, serum glutamic-oxaloacetic transaminase.

painful fetal extraction.[6] The posterior vena cava and aorta can be compressed by the enlarged uterus and its contents during dorsal recumbency. This can cause decreased venous return and cardiac output with resultant decreased uterine and renal blood flow. Although this does not appear to be as serious a problem in dogs and cats, time spent restrained or positioned in dorsal recumbency should be kept to a minimum.[7,8]

Because cardiac work is increased during pregnancy and parturition, cardiac reserve is decreased. Patients with previously well-compensated heart disease may suffer pulmonary congestion and heart failure caused by additional cardiac workload associated with gestation and the increased hemodynamic demand secondary to parturition-associated pain. In such patients, pain and anxiety control is a key component of successful management. However, care must be taken to avoid additional cardiac depression and decompensation induced by excessive doses of sedatives or anesthetics. The use of ecbolic agents during or after parturition can adversely affect cardiovascular function. Oxytocin in large or repeated doses induces peripheral vasodilation and hypotension, which can adversely affect both mother and fetus through decreased tissue perfusion. Ergot derivatives induce vasoconstriction and hypertension.[9]

Pulmonary

During pregnancy, increased serum progesterone concentration enhances respiratory center sensitivity to arterial partial pressure (tension) of carbon dioxide ($PaCO_2$). As a result of increased ventilatory minute volume, $PaCO_2$ progressively decreases during gestation and is near 30 mm Hg at parturition. Because of long-term renal compensation, respiratory alkalosis does not affect arterial pH. Ventilation may be further increased during labor by pain, apprehension, and anxiety. Oxygen consumption increases by 20% owing to the developing fetus, placenta, uterine muscle, and mammary tissue. Arterial oxygen tension remains unchanged.[2]

Pregnancy also affects the mechanics of ventilation. Airway conductance is increased and total pulmonary resistance is decreased by progesterone-induced relaxation of bronchial smooth muscle. Lung compliance is unaffected. Functional residual capacity (FRC) is decreased by anterior displacement of the diaphragm and abdominal organs by the gravid uterus. In addition, during labor, FRC decreases further because of increased pulmonary blood volume subsequent to intermittent uterine contraction. Because of the decrease in FRC, airway closure at end exhalation develops in approximately one-third of human parturients during tidal ventilation.[2] Total lung capacity and vital capacity are unaltered. Because FRC is decreased, hypoventilation induces hypoxemia and hypercapnia more readily in pregnant than nonpregnant patients. Hypoxemia is exacerbated by increased oxygen consumption during labor. Oxygen administration prior to anesthetic induction increases oxygen reserve by facilitating pulmonary denitrogenation. Preoxygenation is advisable if a patient is tolerant.

Induction of anesthesia with inhalation agents is more rapid in pregnant than nonpregnant patients. Equilibration rate between inspired and alveolar anesthetic partial pressure is accelerated by increased alveolar ventilation and decreased FRC. Additionally, increased progesterone and endorphin levels in the central nervous system decrease anesthetic requirements. Minimum alveolar anesthetic concentration values are reduced in pregnant compared with nonpregnant ewes. Thus, anesthetic induction may be extremely rapid, requiring as little as one-fourth to one-fifth the time required for nonpregnant patients.[10] Care must be taken to prevent volatile-agent overdose in pregnant patients.

Gastrointestinal

A number of functional changes in gastrointestinal tract physiology occur with gestation and parturition. Physical displacement of the stomach by the gravid uterus, decreased gastric motility, and increased serum progesterone delay gastric emptying during gestation and are manifest during the last trimester. Acid, chloride, and enzyme concentrations in gastric secretions are increased associated with altered hormone physiology during gestation. Lower esophageal sphincter tone is decreased, and intragastric pressure is increased. Pain and anxiety during labor have been shown to decrease gastric motility further.[2]

As a result of altered gastric function, the risk of regurgitation (both active and passive) and aspiration is greater in parturients. Because increased gastric acidity and decreased gastric muscular tone may be present, metoclopramide and an H_2 antagonist drug (cimetidine, ranitidine, or famotidine) may be administered as part of the preanesthetic protocol.[11] Frequently, patients pre-

sented for cesarean section have been fed or the time of the last feeding is unknown. Parturients should be regarded as having a full stomach, and anesthesia techniques should be selected that produce rapid airway management and control to prevent aspiration of foreign material. Incidence of vomiting is increased by hypotension, hypoxia, and toxic reactions to local anesthetics. Smooth induction of general anesthesia and prevention of hypotension during epidural anesthesia will decrease the incidence of vomiting. Because silent regurgitation can occur when intragastric pressure is high, a cuffed endotracheal tube is preferred for airway management. Passive regurgitation can be induced by positive-pressure ventilation with a face mask or by manipulation of abdominal viscera. Atropine administration may increase gastroesophageal sphincter tone, thereby helping to prevent regurgitation, but may also inhibit the actions of metoclopramide that increase gastric motility and emptying by sensitizing gastric smooth muscle to acetylcholine.[6,11]

Liver and Kidney

Pregnancy induces minor alterations in hepatic function. Plasma protein concentration decreases slightly, but total plasma protein is increased because of the increase in blood volume. Bilirubin concentration is unaltered. Serum enzyme concentrations (serum alanine aminotransferase [SALT] and alkaline phosphatase) are slightly increased, and sulfobromophthalein sodium retention is increased. Plasma cholinesterase concentration decreases. Despite these alterations, overall liver function is generally well maintained.[2]

Decreased plasma cholinesterase may lead to prolonged action of succinylcholine in pregnant patients, particularly if they have been exposed recently to organophosphate parasiticides (e.g., anthelmintic, flea collars, or dips). Normal or slightly elevated blood urea nitrogen or creatinine levels may indicate renal pathology or compromise in parturient patients. It would appear wise in such patients to avoid the use of drugs with known nephrotoxic potential, such as methoxyflurane, aminoglycoside antibiotics, and nonsteroidal anti-inflammatory drugs.

Renal plasma flow and glomerular filtration rate are increased by approximately 60% in pregnant patients, so blood urea nitrogen and creatinine concentrations are lower than in nonpregnant patients.[6] Sodium and water balance are unaffected.

