Anesthetic Considerations in Dogs and Cats with Diabetes Mellitus

Renata S. Costa, DVM, MPhil, GradDipEd, MANZCVS, DACVAA[a,*],
Teela Jones, DVM, MVetSc, DACVAA[b]

KEYWORDS

• Anesthesia • Diabetes mellitus • Dog • Cat • Insulin • Glucose

KEY POINTS

- Whenever possible, procedures for diabetic patients should be performed early in the day to ensure a rapid return to the patient's normal feeding, and insulin regimen and allow for close postoperative monitoring.
- Stabilization of hydration and acid–base status, electrolytes, and blood glucose in diabetic patients before anesthesia is paramount.
- Although there is no consensus regarding preoperative insulin protocol, administration of one-fourth to one-half of the patient's regular dose may result in superior glycemic control compared with withholding insulin or administration of the patients' full dose.
- Blood glucose monitoring every 30 to 60 min will direct additional insulin and dextrose therapy.
- There are no contraindications to any specific anesthetic, analgesic, or sedative agents. Care should be taken with the administration of alpha-2 agonists because they might result in a transient increase in blood glucose. Anesthetic protocols should be tailored to the patient's overall health status, level of anticipated pain, and duration of the procedure.

INTRODUCTION

Dogs and cats with diabetes mellitus (DM) may require anesthesia or sedation for medical and surgical procedures. These procedures may be needed to treat conditions that contribute to insulin resistance such as dental disease, to treat comorbidities secondary to DM, such as cataracts, or they may not be directly related to the disease process. An understanding of the impact of DM on hydration, electrolyte,

[a] Specialty Medicine, Midwestern University, 5715 West Utopia Road, Office 323-K, Glendale, AZ 85308, USA; [b] Anesthesiologist, Summit Veterinary Referral Center, 2505 South 80th Street, Tacoma, WA 98409, USA
* Corresponding author.
E-mail address: Renata.costa.vaa@gmail.com

Vet Clin Small Anim 53 (2023) 581–589
https://doi.org/10.1016/j.cvsm.2023.01.002
vetsmall.theclinics.com

and acid–base status is necessary to properly manage these animals during the perioperative period.

DM commonly affects middle-aged-to-geriatric dogs and cats. In dogs, the disease occurs following pancreatic beta cell loss, resulting in inadequate insulin secretion and hyperglycemia. The canine form of DM bears some phenotypic resemblance to type 1 DM in people (but the underlying cause of beta cell loss is yet undetermined). In most cats, DM resembles type 2 DM in people in that it is the result of impaired insulin secretion and the inability to increase insulin production to adequately compensate for insulin resistance.[1–5] In approximately one-fourth of cats, DM is secondary to hypersomatotropism. Although the causes of canine and feline DM are different, the initial management may include the administration of exogenous insulin to maintain blood glucose (BG) homeostasis and close monitoring is needed to assess treatment adequacy.[6] Stabilization of BG concentrations and resolution of clinical signs indicate successful management. It is important to note that even in treated and stable diabetic dogs, tight glycemic control (euglycemia with BG levels of 60 to 130 mg/dL) may not be achieved. Glycemic levels of well-controlled DM dogs vary throughout the day and BG excursions of 400 to 600 mg/dL could occur. Serial BG monitoring during the perioperative period with the understanding of this expected BG fluctuations throughout the day should guide therapy. Careful administration of exogenous insulin will decrease the risk of the development of hypoglycemic episodes.

Hyperglycemia (BG > 200 mg/dL in dogs and > 270 mg/dL in cats with classic clinical signs of hyperglycemia) is the hallmark of diagnosis of DM and results from impaired uptake of glucose into tissues and increased hepatic gluconeogenesis.[7] Other common serum biochemistry abnormalities include increased liver enzyme activity, cholesterol, and triglycerides. Glucosuria occurs when plasma glucose concentrations exceed the renal threshold. These changes often result in osmotic diuresis, polyuria, and polydipsia (PU/PD). Hyperglycemia increases serum osmolality. Cellular dehydration due to fluid shift from the intracellular into the intravascular space, systemic dehydration, and hypovolemia might ensue. Common electrolyte imbalances in patients with DM include hypokalemia, hypernatremia, hyponatremia, hypophosphatemia, and hypochloremia.[8–13] In dogs, higher morbidity, depression of leukocyte function, increased wound infections, and decreased tissue perfusion have been associated with high BG concentrations.[9,10] Chronic hyperglycemia (>5 years) might lead to retinopathy in dogs with poorly controlled diabetes.[9] As a catabolic condition, DM leads to a reduction in energy stores, protein mass, and ultimately weight loss. These possible alterations in homeostasis increase the overall anesthetic risk in animals with DM.

