CHAPTER 63

Bovidae (Except Sheep and Goats) and Antilocapridae

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GENERAL BIOLOGY

Formerly classified in the order Artiodactyla, even-toed ungulates have been reclassified, on the basis of recent molecular evidence, to the order Cetartiodactyla, which includes the families Cetacea, Hippopotamidae, Camelidae, Suidae, Tayassuidae, Tragulidae, Moschidae, Cervidae, Giraffidae, Bovidae, and Antilocapridae.[23] The last six of these families belong to the suborder Ruminantia. Antilocapridae consists of a single species, the pronghorn *Antilocapra americana*, whereas Bovidae consist of eight subfamilies: Aepycerotinae, Alcelaphinae, Antilopinae, Bovinae, Cephalophinae, Caprinae, Hippotraginae, and Reduncinae. General taxonomy and characteristics of Antilocapridae and Bovidae are listed in Table 63-1.

Antilocapridae

Pronghorns (*Antilocapra americana*) are the sole species of the family Antilocapridae and are distinct from cervids and antelopes in that they possess forked horns, which are shed annually.[1] Five subspecies exist: *A.a. anteflexa, A.a. oregona, A.a. mexicana, A.a. peninsularis,* and *A.a. sonoriensis.* Ranging throughout western North America from northern Mexico to southern Canada, pronghorn are found in open areas of prairies and deserts, eating primarily forbs, browse, and grasses. The Sonoran and Peninsular subspecies are considered Endangered according to federal classification. Although extremely fast runners, they are not agile jumpers, and local populations have been fragmented by fencing.[57] They are extremely fractious, are prone to stress hyperthermia, and may be difficult to maintain in captivity.[10] Pronghorns are fall breeders, producing twins in spring, and are the only known ungulates to exhibit multiple paternity.[7]

Bovidae

The diverse family Bovidae consists of 143 known species, ranging in size from the 3-kilogram (kg) royal antelope to the 1200-kg gaur. Bovids are found across all of mainland Africa and in 30 countries in Europe, the Middle East, and Asia. Four subfamilies exist only in the African continent; none is native to Australia or Antarctica; and only bison (*Bison bison*) are native to the Americas.

UNIQUE ANATOMY

Bovid species are characterized by the presence of horns composed of keratinized sheaths covering a bony prominence of the frontal bone, which are never shed. All males, and the females of some genera, possess horns. Only *Tetracerus quadricornis*, the four-horned antelope, possesses more than two horns. Most bovid horns continue to grow throughout life and are unbranched, varying in shape from short spikes to long, curved, and spiraled structures.

Bovids and pronghorns are true ruminants, possessing four specialized stomach chambers. Pronghorns and other primarily grazing species have a large, stratified rumen, a smaller reticulum, a well-developed omasum, a larger abomasum, and roughly twice the relative intestinal length (25–30 times body length) of browsing species. This anatomy is adapted for digestion of large amounts of cellulose. Browsers have a smaller rumen, with evenly distributed, dense ruminal papillae, and tend to have comparatively larger salivary glands and livers compared with grazers.[51] A gallbladder is usually present in bovids, and the kidneys may or may not be lobulated.[10] Reproductive anatomy is similar to that of domestic cattle in most bovids, with the exception that females of some species such as the Hippotraginae demonstrate duplex uteri, in which the cervix is bifurcated, creating a physical separation between the uterine horns with no uterine body.

Bovid and pronghorn species lack upper incisors and canines. The dental formula is: incisors (I) 0/3, canines (C) 0/1, premolars (P) 3/3, molars (M) 3/3, to a total of 32. Scent glands vary in size and location and may be found in the subauricular, prefrontal, forehead, submandibular, inguinal, interdigital, metacarpal, and preputial regions.

Bovids have an unguligrade stance, walking on well-developed hooves on the third and fourth digits of each foot. The second and fifth digits, if present, are called *dewclaws*. The hooves of each species have a characteristic size and shape adaptively suited to their habitat.

MANAGEMENT AND HUSBANDRY

Population Management

The 21st century has brought a grim outlook to the conservation of nondomestic bovid species. Ever-increasing human populations and their livestock encroaching on natural habitats, agriculture, transportation infrastructure, and fencing are some of the factors causing disruption of habitat and migration and are decreasing population size and genetic diversity across the taxon. In captivity, a loss of nearly 1000 spaces for antelope between 1999 and 2011 and a predicted decline in future space are reported by the Association of Zoos and Aquariums (AZA) Antelope Taxon Advisory Group.[2] Of the 82 species of ungulates in AZA collections, 42% are in decline or have a negative growth rate. Few sustainable bovid populations—those that are able to persist indefinitely without supplementation—exist, either in the wild or in captivity. Over 25% of antelope species are threatened by extinction, three exist in populations of fewer than 500 individuals, and many are not represented by captive populations, all of which increases the risk of extinction.[34] Recent recommendations to manage antelope in larger, less intensively managed groups have been based on (1) the difficulty of maintaining genetic diversity in small, isolated captive populations; (2) the risk of transporting animals for breeding purposes; (3) advanced methodology in genetics and population modeling; and (4) the relative success of large-landscape game ranches in population management.[34,57]

Special Housing Requirements

Pronghorns in the wild are accustomed to wide open spaces in arid regions and may tolerate wide temperature fluctuations. They often do not thrive in captivity and are compromised by high humidity, unnatural social structure, novel stimuli, and enclosed spaces. They are more likely to crawl under fencing than to jump over fencing 1.5 meters (m) or higher, but until accustomed to an enclosure, this fractious species should have visible sight barriers and minimal obstacles near fence lines to reduce trauma. A shelter that does not restrict view may be preferred by pronghorns over an enclosed barn.[10] In captivity, they benefit behaviorally from frequent human proximity from a young age to maintain tractability. Pronghorns are

TABLE 63-1

Taxonomy and General Characteristics of the Family Bovidae[1,26,41]

Genus (# Species)	Common Name	Adult Weight (kilograms)	Female Sexual Maturity (months)	Gestation Length (months)	Lifespan (years)	Feeding Strategy	IUCN Status
SUBFAMILY AEPYCEROTINAE							
Aepyceros	Impala	40–80	18–24	6.5–7	15	I	LC
SUBFAMILY ALCELAPHINAE							
Alcelaphus	Hartebeest	120–200	18–30	8		G	LC
Beatragus	Hirola (Hunter's hartebeest)	80–118	—	7.5–8	—	G	CE
Connochaetes (2)	Black, blue wildebeest	110–180	18–30	8–8.5	20	G	LC
Damaliscus (3)	Topi, tsessebe; blesbok/ bontebok	75–160; 55–80	18–30	7.5–8.5	12–17	G	LC
SUBFAMILY ANTILOPINAE							
Ammodorcas	Dibatag	22–35	12–18	6–7	10–12	B	VU
Antidorcas	Springbok	30–45	6–9	5.5–6	20	I	LC
Antilope	Blackbuck	25–35	18–24	5–6	10–12	I	NT
Dorcatragus	Beira	9–11.5	—	6	—	I	VU
Eudorcas (4)	Mongalla, red-fronted, Red, Thompson gazelle	25–30	9	6	14.5	G	LC; VU; DD; NT
Gazella (10)	Arabian, Indian, Queen of Sheba, Cuvier, Dorcas, mountain, slender-horned, Saudi, Speke, goitered gazelles	15–25	7–12	6–7	12	I	DD; LC, EX; EN; VU; VU; EN; EX; EN; VU
Litocranius	Gerenuk	30–50	12–18	6.5–7	10–12	B	NT
Madoqua (4)	Kirk, Gunther's, silver, Salt's dik-dik	2.2–7	6–8	5–6	10	I	LC
Nanger (3)	Dama (Addra, Mhorr), Grant, Soemmerring gazelles	35–75	6–18	6–6.5	12–14	I; B; G	CE; LC; VU
Neotragus (3)	Suni; pygmy/royal antelope	1.5–6	12–18	6	6–10	B	LC
Oreotragus	Klipspringer	10–18	12	7	15	I	LC
Ourebia	Oribi	15–20	9	6.5–7	14	I	LC
Procapra (3)	Mongolian gazelle	20–29	18–24	6.1	7	G	LC
	Tibetan/Przewalski gazelles	13–32	12–24	5.5–6	8	I	NT; EN
Raphicerus (3)	Steenbok; Grysbok	7–23	6–9	5.5–6	8–12	I	LC
Saiga	Saiga	20–50	8	4.5	6–10	B	CE
SUBFAMILY BOVINAE							
Bison (2)	American; European	545–1,000	24–36	8–10	25–27	G; I	NT; VU
Bos (5)	Gaur; banteng; kouprey	600–1,000	24–36	9–9.5	20–30	G; I; I	VU; EN CE
	Yak	305–820	72	8.5	23	G	VU
	Auroch	—	—	—	—	—	EX
Boselaphus	Nilgai	120–240	18	8	21	I	LC
Bubalus (3)	Indian (Asian) water buffalo	800–1,200	18	10–11	25	I	EN
Bubalus	Anoa; tamaraw	200–300	24–72	9–10.5	20–25	I; G	EN; CE
Pseudoryx	Saola	80–100	Not available	7.5–8	8–9	B	CE
Syncerus	African buffalo	300–900	36–60	11.5	18–20	G	LC
Tetracerus	Four-horned antelope	15–25	—	7.5–8	10	I	VU
Tragelaphus (9)	Greater kudu; bongo; mountain nyala	120–400	14–36	7–9	15–23	I	LC; NT; EN
	Lesser kudu; bushbuck; Nyala; Sitatunga	25–140	9–36	6–8	12–19	I	NT; LC; LC; LC
	Common, giant eland	300–1,000	14–36	9	25	I	LC

Continued

TABLE 63-1

Taxonomy and General Characteristics of the Family Bovidae—cont'd

Genus (# Species)	Common Name	Adult Weight (kilograms)	Female Sexual Maturity (months)	Gestation Length (months)	Lifespan (years)	Feeding Strategy	IUCN Status
SUBFAMILY CEPHALOPHINAE							
Cephalophus (15)	Bush, black, zebra, red-flanked, yellow-backed duiker	7–80	—	—	—	B	CE
	Abbott, Jentink duikers	50–80	—	8	21	B	E
Philantomba	Blue, Maxwell duikers	4–10	0.9–12	6–7.5	10–12	I; B	LC
Sylvicapra	Common duiker	10–20	9–10	6–7	14	B	LC
SUBFAMILY HIPPOTRAGINAE							
Addax	Addax	60–125	18	8.5	19	I	CE
Hippotragus	Bluebuck	—	—	—	—	—	EX
	Roan, sable antelope	190–300	24–36	9	17	I; G	LC
Oryx (4)	Arabian oryx	65–70	18–24	8.5–9	20	I	VU
	Beisa oryx; gemsbok	150–240	18–24	8.5–10	18–22	I	NT; LC
	Scimitar-horned oryx	180–200	18–24	8–8.5	20	I	EW
SUBFAMILY REDUNCINAE							
Kobus (5)	Kob; red lechwe; Nile lechwe; Puku	50–130	18–24	7–9	15–21	G	LC; LC; EN; NT
	Waterbuck	150–250	12–16	8.5–9	18	I	LC
Pelea	Rhebok	18–30	14	7	8–10	I	LC
Redunca (3)	Southern, mountain, Bohor reedbuck	40–95	12	7.75	16	G	LC

B, Browser; *CE*, critically endangered; *EN*, endangered; *EW*, extinct in the wild; *EX*, extinct; *G*, grazer; *I*, intermediate; *LC*, least concern; *NT*, near threatened; *VU*, vulnerable.

relatively tolerant of species with which they have historically grazed (bison, elk, and deer); however, interspecific aggression has been documented.[10]

Housing and husbandry practices for antelope and cattle species vary widely, depending on management goals, climate, and available space. Fences and bomas may be constructed of a variety of materials and should be a minimum of 2.5 m (8 feet) in height and designed with the species size, temperament, and jumping ability in mind. Fences with sight barriers are beneficial in management areas to prevent trauma and between adjacent enclosures to prevent aggression and fence damage. Electric wires may be useful for keeping animals away from fence lines but may also present an entrapment and trauma risk through horn entanglement. Space and temperature recommendations are listed in Table 63-2. Some species may experience regular hoof problems when housed on substrates to which they are not adapted. For example, hoof abscesses may be common in desert species exposed to muddy conditions for prolonged periods. Indoor substrates should be considered with regard to hoof hardness and wear to minimize trimming and hoof lesions.

