Age is not a disease, it is a normal component of the life continuum.

Anesthesia is the careful titration of cardiovascular, respiratory and CNS depressant drugs to achieve unconsciousness, muscle relaxation, freedom from pain and amnesia. As the body ages there are numerous functional physiological changes that occur. Understanding these changes will form the foundation of appropriate anesthetic technique selection. There are an increasing number of geriatric animals in North America and continued developments in both medicine and surgery allows pets to live longer. It is reasonable to assume that more geriatric patients will be presented for procedures requiring general anesthesia. It is increasingly important that veterinarians become aware of the unique physiological changes associated with aging and appreciate how these changes may necessitate alterations in standard therapy and procedures. In veterinary medicine, geriatrics are usually defined as any animal exceeding 75-80% of their predicted lifespan. It is important to note that there can be little correlation between chronologic age and physiologic age, requiring careful individual patient assessment. Additionally, there may also be co-existing diseases present that require additional consideration.

CARDIOVASCULAR

The functional reserve of the cardiovascular system can be considerably reduced with age. Increased ventricular stiffness also causes cardiac output to become more dependent on preload and geriatric patients may be less able to compensate for decreases in preload associated with hypovolemia and vasodilation. Although there is strong evidence that these changes occur in veterinary patients, the significance of these changes are not well documented. Fibrosis and calcification of valves may lead to valvular incompetence and the maximum heart rate that can be obtained decreases with age. There is also evidence suggesting there is a decrease in responsiveness of the myocardium to endogenous catecholamines and an exaggerated responsiveness to exogenously administered catecholamines.

RESPIRATORY

The respiratory system undergoes mechanical changes associated with aging, leading to decreased compliance of the thorax, atrophy of the intercostal muscles and diaphragm, and decreased alveolar elasticity. Despite normal oxygen diffusion in the lung, the mechanical
changes associated with aging result in disruption of the precise matching of ventilation and perfusion required for optimal oxygenation. This results in a linear decline in arterial oxygen tension with age. The ventilatory response to hypoxia and hypercarbia are also markedly blunted. These changes make the geriatric patient far more susceptible to hypoxia and hypercarbia in the peri-anesthetic period. There is also some evidence that protective laryngeal and pharyngeal reflexes are reduced.

RENAL

There is as much as a 10-20% decrease in renal mass with a disruption of the renal microvascular architecture and a significant decrease in functional nephrons. This leads to a decrease in active tubular secretion and reabsorption of drugs and solutes. There is also a virtually linear decline in glomerular filtration rate (GFR) with age and this may be due in part to reductions in renal blood flow, loss of glomeruli and glomerulofibrosis. The decreases in GFR and active tubular secretion can have significant effects on drugs requiring renal excretion for elimination. The changes associated with renal blood flow and microvasculature may make the geriatric kidney less able to respond to nephrotoxic or ischemic insults. The renin-angiotensin system also becomes less responsive and geriatric animals may be less tolerant of hypovolemia and dehydration. As anesthesia often uses drugs causing varying degrees of hypotension and ample fluid therapy, it is important for the anesthetist to be aware of the renal changes associated with aging and to take proactive steps in managing these patients to prevent adverse renal outcomes. Subclinical renal insufficiency may be common in geriatric patients and a small insult (hypotension) may predispose them to later develop signs of failure. Adequate diuresis should be instituted if any concerns exist.

HEPATIC

Liver changes associated with aging are primarily quantitative and include a decreased liver mass and decreased total hepatic blood flow. Both may be decreased up to 50%. Qualitatively, hepatocellular microsomal and nonmicrosomal enzyme function remains normal. The overall effects of these changes on plasma drug concentrations are complex and require a thorough understanding of the metabolism and excretion of a specific drug. In general, most of the commonly used anesthetic drugs (opioids, ketamine, local anesthetics) are dependent on the amount of blood flow to the liver for removal from plasma. Therefore it is reasonable to expect that plasma drug half lives of some of these drugs may be prolonged. However, the clinical effects of most intravenous general anesthetic drugs (alfaxalone, ketamine, propofol) may remain unaltered as redistribution from the plasma to other tissues, rather than metabolism, determines initial recovery from the effects of these drugs.
CENTRAL NERVOUS SYSTEM

