Anesthesia of the Sighthound

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The sighthounds are an ancient group of dog breeds that have been selectively bred for high-speed pursuit of prey by sight. Probably as a consequence of this selection process, these dogs have a number of idiosyncrasies that can potentially adversely affect their anesthetic management. These include (1) nervous demeanor which can lead to stress-induced clinical complications, such as hyperthermia; (2) lean body conformation with high surface-area-to-volume ratio, which predisposes these dogs to hypothermia during anesthesia; (3) hematological differences such as a higher packed cell volume and lower serum protein compared with other dog breeds which may complicate interpretation of preanesthetic blood work; (4) Impaired biotransformation of drugs by the liver resulting in prolonged recovery from certain intravenous anesthetics, especially thiopental; and increased risks of drug interactions. Safe anesthetic management of sighthounds should include sedative premedication and appropriate use of analgesic drugs to minimize perioperative stress. Thiopental, or any other thiobarbiturate, should not be used in these dogs. Propofol, ketamine/diazepam combination, and methohexital are recommended alternative intravenous anesthetics. Avoid coadministration of agents that inhibit drug biotransformation, such as chloramphenicol. Inhalation anesthesia using isoflurane is the preferred anesthetic maintenance technique. Core body temperature should be monitored closely and techniques to minimize hypothermia should be employed both during anesthesia and into the recovery period.

The sighthounds are thought to be one of the original groups of dogs to be selectively bred by man.[1] Probably as a direct consequence, these dogs have a number of anatomical and physiological idiosyncrasies, which can adversely impact anesthetic management.[2] For this reason, owners of sighthounds are often reluctant to allow their dogs to undergo routine clinical procedures that involve general anesthesia. The purpose of this review is to outline the unusual characteristics of this fascinating group of dogs and suggest appropriate modifications of currently used anesthetic techniques to ensure safe and effective anesthesia.

What is a Sighthound?

Sighthounds (aka, gazehounds, windhounds) were originally bred to hunt prey primarily by sight, as opposed to scent. The most obvious common feature of these dogs, however, is their exaggerated anatomical and physiological adaptations to high-speed locomotion, including lean body mass, prominent musculature, long limbs, and deep thorax. Today these dogs are bred to be racers (primarily greyhounds), lure coursers, show dogs, agility dogs, obedience dogs, and family pets. Retired greyhound racers are becoming popular as pets through the efforts of local adoption agencies. All of the common, and some of the rarer, sighthound breeds are illustrated in Fig 1. At present, classification of a dog breed as a sighthound by either breed clubs or encyclopedias is purely subjective, based on body conformation similarities and current, or former, breed purpose.[3] In the near future it may be possible to more rationally group these dog breeds based on genetic relatedness (see Fig 2).[4]

Sighthound Idiosyncrasies and Anesthesia

A number of the idiosyncrasies of sighthounds are relevant to their successful anesthetic management (Table 1)

Disposition. Much like the hot-blooded thoroughbred racehorse, many sighthounds are predisposed to a nervous demeanor and are at higher risk of developing stress-related clinical complications, such as gastrointestinal upset and hyperthermia. Other contributing factors to hyperthermia include elevated environmental temperatures and post-traumatic (including postsurgical) pain. In contrast to malignant hyperthermia, a rare genetic disease of muscle (see later), stress-induced hyperthermia, although life-threatening, responds well to whole-body cooling and appropriate administration of sedatives and analgesics. To prevent stress-induced complications, sedative premedicants and, when indicated, analgesic drugs are highly recommended adjuncts to anesthesia in these animals.

On the other hand, racing greyhounds tend to be more comfortable than pet dogs in a kennel environment. The tendency of these animals to sleep for long periods in the hospital should not be confused with depressed behavior.