Shelter conditions should take into account the natural history of the species and ambient conditions. Desert-adapted animals may tolerate high temperatures (≥38°C [100°F]) provided adequate water and shade are available, but most desert and tropical species need to be housed indoors during the cold season in colder regions. Frostbite and ear tip loss are frequently seen at temperatures below 9°C (15°F). Forest and cold-adapted or altitude-adapted species may require more shade during the warm season, and shelters for all species should provide cover and windbreaks facing away from prevailing winds.[10] Forest species such as duikers will benefit from plantings or other structures that support hiding behaviors. Indoor housing should provide temperatures between 10°C and 27° C (50°F–80°F), with adequate ventilation to control humidity and reduce ammonia concentrations.

Nutrition

Feeding the Neonate

Maternal rejection is not uncommon in captive nondomestic ruminants. If a calf cannot be raised by its dam, hand rearing is labor intensive and requires early intervention to provide the calf with the best chance of survival. Neonatal ruminants acquire immune protection passively through ingestion of maternal colostral immunoglobulins (IgG) in the first 24 to 48 hours of life. The calf's ability to absorb antibodies ends approximately 24 hours after the first meal,[15] and failure of passive transfer (FPT) occurs when inadequate levels of IgG are absorbed during this period. Even calves nursing from their dams may experience FPT by ingesting colostrum in inadequate volume or low IgG content, and FPT calves are highly susceptible to disease, often into the postweaning period. The prophylactic use of parenteral antimicrobials in calves with FPT should be considered but must be combined with colostrum replacement and management practices that minimize pathogen exposure. The first choice for colostrum replacement should be oral administration of fresh or frozen intraspecific colostrum, followed by low-temperature pasteurized cow's colostrum, commercial freeze-dried cow's colostrum replacer, and commercial bovine plasma. Feed calves 10% of their body weight in colostrum, or 5 grams per kilogram (g/kg) colostrum replacer, over the first 24 to 48 hours. Tests for FPT are readily available.[56] If passive transfer is inadequate after 48 hours, calves may receive parenteral conspecific plasma or commercial bovine plasma (20–40 milliliters per kilogram [mL/kg]).

Milk composition varies considerably among species, and a formula's composition should mimic that of the dam's milk in protein, carbohydrate, fat, and total solids. Goat's milk is a good choice for many species, alone or in combination with a milk replacer. However, milk may be low in vitamin E, zinc, copper, and iron, necessitating vitamin and mineral supplementation. Probiotics may also be

TABLE 63-2

Recommended Housing Conditions for Selected Species of Antilocapridae and Bovidae*

Common Name	Native Range	Native Climate	Minimum Barrier Height (feet)	Minimum Exhibit Size (square feet)	Minimum Holding Size (square feet)	Temperature (°F)
Pronghorn	Not available	Temperate	8	600	200	45–100
SUBFAMILY AEPYCEROTINAE						
Impala	African	Tropical	8	600	200	45–100
SUBFAMILY ALCELAPHINAE						
Hartebeest, wildebeest, bontebok, blesbok, topi	African	Tropical	8	600	200	45–100
SUBFAMILY ANTILOPINAE						
Dik-dik, royal antelope, steenbok, klipspringer	African	Tropical	8	200	140	45–100
Suni	African	Arid	8	200	140	45–100
Addra, Mhorr, Dorcas, Speke gazelle	African	Arid	8	400	92	45–100
Grant, Thomson's, slender-horned, red-fronted, Soemmerring gazelle	African	Tropical	8	400	92	45–100
Saudi goitered gazelle	Asian	Arid or tropical	8	400	92	45–100
Cuvier gazelle	African	Arid	8	600	92	45–100
Springbok	African	Arid	8	400	140	45–100
Gerenuk	African	Arid	8	400	140	60–100
Blackbuck	Asian	Tropical	8	400	140	45–100
SUBFAMILY BOVINAE						
Common, giant eland	African	Tropical	10	600	200	45–100
Lowland nyala Eastern bongo Lesser, greater kudu Sitatunga	African	Tropical	8	600	200	45–100
Nilgai	Asian	Tropical	8	600	200	45–100
Bushbuck	African	Tropical	8	400	140	45–100
SUBFAMILY CEPHALOPHINAE						
Crowned, Maxwell blue, red-flanked duiker	African	Tropical	8	200	140	45–100
Bay, black duiker	African	Tropical	8	400	140	45–100
Yellow-backed duiker	African	Tropical	8	600	200	45–100
SUBFAMILY HIPPOTRAGINAE						
Roan, sable antelope	African	Tropical	8	600	200	45–100
Addax, gemsbok scimitar-horned, Arabian oryx	African	Arid	8	600	200	45–100
Beisa, fringe-eared oryx	African	Arid or tropical	8	600	200	45–100
SUBFAMILY REDUNCINAE						
Common, Defassa waterbuck Uganda kob red, Nile lechwe	African	Tropical	8	600	200	45–100
Rhebok	African	Tropical	8	400	140	45–100

*Personal communication: D. Beetem and M. Fischer, AZA Antelope Taxon Advisory Group.

beneficial in establishing a healthy rumen flora. Calves should receive 8% to 15% of their body weight in formula every 24 hours, divided into four to six feedings per day. Resources are available to assist with milk replacer formulation and methods of feeding.[48,59]

In the first 2 to 3 weeks of a ruminant's life, milk digestion occurs in the abomasum and small intestine. Milk deposited into the nonfunctional rumenoreticulum during this period is not digested and may lead to rumenitis and septicemia.[15] For this reason, tube feeding or force feeding a calf with a poor suckle response may be harmful. Closure of the esophageal groove is stimulated by suckling and normally prevents this deposition. If tube feeding is necessary in the first weeks of life, a tube passed to the mid-esophagus may stimulate swallowing and closure of the groove. Additionally, oral administration of 10% sodium bicarbonate or 2% to 5% copper sulfate prior to milk feeding may facilitate groove closure for several minutes. By 2 to 3 weeks, the ruminal papillae are stimulated, and the calf begins to take in small amounts of dry feed. Changes in gastrointestinal (GI) flora occur throughout this period and until weaning (around 4 months), often manifesting as changes in fecal consistency.

Feeding the Adult

Many of the common health problems of nondomestic ruminants have recently been associated with direct or indirect dietary causes.[11] Chronic weight loss, rumen acidosis or rumenitis, laminitis, hoof overgrowth, and periodontal disease have all been attributed, at least in part, to historical feeding of all exotic bovids diets designed for domestic cattle. Cattle are grazing species, but many of the nondomestic Bovidae are intermediate or browse feeders. Browsers are adapted to eating the leaves and twigs of woody plants, intermediate feeders to both browse and grasses, and grazers to consuming grasses (see Table 63-1). All of these forages are fermented by the microbes of the ruminoreticulum, which produce fatty acids, providing energy to the ruminant. The grazer rumen is adapted for fermenting the high cellulose content in grasses through prolonged fermentation and particle retention, compared with the smaller, less muscular browser rumen. Consequently, browsers tend to eat less hay and are often fed higher amounts of pelleted concentrate to compensate for low hay consumption. High levels of easily digested carbohydrates such as starch and sugar, often found in pelleted concentrates, are too rapidly fermented in the rumen, leading to rumen acidosis. The ideal rumen pH range is 6.7 ± 0.5, and variation from this results in disturbance of the microflora. Altered and depleted rumen flora decrease the energy delivered to the ruminant, which results in weight loss. In response, many of these animals will receive increased amounts of concentrate, which compounds the problem. Rumen acidosis and resulting rumenitis may also lead to systemic acidosis, mineral imbalances, and laminitis or abnormal hoof growth.

Appropriately formulated pelleted feed for browsers should be based on a high-fiber forage meal such as aspen, alfalfa, soy or sunflower hulls, or cellulose powder, and should contain (1) a high-pectin, low-sugar energy source such as beet pulp; and (2) limited amounts of grain and corn.[11] A low-starch, high-fiber pelleted diet that meets these criteria has been recently formulated for browsing and intermediate ruminants (Wild Herbivore and Wild Herbivore Plus; Mazuri Zoo Feeds, PMI Feeds, St. Louis, MO). The recommended feed intake is 1.5% to 2.5% of body weight per day in addition to ad libitum grass or legume hay, and supplementation with natural nontoxic browse is recommended for all browsers. Grazers are generally fed commercial herbivore pelleted concentrate diet containing 12% to 18% protein and 16% to 25% acid detergent fiber at approximately 1% body weight per day in addition to hay. Salt blocks should be available at all times, and trace mineral salt blocks should be available to herds primarily on pasture or not receiving trace mineral balanced concentrates.

Adult bovids experiencing negative energy balance and weight loss from illness may require nutritional support during treatment. Commercially available products useful for boosting caloric intake include Low Odor MEGALAC Rumen Bypass Fat (Arm & Hammer, Church & Dwight Co., Inc., Princeton, NJ) and Wild Herbivore Boost (Mazuri Zoo Feeds, PMI Feeds, St. Louis, MO). These compromised animals may also benefit from transfaunation with rumen contents collected from a healthy conspecific. Tube feeding ruminants may be challenging because of the consistency and volume of feed they require; a commercial tube-feeding formula is available for herbivores (Critical Care, Oxbow Pet Products, Murdock, NB).[10]

RESTRAINT AND HANDLING

Restraint is an important aspect of medical practice in nondomestic ruminants, requiring careful planning and experience.[21] Because of the size and fractious nature of the species, most wild bovids require restraint for any type of physical examination for the safety of both the animal and the handlers. Capture and restraint of animals in the wild is conducted by a multitude of means, including drive nets, drop nets, net guns, bomas, chutes, traps, and remote injection. Some of these procedures require helicopters and specialized training and are conducted by full-time capture professionals. In zoologic settings, capture and restraint capabilities depend on the facilities and expertise available, and each procedure conducted must be planned with the animal, handler ability, and equipment in mind.

