Anesthetic management for the correction of a patent ductus arteriosus by means of either surgical ligation or transarterial occlusion in dogs

Anesthesie voor de correctie van een persisterende ductus arteriosus via chirurgie of transarteriële occlusie bij de hond

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ABSTRACT

Patent ductus arteriosus (PDA) is one of the most common congenital vascular abnormalities in the dog. In veterinary medicine, surgical ligation (SL) and transarterial occlusion (TO) are two possible treatments that require general anesthesia.

Two 4-month-old dogs were anesthetized for the correction of PDA, one by SL and the other by TO. Two different anesthetic and analgesic protocols were used, and were chosen to avoid potential complications.

This case report describes two possible anesthetic approaches for PDA corrective surgery (SL and TO).

SAMENVATTING

Persisterende ductus arteriosus (PDA) is een van de meest voorkomende congenitale hartafwijkingen bij de hond. Chirurgische ligatie (SL) en transarteriële occlusie (TO) zijn in de diergeneeskunde twee mogelijke behandelingen en vereisen algemene anesthesie. Bij twee honden van vier maanden oud werd onder algemene anesthesie een PDA behandeld, één via SL en de ander via TO. Twee verschillende anesthesie- en analgesieprotocols, gekozen om potentiële complicaties te voorkomen, werden gebruikt. Deze casereport beschrijft twee mogelijke benaderingen voor de anesthesie van honden voor correctieve PDA-chirurgie (SL en TO).

INTRODUCTION

Patent ductus arteriosus is a congenital continuous communication between the aorta and the pulmonary artery. It is normal in the foetus but it should close within 24 hours after birth. Incomplete closure can result in a shunt of variable size and direction. It is the most common congenital vascular disease in dogs, accounting for nearly 30% of all congenital defects (Patterson, 1968). This defect is more often seen in females (Patterson, 1968), small breeds (Buchanan, 1994) and German Shepherds, Cavaliers and Springer Spaniels (Van Israel *et al.*, 2002). The principal cause of PDA is site-specific hypoplasia of the smooth muscle with excessive elastic tissue within the ductus, resulting in an incomplete constriction of the lumen postpartum (Buchanan, 2007). Typically, if diagnosed early, shunting is from the systemic circulation to the pulmonary artery (left-to-right shunt) (Moise and Short, 1987). Consequences include overcirculation of the lungs, volume overload of the left heart, and in some patients, left-sided congestive heart failure. If not corrected, PDA results in a 1-year mortality that approaches 65% (Eyster *et al*., 1976). Clinical findings include exercise intolerance, cough, breathing difficulty and decreased appetite. Diagnosis can be confirmed by physical examination (auscultation of the heart murmur), thoracic radiography, echocardiography and angiography.

Treatment of PDA involves a complete attenuation of blood flow through the ductus. In the past, thoracotomy and subsequent PDA ligation have been the primary treatment. This technique has been performed in veterinary medicine for many years, with high success rates and acceptable mortality rates from 8% (Eyster *et al*., 1976) to 2% (Johnson, 2007). Hemorrhage is the most important complication of SL (10% of the dogs), being frequently fatal (79%) (Birchard *et al*. 1990). In an attempt to reduce hemorrhage, sodium nitroprusside can be administered intravenously (IV) prior to ligation in dogs to create hypotension via the release of nitric oxide (NO) (Hunter *et al*., 2003; Humm *et al*., 2007). The main disadvantage of thoracotomy is its invasive nature, although puppies in particular seem to recover rapidly from surgery and are often discharged within 24-48 hours (Johnson, 2007).

Less invasive treatments with interventional trans-

arterial techniques using various devices have been developed. In humans, occluders for treatment of small diameter PDA have been used since 1992 (Cambier *et al*., 1992) and their use has been the preferred treatment for patients with suitable PDAs (Hijazi and Geggel, 1994). These techniques were developed to avoid general anesthesia and thoracotomy and to minimize complications and mortality (Bright, 2003). However, general anesthesia is required in veterinary patients.

This case report describes the anesthetic management of two 4-month-old dogs presented for correction of PDA, one by SL and one by TO. Two different anesthetic and analgesic protocols were used, and were chosen to avoid potential complications.