Body Conformation. Compared with many other dog breeds, sighthounds are inherently lean animals with a low body-fat-to-muscle ratio. For instance, greyhounds have been shown to average just 17% of bodyweight as fat compared with 35% in mixed-breed dogs.[5] Although low body fat content is desirable in an athlete, it makes these animals much more susceptible to hypothermia especially during anesthesia when thermoregulatory mechanisms are suppressed. The short, thin coat of breeds like the greyhound and whippet, and the relatively high body-surface-area-to-volume ratio of sighthounds, can also exacerbate this effect.

Hematological Differences. Sighthounds tend to have higher packed-cell volumes (typically 50% to 60%) and red blood cell indices, and lower serum protein (>6.5 mg/dL) and albumin concentrations compared with other breeds.[6,7] These differences are seen in both fit and untrained animals and probably represent genetic adaptations to exercise: increased oxygen-

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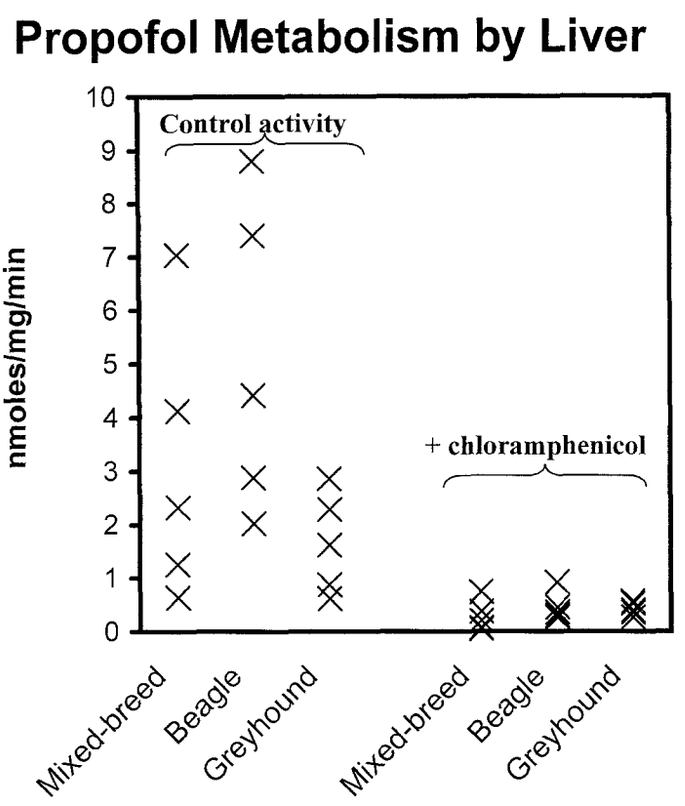

Fig 3. Breed-related differences in liver metabolism of propofol and the inhibitory effect of chloramphenicol (data from this laboratory). High-pressure liquid chromatography was used to measure the rate of *in vitro* biotransformation of propofol to its major metabolite (4OH-propofol) by liver microsomes from male mixed-breed, beagle, and greyhound dogs (5 each) in an NADPH-regenerating incubation system.

"porcine stress syndrome," is caused by dysfunction of the skeletal muscle calcium release channel probably as a result of selective breeding for highly muscled animals.[14] It is therefore not surprising that this syndrome has been reported in greyhounds,[15-17] among other breeds.[18-20] At present it is not known whether MH is more prevalent in some or all of the sighthound breeds; however, based on the small number of reported cases it appears to be a very infrequent complication of anesthesia in dogs. A recent study using both *in vitro* and *in vivo* assays showed no difference in MH susceptibility in greyhounds (n = 7) compared with mixed-breed dogs (n = 6) indicating that at least there is not a ubiquitous susceptibility in greyhounds.[21]

Clinical signs of MH include rapid increase in body temperature, muscle rigidity, tachypnea, and tachycardia. Metabolic and respiratory acidosis, hypoxemia, and circulatory shock are also evident. Myoglobinuria and associated nephrotoxicity can be seen in severe cases. Treatment involves normalization of body temperature, oxygen administration, aggressive intravenous fluid therapy and administration of dantrolene (up to 3 mg/kg IV). Dantrolene is a specific of skeletal muscle calcium channel blocker, which is very effective in treating this condition if given early enough in the course of the disease. In known susceptible animals, MH can be prevented during anesthesia by minimizing stress, avoiding known triggering agents and administering prophylactic dantrolene.[13]

Stress-induced polyuria/polydipsia ("water diabetes") is often seen in racing greyhounds.[2] These animals may be more prone to regurgitation of water during anesthesia. On the other hand, prolonged periods of water deprivation should be avoided in affected animals because urinary concentrating ability is likely to be compromised.