Uterine Blood Flow

Maintaining stable uteroplacental circulation is important to fetal and maternal homeostasis and neonatal survival. Uterine blood flow is directly proportional to systemic perfusion pressure and inversely proportional to vascular resistance created in myometrial blood vessels. Placental perfusion is mainly dependent on uteroplacental perfusion pressure; however, placental vessels have rudimentary mechanisms for changing vascular resistance. Obstetric anesthesia may decrease uterine blood flow and thereby contribute to reduced fetal viability. In addition, uterine vascular resistance is indirectly increased by uterine contractions and hypertonia (oxytocic response). Placental hypotension is induced by hypovolemia, anesthetic-induced cardiovascular depression, or sympathetic blockade producing reduced uterine perfusion pressure. Uterine vasoconstriction is induced by endogenous sympathetic discharge or by exogenous sympathomimetic drugs having α_1-adrenergic effects (epinephrine, norepinephrine, methoxamine, phenylephrine, or metaraminol).[2,12,13] Hypotension induced by adjunctive drugs and increased uterine tone induced by ecbolics should be avoided.

Summary

Parturients are at greater anesthetic risk than are healthy nonparturient patients because of pregnancy-associated physiological alterations. Cardiac reserve diminishes during pregnancy, and high-risk patients can suffer acute cardiac decompensation or failure. Pregnant patients are prone to hypoventilation, hypoxia, and hypercapnia because of altered pulmonary function. Inhalation and local anesthetic requirement is decreased, thus increasing the likelihood of a relative overdose and excessive depression. Finally, emesis or regurgitation and aspiration can occur if induction is not immediately followed by rapid airway control.

Pharmacological Alterations Induced by Pregnancy

Pregnancy-associated alterations in physiological function affect the uptake, distribution, and disposition of anesthetic agents and adjuncts. The concentration of free (nonionized, unbound) drug in maternal plasma depends on uptake from the drug administration site, protein binding, distribution to maternal tissues, placental transfer, biotransformation by maternal liver, excretion, and fetal distribution and metabolism. The effects of pregnancy on several anesthetic agents have been studied. The rate of barbiturate biotransformation appears to be decreased in pregnancy.[14] Also, succinylcholine and procaine metabolism are decreased because of decreased plasma cholinesterase concentration; however, this effect is not clinically significant in most cases.[14] Increases in renal blood flow and glomerular filtration associated with pregnancy should favor renal excretion of drugs. Inhalation anesthetic dose (minimum alveolar anesthetic concentration) is reduced for all agents.

The placenta is highly permeable to anesthetic drugs. The physiochemical properties that make a molecule a good anesthetic drug also enable rapid transfer across the uteroplacental interface. Anesthetic drugs administered to the mother cross the placenta and induce fetal effects proportionate to those observed in the mother. Placental transfer of drugs can occur by several mechanisms; by far, the most important is simple diffusion.

Diffusion across the placenta is determined by molecular weight, the degree to which the drug is bound to maternal plasma proteins, lipid solubility, and degree of ionization. Drugs with low molecular weight (MW < 500 daltons), a low degree of protein binding, high lipid solubility, and poor ionization diffuse rapidly across the placenta. Drugs with high MW (>1000 daltons) that are highly protein bound, have low lipid solubility, and are highly ionized cross the placenta slowly. Most anesthetics and anesthetic adjuncts diffuse quickly across the placental bar-

rier because of their low molecular weight, high lipid solubility, low degree of ionization, and low percentage of protein binding. The muscle relaxant drugs are an exception because they are highly ionized and of low lipid solubility. Although they can be recovered from fetal blood, they are generally regarded as having minimal placental transfer and negligible fetal effect.[14,15] The placenta does not appear to metabolize anesthetics or anesthetic adjuncts.

Physiochemical properties and physiological/pharmacokinetic events that occur within the fetus and dam also affect placental drug transfer.[14] The degree to which a drug is ionized is determined by its pK_a and pH of the patient's body fluids. Drugs that are weak acids will be less ionized as pH decreases.[15] For example, thiopental is a weak acid with a pK_a of 7.6. In acidemic patients (pH < 7.4), a greater proportion of the administered dose is in the nonionized form. As the ionized form of the drug decreases, the dose fraction that is protein bound is reduced, thus effectively increasing the effect on a milligram basis. As a result, it is well recognized that acidemia decreases the required anesthetic dose of thiopental and other barbiturates. Weakly basic drugs such as opioids and local anesthetics are more highly ionized at pH values less than their pK_a.[16] Thus, their effect on the mother and fetus is less on a milligram-dose basis.

Distribution of drug between mother and fetus is also influenced by their respective blood pH. Normally, the fetal pH is 0.1 pH unit less than that of the mother. Thus, weakly basic drugs such as opiates and local anesthetics are found in higher concentration in fetal tissues and plasma than in those of the mother because of ion trapping. The lower fetal pH decreases the concentration of nonionized drug, maintaining the maternal-fetal concentration gradient and increasing nonionized drug transfer across the placenta to the fetus.[17]

Fetal drug concentration is altered by fetal redistribution, metabolism, and protein binding. The drug concentration in the umbilical vein is greater than drug exposure to the fetal organs (brain, heart, and other vital organs). As much as 85% of umbilical venous blood initially passes through the fetal liver, where drug may be sequestered or metabolized. In addition, umbilical venous blood containing drug enters the inferior vena cava via the ductus venosus and mixes with drug-free blood returning from the lower extremities and pelvic viscera (Fig. 45.1). Therefore, the fetal circulation buffers vital fetal tissues from sudden high drug concentrations. Binding of drug to fetal proteins may reduce bioavailability.[14,15] Fetal drug metabolism is not efficient because the fetal microsomal enzyme system is not as active as in later life. Drug concentration and effects in the fetus can be considerably greater and last longer than in the mother. Fetal drug toxicity can be enhanced by fetal or maternal metabolism to more toxic metabolites and by drug interaction.[17]

The administration of a fixed dose of drugs with rapidly decreasing plasma concentration (e.g., thiopental, propofol, or succinylcholine) briefly exposes the fetus and placenta to a high maternal blood drug concentration. This is in contrast to the sustained maternal blood levels of drugs administered by continuous infusion or inhalation, which result in continuous placental transfer of drug to the fetus.[14,17]