Diabetic ketoacidosis (DKA) is a decompensated form of DM. This condition occurs when free fatty acids are used as an energy source. Under the influence of low insulin and high glucagon concentrations (relative to one another), free fatty acids are broken down into ketoacids. Excessive accumulation of ketoacids and glucose in the blood results in life-threatening metabolic disturbances such as metabolic acidosis and hypovolemia. Another less common but possible form of decompensation of animals with DM is a hyperglycemic hyperosmolar syndrome (HHS). This syndrome occurs due to persistent hyperglycemia with BG levels reaching more than 600 mg/dL and decreased access to water followed by decreased glomerular filtration rate. Animals with DKA, HHS, or both, are rarely anesthetized until after emergent treatment of fluid and electrolyte imbalances is performed and insulin is administered to control profound hyperglycemia. Whenever possible, stabilization of animals with severe or uncontrolled disease processes should be performed.

ANESTHETIC CONSIDERATIONS AND MANAGEMENT

Planned procedures for animals with DM should be performed early in the day to allow for rapid return to normal feeding and insulin regimens post-procedure and aimed to minimize the influence of circadian changes in BG concentrations.[14–18] Complete physical examination including baseline blood pressure (BP) and blood work (complete blood count and biochemistry with electrolytes) should be obtained in all dogs and cats with DM before anesthesia. Diabetic patients might be dehydrated, hypovolemic, or both, especially if fasted or anorexic for long periods of time and if PU/PD is still present. Therefore, before anesthesia or sedation, fluid therapy to correct dehydration and electrolyte imbalances should be instituted. Hydration status, acid–base status, and electrolyte imbalances assessment and correction are also imperative in severely hyperglycemic animals and those with DKA or HHS. Dogs with insulin resistance might have concurrent hyperadrenocorticism.[11] This would also require management before anesthesia when possible.

BG concentrations should be closely monitored and will help ensure the appropriate insulin therapy required for each individual patient. Note that a single morning preoperative BG concentration higher than 300 mg/dL does not necessarily mean inadequate glycemic control. Stress hyperglycemia during hospitalization and before procedures may result in increased BG levels. BG should be re-measured in a calmer place within 30 min and further increases in BG may indicate the need for insulin administration before anesthesia.[12–14]

Preoperative Fasting and Insulin Regimen

Although various fasting times and insulin administration protocols have been recommended before anesthesia, there is no consensus statement in veterinary medicine.[12–16,19] In addition, data on pre-anesthetic fasting duration and the incidence of perioperative complications such as regurgitation and gastroesophageal reflux (GER) are controversial. A study in healthy dogs suggested that shorter fasting times (2 to 4 h vs 12 to 18 h) decrease the risk of GER.[20] However, another study reported that consumption of a light meal 3 h (vs 18 h) before anesthesia was associated with greater odds of GER and regurgitation in dogs.[21] In a study of diabetic dogs, no differences in perioperative complications and perioperative BG concentrations were found in animals that were fasted for 12 h and received one-half of their usual insulin dose, and those that were fasted for 6 h and received their full insulin dose.[19] The authors' clinical approach is to aim for fasting times no longer than 12 h to avoid prolonged food withholding and, also, to minimize the risk of subclinical dehydration. For morning procedures, food may be withheld the evening before surgery after 10 pm but a small amount of food could be given in the morning before insulin administration. The optimal fasting time should be determined independently of a patient's daily insulin regimen. Regardless of the daily insulin regimen, adjustments to dose, frequency, or insulin formulation can be made to fast the patient safely for as long as is recommended by the anesthesiologist. More details on managing insulin in a fasted patient can be found elsewhere (Insulin therapy part 1: General Principles, Insulin therapy part 2: Dogs, and Insulin therapy part 3: Cats).