How Can You Safely Anesthetize a Sighthound?

Based on the preceding discussion, examples of anesthetic protocols that have been successfully used by this author in sighthounds undergoing a variety of procedures are given in Table 2.

Sedative premedication with a drug such as acepromazine is highly recommended to reduce perioperative stress particularly in animals with a nervous temperament. Minimal dosages (<0.1 mg/kg body weight), however, should be used since sighthounds appear to be more sensitive than other breeds, and because acepromazine can exacerbate hypothermia. For a similar reason (stress reduction), analgesic medications should be given to animals before undergoing procedures that are likely to be painful.

Thiobarbiturates should not be used for anesthetic induction in sighthounds for reasons described previously. Recommended alternatives include propofol, ketamine (with diazepam), and methohexital. These agents appear to be metabolized more slowly in greyhounds but nevertheless result in acceptable recoveries. Oxymorphone, hydromorphone, fentanyl, and etomidate are also useful for anesthetic induction, especially in animals with cardiac dysfunction, but are generally less widely available because of expense or substance abuse potential. TELAZOL (tiletamine/zolazepam mixture) is not recommended for use in sighthounds because of the propensity for poor anesthetic recoveries. Inhalant anesthetic induction is a safe alternative to intravenous induction in compromised animals provided animals are sufficiently sedated, or otherwise obtunded by their disease state, to avoid struggling during mask application.

In most instances, animals should be intubated and anesthesia maintained by inhalation of either halothane or isoflurane. Although there is no proven advantage of one agent over another, isoflurane would appear to be the preferred inhalant agent in sighthounds since it is metabolized to a significantly lesser extent compared with halothane.[22] Other advantages of isoflurane include cardiovascular stability, especially in animals with cardiac arrhythmias, and rapid recovery.[23] In some cases (for example, major orthopedic procedures), the slower anesthetic recovery associated with halothane may be preferred.

Propofol can be administered by repeated intravenous boluses, or as a constant infusion, to maintain anesthesia for short duration, relatively noninvasive procedures.[7] Combinations of propofol and a potent opioid, such as oxymorphone or fentanyl, can also be used for major surgeries for longer periods in suspected MH susceptible animals, in which inhalant anesthetics are contraindicated. Such long duration infusions, however, tend to be cost prohibitive for routine procedures. There is also a higher risk of prolonged recovery with this technique compared with inhalation anesthesia, since recovery is dependent on drug elimination by liver metabolism instead of excretion through the lungs.

Drug metabolism inhibitors are likely to have an exaggerated effect in sighthounds, since drug metabolism in these animals is inherently compromised. For example, administration of chloramphenicol (50 mg/kg IV), a potent cytochrome P_{450} inhibitor, to greyhounds immediately before a 2-hour infusion