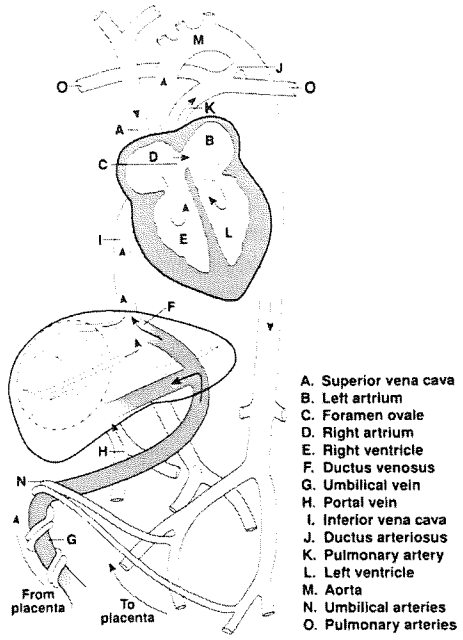

Fig. 45.1. The direction of blood flow in the fetal vascular system is indicated by *arrows*. The darkened vascular segments represent the umbilical blood and its path of flow into the liver and inferior vena cava via the ductus venosus. Blood flow through the foramen ovale and ductus arteriosus provides a direct path to the arterial system, bypassing the lungs. In neonates, the ductus arteriosus and foramen ovale closes shortly after birth. This functional closure results in blood flowing through the neonate's lungs, where it is arterialized as in the adult. The time required for anatomical closure of the foramen ovale in the foal may be as much as 12 months. Two months may be required for permanent closure of the foramen ovale.

Anesthetic Drugs and Cesarean Section

Anesthetic drugs should be carefully chosen and properly administered to avoid excessive maternal depression and to maximize neonatal vigor and viability. As noted above in the pharmacology section, the specific characteristics that make a drug an excellent anesthetic agent are also those that facilitate transplacental transfer and neonatal depression in short order. Therefore, it is prudent to consider that no agent should be used unless distinctly indicated. A brief overview of anesthetic drug classes in periparturient anesthesia follows.

Anticholinergic Agents

Anticholinergic drugs, such as atropine or glycopyrrolate, should be administered to most parturient patients to decrease salivation and inhibit excessive vagal tone that may occur when traction is applied to the uterus.[18,19] Many parturients have recently eaten, increasing the likelihood of regurgitation, which is enhanced by hypoxia or hypotension. The influence of anticholinergics upon emesis is controversial.[6,19] In women, atropine has not been shown to decrease the incidence of emesis at parturition.[19]

Glycopyrrolate increases gastric pH, thus decreasing severity of Mendelson's syndrome should regurgitation and aspiration of vomitus occur.[20] Additionally, because glycopyrrolate does not readily cross the placenta, it does not affect the fetus to the same extent as atropine. Therefore, it may be a more appropriate anticholinergic for use in these patients.

Tranquilizers and Sedatives

Because of their long duration of action, there are no indications for the routine use of these agents in parturient patients.[6,16,17] They should be restricted to markedly apprehensive or excited parturients and only in doses sufficient to induce a calming effect. Acepromazine can induce significant maternal and fetal depression even at relatively low doses. Diazepam and midazolam can induce neonatal depression characterized by absence of vocalization and by lethargy, hypotonus, apnea, and hypothermia immediately following birth.[21–23] It has been suggested that these effects are dose related and can be minimized by administering low doses (<0.14 mg/kg intravenously [IV]) although no safe dose has been established in domestic animals.[23] Residual benzodiazepine-induced lethargy and muscle relaxation in either the mother or neonate can be antagonized with flumazenil, a specific benzodiazepine antagonist administered to effect.[24]

Xylazine rapidly crosses the placenta and induces both maternal and fetal respiratory and circulatory depression. When used in conjunction with ketamine, significant and potentially life-threatening cardiopulmonary changes result in decreased tissue perfusion in healthy dogs.[25] The use of xylazine or xylazine-ketamine combinations probably should be avoided in small animal patients presented for cesarean section. On the other hand, xylazine-ketamine combinations have often been used in mares suffering from dystocia. Little information is available regarding use of detomidine or medetomidine in companion animal cesarean section anesthesia. Their structural and pharmacological similarities to xylazine suggest that similar precautions be observed with their use.

Opioids

These rapidly cross the placenta and can cause neonatal respiratory and neurobehavioral depression.[17,26,27] In addition, fetal elimination may require 2 to 6 days. It appears equianalgesic doses of opioids induce equal degrees of depression. Therefore, the choice of an opioid is based on the duration of desired action. The most commonly used opioids are fentanyl, meperidine, oxymorphone, and hydromorphone, in order of increasing duration of action.[17] Recently, agents having opiate agonist and antagonist activity have been used for obstetric analgesia. These agents include butorphanol and buprenorphine. They reportedly induce less respiratory depression than do pure opiate agonists. Butorphanol provides fairly predictable mild to moderate levels of sedation in some species in addition to its analgesic qualities.

One of the advantages of opioid agonists is that direct antagonists are available to reverse their action. Of the antagonist agents, naloxone (0.04 mg/kg IV) appears to be the most effective. It is a pure antagonist without agonist action. Nalorphine and levallorphan, two other antagonist agents, have opiate activity of their own and can increase respiratory depression induced by other nonopiate agents (e.g., barbiturates, phenothiazines, and inhalation agents). Because all opioid antagonists rapidly cross the placenta, maternal administration before delivery has been advocated to reverse opioid-induced neonatal depression. This technique deprives the mother of analgesia at the time when it is needed most. Therefore, these agents should be administered directly to neonates. Finally, because the action of naloxone is shorter than that of most opioid agonists, renarcotization may occur when naloxone is metabolized and excreted. Thus, both mother and neonates should be carefully monitored for recurring signs of narcosis after opioid reversal with naloxone.[17] Should this occur, additional naloxone can be given.

Sedative-Hypnotics

Thiopental given IV produces rapid induction of basal narcosis for intubation and inhalation anesthesia. The pharmacological effects of thiopental on cardiovascular and respiratory function include increased heart rate, decreased arterial pressure, and changes in peripheral vascular resistance. Cerebral blood flow, oxygen consumption, perfusion pressure, and intracranial pressure decrease with thiopental administration. Apnea is common on induction. Recovery from thiopental is generally rapid because of redistribution and metabolism. Metabolism occurs primarily in the liver. Although thiopental rapidly crosses the placenta, it is also rapidly cleared from the neonatal circulation. Fetal metabolism may contribute to its rapid clearance in utero. Barbiturates can cause neonatal respiratory depression, sleepiness, and decreased activity. Suckling activity is decreased and has been reported to be depressed for 4 days in neonates.[17] These effects are reduced when thiopental is administered in lower doses (<4 mg/kg).[17]

The administration of propofol IV produces rapid induction of basal narcosis for intubation and inhalation anesthesia. The pharmacological effects of propofol on cardiovascular and respiratory function are nearly identical to, but slightly greater than, those of thiopental: Arterial pressure and vascular resistance decrease. Cerebral blood flow, oxygen consumption, perfusion pressure, and intracranial pressure decrease as with thiopental. Apnea is common on induction. Recovery from propofol is prompt and smooth owing to rapid redistribution and metabolism. Metabolism occurs primarily in the liver, but extrahepatic metabolism also occurs. Because of its extensive distribution and rapid metabolism, recovery is very rapid in some species. Although propofol rapidly crosses the placenta, it is rapidly cleared from the neonatal circulation.