A target BG of 150 to 250 mg/dL has been recommended[12] for patients under anesthesia. There are currently no data, however, on the association between levels of glycemic control and post-procedural or long-term outcomes. Based on the available literature, administration of one-fourth to one-half of the usual insulin dose before anesthesia might provide superior perioperative glycemic control in comparison to withholding insulin completely.[15,16] This recommendation though, is only relevant to

patients that are treated with intermediate-acting insulin formulations. In patients treated with basal insulin, there is typically no need for dose reduction in preparation for fasting. Stress-induced-hyperglycemia and increased catecholamine release can promote glycogenolysis, gluconeogenesis, and ketogenesis, which can increase insulin requirements. Preoperative hyperglycemia can result in hyperosmolar diuresis, dehydration, and hypovolemia increasing the risk and severity of intraoperative hypotension.[14,22–24]

Some authors recommend dosing insulin based on baseline BG measurements obtained on the morning of the procedure.[12–14] The same authors, however, recognize the limitations of using single BG measurements to predict insulin requirements. This is even more critical considering the unpredictable pharmacodynamics of most insulin formulations used in veterinary medicine. Careful glucose monitoring is required peri-operatively. We recommend the administration of one-half of the usual insulin dose before anesthesia and another one-fourth dose of insulin if baseline morning BG level is above 250 mg/dL. A safer but more elaborate approach would be to maintain BG concentration either with a CRI of insulin or by administering an ultra-rapid-acting insulin formulation and adjusting the insulin dose based on continuous monitoring. Regardless of the chosen protocol, overzealous insulin administration is best avoided to decrease the risk of hypoglycemia intra- and postoperatively.

Perioperative Blood Glucose Monitoring

BG should be monitored before and after induction of anesthesia, and every 30 to 60 min intraoperatively. Frequency of monitoring may vary depending on BG measured and patient's stability. Continuous glucose monitoring (CGM) device provides close monitoring capabilities and, therefore, if already present, could be used to monitor BG levels throughout anesthesia. If the BG concentration 30 min after induction of anesthesia is similar to the baseline value and within 150 to 250 mg/dL, glucose can be rechecked after 60 min instead of 30 min. However, if BG concentrations show large fluctuations, closer monitoring and possible interventions may be needed. Persistent hyperglycemia above 300 mg/dL may be treated with regular insulin intravenous (IV) or intramuscular (IM) at 20% of the patient's usual dosage of long-acting insulin.[12] Alternatively, the authors also suggest managing persistent hyperglycemia with the administration of 0.1 U/kg IM regular insulin. Development of hypoglycemia necessitates treatment with dextrose infusions (usually 2.5% to 5% at a rate of 5 to 10 mL/kg/h for dogs and 3 to 5 mL/kg/h for cats). Patients with DKA or HHS require more intensive monitoring, regular insulin, and/or dextrose administration, particularly in emergency situations when stabilization of acid–base status and electrolyte abnormalities were not performed preoperatively.

Intraoperative Anesthetic Management

Hypotension and bradycardia are the most commonly reported intraoperative complications in diabetic dogs undergoing phacoemulsification surgery and are reported more frequently in diabetic compared with nondiabetic dogs.[23] This higher risk of hypotension might be due to preexisting hypovolemia secondary to hyperglycemia and osmotic diuresis.[23] Cardiac index of parasympathetic activity was found to be lower in diabetic dogs compared with nondiabetic dogs, although the influence of this lower vagal tone on the development of hypotension was not investigated.[23] Goal-directed IV fluid therapy should be instituted in animals with DM undergoing any procedure. Crystalloid fluids (ie, LRS or Normosol-R) at 5 to 10 mL/kg/h for dogs and 3 to 5 mL/kg/h for cats is adequate for surgical fluid rates in most cases. However, other comorbidities such as heart disease and hydration status need to be considered

when selecting the most appropriate fluid rate. It is vital that ECG and BP be closely monitored throughout anesthesia.

