Cesarean Section in Dogs: Physiology and Perioperative Considerations*

Stewart D. Ryan, BVSc (Hons), MACVSc
Ann E. Wagner, DVM, MS, DACVP, DACVA
Colorado State University

ABSTRACT: Cesarean section is common in small animal veterinary practice. The goal of cesarean section is delivery of healthy, vigorous pups and provision of surgical anesthesia, appropriate analgesia, and rapid return to consciousness for the dam. Changes in maternal respiratory and cardiovascular physiology that occur during pregnancy and neonatal physiology and circulation have a significant impact on anesthetic pharmacokinetics and pharmacodynamics. Various risk factors for maternal mortality and neonatal mortality and vigor have been identified and should influence the perioperative and anesthetic management of patients undergoing cesarean section. Intensive neonatal resuscitation techniques can lead to decreased periparturient neonatal mortality.

Elective or emergency cesarean section is common in preventing or treating dystocia. Anesthetic and perioperative management associated with cesarean section are influenced by altered maternal physiology during pregnancy, differing pharmacokinetics and pharmacodynamics between the fetus and dam, and consideration of maternal well-being as well as viability and vigor of neonates. The availability and experience of personnel, familiarity with various anesthetic techniques, and availability of anesthetic equipment also influence anesthetic management choices. The aim of cesarean section is delivery of healthy, vigorous puppies, with provision of surgical anesthesia, analgesia, and a rapid return to consciousness for the dam.

A variety of anesthetic protocols have been described for cesarean section in dogs.1–8 The basis for many of these protocols is extrapolated from experimental animal studies and the human literature. There are few controlled veterinary studies comparing various anesthetic protocols.1,8 An extensive prospective study on perioperative and anesthetic management for cesarean section in the United States and Canada identified various risk factors associated with anesthetic management of cesarean section, maternal and neonatal mortality and morbidity, and puppy vigor.9–11

A review of anesthetic and perioperative considerations for cesarean section is clinically relevant to practicing veterinarians for several reasons:

• Many new veterinary anesthetic drugs have been introduced,12–15 and the description and more widespread use of balanced anesthetic
techniques have been adopted in the past decade. Many of these techniques and anesthetics are applicable to cesarean section and can easily be incorporated into the general practice setting. Anesthetic monitoring equipment is more widely available, permitting better tailoring of anesthesia to a patient’s needs.

- Maternal mortality associated with cesarean section has decreased significantly in the past 30 years (15% to 1%), but the neonatal mortality rate is still similar (i.e., 15% to 8%–14%). Through the use of appropriate anesthetic protocols and monitoring and effective neonatal resuscitation techniques, further decrease in the neonatal mortality rate should be possible.

- Survey results of current practices for cesarean section have identified several anesthetic and management risk factors associated with maternal mortality, neonatal mortality, and puppy vigor.

- Understanding the changes in maternal and fetal physiology that occur during pregnancy and the pharmacokinetics and pharmacodynamics of anesthetics used is necessary to formulate an effective and safe anesthetic plan for periparturient dogs.

This article reviews the changes in maternal physiology that occur during pregnancy, fetal circulation and physiology, and perioperative factors that influence anesthetic management of cesarean section. Neonatal resuscitation and postoperative care and analgesia of the dam are also discussed.

**MATERNAL PHYSIOLOGY**

Dams and fetuses have an increased metabolic demand during pregnancy. To meet this demand, maternal blood volume progressively increases by approximately 40% during pregnancy. The increase in plasma volume is proportionally greater than the increase in erythrocytes, leading to hemodilution and relative anemia. This progressive normochromic, normocytic anemia develops between days 25 and 30 of pregnancy and is most severe at full term. Hematocrit values at full term can be as low as 30% to 35%. The degree of anemia appears to be greater with an increasing number of fetuses. A right shift in the maternal hemoglobin dissociation curve occurs, allowing more effective delivery of oxygen to maternal and fetal tissue. There is no absolute decrease in erythrocyte mass, and the hematocrit returns to normal within 8 to 12 weeks after parturition as the plasma volume returns to normal. Increased cardiac output proportional to increased blood volume occurs during pregnancy as a result of increased heart rate and stroke volume. Peripheral vascular resistance decreases during pregnancy, resulting from the increased capacity of blood vessels in the uterus, mammary glands, kidneys, striated muscle, and cutaneous tissue, so that the mean arterial blood pressure is maintained and circulatory overload does not accompany the increased cardiac output.

