ELSEVIER
SAUNDERS

Vet Clin Small Anim
35 (2005) 571–580

VETERINARY
CLINICS
Small Animal Practice

Anesthesia for Geriatric Patients

Rachael E. Carpenter, DVM[a,*],
Glenn R. Pettifer, DVM, DVSc[b],
William J. Tranquilli, DVM, MS[a]

[a]*Department of Veterinary Clinical Medicine, University of Illinois, 1008 West Hazelwood Drive, Urbana, IL 61802, USA*
[b]*Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Louisiana State University, Baton Rouge, LA 70803, USA*

Veterinarians are seeing an increasing number of geriatric animals in their daily practice. Often, these patients need to be placed under general anesthesia for dental care, surgical procedures, diagnostic procedures, or treatment of chronic conditions. In 2002, the pet population in the United States was estimated at 100 million. Approximately 30% of those pets are expected to be geriatric [1]. Because there is wide species and breed variation in life expectancy, there is no one specific age that defines an animal as "geriatric"; however, it is generally accepted that a geriatric animal is one that has reached 75% of its expected life span [2]. Because there is little correlation between physiologic and chronologic age, each animal must still be evaluated as an individual. Many older animals remain remarkably fit, whereas others seem to age faster than expected. Age itself is not a disease, but age-related changes and diseases do affect anesthetic management.

Physiology of geriatric animals

Physiologically, elderly animals cannot be considered the same as younger adults. Aging causes a progressive and irreversible decrease in functional reserves of the major organ systems, leading to altered responses to stressors and anesthetic drugs. Such changes in organ system function are covert until the patient is stressed by an illness, hospital stay, or general anesthetic procedure.

* Corresponding author.
E-mail address: recrpntr@uiuc.edu (R.E. Carpenter).

0195-5616/05/$ - see front matter
doi:10.1016/j.cvsm.2004.12.007 *vetsmall.theclinics.com*

Cardiovascular system

Geriatric animals have a decreased cardiac reserve compared with that of younger animals. In the older animal, this often translates into a decreased ability to respond appropriately to the changes brought about by anesthetic drugs. Geriatric animals have varying degrees of myocardial fiber atrophy, which can affect rate and rhythm if the conduction system is involved. The aged heart also has increasing myocardial fibrosis and valvular fibrocalcification. As ventricular compliance decreases in the aging heart, relatively small changes in intravascular volume or venous capacitance become increasingly important determinants of circulatory stability [3]. These changes mean that whereas the geriatric animal is volume dependent, it is also volume-intolerant, because the decreased ventricular compliance is associated with optimal hemodynamic functioning within a narrow range of end-diastolic volume and pressure. The maximal chronotropic response during physiologic stress decreases with age. Additionally, the response to exogenously administered autonomic drugs is decreased. Younger adults can increase cardiac output primarily by increasing heart rate. In geriatric animals, cardiac output is more dependent on increased stroke volume in association with an increase in end-diastolic volume. For this reason, volume depletion during the perioperative period is less well tolerated in geriatric animals than in younger animals [4].

Geriatric animals are increasingly likely to experience degenerative myocardial disease, usually in the form of chronic valvular disease. This degenerative change has the potential to increase the likelihood of myocardial hypoxia associated with the increased myocardial work and oxygen consumption of inefficient pump function [5].

Pulmonary system

Even mild or moderate respiratory depression associated with the administration of some anesthetics can produce significant hypoxia and hypercarbia in the geriatric animal. This arises as a result of a decreased functional reserve capacity in the aging lung. Aging is associated with a decrease in chest wall compliance because of the loss of intercostal and diaphragmatic muscle mass. Vital capacity, total lung capacity, and maximum breathing capacity also decrease. With a reduction or loss of lung elastin, pulmonary compliance is reduced [5]. Anatomic dead space and functional residual capacity increase with age, as do closing volume, air trapping, and ventilation-perfusion mismatch. All these changes tend to lower Pao_2 levels in older patients [6]. Pathologic events like pneumonia, pulmonary edema, or pulmonary fibrosis exacerbate these aging processes. Pulmonary aging serves to render a geriatric animal less tolerant of even transient hypoxia during the perianesthetic period.

