Anesthesia for small animal cesarean surgery and neonatal resuscitation

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Abstract

Anesthesia is a crucial part of cesarean surgery in small animals. Approximately 16% of bitches have dystocia during whelping and > 60% of bitches with dystocia have a cesarean surgery. Performing an emergency cesarean surgery is a routine procedure of paramount importance in small animal obstetrics.[1] Anesthetic management must be tailored to the mother and neonates. Current anesthesia practice assesses each patient to arrive at the best protocol aimed to reduce fetal distress and maximizing neonatal outcomes.

Keywords: Cesarean surgery, neonatal resuscitation, pregnancy

Introduction

Pregnancy is an adaptive multisystem maternal response that allows fetal growth to occur in the best possible environment. To better understand the challenges of providing anesthesia for pregnant animals, we need to comprehend the physiology of pregnancy. The emergency nature of many cesarean surgeries often results in the limited availability of trained and knowledgeable staff. The anesthesia provider must prepare for neonatal resuscitation and postdelivery care when planning for cesarean surgery.

Puppy mortality is ~ two-thirds greater during emergency circumstances compared to scheduled cesareans.[2] In addition, maternal mortality during emergency delivery is increased.[3] Pregnancy creates physiologic and anatomic adaptations associated with an increased metabolic demand imposed by growing fetal and uterine mass. This adaptation returns to prepartum values within 4 - 12 weeks postpartum in women.[4]

Cardiovascular system

Oxygen consumption increases to meet the metabolic demand associated with the growing fetus and reaches its peak during the last trimester. Cardiac output increases by 30 - 40% and gravid uterine blood flow are 20 - 40 times higher than nonpregnant flow. Blood flow to the skin and mammary glands will also increase. The increased cardiac output during pregnancy is associated with a decrease in vascular tone and arterial blood pressure (10%) and an increase in heart rate (55%) and stroke volume. In Beagles, blood volume was increased by 23%.[5]

Because cardiac work is increased during pregnancy and parturition, the cardiac reserve is decreased. Patients with previously well-compensated heart disease may suffer pulmonary congestion and heart failure caused by additional cardiac workload. Plasma estrogens decreased peripheral vascular resistance, increasing cardiac output, whereas systolic and diastolic blood pressures remain unchanged.[6] During labor and in the immediate postpartum period, cardiac output increased an additional 10 - 25% due to blood being extruded from the contracting uterus.[7]

Uterine and placental blood flow are not autoregulated, and factors that affect the flow of blood (hypotension, anesthetic drugs causing vasoconstriction and/or pain) will result in decreased fetal oxygen and nutrition.

Due to the downregulation of α and β adrenergic receptors, and increased vasodilation from prostaglandin drugs, increased dosing of vasopressors and chronotropic drugs may be required.

Ephedrine improves blood pressure in pregnant ewes without decreasing uterine blood flow, whereas dopamine effectively improved maternal blood pressure but decreased uterine blood flow and increased uterine vascular resistance at high doses. Dobutamine treatment increased heart rate markedly and decreased uterine blood flow without changes to MAP and uterine tone.[8] Uterine blood flow decrease is dose-dependent and greater with dopamine than with dobutamine. Recommendations to support blood pressure in pregnant dogs and cats after fluid resuscitation are with a bolus of intravenous ephedrine (0.03 - 0.1 mg/kg) and dobutamine (2 - 4 mg/kg/min). Plasma volume increases relatively more than red cell mass, resulting in pregnancy-related anemia. The magnitude of this correlates with fetal numbers. Blood loss during normal parturition is buffered by the increased blood volume and red cell mass.