Several recent studies have compared the use of propofol in companion animal cesarean section anesthesia with more traditional general anesthesia techniques. In dogs, propofol followed by isoflurane anesthesia resulted in newborn survival rates comparable to epidural anesthesia and superior to general anesthesia induced with thiopental.[28] Cohort retrospective studies by Moon and coworkers[22,23] indicated that administration of propofol IV followed by isoflurane increased puppy vigor, vocalization, and survival following surgery. Their findings were similar to those in the previously reported study by Funkquist et al.[28] Constant-

rate infusion of propofol as a sole anesthetic agent in pregnant ewes demonstrated maternal hemodynamics superior to those of isoflurane anesthesia.[29] The uterine blood-flow profile was similar in both techniques. Propofol-sevoflurane anesthesia in pregnant goats demonstrated that fetal physiology was maintained following propofol administration, but hemodynamic indices decreased after exposure to sevoflurane.[30] These studies support the inclusion of propofol in a balanced general anesthesia protocol for cesarean section. In dogs and cats, the induction dose of propofol is 4 to 8 mg/kg IV. Supplemental doses are 0.5 to 2.0 mg/kg IV. Longer-term constant-rate infusions of propofol to maintain anesthesia may result in some fetal depression, however. The induction dose in sheep and goats is 3 to 5 mg/kg IV.

Etomidate is a short-acting nonbarbiturate hypnotic. In dosages suitable for anesthetic induction, etomidate induces rapid anesthesia with no significant cardiovascular effects in dogs.[31,32] Cerebral blood flow, oxygen consumption, perfusion pressure, and intracranial pressure decrease as with thiopental. Apnea is common on induction. Etomidate is rapidly redistributed and metabolized by hepatic microsomal enzymes and by plasma esterases. Fetal tissue perfusion is well maintained, as shown by more rapid initiation of neonatal spontaneous breathing and greater fetal vitality at delivery than with thiopental.[33] The induction dose of etomidate in non-premedicated dogs and cats is 1.0 to 3.0 mg/kg IV.[34] Based on its rapid elimination profile in cats, etomidate may be suitable for repeated administration IV in low doses in this species.[35] However, repeated administration of etomidate may also cause acute hemolysis, as has been reported in dogs.[36] Etomidate frequently causes pain on IV injection in non-premedicated patients. In addition, myoclonus or involuntary movements can occur upon injection, but can be prevented by premedication with benzodiazepines and/or opioids.

Saffan is a combination of two progesterone-like steroids (alphaxalone, 9 mg/mL, and alphadolone, 3 mg/mL). This agent can be administered intravenously or intramuscularly to cats. Anesthetic induction is smooth and rapid. Cardiovascular depression is proportionate to dose and similar to that of equivalent doses of thiopental or methohexital. Saffan induces less respiratory depression than barbiturates and is compatible with the commonly used preanesthetics, muscle relaxants, and inhalation anesthetics.[37] It has been shown to cross the placenta. Its use in dogs is not recommended because the solubilizing agent (cremaphore) causes severe histamine release. However, it has been used to induce anesthesia in dogs pretreated with antihistamines.[38] Alphaxan-CD has recently been introduced in Australia as a short-acting anesthetic for use in dogs and cats. In this formulation, alphaxalone is solubilized in a cyclodextran carrier void of histamine-releasing properties. It has proved to be an effective short-acting anesthetic with minimal cardiopulmonary depression and few adverse effects. Because of these properties, its use for anesthesia in cesarean section surgery appears promising.

Dissociatives

Ketamine has been used in general anesthesia for cesarean section. In women, doses of less than 1 mg/kg induced minimal neonatal depression.[19,24] Alternatively, thiopental (2 to 3 mg/kg) and ketamine (0.5 mg/kg) have been coadministered to induce anesthesia in parturient women. A more recent publication indicates that low doses of ketamine (3 to 5 mg/kg IV in dogs, 2 to 4 mg/kg IV in cats, and 2 mg/kg IV in horses) may be used for anesthetic induction.[39] Because effective induction doses for these agents are higher in companion animals than humans, neonatal depression is more likely to be associated with their use. A retrospective cohort study in dogs indicated that ketamine use leads to increased puppy risk associated with respiratory depression, apnea, decreased vocalization, and increased mortality at birth.[22,23] For these reasons, ketamine should be used cautiously in this species. No data for comparative fetal viability are available in other species.

Little information is available regarding the use of tiletamine-zolazepam in cesarean section. Based on pharmacological profile, characteristics of this proprietary drug mixture are qualitatively similar to other dissociative-benzodiazepine tranquilizer mixtures. In vivo characteristics of these agents suggest that caution be used in companion animal cesarean section anesthesia, because of their rapid and extensive transplacental transfer and absence of specific antagonist agents.

Neuroleptanalgesia

The combination of opioid and tranquilizer class drugs can induce anesthetic effectively in depressed, exhausted parturients. As noted above, both opioids and tranquilizers extensively cross the uteroplacental interface and may cause significant fetal depression. These agents are usually used as an anesthetic supplement following fetal removal, although they have been successfully used for induction and maintenance prior to fetal extraction. If fetal depression is noted after administration of these agents, oral sublingual administration of naloxone (1 to 2 drops) rapidly reverses opioid effects in neonates. Continuous monitoring for neonatal renarcotization is warranted.[39]

Inhalation Agents

Inhalation anesthetics may be used to induce anesthesia in calm or depressed dams. These agents readily cross the placenta with rapid fetal and maternal equilibration. Thus, the degree of neonatal depression is proportional to the depth of anesthesia induced in the mother. Deep levels of maternal anesthesia cause maternal hypotension, decreased uterine blood flow, and fetal acidosis. Isoflurane, sevoflurane, or desflurane are preferred because induction and recovery of mother and neonate are more rapid. Nitrous oxide can be used to potentiate their effect, thus decreasing the total amount of volatile agent administered. If nitrous oxide is administered at 60% or less, fetal depression is minimal and neonatal diffusion hypoxia does not occur upon delivery.[17–19]

Skeletal Muscle Relaxants

These cross the placenta to a very limited degree and have little effect on neonates when used in reasonable clinical doses; thus, these drugs are very useful in balanced anesthesia techniques for cesarean section to facilitate rapid airway management and provide surgical site relaxation.[15,18,19] Because of its rapid onset of action and relatively brief duration, succinylcholine is a tradi-

tional choice when combined with an ultra–short-acting barbiturate or propofol for induction of anesthesia and airway control. Mivacurium has also been used because of its rapid onset of effect and relatively brief (15 to 20 min) duration of action. Atracurium and vecuronium provide an intermediate (20 to 35 min) duration of action.[39] Their characteristics make them attractive alternatives in longer procedures. The use of long-acting muscle relaxants, such as pancuronium (45 min), is generally avoided because of their length of action when compared with procedure time.[17]

Guaifenesin has been used to relax skeletal muscle in horses, cattle, and small ruminants. Although limited in reports, clinical impressions indicate that transplacental transfer is minimal based on vigor of the newborn after delivery.

