Chapter 26

Dogs and Cats

Richard M. Bednarski

Introduction

The selection of a particular anesthetic regimen is predicated upon the patient's physical status and temperament, the type of procedure for which anesthesia is being considered, anticipation of perioperative pain, the familiarity with anesthetic drugs, the type of facility and available equipment, the personnel available for assistance, and the cost of anesthetic drugs. There is no single best method for anesthetizing dogs or cats, and familiarity with just one anesthetic technique at best limits a veterinarian's ability to perform the myriad of surgical and diagnostic procedures commonly performed in a modern veterinary practice. A debilitated dog or cat undergoing extensive repair of a fractured limb will require a different anesthetic regimen than one undergoing routine neutering, one requiring short-term restraint for radiography, or a geriatric patient requiring extensive dental manipulations.

General anesthesia is characterized by muscle relaxation, unconsciousness, amnesia, and analgesia. Rarely does a single drug provide all of these elements at safe doses. Inhalation anesthetics come closest to satisfying all of these conditions, but even they are more useful when coadministered with anesthetic adjunctive drugs such as opioids, local anesthetics, or neuromuscular junction–blocking agents. As a general rule, when formulating an anesthetic plan, it is best to consider using relatively low doses of several different drugs rather than a large dose of a single drug. For example, apnea resulting from a large bolus of propofol can be eliminated, or its duration shortened, by prior administration of acepromazine, opioids, or α_2-adrenergic agonists, which allow administration of a lower propofol dose.[1] The opioid drugs, although important components of modern anesthetic regimens, by themselves do not produce general anesthesia.[2] Muscle rigidity, salivation, and long recoveries associated with large dosages of ketamine can be lessened when it is combined in reduced doses with opioids, α_2-adrenergic agonists, and central muscle relaxants such as benzodiazepines.[3]

Any chemical restraint or general anesthetic plan must include a provision to control pain if it is present or anticipated. A good analgesic regimen should include drugs sufficient to ensure analgesia during and after the procedure. The one thing that should not vary among anesthetic procedures is the degree of vigilance associated with monitoring an anesthetized dog or cat. Early warning of impending anesthetic difficulty is the single most important factor responsible for decreasing anesthetic-related morbidity and mortality.

Preanesthetic Considerations

Recording a thorough history (Table 26.1) and conducting the physical examination are the most important components of a preanesthetic evaluation. Even young, seemingly healthy, animals presented for routine procedures such as neutering require both. These animals may have never been previously examined by a veterinarian, and congenital disorders, severe parasitism, or heartworm disease may be discovered.

Signalment

Anesthesiologists are often queried about "sensitivity to anesthesia" in a variety of dog and cat breeds. Although several breed-associated anesthesia concerns have been documented, all breeds have been successfully anesthetized by using standard anesthetic regimens, and most reports of "sensitivities" are anecdotal. One well-documented breed-associated anesthetic concern is the altered pharmacokinetics of barbiturates and other anesthetic drugs in sight hounds.[4] Another is brachycephalic breeds and their associated airway anatomical malformations. Since toy breeds have

Table 26.1. Signalment and history, including questions of organ system function

A. Signalment
   1. Age
   2. Breed
   3. Gender
B. Body weight
C. Duration of ongoing complaint
D. Concurrent medications
   1. Angiotensin-converting enzyme inhibitors
   2. H_2 blockers
   3. Antibiotics: aminoglycosides
   4. Cardiac glycosides
   5. Phenobarbital
   6. Nonsteroidal anti-inflammatory drugs
   7. Calcium channel blockers
   8. Beta blockers
   9. Tricyclic antidepressants
E. Signs of organ system disease
   1. Diarrhea
   2. Vomiting
   3. Polyuria-polydipsia
   4. Seizures and personality change
   5. Exercise intolerance
   6. Coughing and stridor
   7. Weight loss and loss of body condition
F. Previous anesthesia and allergies
G. Duration since last meal

a greater surface area–body mass ratio and have a relatively greater metabolic rate, they require careful attention to maintenance of body heat and blood glucose concentrations. Additionally, they require a relatively greater dose of drugs on a per-kilogram basis. Generally, there are no gender-related differences in the response to anesthesia. However, a history of the estrous cycle will often identify recent estrus and thus alert the clinician to the concerns associated with an enlarged and vascularized uterus. This would potentially cause concern regarding blood loss during an ovariohysterectomy. Additionally, the owner of an intact female animal should be queried about the possibility of their animal being pregnant because the stress of surgery and anesthesia may adversely affect the fetus(es).

Age is an important anesthetic consideration. Generally, the very young (less than 11 weeks) and the aged (more than 80% of the expected life span) do not biotransform anesthetic drugs as rapidly as do young, healthy patients.[5] Healthy geriatric patients may only require 25% to 50% of the dose of sedatives, hypnotics, tranquilizers, and opioids given to comparable young healthy animals.

History

In addition to questions concerning organ system function (Table 26.1), the owner should be queried regarding any previous anesthetic episodes, past and present illnesses, and past and current medication history, including history of heartworm prophylaxis.[6] The time elapsed since the last feeding should be noted.