TABLE 2. Examples of Anesthetic Protocols Suitable for Use in Sighthounds

Procedure	Hip Radiographs	Uncomplicated Abdominal Surgery (ovariohysterectomy)	Orthopedic Procedure (Long Bone Fracture Repair)	Major Surgery With Previous or Familial History of MH
Premedication	Acepromazine 0.05 mg/kg IM Glycopyrrolate 0 01 mg/kg IM	Butorphanol 0.2 mg/kg IM Acepromazine 0.05 mg/kg IM Glycopyrrolate 0 01 mg/kg IM	Morphine 1 mg/kg IM Acepromazine 0.05 mg/kg IM Glycopyrrolate 0.01 mg/kg IM	Oxymorphone 0.1 mg/kg IM Acepromazine 0.05 mg/kg IM Glycopyrrolate 0.01 mg/kg IM
Induction	Propofol 2 to 4 mg/kg IV given over 2 to 3 minutes to effect Intubate if risk of regurgitation or airway obstruction	Propofol 2-4 mg/kg IV given over 2 to 3 minutes to effect and intubate **OR** Ketamine/diazepam* 0.05 to 0.1 mL/kg given over 2 to 3 minutes to effect and intubate **OR** Methohexital 3 to 5 mg/kg IV given over 2 to 3 minutes to effect (give initial ½ dose more rapidly to avoid excitement) and intubate	Propofol 2 to 4 mg/kg IV given over 2 to 3 minutes to effect and intubate **OR** Ketamine/diazepam* 0.05 to 0.1 mL/kg given over 2 to 3 minutes to effect and intubate **OR** Methohexital 3 to 5 mg/kg IV given over 2 to 3 minutes to effect (give initial ½ dose more rapidly to avoid excitement) and intubate	Propofol 2 to 4 mg/kg IV given over 2 to 3 minutes to effect Intubate and connect to oxygen source, such as an anesthetic machine that has been flushed to remove inhalant anesthetic
Maintenance	Propofol 0.1 to 0 4 mg/kg/min as a constant IV infusion or 0 5 to 1 mg/kg as incremental IV boluses every 3 to 5 minutes	Isoflurane/oxygen	Isoflurane/oxygen	Propofol 0.1 to 0.4 mg/kg/min as a constant IV infusion or 0.5 to 1 mg/kg as incremental IV boluses every 3-5 minutes
Analgesia	Not usually needed	Buprenorphine 0 01 mg/kg IV after induction and thereafter as needed (generally every 4 to 6 hours)	Epidural morphine 0 1 to 0.2 mg/kg using preservative-free 1 mg/mL preparation. For hind limb procedures, 50% of the volume of morphine can be replaced with 0.5% preservative-free bupivicaine for complete analgesia.	Additional boluses of oxymorphone 0.1 mg/kg IV as needed (generally every 30 to 60 minutes)

*An equal volume mixture of ketamine (100 mg/mL) and diazepam (5 mg/mL).

of propofol increased recovery time to standing from approximately 1 hour (without chloramphenicol) to nearly 10 hours.[24] Concomitant use of drugs that are known to inhibit drug biotransformation with intravenous anesthetic agents should therefore be avoided in sighthounds. Other than chloramphenicol, examples of such drugs include H_2 antagonists (cimetidine, ranitidine), the macrolide antibiotics (erythromycin) and the azole antifungals (ketoconazole, itraconazole).

In addition to routine anesthetic monitoring, close attention should be given to core body temperature because of the propensity for hypothermia in sighthounds. Hypothermia depresses bodily functions and prolongs the duration of recovery from anesthesia.[25] Adequate insulation to reduce body heat loss and supplemental heat sources such as a recirculating warm water blanket or a forced warm air blanket should be provided. The rate of cooling of an animal under anesthesia is also determined in large part by environmental temperature.[26] The ambient temperature of the procedural area should therefore be maintained at a maximal value that is compatible with personnel comfort. Likewise animals should be recovered in a warm area and body temperature monitored until values return to normal.

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Fig 1. Examples of sighthound dog breeds, including Afghan (A), Italian greyhound (B), borzoi (C), greyhound (D), Irish wolfhound (E), ibizan hound (F), pharoah hound (G), whippet (H), basenji (I), saluki (J), Rhodesian ridgeback (K), and Scottish deerhound (L). Other sighthound breeds that may be encountered less frequently include American greyhound, Australian kangaroo dog, azawakh, Central Asian tazi, chart polski, cirneco dell'etna, galgo Espagnol, lurcher, Magya agar, ramphur hound, Russian highland coursing hound, sloughi, and Thai ridgeback. Photos courtesy of the American Kennel Club.[3]

carrying capacity and decreased blood viscosity. Importantly, these normal values should be born in mind when interpreting preanesthetic laboratory tests to avoid misdiagnosis or missed diagnosis of such conditions as anemia, hypoprotenemia, or hemoconcentration. It is also possible, although unproven, that lower serum albumin concentrations in sighthounds may result in an exaggerated effect of drugs that are highly protein bound.