CASE DESCRIPTIONS

Case 1

A 15-week-old, female Jack Russell terrier weighing 3.05 kg was presented to the Cardiology Service of the Queen Mother Hospital for Animals (QMHA), (Royal Veterinary College, London, UK) for further examination of a previously diagnosed continuous heart murmur.

Thoracic auscultation revealed the presence of a grade V/VI, continuous cardiac murmur with the point of maximum intensity over the left axillary region. Further examination with echocardiography confirmed the presence of a PDA with a left to right shunt. The ostium of the ductus appeared narrow, with a diameter of 1 mm. No left atrial or significant left ventricular enlargement was observed. In view of the patient's small size, transarterial occlusion of the PDA by means of a canine Amplatz device was not considered as a suitable option by the surgical team. It was therefore decided to perform a complete surgical ligation of the PDA.

After preanesthetic examination, the patient was classified as ASA (American Society of Anesthesiologists) IV (patient with severe systemic disease that is a constant threat to life). Premedication included acepromazine (0.01 mg/kg; ACP injection, Novartis Animal Health Ltd., UK) and pethidine (4 mg/kg; Pethidine injection BP, Martindale Pharmaceuticals, UK) intramuscularly (IM). An IV 23 G catheter was placed in the right cephalic vein. General anesthesia was induced with propofol administered to effect (4 mg/kg; Vetofol injection; Norbrook Laboratories Ltd., UK) IV 35 minutes after premedication. Following endotracheal intubation using a 5.5 mm I.D. cuffed endotracheal tube (ETT), anesthesia was maintained with isoflurane (Iso-Flo, Abbott Laboratories UK Ltd., UK) vaporized in oxygen, delivered via a modified T-piece. Monitoring (S/5, Datex-Ohmeda Instrumentarium Corp., Helsinki, Finland) included electrocardiography (ECG), pulse oximetry, capnography, central venous pressure (CVP) (via jugular vein), invasive arterial blood pressure (iABP) (via dorsal pedal artery) and oesophageal body temperature. A forced warm air device (Bair Hugger; Arizant Healthcare, MN, USA) was used to help to maintain body temperature. Preservative-free morphine (0.1 mg/kg; Martindale Pharmaceuticals, UK) was administered via the epidural route and correct positioning of the needle was confirmed using the 'hanging drop' technique (Naganobu and Hagio, 2007; Dugdale 2010) with the dog placed in sternal recumbency. Carprofen (2 mg/kg; Carprieve 5%, Norbrook Laboratories Ltd., UK) IV was added as part of a multi-modal analgesic plan. During preparation for surgery, the dog breathed spontaneously. Once inside the operating theatre, the patient was placed in right lateral recumbency and me-