Hepatic system

The overall mass of the liver decreases with increasing age, leading to a decrease in overall hepatic function, including drug clearance [3]. This decrease in hepatic function causes an increase in the plasma half-life of drugs dependent on hepatic excretion, metabolism, or conjugation. Other important considerations in the geriatric patient include the potential for hypoproteinemia, impaired clotting functions, and hypoglycemia from altered hepatic function [5].

Renal system

Normal aging can alter renal function in several ways. Renal blood flow is decreased, making geriatric patients more susceptible to renal failure when exposed to renal ischemia. There is a decrease in the total number of functional glomeruli, and the glomerular filtration rate decreases. As changes in the renal tubules occur, there is an increase in the resistance of the distal renal tubules to antidiuretic hormone. This results in an impaired ability to conserve sodium or concentrate urine, leading to a reduced ability to correct fluid, electrolyte, and acid-base disturbances [6]. Overall, this may make some geriatric animals much less tolerant of body water deficits or excessive fluid administration. Additionally, the plasma half-life of an anesthetic drug eliminated by renal excretion may be prolonged, necessitating a reduction in the dose when used in geriatric patients.

Aged patients are generally more susceptible to renal failure after general anesthesia. The effects of anesthesia and surgery can exacerbate preexisting renal pathologic conditions [5]. General anesthesia typically reduces renal blood flow and glomerular filtration, whereas surgery may result in blood loss, hypovolemia, and hypotension, which can further compromise renal perfusion.

Central nervous system

Cerebral perfusion and oxygen consumption decline with increasing age and may be related to an overall loss of brain mass that correlates with a loss of neurons rather than atrophy of the supportive glial cells. Cerebrospinal fluid volume increases to maintain normal intracranial pressure in the face of this reduction in brain mass [6]. Anatomic and functional redundancy compensates for the loss of cellular elements and neuronal interconnections; thus, function of the central nervous system (CNS) is generally maintained at levels close to those seen in young adults [3]. There are decreased amounts of neurotransmitters, such as dopamine, norepinephrine, tyrosine, and serotonin, in the aging brain, and these substances may demonstrate a reduced receptor affinity [6].

Although not completely understood, one of the overall results of these changes is that geriatric animals have a decreased requirement for anesthetic

agents. It is well documented that minimum alveolar concentration (MAC) decreases linearly with age, and requirements for local anesthetics, opioids, barbiturates, benzodiazepines, and other intravenous drugs seem to be similarly reduced [3,6,7].

Preoperative assessment

Individual geriatric animals may require different anesthetic protocols. As with any animal that is to be anesthetized, a complete history should be taken, with particular attention to previous and current medical problems, current medications, vitamins, and supplements. A thorough physical examination and broad laboratory screening (ie, complete blood cell count [CBC], chemistry panel, urinalysis) are essential in the assessment of the functional status of different organ systems and in the identification of any preexisting problems. Careful auscultation of the heart should be performed in an attempt to identify any underlying cardiac disease or murmur. If a cardiac murmur or arrhythmia is detected, a cardiac workup (eg, chest radiographs, echocardiogram, electrocardiogram [ECG]) may be performed to determine the cause of the murmur. Whenever possible, any significant abnormalities detected by physical examination or preoperative blood work should be corrected before the induction of anesthesia.

Premedication

Preanesthetic sedation reduces stress in anxious patients and decreases the amount of anesthetics needed for induction and maintenance of anesthesia. The choice of premedication depends on the geriatric animal's physical condition, any concurrent disease processes, current medications, and the particular requirements for sedation and analgesia that are dictated by the intended procedure (suggested sedatives and preanesthetics are presented in Table 1).