Drug Hypersensitivity. Thiobarbiturates, such as thiopental and thiamylal,* are commonly used in dogs for intravenous induction prior to gas anesthesia or for maintenance of short-term anesthesia. However, almost 30 years ago it was recognized that greyhounds tended to recover much more slowly from the effects of these drugs compared with other dog breeds.[8] Such a prolonged anesthetic recovery is characterized by a protracted drunken state interspersed with periods of delirium, vocalization, and violent struggling during which there is significant risk of self-injury.[6] In some animals, complete recovery can take more than 8 hours compared with the usual 1 to 2 hours in mixed-breed dogs.

Recovery from thiobarbiturate anesthesia in dogs occurs by redistribution of the drug from brain to muscle and fat with concomitant elimination of the drug from the body by liver metabolism.[9] Slowed recovery in greyhounds was initially attributed to the lean body conformation of these animals

*Thiamylal is currently unavailable in the USA because of manufacturing problems. Future availability is uncertain at present.

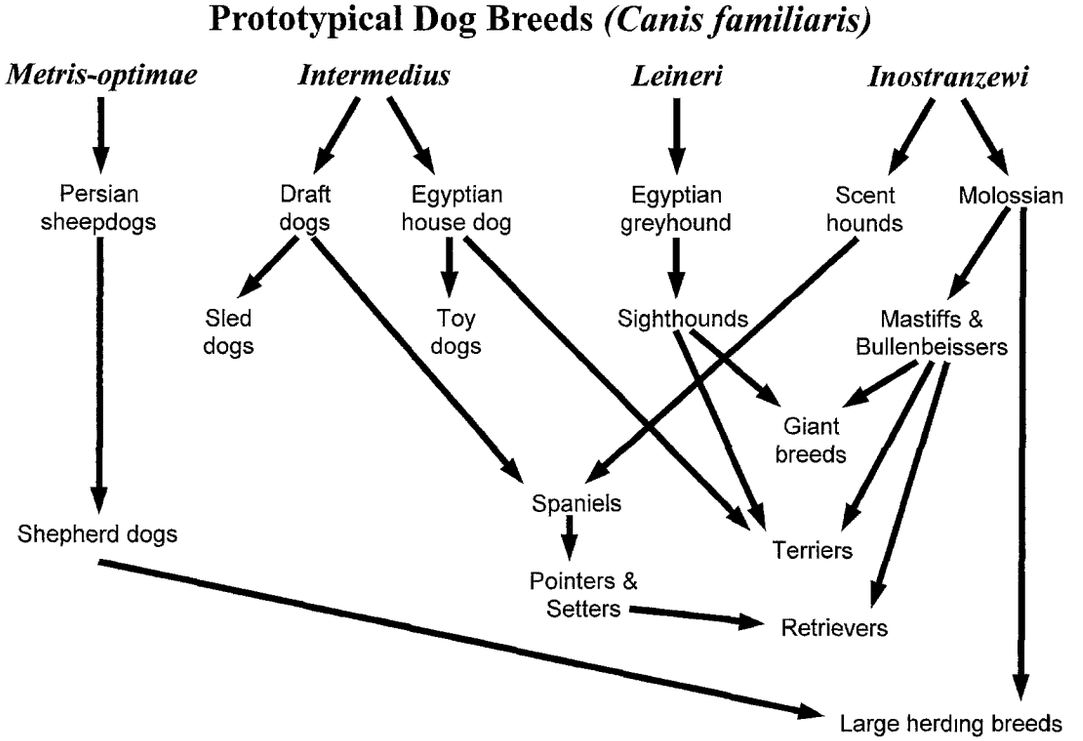

Fig 2. Origin of the modern dog breeds from four prototypical dog breeds (*metris-optimae, intermedius, leineri,* and *inostranzewi*) as proposed more than 25 years ago by Hart[1] based on fossil evidence, geographic derivation and conformational similarities. A recent study by Vila et al[4] indicates that there are in fact four genetically distinct groups of modern domestic dog. However, this study also showed that the origins of individual dog breeds were probably much more diverse than is depicted in this illustration.

resulting in delayed redistribution of the drug.[8] Although this may contribute in part, recent pharmacokinetic studies indicate that this problem primarily results from breed-related differences in drug metabolism.[5,10] Specifically, it was shown that greyhounds have significantly lower hepatic clearance of thiobarbiturates compared with mixed-breed dogs. In addition, the rate of elimination of thiobarbiturates was nonlinear in greyhounds suggesting that enzymatic clearance processes were saturated. In support of this, induction of hepatic enzymes by administration of phenobarbital reduced recovery times in greyhounds to equal that of mixed-breed dogs.[9] A number of other intravenous anesthetics, including propofol and methohexital, also appear to be cleared more slowly in greyhounds although not as severely as are the thiobarbiturates.[5,7,11] Recent *in vitro* studies of dog breed differences in drug metabolism in this laboratory confirm these findings and additionally indicate that this defect is associated with reduced activity of a specific hepatic cytochrome P_{450} enzyme (Fig 3). The molecular genetic basis for this reduced activity is currently under investigation.

