Anesthesia for the Pregnant Cat and Dog

Kushnir, Y. and Epstein, A.
The Koret School of Veterinary Medicine
The Robert H. Smith Faculty of Agriculture, Food and Environment
The Hebrew University of Jerusalem, Israel
Corresponding author: Dr. Yishai Kushnir, Tel: +927-3-9688588 / Fax: +927-3-9688525. E-mail: kushniry@yahoo.com

INTRODUCTION

Anesthesia of pregnant animals, especially for Cesarian section presents a challenge for the veterinarian because the choice of therapy needs to assure a good outcome for both the fetus and mother. A basic requirement of all anesthetic drugs is their ability to cross the blood brain barrier. This capacity comes with the ability to cross the placenta, and therefore all anesthetic drugs will reach the fetus (though not all at similar concentrations). Pregnancy also results in physiologic changes in the dam, due to hormonal and physical changes e.g. increase in body mass and blood volume, which also influence anesthesia. Therefore when choosing sedatives, analgesics and anesthetics, the veterinarian should take into consideration issues such as physiological changes during pregnancy, teratogenicity of the drugs, perfusion and oxygen delivery to the fetus and cardiorespiratory depression in the neonate. This is complicated by the fact that cases that require anesthesia during pregnancy often present as an emergency, and therefore require prompt decision making. In this review we will discuss briefly the physiological changes during pregnancy, the anesthetic approach to pregnant and Cesarian section patients and finally, neonatal resuscitation.

PHYSIOLOGIC CHANGES DURING PREGNANCY

Most of the research into the interactions between pregnancy and anesthesia has been done in humans and in ewes as a research model, and has been extrapolated to companion animals. Although extrapolating between species is problematic it is assumed that many of the changes are similar, because the hormonal changes are similar. Furthermore, the weight of the fetus at term in humans is approximately 5% of the mothers weight, whereas in cats and dogs it is on average 13% and 16% respectively, therefore the effects of the additional weight on the dam should be more pronounced in these species (1). Some of the changes that occur during pregnancy, in cardiovascular function, respiration and in other systems may affect anesthesia. Understanding them may aid in planning a safe anesthetic protocol for pregnant patients.

Pregnancy affects cardiovascular function via several different mechanisms. The increase in fetal weight is followed by an increase in plasma volume; this in turn causes a decrease in PCV and total protein. A decrease in plasma protein concentration may cause a decrease in oncotic pressure, as well as a decrease in protein binding of anesthetic drug. Anesthetic drugs are generally highly protein bound (e.g. propofol above 95%, acepromazine 99%), a decrease in plasma protein may lead to an increase in the free fraction which is the effective drug, thus increasing its effect (2, 3). The increase in volume causes an increase in cardiac output of up to 30-50%, together with a mild decrease in systemic vascular resistance, due to elevated estrogens, that together maintain blood pressure (4, 5). The increased abdominal pressure may compress the caudal vena cava, especially when the patient is in dorsal recumbence (e.g. for C-section or laparotomy). This position decreases venous return, and impairs perfusion to the uterus and fetus causing congestion distally in the spinal vasculature which causes compression in the epidural space and is considered one of the factors that lead to the observed increased sensitivity to spinal anesthesia (6, 7). Uterine blood flow and perfusion are generally proportionate to systemic perfusion and may be assumed normal if sys-

temic blood pressure, perfusion and oxygenation are normal. Uterine contraction may lead to increased vascular pressure, both in the uterus and during major contractions and also systemically (8, 9).

Major changes are seen in the respiratory system during pregnancy. There is a progressive increase in minute ventilation and normal $PaCO_2$ which at term is 28-32mmHg (as opposed to 35-45mmHg in normal patients). This hyperventilation is due to an increased respiratory rate and tidal volume, yet at the same time there is a decrease in reserve volumes, due to increased abdominal pressures and compression atelectasis of lung tissues. Therefore arterial oxygen levels remain similar to non-pregnant patients. The result of this is that any ventilatory depression (caused for example, by anesthetics or position) will cause an immediate decrease in arterial oxygen pressures and saturation (8).