Local Anesthetics

These are frequently used in combination with other agents or as the sole anesthetic agent for regional techniques. Esters of paraaminobenzoic acid (procaine or tetracaine) are metabolized by maternal and fetal pseudocholinesterase. Thus, there is little accumulation of these agents in the fetus. Amide derivatives (e.g., lidocaine, mepivacaine, bupivacaine, etidocaine, and ropivacaine) are metabolized by hepatic microsomal enzymes. After absorption from the injection site, blood levels decrease slowly but can reach significance in the fetus. Neonatal blood concentrations in excess of 3 μg/mL of lidocaine or mepivacaine can cause neonatal depression at delivery. These concentrations rarely occur after epidural administration but can occur with excessive volumes of drug used for local infiltration.[17]

Sympathetic blockade resulting in maternal hypotension and decreased uteroplacental perfusion may occur after epidural injection. This can be controlled by judicious administration of IV fluids to offset increased capacity of the vascular tree.[17] In addition to IV fluids, vasopressors can be used to treat maternal hypotension caused by sympathetic blockade. Because ephedrine acts centrally and has minimal arterial vasoconstrictor properties while increasing venous tone and thereby preload, it can be used to treat maternal hypotension, thus restoring uterine blood flow. Mephentermine acts in a similar manner. Other agents with α-adrenergic activity increase maternal blood pressure by increasing systemic vascular resistance. This may cause uterine blood flow to decrease, and fetal deterioration often occurs. In addition, these agents can stimulate hypertonic uterine contractions, further decreasing uteroplacental perfusion.[17,19]

Anesthetic Techniques for Cesarean Section

General Anesthesia

Cesarean section anesthesia can be accomplished either by regional or general anesthesia. Advantages of general anesthesia include speed and ease of induction, reliability, reproducibility, and control. General anesthesia provides optimum operating conditions with relaxed immobile patients. Tracheal intubation ensures control of the maternal airway, thereby preventing aspiration of vomitus or regurgitated rumen contents. In addition, it provides a route for maternal oxygen administration, thereby improving fetal oxygenation. When general anesthesia is administered properly, maternal cardiopulmonary function is well maintained.[19,39]

General anesthesia may be more appropriate than regional anesthesia in selected clinical situations. These include maternal hypovolemia, prolonged dystocia in which the mother is exhausted and the fetus is severely stressed, maternal cardiac disease or failure, morbid obesity, cases in which the mother is so aggressive or fractious as to preclude regional anesthesia, and brachycephalic dogs with upper airway obstruction. Finally, most veterinarians are more confident of their ability to induce general anesthesia safely than to use regional anesthesia techniques.

General anesthesia does have certain disadvantages. It will likely produce greater neonatal depression than will regional anesthesia. Inadequate anesthetic plane causes maternal catecholamine release, which may result in hypertension and decreased uteroplacental perfusion, leading to both maternal and fetal stress and deterioration of cardiopulmonary function.[12,13,26] Loss of airway protective reflexes following anesthetic induction may produce aspiration and airway management challenges when the trachea is not properly intubated. Aspiration and inability to intubate the trachea successfully are the leading causes of maternal mortality associated with cesarean section in women.[19,39] Fortunately, dogs, cats, and horses are relatively easy to intubate because of their anatomical features. However, ruminants and swine are relatively difficult to intubate, and this presents problems for most veterinarians in rural practice.

Dystocia in mares is an emergency in which duration has a profound effect on the survival of foals.[40] Foals are normally delivered within 20 to 30 min after chorioallantoic membrane rupture. Few foals survive when the duration is increased to 40 min, and none are likely to survive when the duration is 90 min or longer.[41,42] In a recent article, the time from chorioallantoic rupture to delivery was significantly different in surviving foals (71.7 ± 34.3 min) when compared with nonsurviving foals (85.3 ± 37.4 min).[40] This makes dystocia in mares more of an emergency than it is for most species, where as little as 15 min can mean the difference between a live and dead foal. Importantly, the method of resolving a dystocia has an impact on the time from chorioallantoic rupture to birth. Four procedures can be attempted: assisted vaginal delivery (AVD), in which the mare is awake and manually assisted to some degree; controlled vaginal delivery (CVD), where the mare is anesthetized and the clinician is in control of delivering an intact foal; fetotomy, where the dead fetus is reduced to more than one part and removed vaginally in the awake or anesthetized mare; and cesarean section, where the fetus is removed through a uterine incision by celiotomy.[43] It has been suggested that CVD, followed rapidly by cesarean section if initial attempts are unsuccessful, is the best choice for dystocia resolution.[40]

Physical examination, anesthetic induction, and delivery should be accomplished in the shortest period possible when there is the chance of delivering a live foal.[40] Time-consuming methods of anesthetic induction in mares should be abandoned in favor of methods that provide reliable sedation and smooth con-

trolled induction with favorable recoveries. Sedation can be achieved rapidly with xylazine (0.8 mg/kg IV) followed by induction with ketamine (2.2 mg/kg IV) and diazepam (Valium, 0.08 mg/kg IV). Anesthesia is then maintained with isoflurane or halothane in 100% oxygen.[40] While CVD is attempted, the ventral abdomen is clipped and prepped so that, if needed, cesarean section may be accomplished rapidly. In one report this approach to dystocia resulted in 94% of the CVD mares and 89% of the cesarean section mares surviving to discharge with a 42% delivery of live foals. Nearly 30% of foals survived to discharge.[40] In these scenarios, specific choice of anesthetic agent is probably less important than the time to induction and delivery of the foal.