Anticholinergics

Anticholinergics (eg, atropine, glycopyrrolate) should not be used indiscriminately in the geriatric patient. Patients with preexisting cardiac disease may not tolerate the increase in myocardial oxygen demand and work resulting from a marked increase in heart rate. Sinus tachycardia may precipitate acute myocardial failure [5]. In most cases, it is probably best to treat bradycardia as needed with judicious use of anticholinergic drugs on a case-by-case basis. Alternatively, α_2-agonist–mediated reductions in heart rate can be treated by titrating the reversal agent, atipamezole, to achieve the desired reversal of bradycardia. Although some clinicians recommend that α_2-agonists be given in combination with anticholinergics [8], others would suggest that this practice may result in a potentially undesirable

Table 1
Suggested drug doses (mg/kg) of anesthetic drugs in geriatric small animals

Drug	Dog	Cat
Anticholinergics		
Atropine	0.01–0.02 IM, IV	0.01–0.02 IM, IV
Glycopyrrolate	0.005–0.01 IM, IV	0.005–0.01 IM, IV
Sedatives and/or tranquilizers		
Acepromazine	0.01–0.05 IM, SC, IV	0.01–0.05 IM, SC, IV
Diazepam	0.2–0.4 IV	0.2–0.4 IV
Medetomidine	0.002–0.004 IM	0.006–0.008 IM
Midazolam	0.1–0.3 IM, SC, IV	0.1–0.3 IM, SC, IV
Opioids		
Buprenorphine	0.005–0.01 IM, SC, IV	0.005–0.01 IM, SC, IV, PO
Butorphanol	0.2–0.4 IM, SC, IV	0.2–0.4 IM, SC, IV
Hydromorphone	0.1–0.2 IM, SC, IV	0.1–0.2 IM, SC, IV
Morphine	0.05–1 IM, SC	0.002–0.1 IM, SC
Oxymorphone	0.1–0.2 IM, SC, IV	0.05–0.1 IM, SC, IV
Induction[a]		
Etomidate	0.5–1.5 IV	0.5–1.5 IV
Ketamine and/or valium	3–5/0.2–0.4 IV	3–5/0.2–0.4 IV
Propofol	4–6 IV	4–6 IV
Thiopental	2–6 IV	2–6 IV

Abbreviations: IM, intramuscular; IV, intravenous; PO, by mouth; SC, subcutaneous.
[a] All recommended doses should be titrated slowly to effect.

increase in myocardial work and possible arrhythmias [9]. Because of the potential for development of serious side effects, α_2-agonists should be reserved for use in cardiovascularly healthy geriatric animals.

Opioids

Opioids often provide adequate sedation in geriatric animals, with the added benefit of providing analgesia. μ-Agonists (OP_3-agonists; morphine, hydromorphone, and oxymorphone) provide the greatest sedation but may also cause the greatest cardiovascular and respiratory depression. Morphine (and other μ/OP_3-agonists) has the potential to induce vagally mediated bradycardia, which may be prevented with an anticholinergic if needed [10]. Lowering the heart rate can reduce myocardial oxygen demand and consumption and may actually be desirable in some aged patients. Partial agonists (eg, buprenorphine) and agonist-antagonists (eg, butorphanol) provide only mild to moderate analgesia and sedation but also cause minimal cardiovascular and respiratory depression. These agents may be quite useful in the geriatric animal, where concern for cardiopulmonary instability is present but mild sedation and analgesia are desired for the procedure.

Tranquilizers and sedatives

Even though geriatric animals may be calmer than their younger counterparts, it may still be quite valuable to include a tranquilizer in the

anesthetic protocol to reduce the stress associated with hospitalization, treatment, anesthesia, and surgery. The benzodiazepines (eg, diazepam, midazolam) are reversible and produce little to no cardiovascular or respiratory depression, making them appropriate for many geriatric animals. Although benzodiazepine-induced sedation can be unreliable in younger animals, this is less of a concern in geriatric animals. If needed, benzodiazepines can be combined with other premedicants, such as opioids, to achieve the desired level of sedation. In addition, benzodiazepines like diazepam or midazolam can be combined with ketamine for the induction of anesthesia in selected geriatric animals.