Table 26.2. Preanesthesia physical examination

A. Body weight and body condition
   1. Obesity
   2. Cachexia
   3. Dehydration
B. Cardiopulmonary
   1. Heart rate and rhythm
   2. Auscultation
      Heart sounds and murmurs
      Breath sounds
   3. Capillary refill time
   4. Mucous membrane color
      Pallor
      Cyanosis
   5. Pulse character
C. Central nervous system and special senses
   1. Temperament
   2. Seizure, coma, and stupor
   3. Vision and hearing
D. Gastrointestinal
   1. Parasites
   2. Abdominal palpation
E. Hepatic
   1. Icterus
   2. Abnormal bleeding
F. Renal
   1. Palpate kidneys and bladder
G. Integument
   1. Tumors
   2. Flea infestation
H. Musculoskeletal
   1. Lameness
   2. Fractures
I. Pain Assessment

Physical Examination

The preanesthetic physical examination should be thorough, with all body systems considered (Table 26.2). Any abnormality discovered by physical examination or suggested by the medical history should be followed with appropriate laboratory or other suitable diagnostic testing. The assessment of an animal's temperament is critical. Vicious or aggressive dogs will require a different approach to anesthesia than quiet, relaxed individuals.

Laboratory Evaluation

The minimum preanesthetic laboratory data required for young healthy dogs are hematocrit and plasma protein. These tests are easy, quick, and inexpensive. Hematocrit is an indicator of hemoglobin concentration, which directly relates the ability of the blood to transport oxygen to the tissues. As a general rule, a hematocrit of less than 20% indicates the need for perioperative administration of blood or, if available, a hemoglobin-based oxygen-carrying solution. Hemoglobin concentration (g/dL) can be approximated by dividing the hematocrit by 3.

For elective procedures in middle-aged to older animals, or animals treated chronically with medications that could alter liver

or renal function (e.g., nonsteroidal anti-inflammatory drugs, phenobarbital, or antineoplastic chemotherapeutics), a complete blood count, urinalysis, and biochemistry profile should be performed. Other tests should be performed (e.g., thoracic radiographs and/or echocardiography) if the history or physical examination suggests specific organ system disease. A minimum laboratory database prior to emergency anesthesia should include packed cell volume, total protein, and electrolytes (sodium, potassium, and chloride).

Physical Status

Many factors (e.g., age, breed, concurrent disease, surgical procedure, surgeon skill, and available equipment) contribute to the overall anesthetic risk for a given patient. One risk factor is the physical status of the patient. A convenient system of status classification for veterinary patients has been adapted from the American Society of Anesthesiologists.[7] In general, physical status I and II patients appear to be at less risk for anesthetic complications. Physical statuses III through V are usually at greater anesthetic risk. However, this is not to imply that category I and II patients are at no risk from unanticipated anesthetic mishaps (Table 26.3).

Table 26.3. Physical status classification of veterinary patients

ASA Status Level	Patient Description
I	Normal healthy patient
II	Non-incapacitating systemic disease (e.g., obesity, mild dehydration, and simple fractures)
III	Severe systemic disease not incapacitating (e.g., compensated renal insufficiency, stable congestive heart failure, controlled diabetes mellitus, or cesarean section)
IV	Severe systemic disease that is a constant threat to life (e.g., gastric dilation and volvulus)
V	Moribund, not expected to live 24 h irrespective of intervention (e.g., severe uncompensated systemic disturbance)

ASA, American Society of Anesthesiologists.
Procedures performed under emergency conditions are denoted by placing an *E* behind the physical status number.

Patient Preparation

Fasting

Healthy dogs and cats should be fasted for at least 6 h prior to being anesthetized, if possible. Water can be allowed until just prior to anesthesia. Dogs and cats less than 8 weeks old and those weighing less than 2 kg should not be fasted longer than 1 or 2 h, because they are at a greater risk of perianesthetic hypoglycemia. They should receive dextrose-containing intravenous fluids during any prolonged anesthesia (longer than 15 min) and/or serial blood glucose measurements should be performed until fully recovered.

Patient Stabilization

When possible, life-threatening physiological disturbances should be corrected prior to anesthesia (Table 26.4). However, this may not always be possible, and anesthesia should never be delayed if immediate surgical or medical intervention is the only way to save the patient's life.

Table 26.4. A list of conditions that should be corrected prior to anesthesia

A. Severe dehydration
B. Anemia or hypoproteinemia
   Packed cell volume < 20 with acute blood loss
   Albumin < 2.0 g/dL
C. Acid-base and electrolyte disturbances
   pH < 7.2
   Potassium < 2.5–3.0 or > 6.0
D. Pneumothorax
E. Cyanosis
F. Oliguria or anuria
G. Congestive heart failure
H. Severe, life-threatening cardiac arrhythmias

Venous Access

Advantages to inserting an intravenous catheter into a peripheral vein include the following: Tissue-toxic drugs such as thiopental can be administered without fear of perivascular administration, intravenous fluid administration is facilitated, and the circulation is immediately accessible for administration of emergency drugs. The most common site for catheter insertion in dogs and cats is the cephalic vein. The lateral and medial saphenous veins are also easily accessible and may be preferred if surgery is performed on the head or thoracic limbs. The jugular vein can also be used, especially if longer-term indwelling catheters are being placed. Typically, an over-the-needle style of catheter is most suitable for perianesthetic use. A 20-gauge, 2-inch catheter is suitable for most dogs and cats weighing more than 2 kg, and a 22-gauge, 1.25-inch catheter is suitable for those that are smaller. An 18-gauge catheter can be used in medium to large dogs if more rapid fluid administration is anticipated or needed.