Restraint may be classified as physical, behavioral, and chemical, and many procedures in these taxa will require some combination of all three methods. Planning for any restraint procedure should take into account the goal, the conditions (e.g., restraint type and capability, ambient temperature, footing, enclosure size), and the temperament of the animal.[9] Restraint planning should also include plans for alternative physical and chemical restraint and emergency release in case of injury, failure of behavioral compliance, or signs of severe distress in the animal. Safety of the personnel and the patient are the primary considerations. Any manipulation of bovids and pronghorns may result in extreme panic, self-injury, capture myopathy (see Noninfectious Disease), and even sudden death, necessitating efficiency of time and force used to achieve the goal of restraint.

Behavioral Restraint

Continuous development of improved behavioral management techniques in captive settings has allowed for procedures that once required anesthesia to be performed with minimal restraint. Some species accustomed to human proximity may be managed to a degree with little or no physical restraint through training of specific behaviors such as placing feet for hoof trimming. Desensitization and operant conditioning may be used to train animals to move calmly to a restraint area, enter a chute or crate, lie down, or tolerate minor procedures, but special attention to the explosive nature of many bovids requires slow, deliberate movements, quiet conditions, and safety precautions. Movement may be aided by careful design and planning of stalls, doors, hallways and chute approach, and the use of baffle boards may protect the handler and assist in movement.

Physical Restraint

Manual Capture and Restraint

Smaller species may be manually restrained by experienced handlers for brief procedures or induction of anesthesia after being caught by hand or with hoop nets. Restraint should be initiated on an isolated animal in a darkened, quiet, obstacle-free enclosure that is small enough to minimize the risk of injury to the animal but large enough to allow free movement and escape of the handlers. A stall with padded walls and hay or straw floor substrate is optimal for animal safety. A minimum of two handlers should perform the capture, depending on the size and temperament of the animal, and the handlers should wear protective clothing, footwear, eyewear and gloves. Hand restraint in bovids under 5 kg may be accomplished by a single handler by quickly lifting the animal, supporting the abdomen and spine against the handler's body, and restraining the head and legs. Restraint of medium-sized animals may be initiated by catching the head and quickly pushing the animal against a wall, pad, or floor with head restraint and placing a knee under the flank, with a second handler restraining the rear legs. Horns may be used for restraint of most species, but young animals or those with thin horns may be prone to horn avulsion. The head and legs should be tightly restrained to prevent the use of horns and hooves, and placement of a hand or a pad between the hocks may help to prevent self-trauma. The duration of physical restraint should be minimized to prevent distress and hyperthermia, and a clear airway and adequate chest excursion should be ensured at all times. Use of a blindfold may reduce struggling. If an animal is to be restrained repeatedly, short pieces of hosing placed on the horn tips improves safety for the handlers. Release should be coordinated such that handlers act quickly and in concert, directing the animal toward a clear path and to an open area that provides the patient with a sense of refuge and minimizes the risk of injury.

Mechanical Restraint

The development of sophisticated chute systems for hoof stock has allowed for the handling of entire herds of nondomestic bovids rapidly and without chemical restraint.[25] Procedures such as venipuncture, vaccination, tuberculin testing, physical examination, treatment of minor conditions, hoof trimming, and reproductive procedures may be conducted without chemical restraint in an effectively designed chute system. In designing a restraint, considerations such as maneuvering animals from a pen into the chute, the ability to stop and sort animals within the system, the inclusion of movable rear walls for pushing resistant animals, the presence of a scale within the system, and multiple exit routes may be critical to creating a process that is efficient and safe, minimizing time and stress to the animals. Desensitizing animals to any chute system by incorporating movement through the system into the animals' regular routine may greatly facilitate restraint. Many facilities housing large numbers of bovid and equid species are now using chute systems to facilitate preventive medicine, reproductive management, research, and extended treatment of animals, while alleviating the need for repeated chemical restraint.

Mechanical restraints are of three basic types: (1) box chutes or stanchions, (2) drop-floor chutes, and (3) crushes or squeeze chutes. Box chutes are the simplest and least expensive of the three, consisting of a simple pass-through enclosure with front and rear sliding barriers to retain the animal temporarily. Rear entry or exit restraints are not recommended for nondomestic bovids, as many of these animals are reluctant to enter an area with no perceived exit.

Drop-floor chutes are available commercially and consist of a ramp leading to, or a recessed area underneath, an adjustable V-shaped chute with sliding front and rear doors. When the animal is secured in the chute, the floor is dropped such that the animal is suspended by the hips and shoulders (Tamer Drop Floor Chute, Fauna Research, Inc., Red Hook, NY). Most bovids will refrain from struggling without foot purchase, allowing short procedures to be conducted. Width settings for each animal should be carefully established with drop-floor chutes to provide proper restraint, while not overly restricting the abdomen and chest, and duration of procedures should be limited to a few minutes. Drop-floor chutes may be portable or permanently installed.

Squeeze chutes vary from simple adaptations to an aisle way to highly adjustable hydraulic systems. Squeeze chutes developed for domestic cattle have been adapted to larger nondomestic bovids such as wild cattle and bison by adding "crash" gates—barred swinging front doors to prevent bypass of the head gate. Hydraulic squeeze chutes, available commercially (e.g., Hydraulic Tamer, Fauna Research, Inc., Red Hook, NY), provide the most flexible and rapid manipulation of large numbers of animals, as they are adjusted remotely while the animal is in the device. The padded walls of this restraint device are moved hydraulically to apply pressure to the hips and shoulders of the animal and may lift—achieving a result similar to a drop-floor chute—or close down over the animal to provide a darkened enclosed space. Doors installed in the restraint walls provide access for examination, treatment, and venipuncture.

Chemical Restraint

When physical and behavioral restraints are inadequate to maintain control of an animal for the length of time or invasive nature of the desired procedure, chemical restraint is necessary as an adjunct or sole method of restraint. Chemical restraint is commonly necessary in the management of nondomestic bovids and carries significant risks because of the fractious nature of the species, the difficulty of drug delivery, and the unique biology of the taxon. Veterinary practitioners caring for nondomestic Bovidae are constantly evaluating and improving protocols for sedation and anesthesia, as sensitivity to different anesthetics among nondomestic bovids tend to be species-specific. Chemical restraint in this taxon has been the subject of many reviews.[3,10,13,29,53]

Tranquilization and Sedation

Chemical restraint may be accomplished by two means: tranquilization and general anesthesia. Increasingly, neuroleptics of the butyrophenone and phenothiazine families have been used to attenuate the stress response in nondomestic ruminants undergoing intensive management for capture, translocation, isolation, or adaptation to environmental changes.[10,16,44] Licensed for use in humans as antipsychotic agents, these drugs act by blocking D2 dopamine receptors, thereby producing a state of lucid relief from anxiety. Most of the longer-acting formulations have an onset of action of 1 to 3 days, necessitating the addition of short-acting neuroleptics to produce immediate and long-term tranquilization. Table 63-3 lists common formulations and their onset and duration of action, and Table 63-4 lists suggested doses of neuroleptic drugs for tranquilization of pronghorns and bovids. Recommended dosages per kilogram of body weight are inversely proportional to body size. It should be noted that neuroleptic use may improve the ease of captive management of smaller hoof stock by increasing flight distance, but reducing the fear response may have the opposite effect in larger, more aggressive species, resulting in reduced avoidance behavior, reluctance to move, and aggression. Overdosing is known to produce behavioral side effects such as tardive dyskinesia, including abnormal facial and tongue posture, head pressing and other unusual movement patterns, and anorexia. Treatment of clinical signs of overdosing may be accomplished using low doses of xylazine, diazepam, or diphenhydramine.[44]

TABLE 63-3

Onset and Duration of Action of Selected Neuroleptics Used in Bovidae[16,44]

Drug	Route	Onset	Duration
Azaperone	IV	<10 minutes	≤6 hours
	IM	30 minutes	≤6 hours
Haloperidol lactate	IV	<5 minutes	≤8 hours
	IM	<15 minutes	8–18 hours
Zuclopenthixol acetate	IM	1 hour	3–4 days
Zuclopenthixol decanoate	IM	1 week	10–21 days
Haloperidol decanoate	IM	2–3 days	21–30 days
Perphenazine enanthate	IM	hours	7–10 days
Pipothiazine palmitate	IM	2–3 days	21–28 days
Fluphenazine decanoate	IM	3 days	21–28 days

IM, Intramuscularly; *IV*, intravenously.

Induction of General Anesthesia

General anesthesia is induced parenterally by intramuscular or intravenous routes. Intravenous administration may be performed on manually or mechanically restrained animals and provides the advantage of decreased induction and recovery time. However, in larger animals, intravenous administration of a mechanically restrained animal may result in difficulty in removing the rapidly-induced animal from the restraint device. In general, intramuscular induction of an animal with an appropriate regimen in a darkened, quiet enclosure provides a relatively rapid and smooth induction and may minimize the need for anesthetic supplementation because of longer duration of action. Administration of anesthetics intramuscularly (IM) may be conducted by hand, pole syringe, or projectile dart. The use of darts and remote injection systems has been previously reviewed[27] and requires careful planning and experience. Planning an anesthetic event should include considerations such as environmental temperatures, approach, enclosure size, obstacles, and the presence of other animals. Failure to deliver an appropriate dose accurately and quickly to an animal in the wild or in a large enclosure may result in excessive running or pacing injury, capture stress or myopathy, and death. Muscle masses of the rump, shoulder, and neck are preferred sites of remote injection. Failure of induction within an appropriate time (usually 5 to 15 minutes, depending on the regimen) may be caused by many factors, including dart failure,

TABLE 63-4

Suggested Doses of Selected Neuroleptics Used in Adult Bovidae[16,44]

Family	Azaperone	Haloperidol lactate (IM or IV)	Zuclopenthixol acetate	Perphenazine enanthate	Pipotiazine palmitate	Fluphenazine decanoate
Aepycerotinae	0.5	0.2–0.5	1.0	1.0	4.0–4.5	0.5–1.0
Alcelaphinae	0.3–1.0	0.05–0.01	1.0	0.25–1.0	2.0–4.0	0.25–0.5
Antilopinae	0.25–0.5	0.1–1.0	2.0–5.0	1.0–5.0	1.0–2.5	0.5–1.0
Bovinae	0.1–0.5	0.025–0.2	0.3–2.0	0.1–1.0	0.1–1.0	0.25–0.5
Cephalophinae	0.5–1.0	0.25–0.5	—	2.0–5.0	—	—
Hippotraginae	0.5	0.1–0.2	0.5–1.0	0.5–1.0	0.25–0.5	0.25–0.5
Reduncinae	0.5–1.0	0.1–0.2	1.0–2.0	1.0	0.3–2.0	0.25–0.5

Note: All doses are intended for intramuscular use unless indicated.
IM, Intramuscularly; *IV*, intravenously.

inappropriate dosing, and operator error. A partially anesthetized animal is susceptible to capture myopathy, so a decision to repeat induction should be made within 20 minutes of initial dart placement. Supplementation by remote means generally requires a full anesthetic dose, as the animal may be rapidly metabolizing the anesthetic because of stress and activity.