In healthy geriatric animals, low doses of acepromazine may be a suitable choice for premedication. Acepromazine produces general CNS depression and sedation without analgesia. Nevertheless, it has a peripheral vasodilating effect that can cause significant hypotension, which contributes to the development of hypothermia in geriatric animals. When acepromazine is combined with the opioid analgesics, remarkably low doses of the tranquilizer can be used to maximize sedation and minimize the unwanted side effects.

The α_2-agonists may be considered for sedation and premedication in healthy geriatric animals because they are reversible and thus are not dependent on hepatic or renal clearance for recovery. A recent study showed that safe effective sedation could be performed in geriatric cancer patients undergoing daily radiation therapy using a combination of low-dose medetomidine, butorphanol, and glycopyrrolate [11]. Although these animals were all older (average of 8.9 years for dogs and 10.8 years for cats) and had a variety of age-related diseases, they were all identified as being in good cardiopulmonary health before drug administration. The α_2-agonists can cause serious side effects, such as bradycardia, atrioventricular conduction block, increased peripheral vascular resistance, and hypertension, making appropriate patient selection a must, especially when considering use in a geriatric population.

Anesthetic induction

Anesthetic induction may be accomplished using injectable anesthetics or by mask delivery of inhalant anesthetics if necessary. Because many injectable anesthetics demonstrate altered pharmacokinetics and pharmacodynamics, decreased plasma protein binding, and decreased hepatic and renal metabolism and excretion in geriatric animals, the use of these drugs should be undertaken cautiously.

Barbiturates

Barbiturates are highly protein bound and depend on redistribution and hepatic metabolism for termination of activity. As such, they should be used

cautiously in geriatric animals. Decreased protein binding and hypoproteinemia may lead to enhanced drug effects in geriatric animals [3,10]. To minimize the potential for a relative overdose, the lowest possible dose that produces the desired effect should be used. Barbiturates can cause significant cardiovascular and respiratory depression, and their use should be reserved for the healthy geriatric animal.

Dissociative anesthetic agents

The *N*-methyl-D-aspartate (NMDA) antagonist ketamine may be used for the induction of anesthesia in geriatric animals. Ketamine may improve cardiovascular function through stimulation of the sympathetic nervous system [12,13]; however, this may not always be desirable in the geriatric animal. NMDA antagonists may increase heart rate, causing a marked increase in myocardial oxygen demand and consumption that may not be well tolerated by animals with preexisting cardiovascular disease. Because ketamine causes muscle stiffness and rigidity, it is typically combined with a benzodiazepine to ameliorate this undesirable side effect. The effects of ketamine may be prolonged in patients with failing hepatic and renal systems, necessitating the administration of decreased doses in these animals.

Etomidate

Etomidate is a sedative-hypnotic agent with a rapid onset of action and rapid recovery. At doses normally used to produce general anesthesia, etomidate maintains cardiovascular stability, making it a good choice for the induction of anesthesia in animals with clinically significant cardiac disease [10]. Debilitated or sedated patients normally have a smooth anesthetic induction when etomidate is titrated intravenously to effect. Excited animals may exhibit undesirable side effects, such as retching, myoclonus, and apnea, during induction.

Inhalant induction

Inhaled anesthetics may be used for the induction of anesthesia in otherwise sedated or debilitated patients. There are many caveats to the use of inhaled anesthetics for induction. These include the associated severe physiologic stress of protracted induction in the animals and unwanted environmental pollution and exposure of personnel to waste anesthetic gases. An excessive depth of anesthesia can be attained rapidly during the induction of anesthesia with inhalant anesthetics, and animals must be closely monitored and assessed to prevent overdose.

Propofol

Propofol is a good choice for use in most geriatric patients because it is rapidly cleared from the body by many different routes. Recovery is

generally rapid in dogs, even after repeated doses, and metabolism is not dependent on the function of a single organ system. Propofol can induce significant respiratory and cardiovascular depression and should be titrated to achieve the desired effect. Premedication decreases the amount of propofol needed and helps to minimize side effects. Propofol has been shown to cause increased Heinz body production in cats when used for daily induction and maintenance (for an average of 6 days) and should thus be used with caution in this species if daily anesthesia is needed [14].