Intravenous Fluids

The purpose of perianesthetic administration of intravenous fluids is to maintain vascular volume and adequate cardiac preload, which can be decreased as a result of increased vascular capacitance associated with anesthetic drugs, blood loss, and insensible fluid loss. In healthy patients without metabolic disease, a balanced electrolyte solution such as lactated Ringer's solution is most suitable for routine use since most fluid loss during anesthesia is isotonic. A patient's disease process may warrant the use of other fluids, such as normal saline, those containing dextrose, or a colloid solution, such as whole blood, packed red cells or other hemoglobin-based oxygen carrier, plasma, or a plasma

expander.[8] The routine crystalloid administration rate for dogs and cats is 10 mL · kg^{-1} · h^{-1}. This rate can be decreased to 5 mL · kg^{-1} · h^{-1} for the second and subsequent hours of anesthesia if the surgical procedure is associated with minimal blood loss. Preexisting cardiac disease (e.g., mitral valve insufficiency) may warrant reduced fluid administration rates so as to not cause potentially fatal pulmonary edema.

Several styles of fluid administration sets are available. An administration set with a 10-drop/mL calibration is most convenient for patients weighing more than 5 kg. For smaller patients, a calibrated 60-drop/mL drip chamber enables a more precise estimation of proper fluid rate. If very small volumes of fluid are given, or precise volume measurement is desired, a syringe pump may be used. It is convenient to calculate the number of drops per minute necessary to deliver the calculated hourly fluid amount. The following example uses a 10-drop/mL drip set in a 25-kg dog at a rate of 10 mL · kg^{-1} · h^{-1}:

25 kg · 10 mL/kg/h = 250 mL/h
250 mL/h · 10 drops/mL = 2500 drops/h
2500 drops/h ÷ 60 min = 42 drops/min

A danger of perioperative fluid administration to very small animals is inadvertently administering too much fluid by improperly adjusting the drip rate. This can be particularly problematic in cats because they have a relatively small plasma volume relative to their size. A mechanical infusion pump or measured volume administration set will assist with delivery of the correct fluid amount.

Table 26.5. Considerations for selecting an anesthetic plan

A. Procedure to be performed
Duration
<15 min
15 min to 1 h
>1 h
Type of procedure
Minor medical or surgical
Major invasive surgery
Anticipated perioperative pain
B. Available assistance and equipment
Assistance
Ventilatory assist or control
Restraint
Equipment
Anesthetic machine
Type of inhalation anesthetic
Appropriate monitoring devices
C. Patient's temperament
Quiet, relaxed, or calm
Nervous and/or excitable
Vicious
Moribund or comatose
D. Physical status
ASA categories I through V
E. Breed
Sight hound
Brachycephalic
Toy

ASA, American Society of Anesthesiologists (see Table 26.3).

The Anesthetic Plan

Several things should be considered when formulating an anesthetic plan (Table 26.5). In general, the anesthetic or chemical restraint technique rely primarily on local anesthesia, injectable anesthesia, or inhalation anesthesia. These techniques frequently overlap. For example, inhalation anesthesia is usually initiated with injectable anesthetics. Local anesthetic nerve blocks are typically accompanied by general anesthesia.

The remainder of the discussion regarding the choice of anesthetic drugs assumes the reader has reviewed and has a familiarity with the pharmacology of the various anesthetic drugs.[9,10] Although the drug combinations described are suitable for a variety of patients, the reader should refer to the appropriate sections of this text or consult a veterinary anesthesiologist if questions remain about how to anesthetize and monitor specific patients.

Short-Term Anesthesia (Less than 15 Minutes)

Several drugs are available for short-term anesthesia or chemical restraint (Tables 26.6 to 26.9). Immobilization for a short duration not requiring strong analgesia (radiography, suture removal, otoscopic examination, etc.) can be performed most simply with intravenous injectable drugs such as thiopental, propofol, or the ketamine/diazepam combination. These drugs induce rapid and predictable short-term loss of consciousness. Thiopental is relatively inexpensive and is suitable for short-term restraint of most healthy dogs and cats. A disadvantage to its use as a sole anesthetic is that relatively large doses are required, full recovery can take up to 1 h, and recovery can be associated with ataxia and disorientation. These undesirable characteristics are reduced when its administration is preceded by a tranquilizer such as acepromazine or a sedative such as medetomidine. Another disadvantage is that it must be administered intravenously, a problem with fractious or uncooperative animals. Perivascular thiopental administration is associated with local tissue inflammation, pain, and potential tissue necrosis. Perivascular administration should be attended to by infiltrating the area with a crystalloid fluid (e.g., 0.9% sodium chloride) volume equal to three to five times the volume of perivascularly administered thiopental. Additionally, a local anesthetic such as lidocaine and an anti-inflammatory (e.g., methylprednisolone) may be infiltrated near the site of perivascular injection. Another important side effect of thiopental is the significant respiratory depression that can accompany its use. Alternatives to thiopental include propofol, etomidate, and the combinations of diazepam and ketamine or tiletamine and zolazepam (Telazol). The duration of action following a 1-bolus dose of these drugs is generally less than 15 min. Because of its rapid plasma clearance, multiple boluses of propofol, or a propofol infusion, can be used to prolong the duration of restraint without significantly prolonging the duration of recovery.[11]