Many anesthetic regimens have been described for pronghorns and bovids,[3,10,29,53] and these regimens generally consist of ultrapotent narcotics (carfentanil, etorphine, thiafentanil), with or without sedatives or tranquilizers (α_2-agonists, butyrophenones), dissociative cyclohexamines (ketamine or tiletamine), or both. The use of the mixed opioid agonist–antagonist butorphanol tartrate as a component of anesthetic cocktails has been recently reviewed.[6] Historically, the ultrapotent opioid (narcotic) agents carfentanil citrate, etorphine, and thiafentanil oxalate have been the primary components of anesthetic cocktails used in nondomestic bovid species for many reasons: (1) Opioid agents have a relatively wide margin of safety for the patient and are highly potent, allowing for small volumes to be contained in remote delivery darts; (2) they are rapid acting and provide an efficient induction and minimize the risk of hyperthermia; and (3) they are reversible. However, ultrapotent opioids are associated with significant side effects such as suppression of respiration and GI motility, poor muscle relaxation, and renarcotization[46] and carry a risk to human safety, as the lethal human dose of some agents is as low as 20 micrograms (μg).[29] Ultrapotent opioids are Schedule II substances controlled by the Drug Enforcement Agency and thereby require the practitioner to possess special licensing and to follow defined possession, storage, and recordkeeping guidelines. Safety protocols and special training for handling narcotics and exposure emergencies must be maintained for all staff involved in ultrapotent narcotic procedures. Carfentanil citrate is the most potent of the three agents. Etorphine and thiafentanil oxalate may produce desirable effects such as improved muscle relaxation and decreased respiratory suppression in some species. Opioids, particularly carfentanil, may produce general anesthesia when administered alone; however, combination with other agents may reduce the narcotic dose, ease induction and recovery, increase muscle relaxation, and decrease respiratory suppression.

The α_2-agonists reported in bovid anesthetic regimens include xylazine, detomidine, and medetomidine. In general, bovids are more sensitive to the α_2-agonists compared with equids, and these agents may improve muscle relaxation, decrease narcotic doses, and ease induction and recovery. In smaller bovids and pronghorns, these drugs may be combined with cyclohexamines, benzodiazepines, butorphanol, or a combination, eliminating the need for an ultrapotent opioid. α_2-agonists, however, require 20 minutes to reach full effect when administered IM; approaching a recumbent animal prior to this time may result in spontaneous recovery and the need to re-administer the induction dose. α_2-agonists—particularly medetomidine—cause peripheral vasoconstriction, which may result in hypertension, bradycardia, poor mucous membrane color, and second-degree atrioventricular blocks. Use of parasympathomimetics such as atropine or glycopyrrolate to increase heart rate is controversial, as the resulting increased cardiac output may exacerbate hypertension. Medetomidine is available in highly concentrated formulations (Wildlife Pharmaceuticals, Inc., Fort Collins, CO), improving its usefulness for remote delivery in large species.

Dissociative anesthetics include the cyclohexamines ketamine hydrochloride and tiletamine (which is formulated in combination with the benzodiazepine zolazepam). These drugs are rapid acting, carry a high margin of safety, and are often used as adjuncts or supplemental anesthetics either intravenously (IV) or IM at 0.3 to 1.0 mg/kg. However, cyclohexamines are not reversible and thereby may affect duration of and recovery from anesthesia. When ketamine is used as a supplement, antagonism of reversible anesthetics should be delayed until 20 minutes after ketamine administration. This allows for ketamine metabolism and may prevent stormy recovery. Tiletamine, particularly when used without reversal of the zolazepam component (see Table 63-6), may be associated with prolonged recovery.

A partial list of suggested regimens for general anesthesia of bovids and pronghorns by species is presented in Table 63-5, and suggested reversal agents and doses are listed in Table 63-6.

ANESTHESIA AND SURGERY

The risks associated with general anesthesia in any species are confounded in bovids by their physiology, size, and temperament. Measures should be taken during any anesthetic procedure to prevent, identify, and treat hyperthermia, capture myopathy, metabolic derangements, respiratory depression, tympany, circulatory compromise, and regurgitation. Regurgitation is a common reaction to anesthetics and is complicated by positioning and anesthetic-induced ileus and tympany. Consequently, aspiration pneumonia is a significant risk in the unintubated ruminant. Intubation may be performed in most species by using a laryngoscope and a flexible stylet.[3,10] The patient should be at an adequate plane of anesthesia prior to intubation to prevent swallowing and stimulation of regurgitation.[3] Once intubated, the animal should be maintained in ventral or right lateral recumbency to minimize gastric pressure and ease ventilation. The head should be supported, with the nose down to allow regurgitated material to flow from the mouth. Adequate padding should be ensured, especially in heavy-bodied animals, to prevent pressure neuropathy of the limbs. Eye covers and ear plugs are recommended to minimize stimulation during anesthesia.

Intubation offers multiple measures of safety to the anesthetic procedure, including the ability to perform intermittent positive pressure ventilation (IPPV), often necessary to prevent hypoxemia

TABLE 63-5

Combinations of Chemical Restraint Agents Used for Induction of Anesthesia in Selected Species of Antilocapridae and Bovidae*[3,8,10,29,31,53]

	CARF	ETOR	THIA	XYL	MED	DET	KET/AZAP
ANTILOCAPRIDAE							
Pronghorn	0.05			1.0			
		0.1		1.0			
					0.3		5 K
			0.1	0.5			
AEPYCEROTINAE							
Impala	0.02–0.03			± 0.1–0.2			
		0.08–0.10		0.1–0.3			
			0.08				
			0.04	0.5–0.1	Or 0.025–0.05		
					0.20–0.25		3–5 K
ALCELAPHINAE							
Hartebeest	0.01			0.15			
Wildebeest	0.008			0.08			
			0.03	0.1			
Bontebok/blesbok	0.015–0.025			0.2–0.35			1.5–2.5 K
		0.020–0.025		0.2–0.3			0.2–0.3 K
			0.03				0.5 A
					0.05–0.09		1.0–1.3 K
Tsessebe			0.03	0.1			0.3 A
ANTILOPINAE							
Springbok	0.03						
		0.05–0.10		0.15–0.25			
				0.5			9.0 K
Blackbuck	0.05						
		0.1					
					0.25		2.0 K
Addra gazelle	0.015–0.02			±0.20			
		0.03–0.06					
					0.06–0.10		1.8–4 K
Slender-horned gazelle	0.03–0.05			0.10–0.25			
Grant gazelle	0.035						
Thomson's gazelle	0.02–0.03						
		0.05–0.07		0.2–0.45			0.2–0.45 K
Gerenuk					0.06–0. 07		1.5–2.0 K
			0.04				3.5 K
Dik-dik		0.01		0.4			
Suni		0.01		0.4			
				0.2–0.4			15 K
Klipspringer		0.01		0.4			
		0.05					
					0.16		2.1 K
Saiga	0.05–0.1						
BOVINAE							
Bison	0.004–0.008			0.05–0.10			
		0.01		0.05			
				0.5–1			4 K
					0.05–0.08		1.5–2.5 K
Gaur, gayal, banteng	0.006–0.01			0.1–0.2			
		0.01–0.02					
Nilgai	0.02						
		0.03					
Anoa	0.008–0.012			0.06–0.12			

Continued

TABLE 63-5

Combinations of Chemical Restraint Agents Used for Induction of Anesthesia in Selected Species of Antilocapridae and Bovidae—cont'd

	CARF	ETOR	THIA	XYL	MED	DET	KET/AZAP
African buffalo	0.005			0.05			
		0.015		0.1–0.15			
			0.01–0.025		±0.05–0.1		
Giant eland	0.008					0.03	
	0.005–0.007			0.05–0.10			
Common eland	0.01–0.016			0.15–0.20			
		0.02		0.40			
			0.03–0.07	0.1			
				0.8			4 K
Nyala	0.015–0.025			0.10–0.25			
		0.04		0.30			
			0.045		0.05		3–4 K
			0.08	0.3			
Sitatunga	0.04			0.3			
Tibetan yak			0.02	0.15			
Bongo	0.01–0.025			0.1–0.25			
	0.01			0.15–0.2			0.5 K
		0.02–0.05		0.05–0.15			
Greater kudu	0.02–0.25			0.2–0.25			
		0.02–0.03		0.2–0.3			
			0.05	0.25			
CEPHALOPHINAE							
Maxwell duiker	0.025						
		0.02		1			
				0.2–0.3			15–25 K
Blue duiker		0.01		0.40			
				0.3			15 K
					0.2		2.2 K
Yellow-backed duiker	0.02–0.03			0.2			
		0.02		1			
Common duiker			0.01–0.02	0.5			
HIPPOTRAGINAE							
Addax	0.025			± 0.15–0.25			
		0.03–0.04				0.02	
					0.05–0.06		1.0 K
Roan	0.015–0.02			0.15–0.2			
		0.025		0.15–0.25			
			0.01–0.02		0.005–0.006		0.3–0.6 K
Sable	0.015–0.02			0.15–0.2			
		0.015–0.025		0.1–0.2			±0.15–0.2 K
			0.03	0.1–0.2			
Scimitar-horned oryx	0.015–0.03			0.15–0.3			
		0.025		0.15			
		0.05			0.005		
Gemsbok	0.01–0.02			0.1–0.2			
		0.03		0.25			
		0.015		0.15–0.25			0.15–0.25 K
			0.02–0.04		0.02–0.04		1.0 K
Arabian oryx	0.03–0.04			0.25			
		0.03–0.04		0.3			
		0.04			0.005		
		0.045–0.05				0.045–0.05	
					0.03–0.06		1.2–2 K

TABLE 63-5

Combinations of Chemical Restraint Agents Used for Induction of Anesthesia in Selected Species of Antilocapridae and Bovidae—cont'd

	CARF	ETOR	THIA	XYL	MED	DET	KET/AZAP
REDUNCINAE							
Waterbuck	0.01–0.025			0.10–0.25			
		0.03		0.25			
			0.03–0.05	0.2			
Red lechwe	0.02						
	0.01			0.1			
		0.02–0.05		0.1–0.4			0.1–0.4 K
Nile lechwe	0.02			0.25			1.0–2.0 K
			0.02				1.5–3.0 K
Uganda kob	0.035			0.35			
Reedbuck			0.05–0.07	0.2			±0.1 A
Rhebok	0.01			0.4			
		0.01		0.4			

AZAP (A), Azaperone; *CARF*, carfentanil citrate; *DET*, detomidine; *ETOR*, etorphine; *KET (K)*, ketamine; *MED*, medetomidine; *THIA*, thiafentanil oxalate; *XYL*, xylazine.
*Doses are intended for intramuscular injection.