Increased intra-abdominal pressure also causes changes in gastrointestinal function; there is a decrease in lower esophageal sphincter tone, in gastric motility and pH. These changes make the pregnant patient more prone to reflux, vomiting and aspiration (8, 10). Although pregnancy causes a mild decrease in liver function, and an increase in glomerular filtration (up to 60%), these changes are often of no clinical importance (8).

Pregnancy also causes a general decrease in inhaled anesthetic requirement, MAC (Minimal Alveolar Concentration - a measurement of potency in anesthetic gases) decreases progressively and is 40% lower at term (11,12). The mechanism for this is not clear but it is proposed to be due to elevated progesterone levels (13). A similar increase in sensitivity due to elevated progesterone levels is observed following the administration of local anesthetics (10). As stated above, anesthetic drugs pass the placenta and drugs will distribute to the fetus as well, therefore when calculating dose, the total gravid weight should be calculated (11, 14, 15).

ANESTHETIC PROTOCOL FOR NON-OBSTETRIC PROCEDURES

When anesthetizing pregnant animals for non-obstetric procedures, anesthetic protocols should be carefully adapted for each patient. Since the mother supplies both blood and oxygen and essentially metabolizes drugs for the fetus as well as for herself the main considerations concerning the embryo are to take care to ensure adequate perfusion and oxygenation to the fetus, and avoiding teratogens (16,17). The only drug currently used for anesthesia that has been shown to be a teratogen is midazolam, which has been found to be associated with an increase in the occurrence of cleft palate in humans. There is also some evidence indicating that nitrous oxide may also have teratogenic risk and should also be avoided (18). For sedation, low dose of acepromazine can be used. $Alpha_2$ adrenergic agonists such a medetomidine are best avoided as they cause severe cardiovascular depression as well as other side effects (19), and are associated with increased uterine tone. For pain control, opiods can be used, especially those with mild respiratory system side effects such pethidine or butorhpanol (19, 20). For anesthetic induction, propofol, etomidate or ketamine may be administered by slow intravenous injection in order to titrate the dose carefully (19, 20, 21). Patients should be intubated immediately as pregnant dams are highly prone to gastric reflux and aspiration (8).

Maintenance of anesthesia can be carried out with an intravenous or inhalation agent (19, 20). During the whole perianesthetic period, blood pressure, ventilation, oxygenation and perfusion (i.e. mucus membrane color, capillary refill time, urine production etc.) must be monitored and abnormalities corrected rapidly. Preoxygenation may be beneficial in animals that are not stressed by a face mask, and support of ventilation is recommended during the procedure, especially when in dorsal recumbency. Perianesthteic hypothermia should be prevented and corrected if needed. Since most perianesthetic mortalities occur during recovery, monitoring and support should be continued well into the recovery from general anesthesia.

It must be noted that increased abortion rates were observed in horses undergoing anesthesia for colic surgery, and those with episodes of hypotension had an increased risk. In humans undergoing anesthesia there is also a slight increase in preterm birth and abortion. It is, however, hard to differentiate between abortions caused by the disease necessitating anesthesia, the anesthetic and sequellae of anesthesia (such as hypoxemia and hypotension). A finding that illustrates this complexity states that abortion in mares with severe colic treated medically is reported as high as 50% whereas it is around 20% in operated horses, with similar disease (22).

ANESTHESIA FOR CESAREAN SECTION

The most important elements for success in Cesarian section are short as possible anesthetic and surgery time. Therefore familiarity with the anesthetic protocol is an important consideration (19). It is recommended that the chosen protocol used for Cesarian section be practiced occasionally on other anesthetized animals, where it is not contraindicated, in order to improve familiarity with expected effects and adverse events. Prior to anesthesia the dam must be stabilized adequately and abnormalities in glucose, fluids and electrolytes, especially calcium, rectified. All the preoperative preparation of the mother, e.g. shaving, scrubbing and transport to the surgery theatre are to be done while she is awake in order to reduce the time span of anesthesia.