Compensatory cardiovascular baroreceptor mechanisms in response to hemorrhage or hypotension may be attenuated during pregnancy. Cardiac work is increased and cardiac reserve is decreased during pregnancy. Animals with cardiac disease that were previously stable or well controlled on medications can become decompen-sated and develop heart failure during pregnancy and parturition.

During pregnancy, there is decreased functional residual capacity (FRC; the remaining lung volume measured at the end of a normal expiration), decreased total lung volume, and increased minute ventilation and oxygen consumption. Decreased FRC and total lung volume are due to cranial displacement of the diaphragm by the expanding gravid uterus. Oxygen consumption increases because of the metabolic demands of the fetus, uterus, and mammary glands. The combined effect of decreased FRC and increased oxygen consumption makes dogs in late gestation very susceptible to hypoxemia. Any period of apnea can cause rapid maternal arterial hemoglobin desaturation, decreased oxygen delivery to the fetus, and, hence, fetal hypoxia. The most critical time for apnea is at anesthetic induction, so preoxygenation with 3 to 5 L/min of 100% oxygen by face mask before and during induction of anesthesia is highly advisable to decrease the risk of hypoxemia.

The arterial partial pressure of carbon dioxide (PaCO₂) decreases during pregnancy as a result of increased sensitivity of the respiratory center to carbon dioxide and consequent increased minute ventilation. The normal
PaCO₂ in pregnant animals can be as low as 30 to 33 mm Hg compared with 40 mm Hg in nonpregnant animals.24

Hyperventilation, either spontaneous (as can occur with stress, anxiety, or pain during labor) or related to assisted ventilation under general anesthesia, can worsen maternal hypocapnia. Under conditions of hypocapnia, the maternal oxyhemoglobin dissociation curve shifts to the left, increasing the maternal hemoglobin affinity for oxygen (Bohr effect) and decreasing oxygen transfer to the fetus.24,25 Hyperventilation has been associated with increased uterine vascular resistance, leading to reduced uterine blood flow and further compromise of oxygen delivery to the fetus.25

Decreased FRC and increased minute ventilation in pregnant animals allow rapid equilibration between inspired and alveolar inhalant anesthetic concentrations, making induction of inhalation anesthesia more rapid than in nonpregnant animals.19 In addition, the minimum alveolar concentration is reduced by 25% for halothane and 40% for isoflurane in pregnant sheep and humans compared with nonpregnant individuals.26–28 The exact mechanism for this increase in sensitivity is unknown but is thought to be related to increased serum progesterone concentrations exerting a depressant effect on the central nervous system (CNS).18 Therefore, pregnant animals may be at a higher risk of relative anesthetic overdose.

Renal blood flow and glomerular filtration rate increase during pregnancy as a consequence of increased blood volume and cardiac output. This decreases the serum urea nitrogen and creatinine levels compared with those in nonpregnant dogs.29 Insulin resistance can occur during pregnancy as a result of a progesterone-induced increase in growth hormone secretion by the mammary glands.20 This may result in resistance to exogenous insulin therapy in pregnant diabetic bitches as well as hyperglycemia in normal pregnant bitches.20

Dogs undergoing intraabdominal procedures are at increased risk of silent regurgitation during anesthesia.30 Pregnant animals have increased gastric acidity, and the gravid uterus causes increased intraabdominal pressure, leading to reduced gastric and lower esophageal sphincter tone, making regurgitation during anesthesia and possible aspiration or esophagitis more likely.5,18 Although five of the nine dams that died in one prospective study18 had evidence of pneumonia, no definitive association with regurgitation or aspiration could be documented. No studies have specifically examined the risk of regurgitation and aspiration in late pregnant dogs compared with nonpregnant dogs undergoing anesthesia.

**FETAL PHYSIOLOGY**

Drugs that are able to cross the blood–brain barrier are able to cross the placental barrier.18 All anesthetic and sedative drugs cross the blood–brain barrier to exert their desired effects on the CNS; thus they inevitably cross the placenta and exert an effect on the fetus.

Dogs have an endotheliochorial placentation and large areas of zonular implantation, allowing easy transfer of drugs from the maternal circulation to the fetus by simple diffusion.31 Most anesthetics have a low degree of protein binding, low molecular weight, high lipid solubility, and poor ionization—properties that are associated with a ready ability to cross the placental barrier and exert an effect on the fetus.