Many of the age related central nervous system changes have been characterized in humans and are related to changes in sensory and cognitive function that are less easily characterized in animals. As aging progresses, there is an apparent increased sensitivity to anesthetics and anesthetic adjuncts. This has been most clearly demonstrated as a decrease in the MAC of an inhalant anesthetic with increasing age. There is progressive neuron loss, as well as a depletion of central neurotransmitters that may explain the increased sensitivity, but this has not been conclusively determined. There is also a decrease in cerebral perfusion, however, this appears to be an appropriate response related to the decrease in cerebral mass and oxygen demand. Peripherally, there is a loss of motor, sensory and autonomic nerve fibers. This “denervation” can lead to diffuse neurogenic muscle atrophy. Changes in myelination, as well as the number of nerve fibers, may account for the increased sensitivity to local anesthetics observed in geriatric patients. Patients approaching life expectancy periodically awaken from anesthesia with non-specific deficits in cognitive function. This “post-anesthetic fog” often resolves within a few hours or may be present for two or three days.

BODY COMPOSITION (WATER, FAT, MUSCLE) & METABOLISM

As animals age, there are changes in body composition that may impact the distribution and elimination of various drugs. Aging leads to a decrease in muscle mass and gain in body fat as a percent of total body weight. The increase in percent body fat does not necessarily imply that there is an increase in the total amount of body fat; it can be due primarily to a loss of body water and muscle mass rather than an actual gain of adipose tissue. Nevertheless, this change in body composition may lead to altered plasma drug levels. Additionally, it is not uncommon to see absolute gains of body fat. Older pets are often “spoiled with food” and participate in less physical activity. Obesity can then further alter drug disposition, particularly with respect to the lipid soluble drugs. As already mentioned, there is a net loss of body water as a percent of body weight leading to decreased intracellular and blood volume. This may mean that any given dose administered into the contracted blood volume of the geriatric animal may result in higher initial plasma levels than would be expected in a younger animal. Serum albumin is also often lower in geriatrics and hypothetically this may lead to higher amounts of free drug when using highly protein bound products. However, this effect seems to be clinically insignificant. Finally, it is important to remember that basal metabolic rate is often decreased in geriatric patients and that they also have impaired function of the thermoregulatory center, therefore, they are less able to maintain a normal body temperature.
PHARMACOKINETICS & PHARMACODYNAMICS

It is difficult to predict the precise alterations in pharmacokinetics and pharmacodynamics resulting from changes associated with aging, but an appreciation of the overall expected changes should help in selecting appropriate drug doses and anesthetic protocols. In general, it is reasonable to expect that most anesthetic drugs will exert a greater than anticipated effect as a result of greater initial plasma levels, resulting from a contracted blood volumes, and due to the apparent increased sensitivity of the CNS to anesthetic drugs.

Anesthetic drugs are normally characterized by one of two general pharmacokinetic profiles. The first group contains drugs such as ketamine, propofol and to a lesser extent some of the short acting opioids such as fentanyl and alfentanil. These drugs are often administered as a single large intravenous bolus resulting in the rapid achievement of high plasma levels. Drug then quickly redistributes to other body tissues resulting in a reduction of plasma levels and cessation of the clinical effects. The ultimate metabolism and elimination of drug may continue well beyond this initial recovery period. Thus, the effects of altered metabolism may not be clinically apparent unless repeated doses, infusion or intramuscular injections are used. The second group includes drugs such as the longer acting opioids, NSAID’s and some of the sedatives (acepromazine, benzodiazepines). These drugs are more dependent on metabolism for cessation of clinical effect and are more likely to be associated with prolonged effects when metabolism is slowed.

The inhalant anesthetics, because of their unique administration and elimination, are generally less affected by the changes associated with aging. It is important to have a clear understanding of the factors responsible for initial and sustained plasma drug concentrations, distribution, metabolism and elimination of all drugs used in geriatric patients, as normal changes associated with aging could lead to serious side effects of otherwise very safe drugs.

ANESTHETIC PROTOCOLS

The anesthetic management of the geriatric patient should always be individualized to the patient. A full patient assessment should be performed looking for evidence of age associated changes, including mentation, as well as evidence of concurrent disease. Many diseases may be present in a “subclinical” form so routine preoperative evaluation of a CBC, biochemical profile and urinalysis should be encouraged. Additional evaluation may include radiographs, ultrasound or an ECG. In addition, the anesthetist should be aware of the medical history, all concurrent medications and therapies. Before opting for general anesthesia, consideration should be given to techniques using sedation combined with some form of regional anesthesia. Many older patients are quite amenable to this technique; provided proper
regional anesthetic techniques are used. It should be emphasized that a sedative and regional technique should not be used simply to avoid the perceived risks of general anesthesia if general anesthesia will provide more favorable operating conditions for the proposed procedure. It is extremely unfortunate when procedures are performed under less than ideal anesthetic conditions resulting in treatment failure. There is no evidence to suggest that morbidity and mortality are greater using a well performed general anesthetic technique compared to a sedative and regional anesthetic technique. If a sedative technique is an option, the patient still requires careful monitoring and support during the procedure. Oxygen supplementation, pulse oximetry, IV fluid support, and blood pressure and ECG monitoring should all be considered.