As stated, all anesthetics cross the placenta and cause time and dose dependent effects on the fetus. Sedatives should be avoided and premedication is best done solely with an opioid such as pethidine or butrophanol with minimal side effects. An additional advantage in using opioids is that they can be antagonized by naloxone in neonates after delivery (23).

Cesarean section can be managed using a general anesthesia approach, or a regional anesthesia approach using a spinal block, the pros and cons of both methods are described in the following text. Neither method is ideal, so ultimately the correct protocol for each case depends on the medical situation of the patient and the preference and experience of the anesthetist.

Epidural anesthesia can be ideal for many cases of dystocia, however if the veterinarian performing the epidural is not proficient with the procedure, administering an epidural block may take a long time and negatively affect outcome (19, 23). Pregnant dams at term are more sensitive to spinal anesthesia due to the mechanical and pharmacological reasons stated above; therefore the dose of local anesthetic can be reduced by up to one third (23, 24). However spinal anesthesia is not without risk for the newborn, the main risk is from vasodilation caused be sympathetic blockade that leads to hypotension and hypoperfusion (23). Therefore blood pressure and perfusion should be monitored both in the cranial segment and in the hind region of the dam. Epidural anesthesia may be performed by proficient clinicians also under opioid sedation, especially if the dam is depressed or fatigued, thus enabling to avoid general anesthesia and depression of the neonate. There is also an ethical question in performing Cesarian section under epidural anesthesia: on the one hand one might claim that it is unethical to perform surgery on a conscious animal even if they feel no pain, and claim that it is incomparable to women, since the animal doesn't understand the process. On the other hand one might claim that if adequate analgesia is provided the process can be compared to restraint for any other uncomfortable procedure performed routinely on veterinary patients such as abdominal ultrasound, or bone marrow examination with local anesthetic. Epidural anesthesia can be indicated in dams which are depressed or fatigued but not hypovolemic or septic. Local anesthetic may also be infiltrated along the incision line to decrease surgical discomfort. Proper restraint is needed to prevent the animal from moving during epidural injection and the surgical procedure (10, 23).

Epidural anesthesia can be performed with 0.2ml/kg of 2% lidocaine. A 1:1 volume mixture of 2% lidocaine and 0.5% bupivacaine will give a longer block with a similar onset (23, 25). It is also possible to add 0.1mg/kg preservative free morphine to lidocaine for extended analgesia. All preparations must be suitable for epidural administration as many formulations include preservatives that may be neurotoxic. If administered to the subarachnoid space, local anesthetic doses should be decreased to 1/3-1/2 the epidural dose (25). The introduction of an epidural catheter allows for repeated doses when necessary but requires more time to place.

General anesthesia has the advantage of familiarity for most veterinarians, and is also the only option in animals that are aggressive, or have a contraindication to spinal anesthesia such as sepsis or clotting disorders. Sedatives should be avoided when possible, and used only for very aggressive animals (23). Premedication should include an opioid with mild side effects such as pethidine or butorphanol, or short acting opioids like fentanyl, which may necessitate naloxone administration to the neonates (26). Induction may be performed with all induction agents; however outcomes are better with propofol and etomidate (19). Ketamine and thiopental should be used with caution and only when indicated by comorbidities, e.g. if the dam also has an AV block ketamine may be indicated, or if she has head trauma thiopental may

be considered. Gas inductions can be performed on sedated animals, however they offer a slower induction that may be detrimental (19, 23). In anesthetized patients intubation is necessary to avoid aspiration due to the increased risk of vomiting or regurgitation in the periparturient period (8). Maintenance can be managed with isoflurane or sevoflorane, repeated boluses of propofol (or etomidate, with caution due to this drug's potential to cause sustained adrenal suppression, with continuous or repeated dosing). A balanced protocol with an inhalant and an injectable anesthetic may be ideal but technically cumbersome. Nitrous oxide can also be included with minimal risk to the neonate at concentrations under 60% (27).