TABLE 63-6

Common Antagonists for Anesthetic Drugs Used in Antilocapridae and Bovidae

Anesthetic	Preferred Antagonist	Dosage	Comments
Carfentanil	Naltrexone	100 milligram per milligram (mg/mg) carfentanil, intramuscularly (IM)	May be given partially intravenously (IV)
Etorphine	Naltrexone	50 mg/mg etorphine, IM	May be given partially IV
Thiafentanil	Naltrexone	30 mg/mg thiafentanil, IM	May be given partially IV
Butorphanol	Naltrexone	5 mg/mg butorphanol, IM	
Medetomidine	Atipamezole or tolazoline*	5 mg/mg medetomidine, IM 1 milligram per kilogram (mg/kg), IM	
Detomidine	Atipamezole or tolazoline*	0.1 mg/kg, IM 1 mg/kg, IM	
Xylazine	Atipamezole or tolazoline*	0.1 mg/kg, IM 1 mg/kg, IM	
Tiletamine/ zolazepam	Flumazenil	0.01 mg/kg, IV	Ketamine and tiletamine are not reversible

*Intravenous administration of tolazoline in artiodactyls may cause profound hypotension and death.

caused by apnea or inadequate ventilation. IPPV pressure and volume should be less than 25 millimeters of mercury (mm Hg) and 8 to 12 mL/kg, respectively.[10] In larger animals, the use of a demand valve aids delivery of high volumes of oxygen, ensuring adequate tidal volume.[46] Administration of inhalant anesthetics (isoflurane or sevoflurane) via an endotracheal tube provides control of the duration and depth of anesthesia and may assist in management of hypertension or hypotension.

Depth of anesthesia, cardiovascular parameters, respiration, hydration, and GI motility should be monitored in any ruminant undergoing general anesthesia and surgery. Heart rate should be 40 to 80 beats per minute (beats/min), mucous membranes pink and moist (cyanosis indicates <70% oxygen saturation),[30] and capillary refill time less than 2 seconds. Hemoglobin oxygen saturation as measured by pulse oximetry should be greater than 90%, below which arterial partial pressure of oxygen may be less than 60 mm Hg (normal = 70–100 mm Hg).[30] Proper ventilation should maintain end tidal carbon dioxide (CO_2) levels at less than 60 mm Hg. Hydration may be subjectively measured by skin turgor, corneal and mucous membrane moistness, and ocular retraction. Normal partial pressure of arterial carbon dioxide ($PaCO_2$) is 35 to 50 mm Hg, and normal blood bicarbonate is 20 to 30 millimoles per liter (mmol/L).[10] The conditions of recovery from anesthesia are as important to animal and human safety as those during induction. Prior to reversal of anesthesia, the animal should be removed from inhalant anesthesia and adequately ventilated for at least 5 minutes. Maintenance of minimal levels and progressive reduction of inhalant anesthesia during the procedure, in addition to allowing for metabolism of supplemental injected anesthetics, may improve the quality and speed of recovery. The animal should be supported in ventral recumbency in a quiet, darkened enclosure, if possible. Following administration of the reversal agent, the eye cover and the endotracheal tube may remain in place until a swallow response is detected. Gentle removal of a partially inflated endotracheal tube will help to clear regurgitated materials from the pharynx.

Vascular access of most nondomestic bovids is most easily accomplished following a small cut-down with a large gauge needle or scalpel blade.[3] Relatively common conditions requiring surgery

TABLE 63-7

Adult Reference Ranges for Hematologic Parameters of Select Species of Antilocapridae and Bovidae[49]

Parameter*	Pronghorn	Impala	Brindled wildebeest	Thomson's gazelle	American bison	Common duiker	Scimitar-horned oryx	Common waterbuck
WBC (×10³/microliter [µL])	6.470 ± 4.911 (159)	3.528 ± 1.464 (314)	6.918 ± 2.358 (29)	3.855 ± 2.205 (291)	7.152 ± 3.674 (134)	6.200 ± 2.201 (7)	6.275 ± 2.393 (537)	6.354 ± 3.855 (125)
Neutrophils (×10³/µL)	4.879 ± 4.133 (155)	2.028 ± 1.309 (266)	4.174 ± 1.587 (19)	2.623 ± 1.952 (262)	3.544 ± 2.709 (131)	3.154 ± 2.435 (7)	4.179 ± 1.884 (403)	4.170 ± 3.663 (106)
Lymphocytes (×10³/µL)	1.085 ± 0.794 (156)	1.342 ± 0.773 (270)	2.490 ± 2.149 (19)	1.188 ± 0.766 (272)	2.867 ± 1.875 (133)	2.989 ± 1.155 (7)	1.393 ± 0.799 (412)	2.114 ± 1.561 (106)
Monocytes (×10³/µL)	0.181 ± 0.181 (122)	0.105 ± 0.123 (127)	0.230 ± 0.088 (14)	0.094 ± 0.079 (163)	0.264 ± 0.261 (116)	—	0.132 ± 0.185 (347)	0.117 ± 0.129 (59)
Eosinophils (×10³/µL)	0.331 ± 0.424 (104)	0.121 ± 0.125 (144)	0.181 ± 0.119 (14)	0.062 ± 0.094 (59)	0.466 ± 0.478 (115)	0.060 ± 0.026 (3)	0.183 ± 0.263 (315)	0.155 ± 0.245 (47)
Basophils (×10³/µL)	0.085 ± 0.111 (48)	0.031 ± 0.038 (42)	0.163 ± 0.079 (11)	0.046 ± 0.047 (34)	0.125 ± 0.127 (57)	—	0.022 ± 0.046 (219)	0.085 ± 0.043 (18)
RBC (×10⁶/µL)	10.29 ± 1.83 (71)	12.49 ± 6.59 (262)	10.50 ± 3.64 (22)	10.22 ± 1.62 (280)	8.23 ± 1.72 (105)	11.67 ± 1.22 (7)	8.70 ± 1.94 (486)	10.25 ± 2.52 (118)
Hematocrit (%)	41.1 ± 6.8 (170)	42.0 ± 9.1 (319)	42.4 ± 8.7 (31)	48.7 ± 7.3 (317)	44.1 ± 6.8 (141)	54.3 ± 3.4 (7)	37.6 ± 6.7 (590)	44.6 ± 9.1139)

*Values are reported as mean ± standard deviation (number of samples).
RBC, Red blood cells; *WBC*, white blood cells.

include trauma, abscesses, horn fractures and avulsions, hoof abscesses, castration, vasectomy, herniorrhaphy, ovariectomy, ovariohysterectomy, exploratory laparotomy, and tumor excisions. Less commonly, eye enucleation, cesarean section, and surgical treatment of corneal lacerations and ulcers, cataracts, angular limb deformities, GI or urinary obstructions, umbilical abscess, patent urachus, and rectal, uterine or vaginal prolapse are warranted.[10] Laparoscopy is useful in nondomestic bovids for assisted reproduction, minimally invasive abdominal and thoracic exploratory, biopsy, and endosurgical techniques. In large bovids, laparoscopic procedures may require intubation and positive pressure ventilation because of the pressure of the abdominal viscera on the thoracic cavity when the animal has been secured in dorsal recumbency at a head-down tilt.

DIAGNOSTICS

Diagnostics used in nondomestic bovids and pronghorns are similar to those used in domestic cattle, sheep, and goats. Common sites of vascular access include the jugular, cephalic, medial and lateral saphenous, and ventral tail veins, as well as the auricular, facial, medial tarsal, and digital arteries.[10] Cystocentesis is accomplished most easily with the aid of ultrasonography; normal urine pH is 7 to 9.5 with a specific gravity of 1.020 to 1.050.[10] Cerebrospinal fluid (CSF) may be collected from the lumbosacral cistern or the cisterna magna. The specific gravity of normal bovid CSF is 1.004 to 1.008, with less than 40 mg/dL protein and fewer than three white blood cells (WBCs) per microliter.[10]

Hematologic (Table 63-7) and serum biochemistry (Table 63-8) values of nondomestic bovids may vary within and among subfamilies. Measurement of fibrinogen is generally more useful than a WBC count for assessing inflammation in bovids, and protein electrophoresis may be useful in monitoring chronic inflammation. Serum bile acids are a useful measure for monitoring the course of hepatic disease and its response to therapy.[10]

INFECTIOUS DISEASE

Transboundary Animal Diseases

Animals and animal products are transported globally at an increasing rate every year such that entrance of an animal disease to a country formerly free of the disease is considered more a probability than a possibility.[5] Zoologic veterinarians have an increased opportunity to encounter such diseases and should therefore be aware of clinical signs and appropriate reporting and diagnostic plans in case of a suspected reportable disease. A description of foreign (transboundary) animal diseases, emergency procedures, and disinfectants is available in the publication of the *Committee on Foreign and Emerging Animal Diseases of the United States Animal Health Association*.[5] Notifiable diseases listed by the World Organization for Animal Health (OIE) that may affect or be carried by nondomestic bovids are listed in Table 63-9. Rinderpest, formerly listed as notifiable by the OIE, has been reported to have been eradicated worldwide.[35]

Common Infectious Diseases

Nondomestic bovids are susceptible to virtually all of the common infectious diseases of domestic ruminants. Selected diseases of concern to zoologic species of bovids and pronghorns are listed in Tables 63-10 and 63-11. Bacterial infections are of increasing importance in zoologic species because of multidrug-resistant pathogens.[28] Abscesses and other infections caused by pathogens such as *Arcanobacterium pyogenes*, *Fusobacterium necrophorum*, *Staphylococcus*, *Streptococcus*, *Pseudomonas*, and others may lead to systemic infection and death if not treated to resolution, on the basis of culture and sensitivity testing. Strict sanitation measures in hospital settings are required to prevent frequent infections and development of antibacterial resistance of resident organisms. Hoof infections are particularly common in some species, especially in weather and substrate conditions unnatural to the species[60] and may involve lengthy treatment with systemic antibiotics, regional perfusion, hoof curettage, topical treatment, and protective bandaging. Some animals cannot tolerate long-term confinement to allow healing: once infection is eliminated, hoof deficits may, in some cases, be filled with hoof repair material (which may be impregnated with antibiotics), allowing return of the animal to its home enclosure. These materials are worn away as granulation tissue fills the hoof capsule and results in a normal hoof.