**SCALING DRUG DOSAGES FOR AGE**

Scaling of drug doses based upon age alone is often appropriate in geriatric patients. Drug dosages should be scaled further when patients have moderate to severe co-existing disease(s). Appropriate scaling is based upon life expectancy, not a definitive number of years after birth. This is because life expectancies, even among dog breeds, can vary by as much as 12 to 14 years. Doses are scaled approximately 10% at half life expectancy, 25% at three quarters life expectancy, and 50% at life expectancy.(1) Some patients live well beyond life expectancy and drug doses may be scaled even greater in those circumstance. Drug dose is still influenced by temperament, species, procedure to be undertaken, etc.

**PREMEDICATION**

Age is not an adequate reason to disregard any component of a balanced anesthetic protocol. Geriatric patients can be appropriately sedated using nearly any routine premedication protocol as long as doses are scaled appropriately for age and co-existing disease.

Opioids and Benzodiazepines (midazolam, diazepam) have minimal cardiovascular and respiratory effects and are safe options for geriatric patients. Opioids can cause a sinus bradycardia, leading to a decreased in cardiac output and blood pressure. This can be treated or prevented by administering an anticholinergic drug (atropine or glycopyrrolate) if necessary. An additional advantage is that both groups have specific reversal drugs available, naloxone for the opioids and flumazenil for benzodiazepines. The agonist/antagonist (butorphanol) and partial agonist (buprenorphine), on the other hand, do not reverse well with naloxone. Although opioids and benzodiazepines alone often produce unpredictable sedation in young animals, they work well alone or combined in geriatric patients. This author frequently uses midazolam with or without an opioid for premedication of geriatrics. The opioid is chosen to match the anticipated analgesic needs of the patient and the required duration of effect.
Anticholinergics (glycopyrrolate, atropine) are only used when indicated as the sinus tachycardia that often accompanies their use may be undesirable in some patients.

Acepromazine can be used in geriatrics, however, the hypotension and hypothermia associated with its use may not be desirable. Prolonged sedation can also be seen with the use of acepromazine. Although not inherently harmful to the patient, prolonged sedation can lead to prolonged hospital stays, a decreased appetite, and pose danger to the patient if left unobserved. If acepromazine is used, very low doses should be administered as exaggerated effects are often seen.

Alpha-2 agonists (dexmedetomidine, xylazine) should be used very cautiously in geriatric patients and probably only after a very thorough cardiovascular exam. The negative cardiovascular effects (pulmonary hypertension, peripheral hypertension/hypotension, bradycardia, reduced cardiac output) may be detrimental to geriatric patients.

INDUCTION

Ketamine combined with midazolam or diazepam is a popular choice in geriatric patients. It is generally associated with good cardiopulmonary stability (increases HR and BP). However, in some patients the increase in myocardial work can be detrimental. Ketamine can be titrated “to effect” with minimal risk of excitement, especially when diluted to 10 mg/ml with 0.9% NaCl. This reduces the likelihood of inadvertent overdose. The initial recovery from ketamine is due to redistribution of the drug from the plasma. If ratio dosing is used, the author favors a 2:1 volume:volume ratio of midazolam:ketamine. Recoveries are often smooth using this dosing. Diazepam should be drawn into syringes immediately before use because diazepam adsorbs to plastic within minutes.

Propofol has cardiopulmonary effects similar to thiopental (apnea and hypotension) but unlike thiopental, propofol can be titrated “to effect” without the risk of an excitatory phase. Propofol is unique in that it does not rely on hepatic or renal function for its metabolism and elimination. Therefore, recoveries should be rapid and predictable even after repeated doses or infusions. Propofol can significantly depress cardiac function.