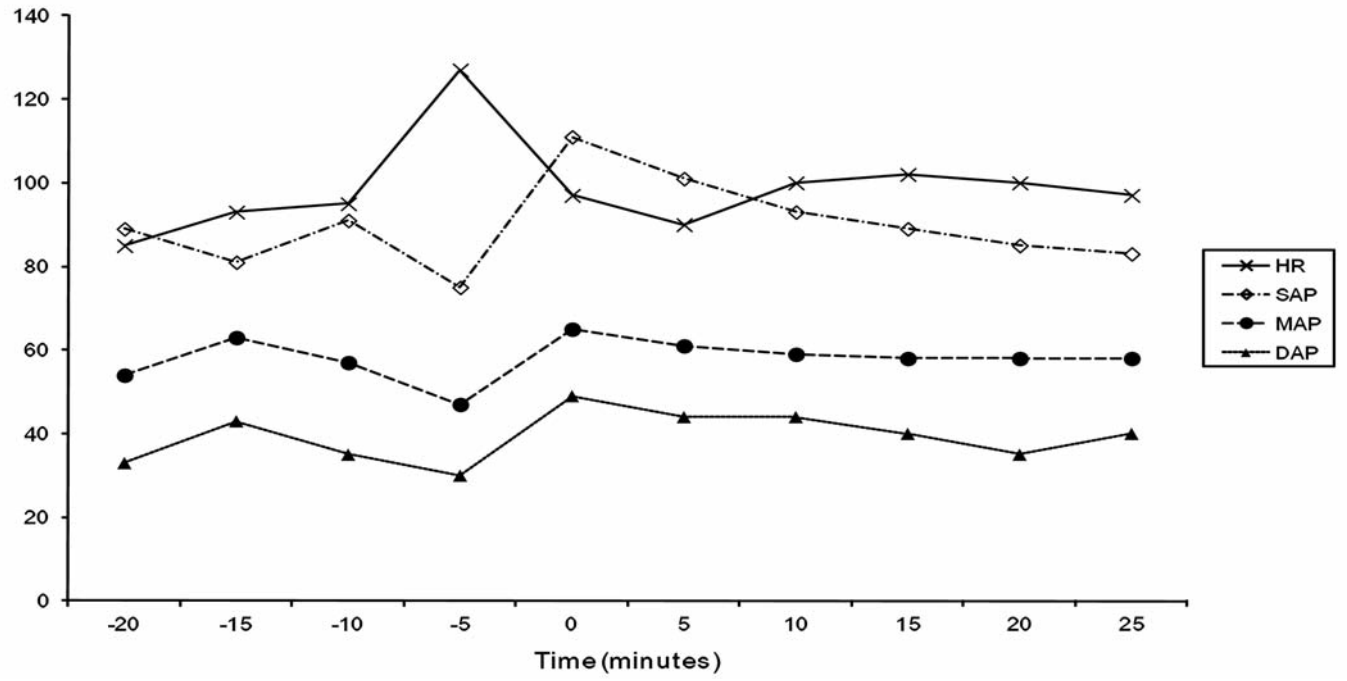

Figure 1. Heart rate (HR) in beats minute-1 and systolic (SAP), mean (MAP) and diastolic arterial pressure (DAP) (mmHg) in case 1. Time 0 refers to surgical ligation.

chanical intermittent positive pressure ventilation (IPPV) was instituted to maintain normocapnia (4.66-6.00 kPa or 35-45 mmHg) (VentiPAC, Smiths Medical International Ltd, UK). A fentanyl (Sublimaze, Janssen-Cilag Ltd., UK) constant rate infusion (CRI) was administered as part of the balanced anesthetic plan at rates ranging between 0.1 and 0.2 µg/kg/minute. The SL technique as described by Fossum (2002) was performed. Intraoperative antibiotic therapy was achieved with IV cefuroxime (20 mg/kg; Zinacef, Glaxo-SmithKline Ltd., UK).

Immediately after SL, slight increases in systolic (SAP), diastolic (DAP) and mean (MAP) arterial pressures were noticed (Figure 1). Heart rate (HR) increased suddenly prior to ligation and remained slightly elevated for the rest of the procedure, compared to previous values. Later, SAP, DAP and MAP remained slightly elevated, with smaller differences between SAP and DAP than during the anesthetic period preceding the SL. Central venous pressure values (between 3 and 5 mmHg) remained stable throughout the procedure. A low oesophageal body temperature was noticed throughout anesthesia (between 34.5-35ºC for 1 hour).

At the end of surgery (surgery and anesthesia lasted 65 and 165 minutes respectively), a chest drain was placed through a small incision at the 6th intercostal space. The chest was lavaged with warm saline and suctioned. At the end of surgery, air (150 mL) was evacuated through the chest drain to re-establish the negative pressure of the pleural cavity.

The patient was allowed to recover in the intensive care unit. Postoperative therapy included carprofen (2 mg/kg, SID) IV, intrapleural ropivacaine (1.5 mg/kg, SID; Naropin 7.5 mg/mL. Astra Zeneca Ltd., UK) and methadone (0.2 mg/kg; Physeptone 10 mg/mL. Martindale Pharmaceuticals, UK) at 2, 6 and 12 hours after the end of the surgery and afterwards at 0.1 mg/kg every 4 hours IV. Recovery was smooth and uneventful. The chest drain was removed 4 hours postoperatively.

The patient was sent home 4 days after surgery with carprofen (2 mg/kg, BID) orally for the following 3 days.

Case 2

A 16-week-old, female Cocker spaniel weighing 7.6 kg was presented at the Cardiology Service of the QMHA for further examination of a previously diagnosed continuous heart murmur.