Dogs with DM may have other comorbidities present such as hypertension.[25] Systemic hypertension, possibly due to increases in peripheral vascular resistance, has been reported in 46% (23/50) of dogs with diabetes.[26,27] Some animals require treatment with antihypertensive medications that could result in severe or refractory hypotension intraoperatively.[28,29] In these cases, positive inotropic agents and/or vasopressors in addition to appropriate volume repletion may be required to manage BP. Invasive BP monitoring, which is the gold standard of BP monitoring is recommended in hypertensive patients, and in any case considered severe or challenging. Noninvasive oscillometric or Doppler BP monitoring and capnography would suffice in absence of invasive pressures.

Perioperative hypothermia is a common complication of anesthesia and sedation, and it can be exacerbated by the low body condition scores of some animals with DM.[23] Hypothermia results in several adverse effects including impaired wound healing and infections. Animals with DM might already be predisposed to delayed wound healing and infections, which is partly due to decreased tissue perfusion. Therefore, active warming should be instituted throughout the anesthetic period. In addition, normal body temperature will support the maintenance of normal physiological variables such as HR and BP and will increase the likelihood of smooth and rapid anesthetic recoveries.

Some dogs and cats with DM are obese, which could affect ventilation during anesthesia. Hypoventilation, especially when a patient is positioned in dorsal recumbency, could be managed with intermittent positive pressure ventilation. Preoxygenation is also recommended to increase the time to desaturation during induction of anesthesia and before endotracheal intubation.[30] Pulse oximetry and capnography are important to assess oxygenation and ventilation during anesthesia. Oxygen supplementation during the recovery period may also be advised, particularly in animals that are hypothermic and shivering, and if desaturation is observed on pulse oximetry.

Anesthetic Protocol

There are no absolute drug contraindications for diabetic patients and a balanced anesthetic protocol with reversible, short-acting drugs that do not, or minimally, affect the glycemic index is preferred. Drug protocols should be selected for each patient based on health status, required procedure, the expected level of pain, and concurrent comorbidities present.

Premedication

Premedication with reversible agents such as pure-mu opioid receptor agonists and benzodiazepines often allows for fast recoveries.[14] For animals requiring more restraint, or animals that are difficult to handle, extra-label IM alfaxalone could be considered as part of a premedication protocol to facilitate IV catheter placement or to allow for short procedures to be performed.[31,32] For example, for an older diabetic cat requiring sedation for a short, minimally invasive procedure, 1 to 2 mg/kg of alfaxalone combined with 0.3 to 0.4 mg/kg of butorphanol IM might suffice. Alpha-2 receptor agonists, common premedication agents, result in transient increases in plasma glucose concentrations.[33,34] In healthy cats, dexmedetomidine administration resulted in a decrease in plasma glucagon and no change in plasma insulin concentrations.[33] Whether or not the effect of dexmedetomidine on hyperglycemia is mediated exclusively by insulin and glucagon or also by a direct effect on gluconeogenesis in the liver and kidneys is currently unknown. Especially in dogs with DM in which beta cells are largely absent by the time clinical disease is apparent,

the clinical effects of the transient increase in BG following administration of drugs such as dexmedetomidine and medetomidine is unlikely to be relevant. However, care should be taken with overzealous insulin administration especially in the presence of alpha-2 agonists as hypoglycemia may ensue once the effects of the alpha-2 agonists wane. The addition of the peripheral alpha-2 antagonist, vatinoxan or MK-467, to alpha-2 agonists appears to inhibit this increase in plasma glucose while maintaining the central sedative effects of the alpha-2 agonist.[34] A new FDA-approved drug for IM canine procedural sedation, Zenalpha, consists of medetomidine combined with vatinoxan, and its use might not result in the transient increase in BG seen when medetomidine is administered alone. However, its effect on glycemic control has not been evaluated in diabetic patients and the drug is not recommended as a premedication before general anesthesia.

Induction of anesthesia

Induction of anesthesia of animals with DM can be performed with any agent used for induction of anesthesia in nondiabetic animals (eg, propofol, alfaxalone, ketamine/midazolam, and ketamine/propofol). The choice of induction agent depends on the animal's health status in general and possible comorbidities with no particular preference with respect to DM.

