

Section 1

Association of Exotic Mammal Veterinarians (AEMV) Sessions

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Exotic Pet Mammals: Current State of Exotic Mammal Practice

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Session #100

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Abstract: Increased awareness of the availability of exotic pet mammal veterinary care, along with an increase in the number of veterinarians willing to provide such care, has likely led to increased demand for veterinary services, even as ownership declined in several categories of exotic pet mammal. Ferret ownership increased from 1991–2001, along with rabbit ownership, but ownership declined for gerbils and other rodents. In 2001, ferret owners were most likely to see the veterinarian (44.9%), while rabbit and guinea pig owners were less likely, at 15.9% and 15.4%, respectively. The dollars spent per household on exotic pets is significantly less than that spent on dogs and cats, yet client expenditures have increased steadily. Educational opportunities for veterinarians have increased and board specialties have been established for avian practice, and steps have been taken towards an exotic companion mammal specialty. Online support and other educational venues, as well as legal issues, are discussed to help the exotic mammal veterinarian stay informed and aware of current issues.

Exotic Pet Mammal Ownership in the United States

The most recent US pet ownership and demographics sourcebook (2002) indicated that in 2001 more households reported owning rabbits than any other exotic mammal (1.7%).¹ In comparison, 0.7% owned hamsters, 0.5% guinea pigs, 0.5% ferrets, 0.2% gerbils, and 0.3% owned a category listed as “other rodents” (Table 1). In order to put these pet ownership statistics into perspective, in the same years 36.1% of US households owned dogs and 31.6% owned cats. Statistics from 2001 also demonstrate that most rabbit and ferret owners own more than 1 animal.

Trends over the last 10 years (1991–2001) are instructive as well. Of the exotic mammals surveyed, ownership of ferrets and rabbits actually increased, while ownership of hamsters, guinea pigs, gerbils, and other rodents reported a distinct decrease (Table 2).

The potential negative of these trends for veterinarians is dramatically overcome by another more significant trend: the likelihood of exotic mammal owners to seek veterinary care for their pets. Of the above exotic mammal categories listed above, in 2001, ferret owners were most likely to see the veterinarian (44.9%), while rabbit and guinea pig owners were less likely, at 15.9% and 15.4%, respectively. However, of the species mentioned, when compared from 1991–2001, the percentage of owners seeking veterinary care for exotic mammals decreased, with the exception of guinea pigs and gerbils (Table 3).

Therefore, from 1991 to 2001 more Americans owned ferrets, but a fewer percentage of them purchased veterinary care. Statistically, this still represents an overall increase in the number of veterinary visits for ferrets, as ferret ownership has risen dramatically in 10 years.

Pet owners who seek veterinary care spend less per household on their exotic mammals than they do on dogs and cats, but the amount spent from 1991–2001 is steadily increasing. From 1991–2001, the amount spent per household

on any specialty or exotic pet rose from \$40.10 to \$106.90. In the same time, expenditure per household for dogs rose from \$131.80 to \$257.40, and cats for rose from \$70.80 to \$156.90 (Table 4).

The dollars spent per household on exotic pets is significantly less than that spent on dogs and cats, but trends clearly show expenditures have increased consistently, and have actually exceeded the rate of increase for expenditures on dogs.

Much of this trend is likely due to increased awareness of the availability of exotic pet veterinary care, along with an increase in the number of veterinarians willing to provide exotic pet care.

In the city of Indianapolis in 1991, the telephone book directory listed only 1 clinic mentioning the availability of veterinary care for exotic pets of any kind. In 2005, there were 5, including 2 clinics advertised as exclusively treating exotic pets.

Table 1. Pet exotic mammal ownership statistics for 2001.

Exotic mammal species	Ferret	Rabbit	Guinea pig	Hamster	Gerbil	Other rodent
% households	0.5%	1.7%	0.5%	0.7%	0.2%	0.3%
Total number in millions	0.991	4.8	0.629	0.881	0.319	0.786
Number animals/household	2.1	2.7	1.2	1.2	1.9	2.5

Table 2. Pet exotic mammal population trends from 1991 to 2001.

Exotic mammal species	Ferret	Rabbit	Guinea pig	Hamster	Gerbil	Other rodent
Population in millions 1991	0.275	4.57	0.838	1.31	0.619	0.875
Population in millions 2001	0.991	4.810	0.629	0.881	0.319	0.786

Table 3. Percentages of exotic mammal owners seeking veterinary care by species from 1991 to 2001.

Exotic mammal species	Ferret	Rabbit	Guinea pig	Hamster	Gerbil	Other rodent
Households seeking veterinary care, 1991	56.3%	16.0%	12.7%	5.0%	2.0%	11.6%
Households seeking veterinary care, 2001	44.9%	15.9%	15.4%	3.6%	5.8%	8.7%

Table 4. Increase in dollars spend per household on exotic and specialty pets vs dogs and cats during the time period 1991–2001.

Species	Exotic and specialty pets	Dogs	Cats
1991	\$40.10	\$131.80	\$70.80
2001	\$106.90	\$257.40	\$156.90

Opportunities for Education and Advancement in Exotic Companion Mammal Medicine

Of veterinary schools in the United States, nearly all now offer some exposure to exotic mammal medicine. However, conversations with senior students from 6 US veterinary schools completing internships at the author's clinic indicated they were overwhelmingly of the opinion they were ill prepared in any aspect of exotic animal medicine and surgery.