Thoracic auscultation revealed a grade VI/VI continuous heart murmur with point of maximum intensity over the left axillary region. Initial examination confirmed the presence of a PDA with a large volume of left to right shunting (ductal ostium with a diameter of 3.5 - 4 mm). Echocardiography also confirmed the presence of severe left atrial and ventricular enlargement (in line with the findings of the previous echocardiogram and thoracic radiographs performed by the referring veterinarian). Concurrent mild aortic and moderate mitral regurgitation were observed. In this case, considering the size of the ductus, transarterial occlusion of the PDA by means of a canine Amplatz occlusion device was chosen as the best (less invasive) treatment option. There was still a possibility, because of the small size of the patient, that the Amplatz device occlusion technique would not be technically feasible and SL would remain the only option.

Four weeks prior to the procedure, oral therapy with an angiotensin converting enzyme (ACE) inhibitor (enalapril (0.3 mg/kg, SID; Enacard, Merial, Har-

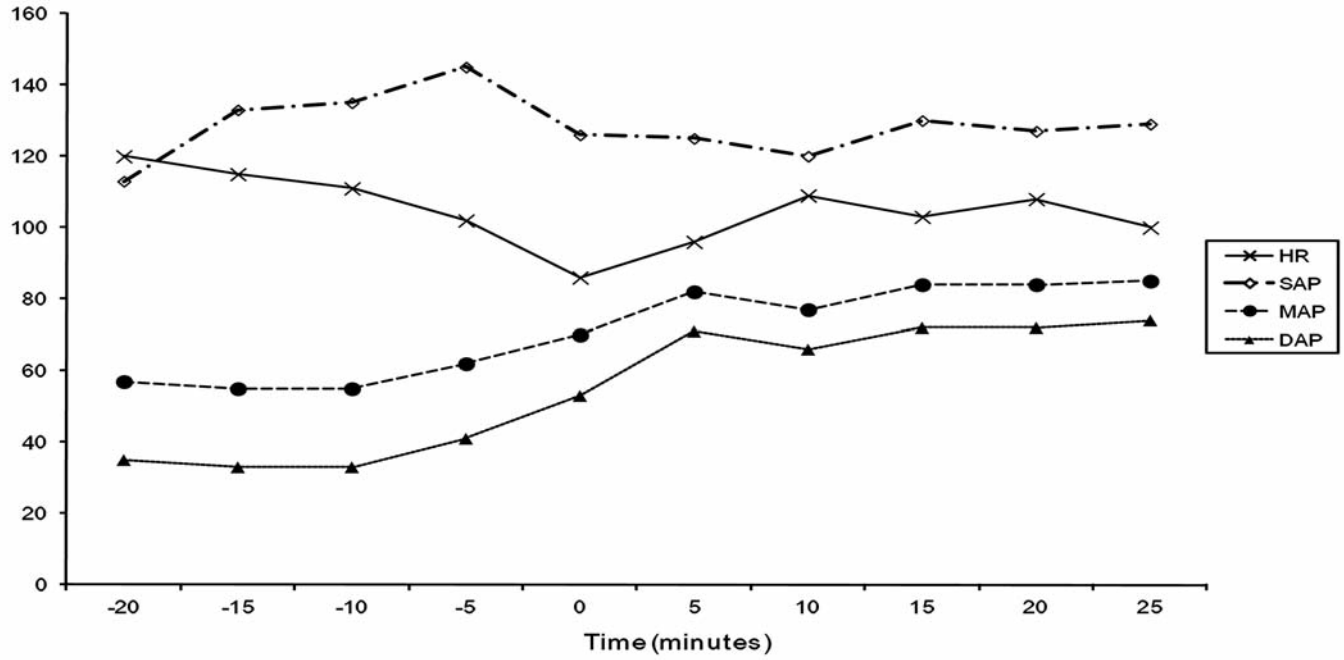

Figure 2. Heart rate (HR) in beats minute^{-1} and systolic (SAP), mean (MAP) and diastolic arterial pressure (DAP) (mmHg) in case 2. Time 0 refers to occluder expansion.