Anesthesia maintenance

Anesthesia maintenance of animals with DM can be performed with any inhalant anesthetics (isoflurane, sevoflurane, desflurane). Constant rate infusions (CRIs) and/or locoregional anesthesia may allow for the reduction in minimum alveolar concentration (MAC), better cardiovascular stability, and provide multi-modal analgesia. MAC-reducing techniques alleviate the negative cardiovascular effects of inhalant anesthetics which are particularly important in patients with comorbidities, dehydration, acid–base, and electrolyte abnormalities that are common in diabetic patients. For example, a maropitant could be administered as part of an anesthetic protocol. It has antiemetic, anti-nausea, and MAC-sparing effects.[35] Decreases in inhalant anesthetic agent requirements may help preserve normal body temperature and maintain more stable and normal BPs during anesthesia. Agents such as ketamine and lidocaine not only provide MAC-sparing effects but also have analgesic properties. The authors often add ketamine to anesthetic protocols (loading dose 0.5 to 1 mg/kg followed by 0.6 to 1.2 mg/kg/h) of dogs and cats undergoing invasive or painful procedures. In addition, in dogs, lidocaine (loading dose 1 to 2 mg/kg followed by 50 mcg/kg/min) has also been used to provide balanced anesthesia.[36] Locoregional anesthesia should be performed whenever possible as it provides reliable MAC-sparing effect and analgesia and has minimal systemic side effects. However, in animals with diabetic neuropathy, regional anesthesia should be avoided in the affected limb(s). The incidence of peripheral neuropathy in dogs is rare and in diabetic cats is approximately 10%.[37]

Adequate analgesia perioperatively will result in smoother procedures and may improve recoveries reducing time to return to normal function, eating, and insulin regimen. Regional anesthesia is completed using bupivacaine, ropivacaine, or lidocaine and is effective at reducing MAC and providing effective analgesia. Ophthalmic nerve blocks (retrobulbar, peribulbar, etc.) before painful procedures such as enucleation are beneficial and should be performed by experienced personnel.[38] Possible risks of such blocks include stimulation of the oculocardiac reflex, globe perforation, intravascular injection, hemorrhage, and nerve damage. Infiltration of liposomal encapsulated bupivacaine (Nocita) can provide up to 72 h of postoperative analgesia.[39]

Neuromuscular blocking agents may be required, particularly in ophthalmic procedures to immobilize the globe. A high proportion of diabetic dogs, approximately 75%, develop cataracts within 1 year of diagnosis and thus require surgery such as phacoemulsification.[40,41] Atracurium has a similar duration of action in diabetic and nondiabetic dogs,[42] whereas vecuronium has been reported to have a shorter duration of action in patients with DM.[43] Diabetic dogs undergoing phacoemulsification may require higher infusion rates of rocuronium than nondiabetic dogs.[44]

Recovery

To ensure continued control of BG, once recovered from anesthesia, it is recommended to feed the patient a small amount of food and return to their usual insulin regimen as soon as possible.[14] Because uncontrolled diabetic patients are prone to immune dysfunction and reduced wound healing, a rapid return to normal glycemic control is recommended. Adequate analgesia has been associated with improved recovery. Therefore, pain evaluations with multidimensional pain scales and an appropriate analgesic plan during the postoperative period should be instituted. To avoid hypo-, hyperglycemia, or development of DKA, BG monitoring, dextrose, and insulin administration should be continued for patients that are not eating. Follow-up communication should be instituted with clients after patients have returned home. Recheck evaluations should be performed for any patient that has not returned to normal eating and insulin regimen the following day.

DISCLOSURE

The authors have no commercial or financial conflicts of interest.