Anesthetic maintenance

Inhalant anesthetics are the agents of choice for anesthetic maintenance in geriatric animals, particularly for procedures lasting longer than 10 to 15 minutes. Halothane, isoflurane, and sevoflurane may be used with success in geriatric animals as long as close attention is paid to the monitoring of anesthetic depth and cardiopulmonary function during the anesthetic period.

Halothane

Halothane has been the cornerstone of anesthetic practice in veterinary medicine for many years, and many geriatric animals have been successfully anesthetized using halothane. With the newer inhalants available, however, it is generally held that the use of halothane should be reserved for healthy animals and avoided in higher risk animals. Halothane causes significant dose-related cardiovascular depression that may not be well tolerated in older patients. Heart rate, contractility, and cardiac output are significantly decreased in a dose-dependent manner [10]. Halothane can also cause profound hypotension because of vasodilation and direct depression of the vasomotor center. Halothane is also known to sensitize the myocardium to catecholamines; thus, it should be avoided in patients with the potential for dysrhythmias. Hepatitis has been reported in human patients after exposure to halothane; thus, chronic liver dysfunction should probably be considered a relative contraindication to its use.

Isoflurane

Compared with halothane, isoflurane better maintains cardiac output in anesthetized animals [10]. In addition, it does not sensitize the heart to catecholamines to the same degree as halothane. Because isoflurane has the potential to cause significant hypotension due to a direct effect on vasomotor tone, the lowest concentration necessary to achieve the desired level of anesthesia should be administered. Overall, there are fewer contraindications to the use of isoflurane in geriatric animals than to the use of halothane.

Sevoflurane

Sevoflurane is a newer inhaled anesthetic that produces extremely rapid induction and recovery. Sevoflurane is less pungent than isoflurane, making it a better choice during the induction of anesthesia with an inhaled anesthetic. Faster induction and recovery, coupled with the increased acceptance of sevoflurane's odor, reduces the stress of inhalant induction and minimizes delay in achieving airway control with endotracheal intubation. Generally speaking, this makes sevoflurane preferable to isoflurane when the induction of anesthesia is performed with an inhaled anesthetic [15].

Monitoring and support

Geriatric animals are less tolerant of a busy hospital environment and are likely to become more stressed than younger animals when taken out of their normal daily routine. Every effort to make their hospitalization stress-free should be made.

Geriatric animals may have some degree of arthritis or muscle wasting, making it harder for them to lie down comfortably on a cage or run floor. If possible, their cages should be well bedded with soft materials (eg, padded beds, orthopedic foam) to ensure their comfort while hospitalized. Additionally, they may be less flexible than younger animals, and care should be taken when their legs are secured during surgery so that they are not pulled too tight, potentially causing soreness in the postoperative period.

Because geriatric animals have decreased thermoregulatory capacity, every effort should be made during the perianesthetic period to keep them warm with warmed fluids, circulating water blankets, and forced air warmers. Hypothermia increases the incidence of arrhythmias, leads to a catabolic state and delayed healing, adversely affects immune function, leads to hypoxia and metabolic acidosis, and prolongs the effects of anesthetic agents [16]. When the body attempts to rewarm itself after surgery by shivering, there is a 200% to 300% increase in oxygen consumption that may lead to increased myocardial work and ischemia or systemic hypoxia in the postoperative period. This may be especially relevant in the geriatric animal with significant loss in functional cardiopulmonary reserve. It is easier to maintain a core body temperature in animals while they are anesthetized and vasodilated than to try to rewarm them externally as the effects of anesthetic drugs are wearing off and they become more vasoconstricted during the recovery period.