Fetal circulation differs from adult circulation in that oxygenated blood enters the fetus at the level of the splanchnic circulation (Figure 1). Maternal blood that is
delivered to the fetus via the umbilical vein has a low partial pressure of oxygen (PO₂)—typically 40 mm Hg. To make efficient use of this blood, fetal hemoglobin has a greater affinity for oxygen than does maternal hemoglobin (i.e., the fetal oxyhemoglobin dissociation curve is shifted to the left compared with the maternal dissociation curve), resulting in a greater fetal hemoglobin oxygen saturation for any given PO₂ (Figure 2). This difference between fetal and maternal hemoglobin is greater in ruminant species than in dogs. Eighty percent to 85% of this blood enters the liver, where most of it bypasses the liver parenchyma via the ductus venosus to enter the caudal vena cava, where it mixes with venous blood. The PO₂ of fetal blood returning to the right atrium is approximately 25 mm Hg, so the fetus is in a constant state of relative hypoxemia compared with maternal values. Any cause of maternal hypoxemia can lead to fetal hypoxia and acidosis. Fetal hypoxemia stimulates vasodilation in the fetal heart and brain and vasoconstriction in the pulmonary vasculature, gut, kidneys, and skeletal tissue. Anesthetics entering the fetal circulation are partially metabolized by the fetal liver and diluted with blood from the caudal circulation before passing to the fetal heart and brain. The clinical effect of fetal circulation is that the heart and brain are relatively protected from perfusion with blood containing high concentrations of anesthetics. Anesthetics that have a short half-life have short peak concentrations in the mother and fetus, whereas anesthetics that are administered continuously (e.g., volatile inhalation agents, constant-rate infusion injectables) may have a persistent depressant effect. Volatile inhalation anesthetics have marked cardiovascular and respiratory depressant properties. Selection of inhalation anesthetics with a low blood solubility and maintenance of the lowest possible gaseous anesthetic concentrations are recommended to minimize neonatal depression.

The hepatic microsomal enzyme systems responsible for drug metabolism are incompletely developed or absent in neonatal puppies and take 3 to 5 weeks to reach adult levels. Drugs that undergo hepatic metabolism have a longer duration of effect in fetuses or neonates.

Table 1 summarizes maternal and fetal physiologic changes that occur during pregnancy and their clinical implications.

### PERIOPERATIVE CONSIDERATIONS

Cesarean section is performed on an emergency basis 58% of the time. Dehydration, hypovolemia, hypotension, exhaustion, hypothermia, toxemia, hypoxia, hemorrhage, and shock may be present if dystocia has been in progress for some time. There is an increased mortality risk for dams and decreased puppy survival when cesarean section is performed on an emergency basis. Puppy mortality associated with emergency cesareans was 12.7% compared with 3.6% for elective cesarean delivery. Small brachycephalic breeds (e.g., fetopelvic disproportion), large breeds (e.g., uterine inertia), and primagravid dogs are more predisposed to dystocia and are, therefore, more likely to undergo emergency cesarean section.

Elective cesarean delivery may be requested for a variety of reasons, including previous dystocia, a breed at high risk for dystocia (e.g., bulldogs), the value of the dam and litter, and convenience. Elective cesarean sections should be done as close as possible to full term to minimize the risk of decreased survivability of the neonates from insufficient development of the respiratory system. The canine gestation period is usually very consistent (i.e., 63 ± 1 days from the preovulatory luteinizing hormone surge to parturition). However, because the gestation range can vary from 57 to 72 days, the use of mating dates is not a reliable predictor of parturition date. The expected parturition date can be determined by measuring serum progesterone levels, which should drop to less than 2 ng/ml within 24 hours before parturition, or by transabdominal ultrasonographic measurements of the gestational sac in early pregnancy or the parietal diameter in late pregnancy. Commercial progesterone assay kits available for in-hos-
A drop in core body temperature to below 100°F (37.8°C) occurs within 24 hours preceding parturition as a result of decreasing serum progesterone levels and is a reliable indicator of impending parturition. Ultrasonographic monitoring of the fetus in late pregnancy with commercially available veterinary-specific fetal monitors can detect fetal stress at an early stage. The advantage of elective cesarean section is the ability to ensure optimal operative and staffing conditions and, it is hoped, decreased neonatal mortality. It is recommended that the time from induction to delivery of pups be minimized to reduce respiratory depression as a result of their exposure to inhalant anesthetics. All equipment and personnel required for anesthetic induction and maintenance, perioperative management, surgery, and neonatal resuscitation should be prepared and available before anesthetic induction (see box on page 39).