REFERENCES

1. Hoenig M. Comparative aspects of diabetes mellitus in dogs and cats. Mol Cell Endocrinol 2002;197:221–9.
2. Nelson RW. Canine diabetes mellitus. In: Ettinger SJ, Feldman EC, editors. Textbook of veterinary internal medicine. 7th edn. St Louis, MO: Saunders Elsevier; 2010. p. 1782–96.
3. Sparkes AH, Cannon M, Church D, et al. ISFM Consensus guidelines on the practical management of diabetes mellitus in cats. J Feline Med Surg 2015;17:235–50.
4. Reusch C. Feline diabetes mellitus. In: Ettinger SJ, Feldman EC, editors. Textbook of veterinary internal medicine. 7th edn. St Louis, MO: Saunders Elsevier; 2010. p. 1796–816.
5. O'Brien TD. Pathogenesis of feline diabetes mellitus. Mol Cell Endocrinol 2002;197:213–9.
6. Rucinsky R, Cook A, Haley S, et al. American animal hospital association AAHA diabetes management guidelines. J Am Anim Hosp Assoc 2010;46(3):215–24.
7. Niessen SJM, Bjornvad C, Church DB, et al. Agreeing Language in Veterinary Endocrinology (ALIVE): diabetes mellitus a modified Delphi-method-based system to create consensus disease definitions. Vet J 2022;289:105910.
8. Greco DS. Diagnosis of diabetes mellitus in cats and dogs. Vet Clin North Am Small Anim Pract 2001;31:845–53.
9. Nishikawa T, Ederlstein D, Brownlee M. The missing link: a single unifying mechanism for diabetic complications. Kidney Int Suppl 2000;77:S-26–S30.
10. Torre DM, deLaforcade AM, Chan DL. Incidence and clinical relevance of hyperglycemia in critically ill dogs. J Vet Intern Med 2007;21:971–5.

11. Miceli DD, Pignataro OP, Castillo VA. Concurrent hyperadrenocorticism and diabetes mellitus in dogs. Res Vet Sci 2017;115:425–31.
12. Nelson RW. Canine diabetes mellitus. In: Feldman EC, Nelson RW, editors. Canine and feline endocrinology and reproduction. 4th edn. St Louis, MO: Saunders Elsevier; 2015. p. 213–57.
13. Behrend E, Holford A, Lathan P, et al. 2018 AAHA diabetes managements guidelines for dogs and cats. J Am Anim Hosp Assoc 2018;54:1–21.
14. Veres-Nyéki KO. Endocrine disease. In: Duke-Novakovski T, de Vries M, Seymour C, editors. BSAVA manual of canine and feline anaesthesia and analgesia. 3rd edn. Quedgeley: British Small Animal Veterinary Association; 2016. p. 375–90.
15. Adami C, Haynes RS, Sanchez RF, et al. Effect of insulin and fasting regimen on blood glucose concentrations of diabetic dogs during phacoemulsification. J Am Anim Hosp Assoc 2020;56:1–6.
16. Kronen PWM, Moon-Massat RF, Ludders JW, et al. Comparison of two insulin protocols for diabetic dogs undergoing cataract surgery. Vet Anaesth Analg 2001; 28:146–55.
17. Halter JB, P£ug AE. Relationship of impaired insulin secretion during surgical stress to anesthesia and catecholamine release. J Endocrin Metab 1980;51: 1093–8.
18. Campbell PJ, Bolli GE, Cryer PE, et al. Pathogenesis of the dawn phenomenon in patients with insulin dependent diabetes mellitus. N Engl J Med 1985;312: 1473–9.
19. Norgate DJ, Nicholls D, Geddes RF, et al. Comparison of two protocols for insulin administration and fasting time in diabetic dogs anesthetized for phacoemulsification: a prospective clinical trial. Vet Rec 2021;188(11):e81.
20. Savas I, Raptopoulos D. Incidence of gastro-oesophageal reflux during anaesthesia, following two different fasting times in dogs. Vet Anaesth Analg 2000; 27:54–62.
21. Viskjer S, Sjöström L. Effect of the duration of food withholding before anesthesia on gastroesophageal reflux and regurgitation in healthy dogs undergoing elective orthopedic surgery. Am J Vet Res 2017;78:144–50.
22. Pascoe PJ. Perioperative management of fluid therapy. In: DiBartola SP, editor. Fluid, electrolyte, and acid–base disorders in small animal practice. 4th edn. St Louis, MO: Saunders Elsevier; 2012. p. 405–35.
23. Oliver JA, Clark L, Corletto F, et al. A comparison of anesthetic complications between diabetic and nondiabetic dogs undergoing phacoemulsification cataract surgery: a retrospective study. Vet Ophthalmol 2010;13:244–50.
24. Kenefick S, Parker N, Slater L, et al. Evidence of cardiac autonomic neuropathy in dogs with diabetes mellitus. Vet Rec 2007;161:83–8.
25. Herring IP, Panciera DL, Were SR. Longitudinal prevalence of hypertension, proteinuria, and retinopathy in dogs with spontaneous diabetes mellitus. J Vet Intern Med 2014;28(2):488–95.
26. Struble AL, Feldman EC, Nelson RW, et al. Systemic hypertension and proteinuria in dogs with diabetes mellitus. J Am Vet Med Assoc 1998;213:822–5.
27. Littman MP. Hypertension. In: Ettinger SJ, Feldman EC, editors. Textbook of veterinary internal medicine. diseases of the dog and cat. 5th edn. Philadelphia, PA: Saunders Elsevier; 2000. p. 179–82.
28. Zuo L, Dillman D. Endocrine disease. In: Hines RL, Jones SB, editors. Stoelting's anesthesia and co-existing disease. 8th edn. Philadelphia: Saunders Elsevier; 2022. p. 439–64.