Much of the previously published recommendations for anesthesia of term mares has been extrapolated from work done in other species and may not be relevant. Goals for delivering anesthesia are no different than for other species, but with a greater emphasis placed on rapid completion of the procedure. Laboring mares are typically agitated and distressed prior to anesthetic induction, and good sedation is therefore important to ensure a smooth and safe induction. Xylazine and detomidine will provide sufficient sedation and can be reversed in neonates after delivery. Detomidine may cause less increase in uterine tone than xylazine and has been suggested by some as the sedative of choice in mares.[44] When butorphanol is combined with xylazine or detomidine, reliable restraint and analgesia occur. The dose of xylazine or detomidine can be lowered when combined with butorphanol, minimizing potential side effects of the α_2-agonists.

There is little work regarding use of tiletamine-zolazepam in mares presenting for dystocia, but based on pharmacological profile, it should be similar to other dissociative-benzodiazepine tranquilizer anesthetic combinations. It has been suggested that because of the potential for ion trapping, the use of benzodiazepines should be avoided in mares presenting for cesarean section,[45] but there is no evidence to support that this occurs excessively in foals. Ketamine is rapidly cleared from maternal and fetal circulation, causes minimal cardiovascular depression, and provides for a smooth induction, making it suitable for induction in pregnant mares. Thiopental is also rapidly cleared from fetal circulation and would be acceptable for inducing anesthesia, though induction may be rough when used alone. Recent work done in pony mares has found that maintenance of anesthesia with propofol or a combination of guaifenesin, ketamine, and detomidine (GKD) preserved cardiovascular function in both the mare and fetus.[46,47] This suggests that GKD could be suitable for anesthetic induction of term mares. Guaifenesin is a centrally acting muscle relaxant that crosses in minimal amounts to the fetal circulation. In the field where equipment is not readily available for delivering inhalation anesthesia, a mixture of guaifenesin-ketamine-xylazine has been infused to effect for up to 1 h to maintain an adequate level of central nervous system depression.[48]

Studies have been done comparing the effects of isoflurane and halothane in pregnant mares, and no marked differences between the two have been demonstrated.[49] Less soluble agents (such as isoflurane and sevoflurane) would have the advantage of being more rapidly cleared from foals after delivery as compared with the more soluble agent halothane.[45]

Monitoring and support of an anesthetized pregnant mare are no different than for any anesthetized horse. Care should be taken to avoid maternal hypoxia in order to maintain fetal oxygenation until delivery. Mechanical ventilation should be considered to help offset the ventilation-perfusion mismatching that occurs. When using positive-pressure ventilation (PPV) to improve oxygenation of mares, arterial blood gases should be assessed shortly after initiating PPV to ensure that the desired increase in PaO_2 is actually occurring. PPV in a mare with severe abdominal distension has the potential to drastically decrease cardiac output to all tissues, including maternal circulation to the foal. Arterial blood pressure should be monitored directly and ideally kept above 70 mm Hg by adjusting anesthetic depth and rate of fluid delivery, and by administering inotropes and vasopressors, as needed.

Mares recovering from dystocia or cesarean section may have a difficult time regaining the strength needed to stand. Special attention should be given to the condition of the recovery stall, and the floor should be cleaned of all obstetric lubricant and dried. Mares should be placed on a well-padded surface in the recovery stall and may be rope assisted during recovery when necessary.

A spectrum of techniques for induction of general anesthesia for cesarean section in dogs and cats have been reported to be satisfactory (Table 45.2).[50] All reported techniques have common strategies for successful patient management which include the following points. Induction of anesthesia must be smooth and rapid. Excitement and struggling associated with excessive restraint and poor technique must be avoided. Intubation should be accomplished quickly and ventilation supported to ensure adequate oxygenation.

Maternal oxygen administration can significantly increase fetal oxygen content. Administration of oxygen to the mother is not associated with a significant decrease in uterine blood flow or fetal acidosis.[17] Fetal red blood cells have a lower 2,3-diphosphoglycerate concentration than do adult red blood cells. Thus, fetal hemoglobin can carry more oxygen at low oxygen tensions than can adult hemoglobin. Physiologically, this is important because it ensures a higher level of hemoglobin saturation at the normally low oxygen partial pressures (PO_2 of umbilical vein, 30 mm Hg) to which the fetus is exposed.[20,51] Inspired oxygen concentrations of 50% or more during general anesthesia result in more vigorous neonates because of improved oxygenation.[17] Therefore, oxygen administration is indicated regardless of the anesthetic protocol.

Tidal and minute ventilation must be critically evaluated during the anesthetic period to avoid either hypoventilation or hyperventilation. The total effect of carbon dioxide on the fetus is not clear, but passive hyperventilation of the dam causes hypocapnia with decreased uterine artery blood flow. This decreased placental perfusion causes fetal hypoxia, hypercapnia, and acidosis. With adequate arterial oxygenation, a modest increase in $PaCO_2$ is well tolerated by the fetus.[17] Adequacy of ventilation and oxygenation may be assessed by observing rate of respiration, excursion of the chest wall and/or reservoir bag, and color of mucous membranes; by implementation of pulse oximetry; and by determination of $PaCO_2$ and PaO_2.

Table 45.2. Selected anesthesia techniques for elective and emergency cesarean section anesthesia in common domestic species.