Table 26.6. Sedatives and tranquilizers

Drug	Dosage (mg/kg)[a]	Comments
Acepromazine	0.025–0.2 IV, IM, SC (3–4 mg maximum)	Mild to moderate sedation of 1- to 2-h duration
Xylazine	0.3–2.2 IV, IM	Moderate to deep sedation, analgesia; 20 min to 1 h
Medetomidine	Dogs, 0.005–0.05 IV, IM Cats, 0.05–0.12 IV, IM	Similar effects to xylazine but 1- to 3-h duration
Diazepam	0.2–0.4 IV, IM	Most useful when combined with other sedatives, opioids, or ketamine Avoid IM in cats and small dogs
Midazolam	0.1–0.3 IV, IM, SC	Similar to diazepam but also useful IM or SC

IM, intramuscular; IV, intravenous; and SC, subcutaneous.
[a]Generally the low end of the dosage range is used IV and in sick or debilitated patients.

Table 26.7. Opioids and opioid combinations

Drug(s)	Dosage (mg/kg)[a]	Comments
Oxymorphone	0.05–0.1 IV, IM, SC	Excitement when used alone in young healthy dogs Duration of analgesia is 1–4 h
Morphine	0.2–0.6 IM, SC	Same as for oxymorphone
Hydromorphone	0.1–0.2 IV, IM, SC	Same as for oxymorphone
Butorphanol	0.2–0.4 IV, IM, SC	Opioid agonist/antagonist Minimal sedation when used alone Duration of analgesia is <1 h in dogs and up to 2–3 h in cats
Buprenorphine	0.005–0.01 IV, IM, SC, PO	Partial opioid agonist with approximately 6-8-h duration
Acepromazine-opioid	0.05–0.1 IV, IM Use dosage ranges for opioids listed above	Can be combined in same syringe Sedation lasts 15 min to 1 h
Midazolam-opioid	0.2–0.3 IV, IM Use dosage ranges for opioids listed above	Can be combined in same syringe Sedation lasts 15–40 min Generally produces poor results in young, healthy animals Not recommended for immobilization of vicious or difficult to handle animals Better quality restraint in older or debilitated animals
Xylazine-opioid	0.4–0.6 IV, IM Use dosage ranges for opioids listed above	Both drugs are reversible; sedation lasts 30–40 min Observe for bradycardia Useful for immobilization of difficult to handle or vicious animals
Medetomidine-opioid	Dogs, 0.001–0.002 IM Use dosage ranges for opioids listed above Cats, 0.004–0.006 IM Use lower end of dosage ranges for opioids listed above	Both drugs are reversible; sedation lasts 30 min to 1 h Observe for bradycardia Useful for immobilization of difficult to handle or vicious animals

IM, intramuscular; IV, intravenous; PO, oral; and SC, subcutaneous.
[a]Use low end of opioid dosage in cats.

Table 26.8. Cyclohexylamines and cyclohexylamine combinations

Drug(s)	Dosage (mg/kg)	Comments
Ketamine	2.0–10.0 IV, IM	Not useful alone in dogs Useful restraint in cats lasts 5–30 min
Ketamine-diazepam and ketamine-midazolam	5.5/0.20 IV	Diazepam and midazolam are equally effective in this combination Useful restraint lasts 5–10 min Poor muscle relaxation
Ketamine-xylazine	10.0/0.7–1.0 IM	Useful restraint lasts 20–40 min
Ketamine-acepromazine	10.0/0.2 IM	Useful restraint lasts 20–30 min
Tiletamine-zolazepam (Telazol)	2.0–8.0 IV, IM	Limited shelf-life after reconstitution Useful restraint for 20 min to 1 h
Telazol-ketamine-xylazine[a]	Cats 0.022 mL/kg	Long recoveries
Medetomidine-ketamine-opioid	Cats 0.03–0.06/5.0 Use opioid dose listed in previous table Dogs 0.015–0.03/3.0 Use opioid dose listed in previous table	Good immobilization Medetomidine and opioid can be reversed Can be used without opioid for restraint alone

IM, intramuscular; and IV, intravenous.
[a]Reconstitute Telazol powder with 4 mL ketamine (100 mg/mL) and 1 mL xylazine (100 mg/mL).