The dam must be handled in a calm and quiet manner to minimize excitement and potential catecholamine release that could cause decreased blood flow to the uterus and fetus. This is especially important in patients with preexisting heart disease because cardiac reserve is reduced and any stress or pain can cause rapid cardiac decompensation. An intravenous catheter should be placed to allow perioperative intravenous fluid therapy and administration of drugs. Correction of abnormalities in electrolyte, acid–base, calcium, or glucose levels should start before surgery. Surgical clipping of the abdomen before induction decreases the time from induction to delivery. It is recommended that the surgeon and surgical instruments be prepared before inducing anesthesia to decrease the time from induction to delivery. Although it is desirable to minimize fetal exposure to anesthetics, at least 15 to 20 minutes should elapse between induction of anesthesia and delivery of neonates to allow the effects

### Table 1. Summary of Maternal and Fetal Physiologic Changes During Pregnancy

<table>
<thead>
<tr>
<th>Physiologic Change</th>
<th>Clinical Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maternal</strong></td>
<td></td>
</tr>
<tr>
<td>• Increased blood volume (by 40% at term)</td>
<td>• Decreased volume of epidural drugs required</td>
</tr>
<tr>
<td>• Relative anemia (packed cell volume = 30%–35% at term)</td>
<td></td>
</tr>
<tr>
<td>• Increased cardiac output (increased heart rate and stroke volume)</td>
<td>• Increased cardiac work</td>
</tr>
<tr>
<td>• Decreased peripheral vascular resistance</td>
<td>• Decreased cardiac reserve</td>
</tr>
<tr>
<td>• Insulin resistance (progesterone mediated)</td>
<td>• Hypertension</td>
</tr>
<tr>
<td>• Decreased functional residual capacity and lung volume</td>
<td>• Hyperglycemia</td>
</tr>
<tr>
<td>• Increased oxygen consumption</td>
<td>• Increased likelihood of hypoxemia (especially at induction)</td>
</tr>
<tr>
<td>• Increased minute volume and alveolar ventilation</td>
<td>• More rapid anesthetic induction</td>
</tr>
<tr>
<td>• Increased progesterone level</td>
<td>• Lower minimum alveolar concentration required for maintenance</td>
</tr>
<tr>
<td>• Decreased PaCO₂</td>
<td>• Hyperventilation may cause fetal hypoxemia</td>
</tr>
<tr>
<td><strong>Fetal</strong></td>
<td></td>
</tr>
<tr>
<td>• Fetal circulation versus neonatal circulation</td>
<td>• Increased likelihood of hypoxemia</td>
</tr>
<tr>
<td>• Immature hepatic and renal metabolic pathways</td>
<td>• Inefficient hepatic drug metabolism</td>
</tr>
<tr>
<td>• Poor thermoregulatory control</td>
<td>• Hypothermia</td>
</tr>
</tbody>
</table>
of injectable induction agents on the fetus to be diminished by redistribution.\(^1\)\(^{15}\)

Adequate support personnel should be available to assist with induction and maintenance of anesthesia, instrumentation for anesthetic monitoring, preparation for surgery, and neonatal resuscitation. A specific area and necessary equipment for neonatal resuscitation should be prepared and specific roles assigned to personnel for resuscitating neonates. Ideally, one person per anticipated puppy should be available to assist with neonatal resuscitation during delivery.

Hypotension as a result of aortocaval compression during supine positioning has been well documented in pregnant women.\(^4\)\(^2\) In the early veterinary literature, it was suggested that a similar situation occurred in full-term pregnant dogs. Research\(^4\)\(^1\)\(^{4}^{\text{,}}\)\(^4\)\(^4\) in both large and small full-term bitches has shown that dorsal (supine) positioning in late or full-term pregnancy does not cause significant aortocaval compression or maternal hypotension. It is postulated that this is because dogs have a bicornate uterus and multiple fetuses, which are less likely to put direct pressure on the caudal vena cava, as well as greater collateral circulation compared with humans. The operating table should be positioned so that the patient’s head is not inclined down, which increases abdominal pressure on the diaphragm, severely compromises ventilation, exacerbates maternal and fetal hypoxemia,\(^2\)\(^4\)\(^1\) and increases pressure on the lower esophageal sphincter, which may increase the likelihood of regurgitation. The operating table should ideally be warmed to minimize maternal hypothermia.