Mycobacterial diseases remain a concern because of the lack of clinical signs in early stages and to the sensitivity and specificity of existing diagnostics. Of most concern are tuberculosis[37] (*Mycobacte-*

TABLE 63-8

Adult Reference Ranges for Serum Biochemical Parameters of Select Species of Antilocapridae and Bovidae[49]

Parameter*	Pronghorn	Impala	Brindled wildebeest	Thomson gazelle	American bison	Common duiker	Scimitar-horned oryx	Common waterbuck
Total protein, gram per deciliter (g/dL)	5.8 ± 1.2 (132)	5.6 ± 0.6 (200)	6.5 ± 0.5 (18)	5.8 ± 0.9 (189)	7.6 ± 1.2 (97)	7.2 ± 0.7 (5)	6.0 ± 0.8 (414)	6.6 ± 1.0 (84)
Albumin (g/dL)	2.8 ± 1.0 (120)	3.3 ± 0.5 (200)	3.9 ± 0.4 (11)	2.9 ± 0.5 (174)	3.6 ± 0.7 (78)	3.3 ± 0.4 (5)	3.3 ± 0.8 (339)	3.1 ± 0.7 (72)
AST, international unit per liter (IU/L)	155 ± 146 (128)	245 ± 124223)	131 ± 88 (21)	185 ± 136 (204)	102 ± 46 (87)	116 ± 27 (6)	106 ± 67 (427)	151 ± 96 (91)
ALT (IU/L)	24 ± 23 (100)	45 ± 20 (195)	106 ± 199 (17)	41 ± 25 (193)	29 ± 18 (52)	11 ± 6 (6)	18 ± 9 (177)	33 ± 19 (94)
ALP (IU/L)	369 ± 412 (104)	241 ± 280 (225)	183 ± 196 (19)	498 ± 841 (219)	98 ± 104 (93)	472 ± 340 (6)	222 ± 347 (427)	281 ± 442 (99)
GGT (IU/L)	—	—	117 ± 19 (12)	—	20 ± 32 (56)	169 ± 64 (3)	25 ± 28 (86)	278 ± 191 (42)
Calcium, milligram per deciliter (mg/dL)	9.4 ± 0.9 (118)	9.8 ± 1.7 (234)	8.1 ± 2.3 (19)	9.3 ± 1.1 (226)	9.3 ± 1.2 (95)	9.4 ± 1.1 (6)	9.4 ± 1.1 (456)	10.6 ± 0.7 (95)
Phosphorus (mg/dL)	8.4 ± 1.5 (113)	7.2 ± 2.0 (228)	6.6 ± 2.2 (15)	6.8 ± 2.3 (216)	7.3 ± 2.7 (88)	6.9 ± 0.8 (6)	6.5 ± 1.9 (432)	7.2 ± 1.9 (87)
Sodium, milliequivalent per liter (mEq/L)	150 ± 4 (119)	150 ± 4 (218)	137 ± 5 (16)	150 ± 5 (216)	141 ± 6 (90)	147 ± 2 (6)	143 ± 4 (436)	147 ± 5 (91)
Potassium (mEq/L)	4.8 ± 0.6118)	4.3 ± 0.8 (223)	5.2 ± 1.2 (16)	4.9 ± 1.1 (221)	4.7 ± 0.6 (90)	6.6 ± 1.7 (6)	4.5 ± 0.6 (444)	4.9 ± 0.8 (92)
Chloride (mEq/L)	106 ± 4 (117)	107 ± 4 (223)	95 ± 3 (14)	107 ± 5 (219)	102 ± 4 (84)	105 ± 4 (6)	103 ± 4 (360)	103 ± 6 (91)
Magnesium (mg/dL)	1.73 ± 0.27 (50)	1.65 ± 0.21 (16)	1.05 ± 0.88 (6)	1.95 ± 0.43 (28)	10.39 ± 8.6 (20)	—	1.60 ± 0.61 (32)	2.12 ± 0.62 (14)
Glucose (mg/dL)	136 ± 50 (133)	148 ± 44 (227)	95 ± 46 (21)	143 ± 57 (226)	145 ± 52 (100)	81 ± 32 (6)	174 ± 71 (427)	157 ± 61 (98)
Urea nitrogen (mg/dL)	29 ± 10 (132)	26 ± 8 (233)	20 ± 8 (21)	27 ± 9 (224)	21 ± 7 (98)	26 ± 9 (6)	24 ± 7 (460)	25 ± 7 (98)
Creatinine (mg/dL)	1.1 ± 0.3 (129)	1.7 ± 0.4 (223)	19.5 ± 52.4 (18)	1.6 ± 0.4 (225)	2.6 ± 0.9 (97)	1.3 ± 0.4 (6)	1.6 ± 0.5 (425)	2.2 ± 0.7 (98)

*Values are reported as mean ± standard deviation (number of samples).
ALP, Alkaline phosphatase; *ALT*, alanine aminotransferase; *AST*, aspartate aminotransferase; *GGT*, gamma-glutamyltransferase.

TABLE 63-9

Transboundary Diseases of Importance to Nondomestic Bovids Listed as Notifiable by the World Organization for Animal Health (OIE)*

Disease	Country/Region of Occurrence	Etiology	Transmission	Comments
Anaplasmosis	Tropical or subtropical climates and some temperate regions	*Anaplasma marginale, A. centrale*	Mechanically or biologically by arthropod vectors	
Anthrax	Worldwide	*Bacillus anthracis*	Ingestion, inhalation, fomites	Zoonotic High mortality
Bovine babesiosis	Tropical and subtropical climates worldwide	*Babesia bigemina*	Vectorborne: ticks	Morbidity and mortality vary
Bovine tuberculosis	Worldwide	*Mycobacterium bovis*	Direct contact Inhalation Milk ingestion	Zoonotic
Bovine viral diarrhea	Worldwide	Flaviviridae, pestivirus	Direct contact	Multifactorial disease
Brucellosis	Asia, Middle East, Mediterranean, sub-Saharan Africa, Peru, and Mexico, western United States	*Brucella abortus*	Ingestion of placental tissues, transmammary Contamination of wounds (human)	Causes late term abortion Zoonotic: undulant fever in humans
Contagious bovine pleuropneumonia	Africa	*Mycoplasma mycoides*	Inhalation	Zoonotic
Echinococcosis or hydatidosis	Worldwide	*Echinococcus granulosus* and other spp.	Carnivore-ungulate cestode cycle	Zoonotic Human disease: organ damage and anaphylaxis
Enzootic bovine leukosis	Worldwide, some countries disease free	Retrovirus	Vertical Bloodborne	Subclinical, lymphocytosis, lymphosarcoma
Epizootic hemorrhagic disease	North America, Far East, Mediterranean	Reoviridae, orbivirus	Vectorborne, biting midges	Increasing in host range
Foot-and-mouth disease	Asia, Africa, Middle East, South America	Picornaviridae, aphthovirus	Direct contact—infected animals, fomites, meat and milk, aerosols	Maintained in African buffalo Highly contagious
Heartwater	Africa, Caribbean	*Ehrlichia ruminantium*	Vectorborne: ticks Colostrum Blood inoculation	
Hemorrhagic septicemia	Asia, Africa, S. Europe, and Middle East	*Pasteurella multocida*	Direct contact with infected animals and fomites	
Infectious bovine rhinotracheitis or infectious pustular vulvovaginitis	Worldwide Eradicated in Austria, Denmark, Finland, Sweden, Switzerland, and Norway	α-herpesvirus	Inhalation	Vaccine available, does not completely prevent infection
Lumpy skin disease	Africa, Middle East	Capripoxvirus	Mechanical vector: mosquitoes and flies Direct contact possible	High morbidity and mortality
Paratuberculosis (Johne disease)	Global	*Mycobacterium avium* subsp. *paratuberculosis*	Infected animals shed bacterium in manure, colostrum, and milk	See Table 63-11
Screwworm (New World, Old World)	Central America, Caribbean, South America, Africa, Middle East, Southeast Asia	*Cochliomyia hominivorax* (New world) *Chrysomya bezziana* (Old world)	Blowfly (myiasis)	Zoonotic Eradication efforts focus on release of sterile flies
Q fever	Worldwide, except New Zealand	*Coxiella burnetii*	Ingestion of milk, urine, feces, amniotic fluid, and placenta	Zoonotic Can be transmitted by ticks
Rabies	Global	Rhabdovirus	Saliva of infected animal Possible by inhalation	Zoonotic

TABLE 63-9

Transboundary Diseases of Importance to Nondomestic Bovids Listed as Notifiable by the World Organization for Animal Health (OIE)—cont'd

Disease	Country/Region of Occurrence	Etiology	Transmission	Comments
Rift Valley fever	Africa	Bunyaviridae, phlebovirus	Vectorborne: mosquitoes	Zoonotic: ingestion of meat
Theileriosis	Africa, southern Europe, Asia, Middle East	Protozoan: *Theileria parva, T. annulata*	Vectorborne: Ticks (*Rhipicephalus, Hyalomma*)	East Coast fever Corridor disease
Trichomonosis	Worldwide	Protozoan: *Trichomonas foetus*	Venereal	Causes abortion and infertility
Trypanosomiasis	Africa, Central/S. America	*Trypanosoma brucei, cruzi, evansi*	Vector-borne: tsetse fly Mechanical: biting flies, esp. tabanids	African sleeping sickness, Chagas disease, Surra
Vesicular stomatitis	South and Central America, Western US Endemic in feral pigs on Ossabaw Island, Georgia	Rhabdoviridae, vesiculovirus	Mechanism unclear—transcutaneous, mucosal	High morbidity, low mortality

*From http://www.oie.int/manual-of-diagnostic-tests-and-vaccines-for-terrestrial-animals/. Accessed June 26, 2012.

TABLE 63-10

Identification and Management of Selected Infectious Diseases of Antilocapridae and Bovidae

Disease	Clinical Presentation/Lesions	Diagnosis	Management
Viral enteritis (coronavirus, rotavirus)	Acute diarrhea Dehydration Malabsorption Neonatal death	Fecal electron microscopy Fecal ELISA IFA	Supportive care Colostrum supplementation Vaccination Sanitation
Bacterial enteritis	Diarrhea Depression Dehydration Asymptomatic	Bacterial culture PCR Histopathology	Supportive care Appropriate antibiotics Vaccination Sanitation
Tuberculosis[37]	Lymphadenopathy Wasting Bronchopneumonia or cough Mild or no clinical signs	Histopathology Intradermal tuberculin test (CT for Bovinae, SCT for other bovids)	Routine testing Identify and remove affected animals Prevent introduction Treatment not recommended
Johne disease (paratuberculosis)[12]	Stage I: subclinical Stage II: subclinical, intermittent shedding Stage III: ill-thrift, wasting, diarrhea Stage IV: lethargy, emaciation, diarrhea, intermandibular edema	Difficult in early stages Histopathology (Stage I-IV) Fecal culture (II-IV) PCR (II-IV) ELISA (II-IV) IFN-γ (II-IV)	Routine testing Identify and remove affected animals Prevent introduction
Malignant catarrhal fever (MCF)	Nasal and ocular discharge Lymphadenopathy Diarrhea, anorexia Fever, death	ELISA VN PCR	Prevent contact of potentially affected carriers with susceptible hosts Supportive care Antiviral medications
Meningeal worm	Ataxia, paresis, circling, hypermetria, abnormal head posture, wasting	Clinical signs Histopathology	Reduce exposure to deer; control snails; deworm every 4 to 6 weeks during spring/summer

CT, Caudal tail fold; *ELISA*, enzyme-linked immunosorbent assay; *IFA*, immunofluorescent antibody; *IFN-γ*, interferon-γ; *L3*, third-stage larva; *PCR*, polymerase chain reaction; *SCT*, single cervical test; *VN*, virus neutralization.