Table 26.9. Injectable anesthetic drugs[a]

Drug	Dosage (mg/kg)	Comments
Thiopental	8.0–20.0 IV	Use lower dosage after premedication
Methohexital	3.0–8.0 IV	Muscle rigidity Best if preceded by a tranquilizer or sedative Duration 3–5 min
Etomidate	0.5–2.0 IV	Duration 5–10 min Myoclonus, gagging/retching
Propofol	4.0–6.0 IV CRI,[b] 0.2–0.8 mg/kg/min	Duration 5–10 min after single-bolus dose Apnea for several minutes with rapid injection
Alphaxalone	1.0–15.0 IV, IM	Use lower dosages after premedication and for anesthetic induction and larger dosages for longer term immobilization

IM, intramuscular; and IV, intravenous.
[a]Injectable combinations using ketamine are listed in Table 26.8.
[b]Constant-rate infusion.

Dissociative-anesthetic combinations (ketamine-diazepam or tiletamine-zolazepam) produce less muscle relaxation than thiopental or propofol. They also are associated with increased salivation and dysphoria upon recovery. However, dissociative-anesthetic combinations generally produce less respiratory and cardiovascular depression than other available short-acting injectable anesthetics. Muscle relaxation and recovery quality are improved and salivation lessened when dissociatives are given with or preceded by a tranquilizer or sedative.[12]

Sedative/opioid combinations are suitable for short-term restraint for minimally invasive procedures or those procedures not requiring general anesthesia. An advantage is that one or both of

Table 26.10. Antagonists of various classes of anesthetic drugs

Drug	Dosage (mg/kg)
$Alpha_2$	
Yohimbine	0.1 IV, IM
Atipamezole	0.04–0.5 IM[a]
Benzodiazepine	
Flumazenil	0.01–0.2 IV[b]
Opioid	
Naloxone	0.002–0.02 IV, IM[c]

IM, intramuscular; and IV, intravenous.
[a]Dosage in milligrams is equal to five times the previously administered dosage of medetomidine.
[b]Begin with lowest dosage and repeat, if necessary, to effect.
[c]Use lowest dosage for "partial" reversal and highest dosage for complete reversal (refer to text for explanation).

these components can be reversed, enabling a rapid return to preanesthetic mentation and function (Table 26.10). Propofol or thiopental can be added to the regimen when complete immobilization or general anesthesia is necessary.

Alphaxalone is a neurosteroid anesthetic drug that produces hypnosis and muscle relaxation by enhancing $GABA_A$ receptor ion conduction. Immobilization is characterized by excellent muscle relaxation and hypnosis in dogs and cats. It is solubilized in cyclodextran and thus does not induce histamine release as did the Cremaphor vehicle used in Saffan (alphaxalone and alphadolone). It can be administered intravenously or intramuscularly, and its duration of action is dose dependent. It is compatible for use following commonly used preanesthetic sedatives and tranquilizers.[13]

The relatively cumbersome nature of inhalation anesthesia makes it inconvenient for use in very short procedures. However, the rapid induction and recovery associated with isoflurane and sevoflurane make them suitable for short-term anesthesia, particularly in neonates or those animals with severe organ system compromise. Mask induction with inhalant anesthetics should be preceded by preanesthetic administration whenever possible to reduce the stress and anxiety (and catecholamine release) associated with the initial breathing of high concentrations of inhalant anesthetics.

Intermediate-Term Anesthesia (15 Minutes to 1 Hour)

For procedures of intermediate duration that do not require good analgesia, thiopental, ketamine/diazepam, and propofol can be used and redosed to effect. Typically, one-third to one-half of the induction dose is administered slowly to prolong the anesthetic effect. Thiopental and ketamine/diazepam should not be redosed many times. Their initial duration of action following bolus administration primarily depends on redistribution away from the brain to other tissues, such as muscle. However, when these tissues are saturated with drug, redistribution greatly slows, and metabolism becomes the rate-limiting factor for awakening. Propofol, because of its relatively rapid clearance and large volume of distribution, can be administered repeatedly to dogs by using small boluses or by constant-rate infusion (Table 26.9).

Invasive surgical procedures such as feline onychectomy or canine and feline gonadectomy typically require 15 min to 1 h of anesthesia, accompanied by good perioperative analgesia. Several options are available (Table 26.8). A combination of Telazol, ketamine, and xylazine is suitable for cats, although its use has been associated with prolonged recoveries.[14] An alternative is the combination of medetomidine, ketamine, and an opioid. Inclusion of an α_2-adrenergic agonist in the combinations suggests that partial antagonism of the anesthetic and analgesic effects with atipamezole is possible, if required. Inhalation anesthesia is also appropriate for procedures of intermediate duration and may be the most convenient. Inhalant anesthetic delivery of this duration usually requires intubation and careful monitoring, but has the benefit of enabling a rapid adjustment of the depth of anesthesia should anesthetic conditions change unexpectedly (e.g., loss of blood or respiratory arrest).

Long-Term Anesthesia (Longer Than 1 Hour)

Long procedures are best managed with inhalation anesthesia. Awakening from sevoflurane and isoflurane anesthesia is predictably rapid. Even sick and debilitated patients recover from prolonged periods of inhalation anesthesia relatively quickly, and liver or renal impairment does not directly affect drug clearance. Injectable anesthesia using intramuscularly or intravenously administered drugs has been described.[15–18] Those techniques that involve infusion of propofol and opioid combinations along with reversible tranquilizers or sedatives are most suitable for prolonged anesthesia because of propofol's predictably rapid clearance. Those techniques involving nonreversible drugs are less suited for prolonged immobilization because of the attendant prolonged recovery. Most anesthetic techniques are associated with some degree of respiratory depression and a loss of the protective swallowing reflex, so tracheal intubation and a means to assist ventilation are essential to reducing anesthetic risk.