As discussed previously, geriatric animals are less tolerant of volume overload than juvenile or middle-aged animals. Aggressive fluid therapy may result in excessive intravascular and extravascular volume, leading to congestive heart failure and pulmonary edema in geriatric animals that are unable to excrete a salt and water load efficiently [6]. The goal for fluid therapy in aged animals should be the correction of any specific deficits and the maintenance of adequate tissue perfusion and oxygen delivery.

Summary

Choosing the best anesthetic agents for each geriatric animal does not in itself ensure a successful outcome. Aggressive, careful, vigilant monitoring during the anesthetic and recovery periods is required to detect and correct alterations in homeostasis that may develop during the perianesthetic period. With appropriate preoperative screening, informed choice and judicious dosing of anesthetics, and careful monitoring and supportive care, the risk of anesthesia in geriatric animals can be greatly reduced.

References

[1] Wise JK, Heathcott BL, Gonzalez ML. Results of the AVMA survey on companion animal ownership in US pet-owning households. J Am Vet Med Assoc 2002;221:1572–3.
[2] Goldston RT. Introduction and overview of geriatrics. In: Goldston RT, Hoskins JD, editors. Geriatrics and gerontology of the dog and cat. Philadelphia: WB Saunders; 1995. p. 1–10.
[3] Muravchick S. Anesthesia for the elderly. In: Miller RD, editor. Anesthesia. 5th edition. Philadelphia: Churchill Livingstone; 2000. p. 2140–56.
[4] Thurmon JC, Tranquilli WJ, Benson GJ. Anesthesia for special patients: neonatal and geriatric patients. In: Thurmon JC, Tranquilli WJ, Benson GJ, editors. Lumb and Jones' veterinary anesthesia. 3rd edition. Baltimore: Williams & Wilkins; 1996. p. 844–8.
[5] Paddleford RR. Anesthesia. In: Goldston RT, Hoskins JD, editors. Geriatrics and gerontology of the dog and cat. Philadelphia: WB Saunders; 1995. p. 363–77.
[6] Pettifer GR, Grubb TC. Anesthesia for selected patients and procedures: neonatal and geriatric patients. In: Thurmon JC, Tranquilli WJ, Grimm KA, editors. Lumb and Jones' veterinary anesthesia. 4th edition. Baltimore: Williams & Wilkins; in press.
[7] Eger EI. Anesthetic uptake and action. Baltimore: Williams & Wilkins; 1974. p. 1–25.
[8] Grimm KA, Thurmon JC, Olson WA, et al. The pharmacodynamics of thiopental, medetomidine, butorphanol and atropine in beagle dogs. J Vet Pharmacol Ther 1998;2: 133–7.
[9] Ko JC, Fox SM, Mandsager RE. Effects of preemptive atropine administration on incidence of medetomidine-induced bradycardia in dogs. J Am Vet Med Assoc 2001;218:52–8.
[10] Stoelting RK. Pharmacology and physiology in anesthetic practice. 3rd edition. Philadelphia: Lippincott, Williams & Wilkins; 1999. p. 36–157.
[11] Grimm JB, deLorimier LP, Grimm KA. Medetomidine-butorphanol-glycopyrrolate sedation for radiation therapy: an eight-year study [abstract]. In: Proceedings of the Veterinary Midwest Anesthesia and Analgesia Conference. Columbus: The Ohio State University; 2004. p. 18.
[12] Kohrs R, Durieux ME. Ketamine: teaching an old drug new tricks. Anesth Analg 1998;87: 1186–93.
[13] Wright M. Pharmacologic effects of ketamine and its use in veterinary medicine. J Am Vet Med Assoc 1996;209:967–8.
[14] Andress JL, Day TK, Day D. Effects of consecutive day anesthesia on feline red blood cells. Vet Surg 1995;24:277–82.
[15] Johnson RA, Striler E, Sawyer DC, et al. Comparison of isoflurane with sevoflurane for anesthesia induction and recovery in adult dogs. Am J Vet Res 1998;59:478–81.
[16] Kaplan RF. Hypothermia/hyperthermia. In: Gravenstein N, editor. Manual of complications during anesthesia. New York: JB Lippincott; 1991. p. 121–50.