Volume resuscitation

Reflexes that increase heart rate, vasopressin, and cortisol concentrations are reduced in pregnant dogs and this reduction may contribute to the inability of pregnant animals to achieve normal cardiovascular homeostasis during hemorrhage.[9]

Based on human literature, conventional guidelines for the treatment of hypotension secondary to hemorrhage during cesarean surgery recommend a rapid infusion of a crystalloid solution to restore normal blood pressure as quickly as possible. This premise is based, in part, on clinical studies, and substantial laboratory data; hemorrhagic shock in animals produced with a controlled hemorrhage model was reversible when shed blood was replaced with 2 - 3 times that volume of crystalloid solution. However, resuscitation with crystalloid fluids means that large amounts are needed that may induce acidosis and coagulopathy, interstitial edema formation, and microcirculation impairment. Furthermore, rapid fluid resuscitation is not without consequences and can worsen the outcome by disruption of early soft thrombus, coagulopathy, hemodilution, and rebleeding.

Restrictive or permissive resuscitation has recently been advocated as an alternative to the current standard care. In animal studies, military settings, and studies of nonpregnant trauma patients, controlled hypotensive resuscitation has been investigated.

Aggressive fluid resuscitation to restore near-normal mean arterial pressure of 80 mm Hg during uncontrolled hemorrhage induced massive blood loss and excessive hemodilution.[10] Controlled fluid resuscitation to maintain a mean arterial pressure of 40 mm Hg in the presurgical treatment of severe and uncontrolled hemorrhagic shock decreased further blood loss, prevented excessive hemodilution and coagulopathy, improved the early survival rate, and reduced apoptosis of the visceral organs. Studies evaluating controlled fluid resuscitation in pregnant small animals are needed.

Respiratory system

Tidal volume increases by 70%, despite the enlarged abdomen and anterior movement of the diaphragm due to an increase in respiration rate and minute ventilation. Oxygen consumption increases by 20% owing to the developing fetus, placenta, uterine muscle, and mammary tissue. Arterial oxygen tension remains unchanged. Pregnancy also affects the mechanism of ventilation. Airway conductance is increased by progesterone-induced relaxation of bronchial smooth muscles. Lung compliance is unaffected. The functional residual capacity is reduced by the anterior movement of the diaphragm and leads to decreased oxygen reserves within the lungs. Hypoventilation and apnea can more readily result in hypoxemia and hemoglobin desaturation. Hypoxemia is exacerbated by increased oxygen consumption during labor. It is advised to preoxygenate every patient before induction of anesthesia and monitor for signs of respiratory depression and hemoglobin desaturation.

Gastrointestinal system

Gastrointestinal tract is affected by 2 main changes during pregnancy; smooth muscle relaxation from progesterone and relaxin effects, and expansion of the growing uterus. As a consequence, there is prolonged gastrointestinal transit time and slower gastric emptying leading to constipation. Concentrations of peptide hormone and gastrin increase in pregnant dogs, causing an increase in the production of stomach acid. Rapid intubation with a cuffed endotracheal tube will help protect the airway and prevent aspiration. There may be a benefit of H2 antagonists and proton pump inhibitors; however, further research is warranted. Food should be withheld before planned cesarean surgery due to the increased risk of regurgitation and decreased lower esophageal sphincter tone. Liver maintains the normal size and blood flow; however, albumin production is decreased, increasing plasma volume and perhaps changing drug pharmacokinetics and dynamics.

Central nervous system

Minimum alveolar concentration is decreased by 16 - 40% due to increased endorphin production.

Weight gain

Metabolic rate during pregnancy increases ~ 15% (humans). During the last 3 - 4 weeks of pregnancy, a bitch's body weight will increase by 15 - 25%. In queens, the bodyweight increases in linear growth, with a total weight gain of up to 38% of prepregnant body weight at the end of pregnancy.[11]

Epidural and spinal compartment

Regional anesthesia (epidural or subarachnoid) has the advantages of technique simplicity, minimal exposure to the fetus to drugs, less intraoperative bleeding, muscle relaxation, and analgesia. Epidural veins are thin-walled and valveless. The volume of the epidural and the subarachnoid space is reduced as a result of increased size in epidural veins. Epidural pressure is unchanged in pregnancy but increases during contraction. There is an increased sensitivity and distribution to local anesthetic agents during pregnancy and parturition. Due to venous enlargement, only two-thirds of the nonpregnant epidural dose is required for regional analgesia. Spinal cord terminates at the level of the sixth lumbar vertebra in dogs and between L7 and mid-sacrum in cats. The advantage of epidurals and spinal analgesia is that there are minimal effects on the fetus. Local anesthetics given into the epidural space may result in systemic hypotension due to vasodilation. Animals that have received spinal or epidural analgesia should be monitored until their motor function has returned.