Species	Drug or Technique		
	Elective Cesarean Section	**Emergency Cesarean Section**	**Comments**
Dog	1. Lumbosacral epidural 2. Anticholinergic Propofol, 4–8 mg/kg Isoflurane or sevoflurane Post–removal pain meds 3. Anticholinergic Fentanyl, 3 µg/kg Propofol, 4–8 mg/kg Isoflurane or sevoflurane	1. Lumbosacral epidural 2. Sevoflurane or isoflurane mask induction 3. Anticholinergic Fentanyl, 3 µg/kg Propofol, 4–8 mg/kg Isoflurane or sevoflurane 4. Anticholinergic Fentanyl, 3 µg/kg Propofol, 4–8 mg/kg Line block Atracurium, 0.2 mg/kg	1. May require assistant to restrain epidural patients 2. Give oxygen to all patients as soon as possible 3. Monitor heart rate and redo anticholinergic if needed 4. Minimal inhalant agent dose until all fetuses are removed 5. May need to reverse fentanyl with sublingual naloxone if fetus is depressed
Cat	1. Propofol, 4–8 mg/kg Laryngeal anesthesia Sevoflurane or isoflurane Additional analgesia following fetal removal 2. Fentanyl, 3–5 µg/kg Propofol, 4 mg/kg Laryngeal anesthesia Sevoflurane or isoflurane Additional analgesia following fetal removal	1. Ketamine, 3 mg/kg Fentanyl, 3–5 µg/kg Lumbosacral epidural 2. Ketamine, 3 mg/kg Fentanyl, 3–5 µg/kg Propofol, 2–4 mg/kg Sevoflurane or isoflurane Additional analgesia following fetal removal	1. May require assistant to restrain epidural patients 2. Give oxygen to all patients as soon as possible 3. Minimal inhalant agent dose until all fetuses are removed 4. May need to reverse fentanyl with sublingual naloxone if fetus is depressed
Horse	1. GGE to effect Ketamine, 2 mg/kg Isoflurane or sevoflurane Caudal epidural for pain management 2. GGE to effect Thiopental, 4–6 mg/kg Isoflurane or sevoflurane Caudal epidural for pain management	1. GGE to effect Ketamine, 2 mg/kg Isoflurane or sevoflurane Caudal epidural for pain management	1. Standing restraint not performed in horses for cesarean section anesthesia 2. Postoperative pain management similar to that for colic patients
Cattle	1. Xylazine, 10 mg Paravertebral block 2. Xylazine, 10 mg Inverted "L" block 3. Incisional line block 4. Xylazine, 10 mg GGE to recumbency Isoflurane or sevoflurane following intubation	1. Xylazine, 10 mg Paravertebral block 2. Xylazine, 10 mg Inverted "L" block 3. Incisional line block 4. Xylazine, 10 mg GGE to recumbency Isoflurane/sevoflurane following intubation	1. Avoid recumbency with regional techniques 2. Can reverse xylazine in newborns if depression is noted 3. Supplemental analgesia in postoperative period as warranted 4. Caudal epidural to reduce postparturient "straining"
Sheep/Goat	1. Lumbosacral epidural Sedation 2. Incisional line block Sedation 3. Propofol, 4–6 mg/kg Isoflurane or sevoflurane	1. Lumbosacral epidural Sedation 2. Incisional line block Sedation 3. Propofol, 4–6 mg/kg Isoflurane or sevoflurane	1. Sheep have a high pain sensitivity 2. Variable and inconsistent response to opioids for pain management 3. α_2 Agents are frequently selected for supplemental analgesia

(*continued*)

Table 45.2. Selected anesthesia techniques for elective and emergency cesarean section anesthesia in common domestic species (*continued*).

	Drug or Technique		
Species	**Elective Cesarean Section**	**Emergency Cesarean Section**	**Comments**
Pig	1. Lumbosacral epidural Sedation 2. Incisional line block Sedation 3. Propofol, 4–6 mg/kg Isoflurane or sevoflurane	1. Lumbosacral epidural Sedation 2. Incisional line block Sedation 3. Propofol, 4–6 mg/kg Isoflurane or sevoflurane	1. Will need sedation in addition to regional analgesia in elective section 2. Good response to opioid analgesic agents following fetal removal 3. NSAIDs are frequently used for pain management
Llama	1. GGE to effect 2. Propofol, 2–4 mg/kg 3. Isoflurane or sevoflurane	1. GGE to effect 2. Isoflurane or sevoflurane	1. Limited reports in literature 2. Pain management following fetal removal as per other procedures

GGE, guaifenesin glycerate ester; NSAIDs, nonsteroidal anti-inflammatory drugs.

Regional Anesthesia

This is a well-established technique for cesarean section.[16] There is an increased sensitivity and distribution to local anesthetic agents during gestation and parturition. As a result, the dose of local anesthetic for epidural or spinal anesthesia can be reduced by approximately one-third in pregnant patients as compared with nonparturients. Regional anesthesia (epidural or subarachnoid) has the advantages of technique simplicity, minimal exposure of the fetus to drugs, less intraoperative bleeding and, because the mother remains awake, minimal risk of aspiration.[52] In addition, muscle relaxation and analgesia are optimal. Caudal spinal anatomy in the lumbosacral region varies by species. The spinal cord terminates at the level of the sixth lumbar vertebra in dogs, reducing the risk of subarachnoid (true spinal) injection of the anesthetic agent. The spinal cord terminates variably between L7 and midsacrum in cats, making subarachnoid injection a greater possibility.[53] In swine and ruminants, the spinal cord terminates at the midsacrum, making subarachnoid injection a possibility at the lumbosacral junction.

Epidural anesthesia has been successfully used in dogs and cats for cesarean section anesthesia. Traditionally, a short-acting local anesthetic (2% lidocaine) is administered at a dose of 1 mL per 3.25 to 4.5 kg of body weight in the epidural space to provide surgical site anesthesia. In recent years, epidurally administered drugs, including lidocaine and bupivacaine in a 1:1 volumetric mixture, have provided extended duration of surgical anesthesia and pain management in the early recovery period. This may be supplemented with epidural opioids and α_2-adrenergic agonists to extend the postoperative analgesic period.

Spinal techniques work well in sows, sheep, and goats. The technique is well established and not difficult. When using this technique, it is sometimes necessary to restrain a sow's head and forelimbs. If pigs are sedated and restrained in lateral recumbency with the head extended, the soft palate may occlude the airway and the patient may suffocate. This has been observed in sows and gilts undergoing cesarean section with spinal anesthesia without additional sedatives or tranquilizers. Because cesarean section in swine is often viewed as a last-ditch effort by producers, it is often delayed until the sow's condition has deteriorated severely. Thus, a high percentage of sows presented for cesarean section are hypovolemic and hypotensive. Fluids can be readily administered to sows via indwelling catheters placed into the ear veins prior to anesthetic administration. This will restore circulating volume and offset hypotension induced by spinal techniques.

Spinal anesthesia often induces recumbency, which may not be desirable in large ruminants. If the veterinarian prefers, standing cesarean section in cattle may be performed using either a proximal or distal paralumbar block. In cows that are in poor condition, exhausted, or in shock, the distal technique is preferred because it does not induce a scoliosis-like position and the cow is more likely to remain standing throughout the procedure.

Disadvantages of epidural or subarachnoid anesthesia include hypotension secondary to sympathetic blockade. Hypotension induced by epidural anesthesia can be managed with IV fluid and catecholamine administration. Lactated Ringer's solution or 0.9% or 0.45% sodium chloride mixed with equal volumes of 5% dextrose solution can be administered at approximately 20 mL/kg over 15 to 20 min to maintain arterial blood pressure. When hypotension is severe, ephedrine may be administered (0.15 mg/kg IV). Hypotension and visceral manipulation during the procedure can cause nausea and vomiting.[54] Because the dam remains conscious, the forelimbs and head often move. This precludes the use of a spinal technique in highly excited or fractious patients and in mares, because they become hysterical when they are unable to stand.