The main advantage of regional anesthesia, therefore, is the lower doses of anesthetics to which the neonates are exposed. On the other hand general anesthesia offers the benefit of familiarity to most small animal veterinarians, as well as the advantage of an endotracheal tube and oxygen administration. Both methods have obvious disadvantages, epidural is contraindicated in some patients, and impossible to perform without anesthesia in others, and also may cause profound hypotension. General anesthesia causes cardiopulmonary depression of both the dam and the neonate. When choosing which of these methods one wishes to use, the issues mentioned above need to be considered individually for each case (23).

In all cases, as stated, time is a most important factor for successful Cesarian section. Different surgical techniques are described for Caesarian section and they are not subject of this article. However, the en-block technique, in which ovariohysterectomy is performed before delivering puppies is found to be unfavorable in comparison to the traditional approach. The en-block technique is indicated when infectious material is suspected in uterus and spillage should be avoided (19).

Postoperative analgesia must take lactation into consideration (19, 23, 26). Codeine and morphine are compatible with nursing in dogs. Aspirin and acetaminophen and dipyrone are compatible in humans for pain management after birth, and levels of commonly used non-steroidal anti-inflammatory drugs (NSAIDs) e.g. ketoprofen and carprofen in milk are very low (23, 28). NSAIDs may inhibit organ maturation in neonates and should be used cautiously, however it appers that most analgesics can be used in the postpartum dam (19).

RESUSCITATION OF NEWBORNS

Following Cesarean section, newborns are severely depressed in contrast to normal delivery, and may require resuscitation. Resuscitation of neonatal cats and dogs is beyond the scope of this paper and has been reviewed recently (26), yet it is an essential part of a successful Cesarian section and therefore some main issues will be addressed. Depresion in neonates is due to the effects of anesthetic drugs and the consequential cardiovascular and respiratory depression, as well as due to prolonged labor. Depression by the anesthetic procedure is both time and dose dependent, but even under optimal conditions some depression is apparent (22). Therapy is oriented towards providing a warm environment and stimulating cardiovascular and respiratory system and, if needed, antagonizing anesthetic drugs used.

Several preparations must be made before a Cesarean section in order to resuscitate the newborns. Oxygen supply should be available, and a box pre-warmed with a warm air device, hot water bottles (care must be taken in order to avoid burns), dry, warmed towels, syringes for suction of mouth and nose, hemostats for clamping the umbilical cords, small endotracheal tubes or large gauge intravenous catheters to use instead of endotracheal tubes in small species, such as cats. Necessary monitoring devices are neonatal stethoscopes or ultrasound Doppler probes to assess heart beats. Drugs to be prepared in advance are naloxone for reversing opioids and doxapram for stimulating breathing (23, 26). In any case, assisting staff must be well trained for treating neonatal puppies. Ideally, there should be one person per puppy. Hypothermia is a primary issue to be prevented and treated. This is done by keeping the dam warm during procedure, and as soon as the puppy is delivered, it should be dried gently with a warm towel (23). Massaging the puppy gently also stimulates the respiratory and cardiovascular systems. The mouth and nose should be cleaned and if necessary suctioned with a tomcat or venous catheter connected to a syringe (26, 27).

Respiration should be assessed and if no breathing is discerned ventilation support is given by a tight sealing face mask or by insertion of endotracheal tube or catheter into the trachea. Additionally, doxopram can be given sublingually. Bradycardia is often seen in puppies delivered by Cesarean section and it is due to hypoxia and is not vagally mediated (26). Therefore, correcting hypoxia will result in increasing

heart rate and will restore perfusion. Placing a few drops of 50 % dextrose under the tongue can be helpful. Naloxone can be given systemically or under the tongue for reversing opioids if indicated, at any stage. During the entire resuscitation, puppies should be warmed and provided with supplemental oxygen. The dam and puppies should be reunited as soon as clinically possible, with monitoring and support continued as needed (10, 23, 26).

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