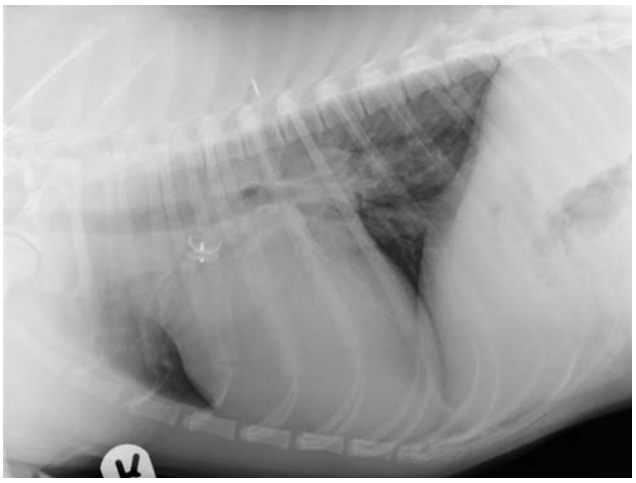

Figure 3. Intraoperative radiography to confirm the exact positioning of the occluder.

low, Essex, UK)) was begun. After preanesthetic examination, the patient was classified as ASA IV. Premedication was with pethidine (4 mg/kg, IM). An IV, 23 G catheter was placed in the right cephalic vein. General anesthesia was induced with etomidate (0.9 mg/kg; Hypnomidate, Janssen-Cilag Ltd., UK) and midazolam (0.3 mg/kg; Hypnovel, Roche Products Ltd., UK) IV 45 minutes after premedication. The trachea was intubated using a 7 mm I.D. cuffed ETT and anesthesia was maintained with isoflurane vaporized in oxygen delivered via a mini-Lack system. Monitoring was the same as described in case 1 (with no CVP). The patient received cefuroxime (20 mg/kg) and furosemide (2 mg/kg; Dimazon 5%, Intervet Ltd., UK) IV. After transport from the preparation room to radiography, and positioning in left lateral recumbency, IPPV was instituted to maintain normocapnia. Fentanyl (0.1 µg/kg/minute) and lidocaine (50 µg/kg/minute; Lidocaine Hydrochloride 2%, Hameln Pharmaceuticals Ltd., UK) were infused IV during the procedure.

An Amplatz canine duct occluder (ACDO) (Infiniti Medical™) was placed per catheter, through the femoral artery, as previously described (Nguyenba and Tobias, 2007; 2008). The procedure lasted 3 hours. During the placement of the occluder, some ventricular premature contractions (VPCs) were observed. In this case, clear increases in DAP and MAP were noticed together with a small decrease in SAP (Figure 2). Moreover, a more pronounced dicrotic notch in the arterial blood pressure waveform was observed after occlusion. Heart rate showed a progressive decrease before occlusion and increased after ligation. Body temperature was kept above 36.2ºC during the whole procedure. Intraoperative radiographs showed the correct position of the occluder (Figure 3).

Once the procedure had been completed the patient continued to breathe 100% oxygen and received acepromazine (0.01 mg/kg), buprenorphine (0.02 mg/kg; Buprecare 0.3 mg/mL, Animalcare Ltd, UK) and furosemide (1 mg/kg) IV.

The patient was sent home 3 days after the procedure with benazepril (0.7 mg/kg, SID; Benazecare, Animalcare, York, UK) and furosemide (1.3 mg/kg, BID; Frusecare, Animalcare, York, UK) orally until further instructions.

After the procedure, the continuous heart murmur disappeared. A systolic murmur was still present.

DISCUSSION

Over the last decade, minimally invasive methods have become more popular in veterinary medicine. Transarterial occlusion using Gianturco occluders in dogs was first performed in 1994 (Miller *et al*., 1999). Coils, Amplatz vascular plugs and Amplatz duct occluders can be used in dogs (Johnson, 2007). Case reports show TO to be a safe and efficacious treatment choice in dogs with PDA (Fellows *et al*., 1998; Campbell *et al.*, 2006; White, 2009) with benefits including minimal invasiveness (only a very small incision over the femoral vessels) and decreased complication rates, whereas disadvantages include increased procedure time (depending on the clinician's experience) and decreased initial success rate (Bright, 2003). Potential complications are pulmonary embolization of occluders (3%), arterial embolization (<5%), recanalization of the PDA (5-20%) and hemolysis secondary to mechanical damage to erythrocytes (Daniels *et al*., 1998; Van Israel *et al*., 2001; Turner *et al*., 2002; Galal, 2003; Saunders *et al*., 2004).