Local Anesthesia

Local infiltration or field block may be used, but these techniques have several disadvantages when compared with regional tech-

niques. Infiltration requires larger amounts of anesthetic agent, which are absorbed and can create fetal depression. In addition, muscle relaxation and analgesia are not as profound or as uniform when compared with regional anesthesia. In many cases, field block is supplemented with heavy sedation or tranquilization to calm and stabilize a dam; these agents further contribute to maternal and fetal depression. For these reasons, field block is often abandoned for either general or epidural anesthesia.

Care of Newborns

Following delivery, the newborn's head is cleared of membranes and the oropharynx of fluid. The umbilical vessels should be milked toward the fetus to empty them of blood, clamped approximately 2 to 5 cm from the body wall, and severed from the placenta. Neonates can then be gently rubbed with a towel to dry them and stimulate breathing. It may also be helpful to swing neonates gently in a head-down position to help clear the respiratory tree of fluid. Vigorous motion should be avoided because amniotic fluid is readily absorbed in the lungs and contributes to distribution of pulmonary surfactant in the alveoli. The head and neck should be supported to avoid whiplash and prevent injury.

Flow-by oxygen administration in the vicinity of the muzzle is helpful to increase heart rate and oxygen delivery to tissues in distressed, exhausted neonates. Reversal of opioids by sublingual administration of 1 to 2 drops naloxone is warranted in cases where opioids were administered as part of the general anesthesia technique. An oral dose of 2.5% dextrose (0.1 to 0.5 mL) is helpful to improve energy substrates required for initial breathing effort in stressed neonates. Finally, maintaining warmth is vital because hypothermia can occur rapidly after birth.

A small IV catheter may be used to intubate and support oxygen delivery in neonates that will not initiate breathing, and their breathing can be artificially supported by using a syringe and three-way valve attached to an oxygen source. As a final measure, doxapram can be used to stimulate breathing in neonates. In pups, a dosage of 1 to 5 mg (approximately 1 to 5 drops from a 20- to 22-gauge needle) is topically administered to the oral mucosa or injected intramuscularly or subcutaneously. In kittens, the dosage is 1 to 2 mg (1 to 2 drops).[50] Airways must be clear before doxapram administration. External thoracic compressions may be warranted if heart rate is slow and does not respond to support measures. A rapid physical examination checking for genetic defects (cleft palate, chest deformity, or abdominal wall fusion) is also important to determine whether viability is present.

When general anesthesia is used in ruminants or horses, an alternate method of managing neonates may be used to good advantage. After uterine incision, the fetal head is delivered through the incision, the oropharynx is cleared of fluid, and the trachea is intubated with a cuffed tube. The fetus can then be delivered and the umbilicus severed. Because the uteroplacental and umbilical circulation is preserved until the airway is secured, hypoxia is prevented. Once the fetus is delivered, ventilation can be supported, if necessary, via a bag valve mask resuscitator.

After completion of surgery and recovery from anesthesia, the young can be introduced to their mother. If introduction is delayed, the neonates should be exposed briefly to the mother to provide colostrum and then kept in a warm environment until anesthesia recovery is complete to avoid accidental crushing. If regional anesthesia was used, they can be placed with their mother as soon as the surgery is complete.

Perioperative Pain Management

This represents a challenge in cesarean section patients because of concerns regarding transfer of anesthetic and analgesic drugs into milk and its impact on neonates. This area has been extensively studied in people and in food-producing species. Most of the current information is from humans and cattle; however, because of the similarity of the lactation process in all mammals, the information may be extrapolated to other species.

The phenothiazine tranquilizer chlorpromazine does not appear to transfer to milk at levels that cause fetal depression.[55] No corollary evidence is available for acepromazine, but similarity in molecular structure coupled with clinical experience supports a similar effect on newborns. The benzodiazepine class tranquilizer diazepam significantly crosses into milk and may cause lethargy, sedation, and weight loss in newborns.[56] Other class members, including clonazepam and alprazolam, induce drowsiness, hypotonia, and apnea in newborns after nursing episodes. The effect of lorazepam and midazolam are unknown; however, based on the effects attributed to other class members, they should be used with caution in lactating mothers. Xylazine transiently increases in milk and then decreases to nondetectable levels by 12 h after administration.[57] Detomidine (80 μg/kg) can be detected at a low level in milk after administration but is nondetectable by 23 h later.[58]

Codeine, propoxyphene, and morphine are well tolerated by newborns when used in maternal pain management, even when repeat doses are administered over several days.[59] Meperidine (pethidine) has been reported to cause decreased suckling behavior and sedation when used in serial doses.[59,60] Fentanyl (100 μg) and sufentanil (10 to 50 μg) are not detectable in breast milk after epidural administration in humans.[61]

Thiopental has been detected in colostrum and breast milk after a single bolus induction dose (5 mg/kg) in women.[62] Long-acting barbiturates such as phenobarbital are contraindicated because of their extensive presence in milk.[55] Propofol is detectable in colostrum and milk after a single-dose administration.[63] However, little clinical effect is noted based on excellent newborn vitality immediately after delivery.[22,23] The residual presence of inhalation anesthetic agents in milk is not known; however, clinical experience suggests that prolonged neonatal sedation following clinical recovery of dams is not common.

Local anesthetic drugs (e.g., lidocaine and bupivacaine) and first-generation bupivacaine metabolites are excreted in milk after their epidural administration in humans. Although these agents are detectable in milk, their influence on neonates is negligible based on maximum Apgar (activity, pulse, grimace, appearance, and respiration) scores at delivery.[64]

Nonsteroidal anti-inflammatory drugs appear to reach only limited levels in milk after maternal administration. In humans,

acetaminophen and aspirin are considered compatible with breast feeding.[59] Studies evaluating carprofen in cattle indicated that milk levels were below detectable limits (<0.022 μg/mL) after a single-dose administration. After experimental induction of mastitis, carprofen was detected at low levels (0.16 μg/mL) for 12 h following single-bolus administration and decreased to undetectable levels (<0.022 μg/mL) by 24 h.[65] Following a single dose of ketoprofen (3.3 mg/kg) in cattle, nonquantifiable concentrations of ketoprofen were detected in milk for only 2 h.[66] Similar results have been reported in lactating goats.[67]

With the possible exception of the nonsteroidal anti-inflammatory drugs and their potential for inhibiting newborn organ maturation, it appears that most commonly used analgesic drug classes may be safely administered during the lactation period without adverse effects on newborns.

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