The surgical technique for cesarean section via hysterotomy is well described.\(^4\)\(^5\)–\(^4\)\(^7\) One variation on traditional hysterotomy that considerably decreases anesthetic time and may be indicated for a very compromised dam is en bloc ovariohysterectomy.\(^4\)\(^8\)\(^9\) In this technique, the ovarian and uterine stumps are clamped and the uterus, still containing the fetuses, is removed within 60 seconds of clamping. The neonates are delivered from the uterus, outside the abdominal cavity, and resuscitated by assistants. The neonatal survival rate with this technique was similar to other reported survival rates for medically or surgically managed dystocia.\(^4\)\(^8\)

Indications for ovariohysterectomy after delivery of neonates include a grossly infected or gangrenous uterus, emphysematous fetuses, severe toxemia, or extremely prolonged dystocia.\(^4\)\(^1\) Hypotension is a particular concern when concurrent ovariohysterectomy is performed and should be preemptively treated with intravenous fluid boluses before removal of the uterus.\(^4\)\(^1\)

Maternal morbidity, based on length of hospital stay and postoperative complications, is greater in dams that had cesarean section and concurrent ovariohysterectomy compared with those that had cesarean hysterotomy alone.\(^3\)\(^3\) Ovariohysterectomy during a cesarean section does not adversely affect lactation. Ovariohysterectomy was performed during cesarean section in 19% of cases in one retrospective study\(^3\)\(^3\) of canine dystocia.

An uncomplicated cesarean section is classified as a clean-contaminated procedure, and routine perioperative prophylaxis is not indicated. Perioperative intravenous antibiotic therapy is indicated if fetal death has occurred, uterine infection is suspected, there has been a break in asepsis, or gross evidence of infection (e.g., decomposed fetus, gangrene) is present. Appropriate antibiotic selection should be based on the expected

---

**Equipment Checklist for Neonatal Resuscitation**

- Adequate personnel (ideally, one person per puppy)
- Bulb syringe or suction device for clearing secretions from the oral cavity
- Warm, dry towels
- Radiant heat source
- Oxygen source and small face mask or oxygen induction chamber
- Small endotracheal or nasogastric tube or tomcat or intravenous catheter for neonate intubation
- Appropriate drugs
  - Atropine
  - Naloxone
  - Flumazenil
  - Glucose (25%)
  - Epinephrine
  - Doxapram
- Warmed intravenous fluids and intravenous catheters
- Stethoscope
- Suture material and scissors for ligating the umbilical cord

---

**Pregnant dams are most prone to hypoxemia during anesthetic induction.**
microbial population, which includes *Escherichia coli* and *Staphylococcus* spp. First- or second-generation cephalosporins (e.g., cefazolin, cefoxitin) would be appropriate antimicrobial choices for perioperative intravenous use. In a study of 22 uterine bacteriologic samples collected from patients undergoing cesarean section or ovariohysterectomy, 21 of 22 samples yielded no growth of aerobic organisms. The routine use of postoperative antibiotics after uncomplicated cesarean section is not justified.

**NEONATAL RESUSCITATION**

Neonates delivered by cesarean section have a higher mortality rate at birth and within the first 24 hours of life than do naturally delivered puppies, so resuscitative efforts should be vigorous in these puppies. Puppies from brachycephalic dams have a higher mortality rate compared with nonbrachycephalic breeds, so particular effort may be required in resuscitating this subpopulation of puppies.

After delivery, placental membranes should be removed from the neonate’s body and head. The oropharynx should be cleared of respiratory secretions by gentle suctioning with a bulb syringe or aspirator. Swinging the neonate to remove secretions is widely practiced but has no benefit over careful suction and can be detrimental if the head and neck are not correctly supported. The chest wall should be vigorously rubbed not only to remove placental fluids but also to stimulate spontaneous breathing. Vocalization is a good sign that the lungs are well expanded. With the onset of spontaneous respiration, any inhalant anesthetic in a neonate will be quickly eliminated. Neonates are commonly hypoxemic after delivery, which is clinically evidenced by fetal bradycardia. Supplemental oxygen should be provided by face mask or by placing the puppies in an oxygen induction chamber once spontaneous respiration has been established (Figure 3). In severe cases of respiratory depression with hypoxemia, endotracheal intubation with a small endotracheal tube or tomcat or intravenous catheter can be attempted to provide more efficient oxygen delivery with manually assisted ventilation.