Premedication

Inhalation anesthesia can be initiated without premedication; however, administration of a sedative, tranquilizer, opioid, or combination of these drugs is recommended prior to induction (Tables 26.6 and 26.7). Preanesthetic drugs aid in restraint, reduce apprehension, decrease the quantity of potentially more dangerous drugs used to produce general anesthesia, facilitate induction, enhance perioperative analgesia, and reduce arrhythmogenic autonomic reflex activity. Premedications are usually administered intramuscularly or subcutaneously 15 to 20 min before induction. The choice of premedication depends on signalment, temperament, physical status, concurrent disease, the procedure to be performed, and personal preference (Table 26.11). For procedures associated with postoperative pain, premedication should include an

Table 26.11. Suggestions for premedication in dogs and cats[a]

Dogs	Premedication
Young normal healthy	Acepromazine
	Xylazine
	Medetomidine
	Any of the above with an opioid agonist if moderate to severe perioperative pain is anticipated; any of the above with butorphanol or buprenorphine if less intense pain is anticipated or for moderate restraint
Aggressive/vicious	Acepromazine–opioid agonist
	Medetomidine–opioid agonist
	Xylazine–opioid agonist
Geriatric	Acepromazine (low end of dosage range)
	Midazolam-opioid
Painful procedures	Acepromazine–opioid agonist
	Midazolam–opioid agonist
Cats	Acepromazine-opioid (low dosage)
	Ketamine (low dosage)
	Ketamine (low dosage–acepromazine)
	Xylazine or medetomidine (young and healthy)
	Telazol (low dosage)

[a]These drugs or drug combinations should be administered between 15 and 30 min prior to anesthetic induction.

analgesic such as an opioid or α_2-adrenergic agonist and possibly a nonsteroidal anti-inflammatory drug. Fewer analgesics are typically needed postoperatively when analgesics are administered preemptively.[19] Repeated patient assessment following surgery is needed to assess the adequacy of analgesia, and additional analgesics should be administered when needed.

Induction

Induction is most easily accomplished in most animals with propofol, etomidate, dissociative anesthetic–benzodiazepine combinations, or thiopental (Table 26.9). Advantages to an intravenous method of induction include rapid loss of consciousness and ability to quickly intubate endotracheally. Alternatives to these rapid intravenous induction protocols include higher-dose intramuscular dissociative anesthetic–benzodiazepine administration, chamber or mask inhalant induction, or high-dose intravenous opioid induction. These techniques can be useful in special circumstances, but for routine use in healthy dogs and cats their disadvantages generally outweigh their advantages.

Chamber/Mask

One disadvantage to chamber and mask induction is the associated waste-gas pollution. Another is the struggling and associated stress during the induction phase.[20] Mask induction is most easily accomplished in moribund animals and small tractable dogs. Prior tranquilization or sedation enhances the quality and speed of induction.[21] Isoflurane and sevoflurane are the most suitable inhalants because they produce a relatively rapid induction.[22] Relatively high oxygen flow rates (4 L/min for chamber and 3 L/min for mask) and vaporizer settings (3% to 5% isoflurane and 5% to 7% sevoflurane in healthy animals) are used. The use of nitrous oxide is not necessary during chamber or mask induction.[23] With chamber induction, once the animal loses its righting reflex and is unresponsive to the chamber being tilted from side to side, the animal is removed from the chamber and induction is continued using an appropriately sized mask and the vaporizer setting used during the chamber phase. Mask induction (not preceded by a chamber) is begun by exposing the animal to the mask and oxygen. The inhalation concentration is slowly increased to 3% to 5% for isoflurane and 5% to 7% for sevoflurane. This is accomplished with a non-rebreathing or rebreathing circuit by gradually increasing the vaporizer setting over 2 to 4 min. Use of a non-rebreathing anesthetic system (e.g., the Bain coaxial system [see Chapter 17]) will facilitate a more rapid induction because the time-consuming exchange of the room air in the reservoir bag, breathing circuit, and carbon dioxide absorber of a circle system with anesthetic-laden gas from the vaporizer is not necessary.

Intravenous High-Dose Opioid Induction

A disadvantage to opioid induction is the attendant relatively slow loss of consciousness. Advantages include good cardiovascular stability (although severe bradycardia may be seen when anticholinergics are not coadministered) and the attenuation of the stress response associated with anesthesia and surgery. Opioid induction works best in debilitated dogs and is not recommended in cats or young healthy dogs that are not well sedated. Incremental doses of an opioid agonist (Table 26.7) are alternated with small incremental doses of diazepam or midazolam (Table 26.6) until the dog can be intubated.