TABLE 63-11

Selected Differential Diagnoses for Nondomestic Bovids and Pronghorns

Viral	Bacterial	Parasitic	Fungal
MULTISYSTEMIC DISEASES			
Adenovirus	Anaplasmosis	Besnoitiosis	Aspergillosis
Bluetongue virus	Anthrax	Toxoplasmosis	Blastomycosis
Bovine viral diarrhea	Chlamydiophilosis	Cestodiasis	Candidiasis
Epizootic hemorrhagic disease	Leptospirosis		Coccidioidomycosis
Encephalomyocarditis			Cryptococcosis
Malignant catarrhal fever			
RESPIRATORY SYSTEM DISEASES			
Infectious bovine rhinotracheitis	Mycoplasmosis	Lungworm (*Dictyocaulus*, *Protostrongylus)*	Aspergillosis
Parainfluenza (PI-3)	Pasteurellosis		
Bovine respiratory syncytial virus			
GASTROINTESTINAL SYSTEM DISEASES			
Coronavirus	*Clostridium perfringens* (A, B, C, E)	Amebiasis	Candidiasis
Rotavirus	Colibacillosis	Coccidiosis	
	Campylobcter jejuni	Cryptosporidiosis	
	Yersinia spp.	Giardiasis	
	Salmonella spp.	Nematodiasis	
		Liver flukes	
		Rumen flukes	
REPRODUCTIVE SYSTEM DISEASES			
Akabane virus	Brucellosis	Neosporosis	
Infectious pustular vulvovaginitis (BHV-1)	Q fever	Trichomoniasis	
	Campylobacter foetus		
INTEGUMENTARY/MUSCULOSKELETAL SYSTEM DISEASES			
Contagious echthyma (parapox)	Actinomycosis	Parafilariasis	Dermatophytosis
Poxvirus	*Corynebacterium*	Scabies	Dermatophilosis
	Pseudomonas spp.	Ticks	Sporotrichosis
	Fusobacterium spp.	Lice	
	Staphylococcus spp.	Warbles, bots, grubs	
	Streptococcus spp.	Screwworm	
	Arcanobacterium pyogenes	Flies	
	Blackleg/gangrene (*Clostridium* spp.)	Sarcocystosis	
NERVOUS SYSTEM DISEASES			
Spongiform encephalopathy*	Listeriosis	Meningeal worm	
Eastern equine encephalitis	Tetanus		
Equine herpesvirus			
Rabies			
CIRCULATORY SYSTEM DISEASES			
	Eperythrozoonosis	Babesiosis	
		Cytauxzoonosis	
		Trypanosomiasis	
		Theileriosis	

*Prion disease.

rium bovis) and Johne disease[12] (*Mycobacterium avium* subsp. *paratuberculosis*) (see Table 63-10).

Transmissible spongiform encephalopathies have been rarely reported in zoo bovids and are suspected to be caused by cross-species transmission of bovine spongiform encephalopathy (BSE).[47]

Emerging Infectious Diseases

Deforestation, altered migration, increased international travel, and globalization of trade are some of the factors leading to the rapid evolution, emergence, and host susceptibility changes of diseases in recent decades. Diseases reported to be emerging in bovids because of increasing prevalence, host susceptibility, or both include Schmallenberg virus infection,[4] bovine besnoitiosis (*Besnoitia* spp.),[19,24] bartonellosis,[33] epizootic hemorrhagic disease (EHD),[18] Johne disease (*Mycobacterium avium* subsp. *paratuberculosis*), malignant catarrhal fever, and equine herpesvirus infection. Malignant catarrhal fever and equine herpesvirus infection are of particular note because of their uncharacterized host susceptibility and the likelihood of these herpesviruses causing severe clinical disease in nondomestic bovid species.

Malignant Catarrhal Fever

Malignant catarrhal fever (MCF), a γ-herpesvirus of the genus Macavirus, is incompletely characterized and of importance to zoologic and wild bovid species and pronghorns. Currently, 10 viruses have been recognized within the MCF group, six of which are clearly associated with clinical disease.[32] The two most well-documented viruses, sheep-associated (SA-MCF) and wildebeest-associated MCF

(WA-MCF), are caused by ovine herpesvirus 2 (OvHV-2) and alcelaphine herpesvirus 1 (AlHV-1), respectively. Both viruses are carried asymptomatically in the reservoir host species (after which they are named), are pathogenic to other species, and are shed through ocular and oronasal secretions. WA-MCF is generally transmitted by calves from birth up to 4 months of age, but lambs are generally not infected with OvHV-1 until after 2 months of age and shed the pathogen intensively from 6 to 9 months of age. Lambs may, therefore, be separated from dams and raised virus-free.[32] Other described MCF viruses include hippotragine (HipHV-1) and alcelaphine 2 (AlHV-2) MCF, isolated from roan antelopes and hartebeests, respectively, but the epidemiology of these viruses remains poorly understood. Oryxes, ibexes, muskoxen, and aoudads are also known to harbor MCF viruses of unknown pathogenicity. Species susceptible to disease caused by MCF viruses include cattle, bison, deer, and pigs, but sporadic cases of MCF or MCF-like disease in a variety of captive nondomestic bovids have been reported.[22,32] Susceptible hosts may be subclinically or clinically affected. Bison are known to be 1000 times more susceptible, compared with cattle, to clinical SA-MCF,[32] and bongos have been recently reported to acquire fatal MCF from Nubian ibexes.[22,32] The clinical presentation of MCF is variable but usually includes profuse nasal and ocular discharge, corneal opacity, diarrhea, enlarged lymph nodes, fever, anorexia, and often death within 24 to 72 hours. Pathologic findings include lymphoproliferative vasculitis and epithelial necrosis. Identification of clinically relevant reservoir species is complicated by the incomplete characterization of these complex and evolving viruses: serologic tests distinguishing OvHV-2 and AlHV-1, however, are available. In the face of a suspected outbreak in a mixed-species situation, a multiplex PCR is the first choice diagnostic.[32]

Equine Herpesviruses

Equine herpesvirus (EHV-9) has been reported to cause fatal encephalitis in a number of non-equid species, including Thomson's gazelles and blackbucks.[14,55] The epidemiology of this virus outside its natural host has not been completely elucidated; EHV-9 and the closely-related EHV-1 have been transmitted to aberrant hosts both directly and indirectly. This, as well as the potentially wide species susceptibility, has led to recent concern about the zoologic setting creating unnatural proximity among geographically diverse species, encouraging cross-species disease transmission.

PARASITIC DISEASES

Ectoparasites found on nondomestic bovids include sucking and chewing lice; warble and bot flies, ticks, mites, various mosquitoes, biting midges, sand flies, black flies, tabanid flies, louse flies, and muscoid flies. Control of ectoparasites may use multiple methodologies, including life cycle disruption, baiting and trapping, and biologic control agents, although the most commonly used methods are topical and parenteral parasiticides.[10,45]

Protozoal diseases affecting bovids include opportunistic amebiasis, babesiosis, besnoitiosis, coccidiosis (*Eimeria* spp. and *Isospora* spp.), cryptosporidiosis (*Cryptosporidim parvum* and *C. muris*-like sp.), cytauxzoonosis, giardiasis *(Giardia duodenalis),* hepatozoonosis, neosporosis *(Neospora caninum),* sarcocystosis (*Sarcocystis* spp.), theileriasis (*Theileria* spp.), toxoplasmosis *(Toxoplasma gondii),* and trypanosomiasis (*Trypanosoma* spp.).[10,45] Cestodes commonly affecting bovids include *Echinococcus*, *Moniezia*, *Taenia*, and *Thysanosoma*. The most common GI nematodes of captive bovids are the *Haemonchus*, *Ostertagia*, *Nematodirus*, *Strongyloides*, and *Trichuris*, although a number of other parasites are found to cause diarrhea, ill-thrift, and anemia.[45] Meningeal worm (*Parelaphostrongylus tenuis)* infestation is a regional disease carried asymptomatically in the subdural sinuses of white-tailed deer and is transmitted to aberrant hosts (nondomestic bovids, cervids, camelids, and goats) through ingestion of third-stage larvae in feces. Larvae migrate in the spinal cord, causing clinical signs and often death. Identification and management are discussed in Table 63-10.

Management of Gastrointestinal Parasites

Effective control programs must be multifactorial, as reliance on parenteral parasiticides has led to widespread anthelmintic resistance.[20] Such programs may be extremely labor intensive and involve (1) routine parasite monitoring, (2) larval drug sensitivity assays, (3) pasture larval counts, and (4) alternatives to pharmaceuticals for parasite control. Nonpharmaceutical strategies for reducing parasite burdens, which are reviewed thoroughly elsewhere,[20, 45,50] include decreasing stocking density, pasture rotation, elevating feed and browse, feeding tannin-containing plants such as sericia lespedeza (*Lespedeza cuneata*) and nematode-trapping fungi,[50] and providing refugia (untreated nonclinical animals) for susceptible parasites to dilute the frequency of resistant alleles.[52] The use of oral copper oxide wire particles (COWP; Copasure, Butler Schein Animal Health, Dublin, OH) is increasing in zoologic institutions with some success.[20] Although dosing for nondomestic artiodactyls has not been thoroughly investigated, the manufacturer's recommended dose of COWP for cattle (70–225 kg) is 12.5 g, and 2 to 6 grams per animal has been reported efficacious and without toxicity in sheep and goats.[50] COWP may be administered in capsules or feed, are effective against abomasal parasites only, and should be limited to no more than every 6 to 12 month usage, with careful monitoring of fecal parasite levels and attention to potential toxicity. Pharmaceutical parasiticides used in nondomestic bovids include albendazole, amprolium, decoquinate, doramectin, eprinomectin, fenbendazole, ivermectin, levamisole, metronidazole, morantel, moxidectin, oxfendazole, praziquantel, pyrantel, selamectin, and sulfa/trimethoprim, with dosages similar to those used in domestic bovids.[10]

NONINFECTIOUS DISEASE

Common noninfectious diseases of wild and captive bovids are characterized as traumatic injuries, congenital and growth disorders, and degenerative; environmental (hypothermia, frostbite); dental (periodontal disease, dental abscessation); GI (choke, foreign bodies, abomasal impaction, rumen acidosis or rumenitis, tympany); metabolic (hypocalcemia/hypomagnesemia, capture myopathy); renal or urinary (urolithiasis, renal failure); toxic; reproductive (abortion, fetal mummification, dystocia); nutritional; and neoplastic diseases.[10] Capture myopathy remains a significant concern in management of nondomestic bovids.