**Effective neonatal resuscitation requires planning and a coordinated team approach among the anesthetist, surgeon, and nursing staff.**

Neonates have a high surface area to body-weight ratio and poorly developed thermoregulatory mechanisms, making them very susceptible to hypothermia. Puppies should be immediately dried with a warm, dry towel and placed under a radiant heat source. The umbilical cord should be clamped and ligated approximately 2 cm from the body wall and the placenta removed distal to this level.

Agents that are reversible and could cause neonatal respiratory or CNS depression should be antagonized. The depressant effects of opioids administered to dams can be reversed with naloxone (0.04 mg/kg or 1 to 5 µg [~1 drop] sublingually, SC, IM, or via the umbilicus) in neonates. Neonates should be monitored carefully because the duration of effect of naloxone is shorter than that of many opioids and narcosis may recur, requiring a second dose of naloxone. Flumazenil, a specific benzodiazepine antagonist, can be administered at 0.1 mg/kg IV or via the umbilicus to reverse the effects of benzodiazepines.

Doxapram is a general CNS stimulant. It causes respiratory stimulation as a result of direct stimulation of the medullary respiratory centers and possibly through reflex activation of carotid and aortic chemoreceptors. Doxapram is used extensively in veterinary neonatal resuscitation, with 34% of pups delivered by cesarean

**Figure 3. Neonatal resuscitation.** Note the radiant heat source and anesthetic induction chamber used as an oxygen cage.
section receiving doxapram in a recent survey. It can be administered at a dose of 1 to 5 mg sublingually, SC, or via the umbilical vein. Transient increases in respiratory rate and volume occur, but improvements in arterial oxygenation usually do not ensue because doxapram increases the work associated with respiration, resulting in increased oxygen consumption and carbon dioxide production. The early veterinary literature promoted routine use of doxapram in neonates delivered by cesarean section. This retrospective study was based on a small number of deliveries, had no control population, and did not follow up on puppy survival beyond discharge. Further research and better understanding of the pharmacodynamics of doxapram indicate that it has a short duration of action and is likely to be ineffective if neonates are hypoxic. Therefore, rather than routine indiscriminate use, the role of doxapram in neonatal resuscitation should be reserved for neonates that are apneic but not hypoxic. Oxygen supplementation, manual stimulation of respiration, provision of radiant heat, and reversal of opioids or benzodiazepines should be the first line of neonatal resuscitation.

Acupuncture at the GV26 site (i.e., nasal philtrum) has anecdotally been reported to stimulate respiration in neonates. No controlled studies have been conducted to evaluate this method against standard resuscitation techniques, so its true efficacy cannot be determined at this time.

**POSTOPERATIVE CARE OF DAMS**

Oxytocin can be used to promote uterine involution if there has been excess uterine bleeding or fetal placentae could not be completely removed from the endometrium. Contraction of the uterus causes return of blood volume to the maternal circulation, helping replace blood loss sustained during parturition. Oxytocin can be administered at a dose of 2 IU/kg (maximum: 20 IU) IM or IV.

Providing analgesia for dams is important to allow early active suckling of neonates. Local infiltration of surgical wounds (before or after surgery) with lidocaine (2 mg/kg) or bupivacaine (2 mg/kg; alone or in combination with lidocaine) is encouraged for regional analgesia as part of a balanced anesthetic protocol. The local anesthetic volume can be diluted with 0.9% sodium chloride to increase the total volume. Epidural analgesia can be provided using a variety of agents, the most common being morphine. Parenteral opioids provide excellent analgesia and can be administered via injection, orally, or transdermally. Opioids have the potential for sedation. NSAIDs can be used alone or in conjunction with opioids to potentiate the effect of the opioid. Tramadol is an opioid-like drug that provides analgesia, especially when used in combination with an NSAID, and has few apparent side effects.