Drugs, placenta, and fetus

All drugs used in medicine have the potential to produce both beneficial and harmful effects, particularly in pregnancy where these effects must be considered by 2 or more patients, rather than 1 patient. Lipophilic molecules (up to a molecular weight of 1000) diffuse simply across the placenta. Hydrophilic molecules diffuse slower. Less is known regarding the extent of drug passage across the placenta in dogs and cats.

Placenta has some ability to metabolize drugs and some carrier ability via proteins on the maternal and fetal sides. Developing fetuses are most vulnerable to teratogenic drug effects during the first trimester (the first 20 days of pregnancy in dogs and cats). Most anesthetic drugs have molecular weights < 300 Daltons and are lipid-soluble. The large surface of the placenta allows anesthetic drugs to readily cross. In sheep, medetomidine, propofol, ketamine, and etomidate rapidly cross the placenta to develop high fetal concentrations. Exceptions are glycopyrrolate, a large polar molecule, and neuromuscular blocking agents.

Inhalation anesthetics are highly lipid-soluble and cross the placenta. Isoflurane, sevoflurane, and desflurane have low blood:gas coefficients. If the neonate breathes at delivery, these agents are rapidly cleared. In healthy beagles, sevoflurane induction resulted in a briefer loss of palpebral reflex, negative tail clamp response, time to tracheal intubation, and better quality of induction compared to isoflurane. Both anesthetics were associated with a rapid and smooth recovery.[12]

Effects of opioids and NSAIDs

Maternal treatment of opioids will result in a placental transfer of the opioids to the fetus. The extent of this transfer differs among opioids and solubility has been postulated as the cause.[13] Placental transfer of buprenorphine tends to be low (< 10% of placental buprenorphine reaches the fetus), whereas highly lipid-soluble opioids such as fentanyl, reach higher concentrations and persist in the fetus long after clearing the maternal circulation.[14-16]

Respiratory depression is the most notable difference in neonates as small changes in tidal volume or respiratory rate can result in life-threatening hypoxia. After a cesarean surgery, a newborn is dependent on its respiratory system for gas exchange, and opioid-induced respiratory depression can lead to increased neonatal mortality. In addition, an apparent lack of milk production with buprenorphine in rats decreased viability and lactation indices.

Nonsteroidal antiinflammatory drugs

Nonsteroidal antiinflammatory drugs (NSAIDs) inhibit inflammation and produce analgesia by decreasing prostaglandin synthesis. Prostaglandins cause vasodilation, increase vascular permeability, and sensitize pain receptors to noxious stimuli. NSAIDs have minimal effects on normal cardiovascular and respiratory systems and have been studied in humans during pregnancy and lactation. In the third trimester, NSAIDs and aspirin are usually avoided because of substantial fetal risks such as renal injury, oligohydramnios, constriction of the ductus arteriosus (with potential for persistent pulmonary hypertension in the newborn), necrotizing enterocolitis, and intracranial hemorrhage. Maternal parenteral treatment or ingestion of most NSAIDs results in low infant exposure via breastmilk, such that both cyclooxygenase-1 and cyclooxygenase-2 inhibitors are generally considered safe, and preferable to aspirin when breastfeeding. Excretion in breast milk is minimal.[17]

Patient management

Preanesthetic evaluation should include a thorough physical examination and evaluation of blood work, emphasizing packed cell volume, total proteins, glucose, and calcium concentrations for animals in active labor. An intravenous catheter should be placed to give intravenous fluids and drugs. Preoxygenation is critical because oxygen delivery to the placenta is an important factor when it comes to fetal mortality. Delivering oxygen by face mask for 3 minutes prolongs the onset of desaturation in healthy dogs induced with propofol.[18]