TABLE 1. Characteristics of Sighthounds That may Affect Anesthetic Management

Characteristics	Clinical Consequences	Management
Nervous temperament	Easily stressed	Ensure adequate sedation and analgesia
	Stress hyperthermia	Reduce core temperature
		Administer intravenous fluids, sedatives, and analgesics as needed
Low fat-to-muscle ratio High surface-area-to-volume ratio	Susceptible to hypothermia	Provide adequate insulation and supplemental warmth, such as recirculating hot water blanket or forced hot air heater
Impaired liver drug metabolism	Slowed recovery from some intravenous anesthetics	Avoid using thiobarbiturates (thiopental or thiamylal)
		Induce anesthesia with propofol, ketamine/diazepam or methohexital
	Drug interactions more likely	Avoid coadministration of drugs that inhibit drug biotransformation such as chloramphenicol, erythromycin, cimetidine, ranitidine, ketoconazole, and itraconazole

At this time it is not known whether all greyhounds or, for that matter, which sighthound breeds are affected. Anecdotal evidence of uncomplicated use of thiobarbiturates in greyhounds by some practitioners indicates that there are differences between individual animals probably related to genetic factors and previous drug exposure. It has also been suggested that some nonsighthound breeds of dog, including collies and soft-coated wheaton terriers, have a similar anesthetic sensitivity. Although this has yet to be substantiated, it is possible that these breeds may share a common ancestry and genetic anomaly with the sighthounds (Fig 2). The most prudent strategy at this time is to avoid using thiobarbiturates in all sighthounds. Suitable alternative anesthetic agents are discussed later in this review.

Disease Susceptibility. There are a number of diseases that appear to be more prevalent in certain sighthound breeds that are worthy of discussion.

The large sighthound breeds, especially the Irish wolfhound appear to have a relatively high incidence of dilatative cardiomyopathy.[12] Because of the substantial risks of general anesthesia with this disease, these animals should be routinely screened for signs of cardiac dysfunction including exercise intolerance, cough, elevated resting heart rate, weak pulses or heart murmur.

Malignant hyperthermia (MH) is a rare but life-threatening genetic disorder of skeletal muscle in humans, pigs, dogs, cats, and horses that is triggered by anesthetic agents, primarily the volatile inhalants, and stress.[13] The defect in the pig, also called

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