**SUMMARY**

Maternal cardiovascular and respiratory physiologic changes that occur during pregnancy alter the pharmacokinetics and pharmacodynamics of injectable and inhalation anesthetics. Cardiovascular changes include increased blood volume, relative anemia, increased cardiac output, increased cardiac work, and decreased peripheral vascular resistance; respiratory changes include decreased FRC, decreased total lung volume, increased minute ventilation and oxygen consumption, and decreased PaCO₂. Anesthetics administered to dams cross the placenta and exert an effect on neonates. Good preparation, adequate personnel, and a team approach can improve the success of neonatal resuscitation.

Identification of risk factors, such as brachycephalic breeds and emergency presentation, and recognition of physiologic changes and their impact on anesthetics can allow appropriate anesthetic and perioperative management and intensive neonatal resuscitation, leading to improved maternal and neonatal survival and vigor.

**REFERENCES**

Cesarean Section in Dogs: Physiology and Perioperative Considerations


**ARTICLE #2 CE TEST**

This article qualifies for 2 contact hours of continuing education credit from the Auburn University College of Veterinary Medicine. Subscribers may purchase individual CE tests or sign up for our annual CE program. Those who wish to apply this credit to fulfill state relicensure requirements should consult their respective state authorities regarding the applicability of this program. To participate, fill out the test form inserted at the end of this issue or take CE tests online and get real-time scores at CompendiumVet.com.

1. Canine maternal cardiovascular changes that occur in late pregnancy include
   a. increased total blood volume, relative anemia, and increased peripheral vascular resistance.
   b. increased total blood volume, relative anemia, and decreased cardiac reserve.
   c. decreased total blood volume, iron-deficiency anemia, and increased cardiac work.
   d. decreased total blood volume, microcytic anemia, and decreased cardiac output.

**COMPENDIUM**

Test answers now available at CompendiumVet.com

January 2006
2. Canine maternal respiratory changes that occur in late pregnancy include
a. increased FRC, increased minute ventilation, and decreased \( \text{PaO}_2 \).
b. decreased FRC, decreased minute ventilation, and increased \( \text{PaCO}_2 \).
c. decreased FRC, increased minute ventilation, and decreased \( \text{PaCO}_2 \).
d. increased FRC, decreased total lung volume, and decreased \( \text{PaCO}_2 \).

3. Decreased FRC is due to
a. cranial displacement of the diaphragm by the gravid uterus.
b. relative maternal anemia and increased cardiac output.
c. increased metabolic demands of fetuses.
d. increased fat reserves in preparation for lactation.

4. The minimum alveolar concentration for gaseous inhalation agents used for anesthetic induction and maintenance in animals in late pregnancy is __________ compared with that for nonpregnant animals.
   a. decreased
   b. unaltered
   c. increased
   d. three times more

5. Fetal hemoglobin has a(n) __________ affinity for oxygen compared with maternal hemoglobin.
   a. lesser
   b. equivalent
   c. greater
   d. variable

6. Compared with elective cesarean section, emergency cesarean section is
   a. safer for dams and associated with increased puppy survival.
   b. associated with an increased mortality risk for dams and decreased puppy survival.
   c. associated with a decreased mortality risk for dams and increased puppy survival.
   d. safer for dams but associated with decreased puppy survival.

7. Which statement regarding canine parturition is incorrect?
   a. Mating dates are a reliable indicator of parturition date.
   b. Body temperature falls below 100°F (37.8°C) within 24 hours before parturition.
   c. Serum progesterone levels fall to less than 2 ng/ml within 24 hours before parturition.
   d. Intravenous fluids should be administered to all patients undergoing cesarean section.

8. Ovariohysterectomy during cesarean section
   a. decreases the amount of milk produced and the length of lactation.
   b. is indicated for all dogs undergoing cesarean section.
   c. may be associated with hypotension during surgery.
   d. should not be performed if the fetuses are dead.

9. Which statement(s) regarding neonatal resuscitation is true?
   a. Neonates are very susceptible to hypothermia.
   b. Cesarean-delivered puppies have a higher mortality rate at birth than do naturally delivered puppies.
   c. Opioids and benzodiazepines can cause depressant effects in neonates and should be reversed with the appropriate agents.
   d. all of the above

10. Which is not required for neonatal resuscitation?
    a. an oxygen source
    b. a radiant heat source
    c. a warm, dry towel
    d. oxytocin