The recently approved anesthetic induction drug Alfaxalone (Alfaxan®, Jurox Pty Ltd; NSW, Australia) can be used for anesthetic induction in geriatric patients. Anesthetic inductions using alfaxalone have similar qualities compared to propofol, providing relaxation and a smooth induction. Alfaxan is more cardiac sparing compared to propofol but apnea may occur. Alfaxalone should be administered similar to propofol, slow and steady to effect. Published anesthetic induction doses are between 4 and 5 mg/kg in young, healthy, un-premedicated patients. Doses
should be scaled due to age and the presence of any co-morbid conditions. Usual induction doses in geriatric dogs and cats are between 0.25 and 1 mg/kg IV.

Etomidate might be the most appropriate choice for anesthesia induction of patients with cardiopulmonary dysfunction. It has minimal effects on the cardiopulmonary system. Etomidate can be associated with rough recoveries and transiently suppresses adrenocortical function.

**MAINTENANCE**

Inhaled anesthetics are commonly used for maintenance of anesthesia. Modern inhalants are more easily titratable (compared to methoxyflurane) and do not depend on metabolism to any significant degree for removal from the body. However, all inhalants are associated with significant dose dependent cardiovascular and respiratory depression. It is therefore important to use a balanced anesthetic technique that includes appropriate analgesia to decrease the required amount of inhalant. Sevoflurane, isoﬂurane and desflurane all have a low potential for sensitizing the myocardium to catecholamine induced arrhythmias. Sevoflurane may be the preferred inhalant for use in geriatric patients due to its ability to be finely control anesthetic depth and support ventilatory function. Some geriatric patients are exquisitely sensitive to the vasodilatory effects of the inhalant anesthetics and may have wide swings in arterial blood pressure with tiny changes in inhalant concentration. Isoflurane may also be used, but is less titratable for fine control of anesthetic depth and significantly depresses respiratory function (compared to sevoflurane). Desflurane is a newer inhalant that has extremely rapid induction and recovery characteristics but requires a very special vaporizer that is not practical in private veterinary clinics. Desflurane has cardiopulmonary effects similar to isoﬂurane and sevoflurane.

Regional anesthetic techniques are very effective for reducing inhalant anesthetic requirements and their use should be considered in all general anesthetics when appropriate. Intraoperative analgesics should also be used to decrease inhalant requirements and the cardiopulmonary depression associated with the inhalants. Intraoperative monitoring should include blood pressure, capnography, pulse oximetry, heart rate and rhythm, temperature, and frequent assessment of reflexes. The geriatric patient requires added vigilance and the anesthetist should be prepared to support the patient as needed. An IV catheter should be placed and maintenance IV fluids should be administered. Supplemental heat is also recommended as geriatric animals are less able to maintain normal body temperatures.

**RECOVERY**

It is important to view the recovery from anesthesia with equal importance to the induction, particularly in geriatric animals. Geriatric patients may have pre-existing sensory
deficits (vision, hearing) that increase the stress associated with hospitalization and recovery from anesthesia. Although not conclusively studied, it is likely that geriatric animals suffer from the similar post anesthetic cognitive impairments as humans. This may account for the unexpected dysphoria often seen in geriatric animals in the immediate post-anesthetic period as well as some of the residual effects occasionally described by owners (even weeks after anesthesia). The elderly patient may also suffer from chronically painful conditions requiring additional attention to body position during anesthesia and recovery. Geriatric patients have a poor ability to maintain body temperature during anesthesia and consequently can be expected to be mildly hypothermic if active re-warming is not provided intra-operatively. In general, attempts should be made to ensure all patients have a smooth and comfortable recovery. This may necessitate the continued use of active re-warming systems, additional doses of sedatives, appropriate analgesic use, quiet recovery areas, supplemental oxygen, cardiopulmonary support and evacuation of the patient’s bladder.

Postoperative pain management is an important component of the overall anesthetic plan. There has been some suggestion, mostly in humans, that the perception of pain is reduced in the elderly. However, the evidence supporting such a conclusion remains inconclusive. Elderly patients should be treated just as aggressively as younger patients for pain management. However, one needs to have an increased awareness of the possible side effects; especially if doses are not adjusted to reflect the underlying changes associated with aging and concurrent disease. Each patient should be treated as an individual, and their analgesic needs should be carefully evaluated and regularly re-assessed to keep them comfortable. Changes in mentation may be more common in geriatric patients with opioid administration that has not been scaled properly for age.

Finally, geriatric patients may not have the functional organ reserve to tolerate even minor physiological insults associated with anesthesia. It is important for quality-control purposes that good follow up is done with post anesthetic patients as not all negative sequelae from anesthesia will be recognized in the immediate post-operative period. The early recognition of problems in a patient may improve treatment outcome and the information gained may help prevent future complications.

Useful Reference