In case 2, an Amplatz canine duct occluder (Infiniti Medical™) was used. This occluder is a self-expanding device made from a nitinol wire mesh and is sufficiently soft to be able to conform to the shape of the PDA. These plugs are normally used to occlude medium sized PDAs, of approximately 4-7 mm diameter. After the placement of a guiding catheter, the ACDO was introduced through the femoral artery retrogradely into the aorta. A distal flat disk positioned on the pulmonary arterial side of the ductal ostium provides secure positioning in the pulmonary artery. As the device is implanted, the proximal cupped disk expands to conform to the shape of the ductal ampulla, with the waist of the device spanning the pulmonic ostium of the ductus and the dense nitinol mesh occluding the communication (Nguyenba and Tobias, 2007).

In a retrospective study by Goodrich *et al.* (2007), SL and TO were considered as acceptable treatments for PDA, with similar procedure times and mortality rates.

From the perspective of anesthesia, patients for correction of a PDA are generally young and in good health. If the ductus is large or if PDA has not been recognized early, there can be significant enlargement of the left ventricle, which can finally result in cardiac failure due to volume overload (Pascoe, 2007).

Anesthetic management in PDA patients ideally should be performed with drugs that prevent hemodynamic changes. In typical PDA patients, SAP is usually normal to high. However, DAP is usually very low because of the connection of the systemic circulation to the low-resistance pulmonary system. Due to the low DAP, MAP is normally in the 50-60 mmHg range. When the ductus is ligated or occluded (which effec-

tively increases systemic vascular resistance), a sudden increase in DAP with a minimal change in SAP is usually observed (Pascoe, 2007). Furthermore, the HR decreases (Branham's sign) in response to the increased MAP (baroreceptor response) (Hellyer, 1992). Administration of antimuscarinic drugs (atropine or glycopyrrolate) can be used to counteract this sinus bradycardia and it has been advocated as part of the premedication protocol (Pascoe, 2007). Other authors, however, do not recommend the use of atropine for this reflex bradycardia (Clutton, 2007).

In the patients of the present cases, these expected changes in blood pressure were more evident in case 2 than in case 1 (Figures 1 and 2) and hypotension did not occur during anesthesia. Positive inotropes may be used during the procedure to maintain SAP over 90 mmHg when necessary. Hypertension should also be avoided as it can increase the risk of bleeding as well as of increasing myocardial work and myocardial oxygen demand, which could lead to myocardial ischemia and cardiac arrhythmias. Furthermore, hypertension can result in retinopathy, blindness and renal failure (Egger, 2007).

In case 1, HR increased suddenly prior to ligation (probably due to cardiac manipulation) with a slight decrease after ligation (Branham's sign and/or reduction of surgical stimulation). After ligation and for the rest of the procedure, HR tended to be constant, although slightly higher than pre-ligation values. In contrast, in case 2 where minimal surgical stimulation was present, HR slightly decreased prior to occlusion, with a clear drop in HR after the ACDO occluded the PDA.

In view of the pathophysiological cardiovascular changes observed with a PDA, peripheral vasoconstrictors should be avoided since an increase in SVR tends to increase the left-to-right shunt through the ductus and may lead to pulmonary edema (Pascoe, 2007). On the other hand, large decreases in systemic vascular resistance (SVR) should also be avoided, since these may cause hypotension and possibly even shunt reversal (right-to-left shunt) if the pressure in the pulmonary artery exceeds the pressure in the aorta. Phenothiazines and butyrophenones are premedicants that induce a significant reduction in SVR and should be used with caution in PDA patients. However, in less severe cases, modest reductions in SVR increase systemic blood flow and may reduce left-to-right shunt before ligation. Therefore, in case 1, a low dose of acepromazine (0.01 mg/kg), which causes systemic vasodilation, was administered IM in combination with the short acting mu-opioid agonist, pethidine (4 mg/kg). Premedication in case 2 was achieved with pethidine alone, which produces mild sedation at analgesic doses (3-5 mg/kg) (Kerr, 2007).