Capture Myopathy

Capture myopathy was first described decades ago and remains a significant concern in pronghorns and bovids under all conditions of management.[42,54] The syndrome is most often associated with prolonged pursuit, capture, restraint, transportation, and high ambient temperatures, although many other stress-inducing factors may precipitate its development. Capture myopathy is most commonly characterized by ataxia, metabolic acidosis, muscle necrosis, and myoglobinuria; however, several closely related syndromes have been described (Table 63-12). In general, the pathophysiology of the disease includes exhaustion of muscular adenosine triphosphate (ATP) (skeletal and cardiac), decreased oxygen delivery to tissues, and increased production of lactic acid leading to muscle necrosis, myoglobin release, and renal failure. Predisposing factors include species (reported to be common in pronghorn, nyala, tsessebe, duiker, roan, hartebeest, eland, springbok, kudu, and impala[17]); environment (high temperature and humidity); capture or restraint; underlying conditions (pregnancy, advanced age); and vitamin E or selenium deficiency. By the time signs of capture myopathy are obvious, treatment is generally unrewarding. Prevention consists primarily of careful restraint planning and includes limiting pursuit to less than 3 minutes; avoiding capture in ambient temperatures over 20° C; reducing visual and auditory stimulation during restraint; minimizing restraint time; and using sedation and general anesthesia, when warranted. If, despite careful planning, an animal becomes highly stressed, hyperthermic, or hypoxemic during capture,

TABLE 63-12

Four Syndromes of Capture Myopathy in Nondomestic Ruminants[42,54]

Syndrome	Conditions	Clinical presentation	Pathologic findings
Capture shock (hyperacute) syndrome	Occurs during or within 6 hours after capture	Ataxia, tachypnea, tachycardia, hyperemic mucous membranes, hyperthermia, weak pulse, sudden death	Pulmonary congestion and edema; intestinal hemorrhage; small areas of necrosis of skeletal and cardiac muscle, brain, liver, adrenal glands, lymph nodes, spleen, pancreas, and renal tubules
Ataxic myoglobinuric (acute) syndrome	Most common syndrome, occurring hours to days after capture	Ataxia, torticollis, myoglobinuria, death with elevated AST, CK, LDH, BUN	Dark colored urine, dark, swollen kidneys, pale streaking of skeletal muscle, renal tubular dilation and necrosis with myoglobin casts
Ruptured muscle (subacute) syndrome	Occurs 24 to 48 hours following capture	Hindquarter weakness, recumbency with extremely elevated AST, CK, LDH BUN may be normal	Subcutaneous hemorrhage of rear limbs, multifocal soft lesions and ruptures in muscles, severe, diffuse skeletal muscle necrosis
Delayed-peracute (chronic) syndrome	Occurs rarely, at least 24 hours but may be up to 30 days following capture	Normal appearance when undisturbed, but acute stress results in attempt to flee followed by ventricular fibrillation and sudden death	No lesions or small pale foci of rhabdomyolysis, particularly in hindlimbs

AST, Aspartate aminotransferase; *BUN*, blood urea nitrogen; *CK*, creatine kinase; *LDH*, lactate dehydrogenase.

treatment may be successfully provided to prevent fatal myopathy. Aggressive fluid therapy and treatment of metabolic acidosis should be initiated as early as possible. Point-of-care analyzers are helpful in evaluating acid–base and electrolyte disturbances and guiding treatment. Sodium bicarbonate administration may be given as a bolus (1–2 milliequivalents per kilogram [mEq/kg]) and re-administered, as indicated by blood gas analysis. In a normal animal, lactate should be less than 2 mmol/L; a lactate value greater than 5 to 6 mmol/L carries a poor prognosis.[30] Administration of corticosteroids, dimethyl sulfoxide (DMSO, 10% in intravenous fluids), or a combination of both may be preferable to nonsteroidal anti-inflammatory drugs (NSAIDs) for the control of inflammation because of the likelihood of renal compromise with NSAIDs and may also protect vascular integrity. Following initial treatment, patients should be kept in a cool, quiet area and monitored closely for adequate renal output (1 mL/kg/hr)[30] for several days.

REPRODUCTION

General characteristics of the bovid reproductive cycle include a 24- to 72-hour estrous period and an 18- to 25-day luteal phase. Male behavior such as following, foreleg kicking, chin resting, and mounting may be good indicators of estrus; however, females will generally only stand to be mounted by a male during peak estrus. Seasonality varies among artiodactyls and may shift to some degree ex situ. Species from higher latitudes tend to be more seasonal compared with tropical species.[58]

Onset of sexual maturity may vary widely within and among species and is influenced by diet and general health (see Table 63-1). In herd settings, the removal of the breeding male may accelerate sexual maturity in young males. Fertility assessment in males is best achieved by microscopic examination of spermatozoa, collected by electroejaculation under general anesthesia. Most healthy bovid species produce highly concentrated spermatozoa with over 50% motile cells. Diagnosis of pregnancy may be made through rectal palpation or ultrasonography in many bovids; however, the risk of anesthesia, if necessary, may outweigh the benefit of early pregnancy diagnosis in many fractious species. Fecal progestin assays, available in many laboratories, provide a means of noninvasive pregnancy diagnosis but require repeated collection of multiple fecal samples over many weeks.[38]

Assisted Reproduction

As the sustainability of nondomestic bovids in captive collections becomes less certain, the development of assisted reproductive techniques becomes more important to species' success because of the potential to facilitate the infusion of new genetics into a herd while eliminating the cost and risk of transportation. These techniques also have the potential advantage of reducing the risk of disease transmission, but international transport of gametes remains challenging because of the risk of transboundary disease transmission.[43] Because assisted reproduction has been widely used in domestic cattle, techniques have been adapted from domestic protocols for many nondomestic species.[39] However, species differences in estrous cycle length, sensitivity to exogenous hormones, and stress response have limited the success of using domestic bovine protocols in bovids. In general, estrus synchronization protocols must be developed through research on each species. To date, estrus synchronization and artificial insemination using frozen-thawed semen have been successful in the eland, banteng, gaur, addax, scimitar-horned oryx, suni, blackbuck, Speke gazelle, Mhorr gazelle, and springbok.[39,43]

Perinatal Care

Neonatal mortality rates among nondomestic bovids are often over 30%. Because management techniques differ significantly between these animals and their domestic counterparts, an understanding of the special needs and risks involved in dam and neonate management may prevent unnecessary problems and losses, as previously reviewed.[56] Housing should provide the opportunity for seclusion, adequate ventilation and drainage, and exposure to sunlight. Species with strong herd instincts may be most successful when housed with conspecifics and in a familiar environment during calving. In temperate areas, careful timing of breeding to favor mild-season calving may also improve neonatal survival. One month prior to expected parturition, the energy ration should be increased and special attention paid to the provision of adequate calcium and minerals, particularly if the regional soil is deficient in specific minerals such as selenium.

TABLE 63-13

Diagnosis and Treatment of Common Conditions in the Sick Neonatal Ruminant

Condition	Diagnostic Findings	Treatment
Hypothermia	Body temperature < 37°C (99°F)	Warm neonate slowly (2°F per hour) using dry circulating air, blankets, heat lamps, and warmed intravenous fluids or warmed oral colostrum.
Hypoglycemia	Blood glucose <60 milligrams per deciliter (mg/dL)	500 milligrams per kilogram (mg/kg) (10 milliliters per kilogram [mL/kg] 5% solution) dextrose intravenously over several minutes Repeated dosing may be necessary Once corrected, maintain glucose administration at least 250 mg/kg/day until neonate accepts food or begin parenteral nutrition
Metabolic acidosis	Base deficit >10 millimoles per liter (mmol/L) Blood pH <7.25	Intravenous sodium bicarbonate (1.3%): Milliequivalent bicarbonate (mEq HCO_3) = Base deficit × body weight × 0.5, or Empirical treatment with 1–2 mEq/kg
Hypoxemia	Saturation of arterial oxygen (SaO_2) <90% Partial pressure of arterial oxygen (PaO_2) <70 mm Hg	Nasal insufflation with 5–10 liters per hour (L/hr) oxygen or ventilation
Septicemia	Blood culture positive Elevated or reduced white blood cell count Fibrinogen > 500 mg/dL >2% band neutrophils	Initiate broad-spectrum intravenous antibiotics Consider plasma transfusion Maintain body temperature, hydration, acid–base balance, and blood glucose Provide adequate nutrition

From Wolfe BA, Lamberski NL: Approaches to management of neonatal nondomestic ungulates. *Vet Clin North Am Exot Anim Pract* 15(2):61–72, 2012.[56]

Impending parturition may be signified by teat and udder enlargement (weeks) and vulvar swelling or relaxation (days) prior to parturition. Dams will often seek isolation and give birth at night. Dystocia is not uncommon, particularly in species of limited genetic diversity, and represents an important risk factor for morbidity and mortality in calves. If birth intervention is required, many dams will not accept an offspring following general anesthesia, resulting in failure of passive transfer (FPT) and the need for hand rearing.

Neonatal Care

Close observation of neonates soon after birth is important to document normal behavior and nursing.[56] Although in many wild cattle and gazelle species, the neonate will stand and follow the dam soon after birth, most other nondomestic ruminants are "hiders" and are left by their mothers to lie motionless for long periods.[58]In these species, finding the neonate and observing nursing may be a challenge. Neonates should be observed nursing within a few hours of birth, and a calf that is weak, unresponsive to stimulation by the dam, unable to stand soon after birth, or fails to nurse warrants evaluation.

Timely intervention is critical, but the decision to treat an unthrifty neonate may be complicated. Maternal neglect is common in dams that are inexperienced or stressed, but when a healthy, experienced dam abandons her offspring, it may point to an underlying problem compromising the viability of the offspring. The costs of committing to treatment and hand rearing, the likelihood of success, and the future of the neonate must all be taken into account in the decision to remove a high-risk neonate from the care of its dam.

Guidelines for the diagnosis and treatment of common neonatal conditions are listed in Table 63-13. Following normal birth, mild metabolic acidosis is common for up to 48 hours. However, severe acidosis may result in weakness, inability to nurse, and FPT. Clearing the airway and providing whole-body and nasal stimulation may stimulate respiration. Neonates born to anesthetized dams may have pharmacologic respiratory depression and should receive specific antagonists. Oxygen therapy has been shown to improve neonatal survival in at-risk domestic calves.[40] Intravenous fluid therapy may improve the chance of survival and provides a means of rapidly treating metabolic abnormalities. Treatment for acidosis with sodium bicarbonate (see Table 63-13) should only be administered after the establishment of a normal breathing pattern and may otherwise exacerbate respiratory acidosis. Provision of an external heat source 24 hours or more after parturition may improve thermoregulation, oxygen saturation, tidal volume, and respiratory rate.[40]

Common causes of illness in neonatal ruminants include acidosis, hypothermia, hypoglycemia, dehydration, pneumonia, and septicemia, each of which may be rapidly fatal.[36] Physical examination findings of hypothermia or hyperthermia, tachycardia, tachypnea, hyperemia or petechiae of mucous membranes, increased capillary refill time, cold extremities, diminished peripheral pulse, and inability to correct hypoglycemia despite treatment are suggestive of septicemia. Supportive treatment for neonatal septicemia should include provision of a clean, warm, lowly lit environment; soft, clean bedding; intravenous fluid supplementation; and plasma transfusion, colostrum supplementation, or milk-based nutritional support, depending on the age and condition of the neonate. Bedding should be changed frequently as septicemic neonates are usually too weak to stand and therefore susceptible to urine scald and corneal irritation or ulceration.

PREVENTIVE MEDICINE

Well-designed preventive medicine protocols, including quarantine, regular disease screening, vaccination, sanitation, and vermin control, are important to the successful maintenance of nondomestic bovid collections. Annual vaccination for diseases of particular concern such as *Clostridium* species and rabies is commonly performed. Regional disease risks should be considered, as vaccination for some diseases following an outbreak may interrupt the disease cycle. Live vaccines should be used with caution in nondomestic ruminants.

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