29. Hopper K, Brown S. Hypertensive crisis. In: Silverstein D, Hopper K, editors. Small animal critical care medicine. 2nd edn. St Louis, MO: Saunders Elsevier; 2015. p. 51–4.
30. Ambros B, Carrozzo MV, Jones T. Desaturation times between dogs preoxygenated via face mask or flow-by technique before induction of anesthesia. Vet Anaesth Analg 2018;45:452–8.
31. Tamura J, Ishizuka T, Fukui S, et al. Sedative effects of intramuscular alfaxalone administered to cats. J Vet Med Sci 2015;77(8):897–904.
32. Murdock MA, Riccó Pereira CH, Aarnes TK, et al. Sedative and cardiorespiratory effects of intramuscular administration of alfaxalone and butorphanol combined with acepromazine, midazolam, or dexmedetomidine in dogs. Am J Vet Res 2020;81(1):65–76.
33. Bouillon J, Duke T, Focken AP, et al. Effects of dexmedetomidine on glucose homeostasis in healthy cats. J Feline Med Surg 2020;22:344–9.
34. Restitutti F, Raekallio M, Vainionpää M, et al. Plasma glucose, insulin, free fatty acids, lactate and cortisol concentrations in dexmedetomidine-sedated dogs with or without MK-467: a peripheral α-2 adrenoceptor antagonist. Vet J 2012; 193(2):481–5.
35. Boscan P, Monnet E, Mama K, et al. Effect of maropitant, a neurokinin 1 receptor antagonist, on anesthetic requirements during noxious visceral stimulation of the ovary in dogs. Am J Vet Res 2011;72(12):1576–9.
36. Ortega M, Cruz I. Evaluation of a constant rate infusion of lidocaine for balanced anesthesia in dogs undergoing surgery. Can Vet J 2011;52:856–60.
37. Estrella JS, Nelson RN, Sturges BK, et al. Endoneurial microvascular pathology in feline diabetic neuropathy. Microvasc Res 2008;75(3):403–10.
38. Shilo-Benjamini Y. A review of ophthalmic local and regional anesthesia in dogs and cats. Vet Anaesth Analg 2019;46:14–27.
39. Lascelles BDX, Rausch-Derra LC, Wofford JA, et al. Pilot, randomized, placebo-controlled clinical field study to evaluate the effectiveness of bupivacaine liposome injectable suspension for the provision of post-surgical analgesia in dogs undergoing stifle surgery. BMC Vet Res 2016;12.
40. Beam S, Correa MT, Davidson MG. A retrospective-cohort study on the development of cataracts in dogs with diabetes mellitus: 200 cases. Vet Ophthalmol 1999;2(3):169–72.
41. Plummer CE, Specht A, Gelatt KN. Ocular manifestations of endocrine disease. Compendium Continuing Educ Vet 2007;29(12):733–43.
42. Leece EA, Clark L. Diabetes mellitus does not affect the neuromuscular blocking action of atracurium in dogs. Vet Anaesth Analg 2017;44:697–702.
43. Clark L, Leece EA, Brearly JC. Diabetes mellitus affects the duration of action vecuronium in dog. Vet Anaesth Analg 2012;39:472–9.
44. Haga HA, Bettembourg V, Lervik A. Rocuronium infusion: a higher rate is needed in diabetic than nondiabetic dogs. Vet Anaesth Analg 2019;46:28–35.