For the induction of anesthesia, propofol IV was used in case 1. Propofol has been shown to produce a significant decrease in SAP in dogs premedicated with acepromazine (Smith *et al.*, 1993), which makes it a less than ideal combination in the present case. In case 2, co-induction of anesthesia with etomidate (0.85 mg/kg) and midazolam (0.3 mg/kg) was used. Etomidate is the induction agent of choice in animals with severe cardiac disease because it has been reported to maintain arterial blood pressure during the first few minutes of anesthesia, in contrast to propofol, although it provides a similar duration of anesthesia. A higher incidence of adverse reactions during induction, as well as rougher recoveries, have been associated with etomidate induction (Sams *et al*., 2008). Midazolam reduces the doses of drugs that are required to induce and maintain anesthesia in dogs. However, it can be associated with excitement and increased motor activity (Stegmann and Bester, 2001). Combinations of etomidate with diazepam (Humm *et al*., 2007) and opioids have been successfully used in high-risk patients (Kästner, 2007). Retrospectively, the induction protocol chosen in case 2 was a better option than in case 1.

For the maintenance of anesthesia, isoflurane vaporized in oxygen was used in both cases. Inhalant anesthetics inhibit autonomic outflow (Yamamura *et al*., 1983) and cause dose-related cardiorespiratory depression (Steffey and Howland, 1978; Mutoh *et al*., 1997). Relatively high doses of inhalant anesthetics are necessary to inhibit the cardiovascular responses to nociception (Roizen *et al*., 1981) and when these drugs are used at concentrations necessary to produce surgical anesthesia, hypotension and substantial decreases in cardiac output/tissue oxygen delivery may follow. To avoid these negative effects, total intravenous anesthesia (TIVA) could be an alternative for the induction and maintenance of anesthesia (Musk and Flaherty, 2007).

In both patients, CRIs were used as part of a balanced anesthetic plan. A fentanyl CRI (case 1) and fentanyl and lidocaine CRIs (case 2) were administered. Fentanyl CRI provides dose-dependent analgesia and dose-dependent MAC reduction of the inhalant anesthetic at clinically used doses (Murphy and Hug, 1982). Intravenous lidocaine was used to avoid the incidence of ventricular arrhythmias when placing the occluder (case 2), as it is primarily used in the management of ventricular arrhythmias, particularly those induced by myocardial infarction or cardiac surgery (Calvey and Williams, 2001a). Furthermore, the analgesic properties of intravenously administered lidocaine have been demonstrated in humans (Wallin *et al.*, 1987), rats (Woolf and Wiesenfeld-Hallin, 1985) and ponies (Murrell *et al.*, 2005) and an additional isoflurane sparing effect has been reported in dogs (Valverde *et al.*, 2004) with a MAC reduction of up to 43%.

In case 1, epidural morphine (0.01 mg/kg) was administered. In dogs undergoing thoracotomy, epidural morphine has been shown to be more effective in the treatment of postoperative pain than when administered IV (Popilskis *et al*., 1993), and may result in alleviation of pain for up to 24 hours (Jones, 2001). Furthermore, intrapleural ropivacaine was administered to produce local anesthesia. Ropivacaine has been widely used for postoperative pain relief. It has several benefits over bupivacaine, with better differentiation between sensory and motor blockade, less cardiotoxicity,

a shorter half-life and a more rapid clearance (Calvey and Williams, 2001b).

Peri- and postoperative furosemide (diuretic) and postoperative benazepril (ACE inhibitor), as chronic therapy for congestive heart failure was administered in case 2. Stabilization and treatment of heart failure should be carried out in more critical patients before anesthesia (Clutton, 2007).

Efforts should be made to prevent hypothermia, especially when SL is performed (the exposed open thorax promotes heat loss). The prevention of hypothermia and close monitoring of body temperature in these patients are strongly recommended.

CONCLUSION

Different anesthetic techniques can be used for SL and TO, but whichever premedication/induction protocol is used, it should preserve cardiovascular function. The invasive nature of SL via thoracotomy requires careful control of pain and therefore a good balanced anesthetic plan should include analgesia, isoflurane-sparing effects and avoidance of ventricular arrhythmias.

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