Anesthetic Maintenance

The maintenance phase of anesthesia begins when unconsciousness is induced and ends with discontinuation of anesthetic deliv-

Table 26.12. Vaporizer settings[a]

Drug	Induction Phase (%)	Maintenance Phase (%)
Halothane	3	1–2
Isoflurane	3	1.5–2.5
Sevoflurane	4–5	2–4

[a]Listed vaporizer settings assume a fresh-gas flow of 1 to 2 L/min during the induction phase (first several minutes following induction with injectable drug), and a fresh-gas flow of 10 mL/kg/min during the maintenance phase. Low-flow system vaporizer settings are typically 1 to 2% higher. Refer to text for discussion of mask or chamber induction.

ery. After the loss of consciousness, a properly sized cuffed endotracheal tube or alternative airway is usually inserted to enable assisted ventilation, if necessary, and protect against aspiration of oropharyngeal contents. Adequate cardiovascular function is rapidly verified and the anesthetic vaporizer turned on. The initial and subsequent anesthetic vaporizer settings (percentage concentration of inhalant) vary with the condition of the patient, the type of breathing circuit used, and the fresh-gas flow rate (Table 26.12). The relatively high fresh-gas flow rate and vaporizer setting that are initially used after induction are decreased to maintenance settings when the patient nears the desired anesthetic plane (usually when palpebral reflex disappears and the heart rate begins to decrease). The vaporizer setting is adjusted according to signs of anesthetic depth. The most useful signs of anesthetic depth in dogs and cats include a combination of muscle tone (assessed by opening the mouth its full extent), heart and respiratory rates, and systemic blood pressure. All but systemic blood pressure are easily and inexpensively monitored and should be performed routinely. Other monitors that may be used include a pulse oximeter and a capnometer. Pulse oximetry noninvasively provides an estimate of hemoglobin's oxygen saturation (normal $\geq$ 95%). This information along with packed cell volume or hemoglobin concentration indicates the oxygen content of arterial blood. A capnometer noninvasively assesses ventilation by monitoring respiratory rate and end-tidal expired (related to arterial) carbon dioxide partial pressure. End-tidal CO_2 monitors can also identify problems with the gas delivery system such as malfunctioning one-way valves and exhausted CO_2 absorbent, especially when graphic display of the CO_2-time profile is provided (i.e., capnogram).

The Anesthetic Record

This is part of the permanent patient record and should include notation of patient status; the anesthetic drugs used, including time of administration; dose and effect; duration of the surgery; and notation of significant perioperative events. Ideally, heart rate, respiratory rate, blood pressure, and any other variables monitored should be recorded at regular intervals (5 to 10 min). Recording these data at regular intervals creates a visual aid that assists in determining the change in patient status during the anesthetic period. For example, a steadily increasing heart rate accompanied by a steadily decreasing blood pressure during a 15-min interval could signal hypotension caused by fluid loss or excessive anesthetic depth. This is easily observed on the anesthetic record but may not be noticed without the visual prompt of the data recorded over time.

Perioperative Analgesia

Concurrent administration of various analgesic drugs during inhalation anesthesia is useful to enhance intraoperative and postoperative analgesia. These drugs can be continued into the postanesthetic period to maintain analgesia. Infusions of low doses of ketamine, lidocaine, opioids, and their combinations have been described as adjuncts to inhalation anesthesia (Table 26.13).[24–26] When using these drugs, the concentration of inhalant anesthetic can often be significantly reduced. Increased respiratory depression is a concern, and the adequacy of ventilation should be closely monitored.

Recovery

Recovery begins when the procedure for which a patient has been anesthetized is finished, and the anesthetic drugs have been discontinued. Patient status should be monitored regularly during recovery until the patient is conscious, extubated, and heart rate, respiratory rate, and body temperature have returned to normal. Young healthy animals undergoing routine procedures usually do not need supplemental oxygen during recovery. However, contin-

Table 26.13. Drugs and drug combinations administered by constant-rate infusion to enhance intraoperative analgesia

Drug(s)	Infusion Rate	Comments
Ketamine	2–10 μg/kg/h	Useful as an adjunct to other perioperative analgesics
Fentanyl	1–5 μg/kg/h	Useful alone or with other perioperative analgesics; first administer loading dose of 2 μg/kg
Lidocaine	40 μg/kg/min	Useful as an adjunct to other perioperative analgesics; loading dose of 2 mg/kg
Morphine-lidocaine-ketamine	0.24/0.3/0.06 mg/kg/h[a]	Useful alone or with other perioperative analgesics

[a]To 1 L of crystalloid, add 24 mg morphine, 300 mg lidocaine, and 60 mg ketamine. Administer at 10 mL/kg/h intraoperatively. Concentration can be adjusted (increased) to fit postoperative maintenance fluid rates.