Drug choices

Propofol or alfaxalone are the drugs of choice for anesthetic induction in cesarean surgery. They both have a short half-life, rapid hepatic and extrahepatic clearance, and manageable respiratory and cardiovascular side effects. Compared to propofol, alfaxalone induction resulted in improved puppy viability and may provide a slightly better quality of anesthesia for bitches.[19] Although there was no significant difference in puppy mortality, the alfaxalone group had a higher Apgar score compared to the propofol group in the first 60 minutes of life with no impact on long-term viability.[20] Apgar score provides a simple and useful tool to evaluate canine newborns.[21] This may be of clinical relevance when performing a cesarean surgery after-hours with limited support to observe puppy recovery. Giant-size purebred pups had a higher Apgar score with alfaxalone compared to propofol.[21] Data comparing alfaxalone and propofol in cats are sparse. Alfaxalone had a less adverse influence on respiration compared to propofol in cats premedicated with medetomidine and may be a better choice when mechanical ventilation was unavailable.[23]

Ketamine has been associated with decreased puppy vigor. The use of inhalation anesthetics for maintenance has the benefit that inhalant anesthetics are mostly eliminated through ventilation; however, inhalants depress ventilation, therefore it is recommended to maintain a light plane of anesthesia to minimize inhalant delivery across the placenta.

Remifentanil is an ultrashort-acting opioid that is metabolized by esterase throughout the body. Remifentanil crossed the human placenta rapidly, metabolized, and redistributed, without changing the pH value of neonatal umbilical arterial blood. Remifentanil did not change Apgar scores and was without neonatal adverse effects.[24] The author routinely uses remifentanil as continuous rate infusions (0.1 - 0.2 µg/kg/minute) in cesarean surgeries to reduce inhalant concentrations and minimize systemic effects of inhalants.

Fetal physiology and neonatal resuscitation

Placenta acts as a barrier similar to the blood-brain barrier in the sense that drugs that cross the blood-brain barrier will also cross the placenta to the fetus. The fetal environment is more acidic compared to the maternal side, and more basic drugs (e.g., lidocaine) can become trapped in the fetus. The first breath after birth is stimulated by fetal hypoxia, hypercarbia, a lower body temperature, and increased sensory input from passing through the birth canal. Neonatal resuscitation involves supplying tactile stimulation by vigorously drying it

with an absorbent towel, emphasizing the perianal and abdominal areas. The oral cavity should be cleared of fluid by using a suction bulb; however, strong suction should be avoided to reduce damage to the delicate neonatal mucosa.

Bradycardia is a sign of hypoxemia and if spontaneous breathing is not obvious, vigorous rubbing should be continued and supplemental oxygen should be given via an endotracheal tube. A short-bladed laryngoscope can help visualize epiglottis and a flexible 14- or 16-gauge intravenous catheter can be modified into an endotracheal tube. Acupuncture point GV 26 has been successfully used for stimulating respiration in CPR and neonatal resuscitation. GV 26 is located in the midline of the philtrum of dogs and cats, level with the lower edge of the nostrils. GV 26 can resuscitate newborn animals that have a heartbeat but that are delayed in taking their first breath. Neonatal heart rate is best counted by palpating a precordial pulse. Normal heart rate should be > 200 beats per minute.[25] Using atropine to stimulate heart rate proves ineffective because bradycardia is not parasympathetically mediated at that age, but rather caused by severe hypoxia. If opioids were given, naloxone should be used sublingually or through the umbilical vein to reverse opioid-based respiratory depression. If drugs are given through the umbilical vein, a thin-walled structure within the umbilical stump, they should be diluted to 0.5 ml volume to facilitate injection and absorption. There is no evidence in the literature to suggest that doxapram stimulates ventilation in the newborn.

Conflict of interest

None to declare.

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