uous use of pulse oximetry is helpful to identify unexpected postanesthetic hypoxemia. Hypoxemia caused by respiratory depression, atelectasis-related ventilation/perfusion mismatch, and/or rapidly decreased fraction of inspired oxygen (e.g., near 100% oxygen to 21% room air) is easily addressed if detected early. If nitrous oxide was used during anesthetic maintenance, the breathing circuit should be repeatedly flushed with oxygen and the patient allowed to breathe an oxygen-enriched gas mixture for 5 to 10 min after discontinuation of nitrous oxide. This helps prevent the diffusion hypoxia that can develop if the inspired oxygen concentration suddenly decreases while nitrous oxide is rapidly moving from the blood into the alveolar gas. Sick or debilitated dogs and cats benefit from supplemental oxygen during recovery, particularly if hypothermic, because shivering can significantly increase oxygen consumption. The tracheal tube cuff should be deflated and untied when a patient is disconnected from the anesthetic machine. This permits extubation in the event that the patient rapidly awakens and begins chewing, but care should be exercised when moving the animal to the recovery area so premature accidental extubation does not occur. If an esophageal stethoscope or temperature probe was used, it should be removed at this time. Dogs and cats should be extubated as soon as the swallowing reflex occurs, unless there is a specific contraindication to removing the tracheal tube at this time (e.g., brachycephalic airway syndrome). Dogs and cats should never be left to recover unobserved. Recover patients in a well-ventilated area to minimize exhaled anesthetic gas pollution of the workspace.

Occasionally, a dog or cat will awaken suddenly from anesthesia, become disoriented, and will vocalize, paddle, and appear incoherent. This sudden arousal can be caused by emergence delirium or pain, and it is important to distinguish between them. Emergence delirium occurs most frequently in non-premedicated animals and in particular those awakening rapidly from anesthesia. With emergence delirium, the dog or cat will typically soon become quiet and more comfortable, usually within 10 min. A quiet, reassuring voice and restraint are all that are usually necessary to guide the animal through this period of excitement. If pain is believed to be the cause of the rough recovery, rapid-acting opioid analgesics (e.g., fentanyl) should be administered intravenously. Postoperative pain control is managed best with preanesthetic analgesic administration of relatively long-lasting analgesics, local anesthetics, and attention to signs of pain.

Dogs or cats receiving perioperative fluids can develop a fully distended or overdistended urinary bladder that can cause signs of discomfort. If a full bladder is palpated, it can be gently expressed before recovery. Occasionally, a low dose of acepromazine (0.03 to 0.05 mg/kg intravenously) is necessary to quiet an excited animal.

Perioperative Hypothermia

Because of the loss of normal thermoregulatory core-to-periphery temperature gradients and impaired central thermoregulatory responses, some decrease in core body temperature is unavoidable during anesthesia and surgery. The patient's temperature should be monitored, especially if supplemental heat sources are used (e.g., forced warm-air systems), because accidental hyperthermia is possible. It is more effective to prevent hypothermia rather than trying to warm a hypothermic patient during recovery, because skin vasoconstriction in response to hypothermia inhibits warming of blood near the body surface. Anesthetic-induced vasodilation facilitates warming and heat gain. Insulating and warming devices should be used during anesthesia and recovery.[27] Devices that are available for warming patients include circulating warm-water heating blankets, infrared heat lamps, incubators, and circulating warm-air blankets. Electric heating pads should never be used, because they have been associated with severe burns.[28] These burns usually are manifest from several days to 1 week after contact with the heating pad. The burn pattern often traces the pattern of the heating wire within the blanket. Care must be used with heat lamps or surgical gloves filled with warm water, because they also have produced thermal burns by being placed too close to unprotected skin. An advantage of using warm water and forced-air heating blankets is that temperature is uniform over their entire surface, and their maximum temperature is well below 105°F, the maximum safe patient heating-source interface.[29] Warming will be hastened if the patient's limbs are cocooned within the warming device. Incubators are convenient for warming small dogs and cats, and, if needed, supplemental oxygen can also be introduced through the incubator during the warming period. A circulating warm-air blanket that cocoons the patient is the most effective device for maintaining body temperature and perioperative warming.[29,30]

Delayed Anesthetic Recovery

Occasionally, a dog or cat that received several drugs during the anesthetic episode will remain mildly hypothermic and unresponsive. In these instances, consideration should be given to antagonism of reversible drugs (α_2-adrenergic agonists or opioids) that were given as part of the anesthetic regimen. Relatively small intravenous boluses of naloxone (2 to 3 μg/kg) can be used to reverse the central nervous system and thermoregulatory depression associated with the opioids while leaving opioid analgesia mostly intact.

Severe hypoglycemia is an easily corrected problem that can result in delayed anesthetic recovery. Blood glucose concentration should be measured if hypoglycemia is suspected, and intravenous dextrose-containing fluids given until blood glucose concentrations normalize. Arterial hypotension associated with blood loss or poor cardiac function cause altered mentation and slow recovery. Periodic measurement of arterial blood pressure during recovery, especially in debilitated patients, is warranted. Hypercarbia ($PaCO_2$ approaching 100 mm Hg) associated with respiratory-depressant anesthetic and adjunctive drugs may cause severe mental impairment and possibly respiratory arrest. Use of capnometry or arterial blood-gas analysis during the anesthetic and recovery period helps facilitate early detection and correction of respiratory depression. Occasionally, animals with undiagnosed, compensated central nervous system disease (e.g., hy-

nay decompensate under anesthesia, resulting
function. Prevention of hypercarbia, hypoxem
n and rapid implementation of resuscitative me
nitol and controlled ventilation) may limit br
ed recovery. Many problems that lead to delay
anesthesia can be prevented or otherwise manag
te patient monitoring during and after anesthe

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