A casual survey of 10 veterinary schools with some reputation for offering exotics training revealed a wide range in the quantity and quality of avian and exotic course work available for students, and exotic medicine and surgery services offered in school-associated veterinary clinics. It is very difficult to compare programs and services, as not all schools are able to quantify educational opportunities in the same way. Of interest is the number of faculty members dedicated solely or primarily to exotic companion mammal medicine, which ranged from 0 to 6.

A number of institutions and private practices offer intern and externship opportunities in exotic animal medicine. Facilities specifically listing exotic/wildlife/zoo internships opportunities with the Veterinary Internship Residency matching Program (VIRMP) include 6 universities (Kansas, Louisiana, Oklahoma, Tufts Cummings School of Veterinary Medicine, Western College of Veterinary Medicine, and the University of Guelph in Ontario,) and 8 private practices. Four universities (Davis, Cornell, Tennessee, and Wisconsin) and 2 privately owned practices listed residency opportunities.²

The number of continuing education opportunities continues to climb, as state, university, and private organizations add exotic sessions to their educational line up. A few are even exotic-only, including the 4-day International Conference on Exotics.³

In 2006, the North American Veterinary Conference offered 3 entire days of continuing education dedicated to exotic companion mammal medicine, comprising 27 individual sessions taught by 7 internationally known speakers.⁴ Attendance at small mammal sessions is on average higher than at avian, zoo, or wildlife sessions, and has increased by nearly 50% from the years 2004 to 2006. Ten years ago, programs were generally limited to 1 day each of small mammal, avian, and reptile medicine (S. Barten, personal communication, May 2006).

In 1993, the American Board of Veterinary Practitioners (ABVP) established a board specialty for avian practice, with rigid requirements for certification, and in 2006 listed 118 board-certified avian specialists from the US, Canada, and the Netherlands.⁵ In the same year, the European veterinary community established ECAMS, the European College of Avian Medicine and Surgery.⁶ In 2005, the Association of Exotic Mammal Veterinarians began steps for establishment of an Exotic Companion Mammal specialty through ABVP.⁷ An update on the current status of this project will be presented at this conference.

The American College of Zoological Medicine (ACZM)⁸ also offers an opportunity to become board-certified in all classes of exotic animals, including pet mammals.

Support and Resources for Exotic Mammal Veterinarians

The number of textbooks on exotic pet medicine has increased dramatically since Harkness and Wangner's 1977 first edition of *The Biology and Medicine of Rabbits and Rodents*. A casual count revealed over 60 specialty books and journals, many of them specifically for exotic companion mammals, including 1 textbook dedicated specifically to rabbit and rodent dentistry.^{9,10}

In the United States, the Association of Avian Veterinarians (AAV) began in 1980 as a group of 175 veterinarians.¹¹ Today, membership tops 3300 veterinarians from 43 countries.¹¹ The Association of Exotic Mammal Veterinarians (AEMV) was formed in 2002 and now claims nearly 500 members.⁷

On-line support includes Veterinary Interactive Network (VIN), and professional forums such as the Exotic Forum sponsored by ExoticDVM.^{3,12}

The Legalities of Exotic Mammal Pet Ownership

Ownership of exotic mammals is not always clear cut, and may fall under regulatory control. States, townships, and communities may choose to define what it considers acceptable and unacceptable pets.¹² While the keeping of mammals generally considered domestic, such as the rabbit and guinea pig, is seldom challenged, other exotic mammals may not fare the same.

The AVMA has struggled for years to come up with recommendations on exotic pet ownership. The Council of Public Health and Regulatory Veterinary Medicine has suggested AVMA state "The American Veterinary Medical Association opposes keeping wild animals as pets."¹³ The deficiencies of such a simple statement are readily apparent. The general banning of "wild" animals completely ignores wide differences in general pet suitability.

AVMA has published a draft position statement on the keeping of wild indigenous and exotic animals that appears to make distinctions based on pet suitability, safety, and husbandry requirements.¹⁴ A supplement to the draft position specifically lists a number of exotic mammals classified as high-risk potential or as having unique husbandry requirements and therefore not recommended as pets (Table 5). AVMA supports the development of minimal standards required for ownership of these classes of animals.

Updated draft versions can be viewed at www.avma.org/issues/policy/default.asp.

Table 5. Supplement to the AVMA draft position statement on the keeping of wild indigenous and exotic animals: mammal species with high risk potential or unique husbandry requirements.

Large carnivorous members of the family <i>Felidae</i> except <i>Felis domesticus</i> (domestic cat)
Large carnivorous members of the family <i>Canidae</i> except <i>Canis domesticus</i> (domestic dog)
Any member of the family <i>Ursidae</i> (bears)
Any member of the family <i>Elephantidae</i> (elephants)
Any member of the family <i>Rhinocerotidae</i> (rhinoceros)
Any member of the family <i>Hippopotamidae</i> (hippopotamus)
Marine mammals
Non-human primates

Barriers to Exotic Mammal Practice: Lack of Information

Practitioners have access to a myriad of continuing education opportunities, including conferences, specialty course work, and published resources. As in every other technical field, some sources of information are superior to others. A number of well-known and popular resources contain information best described as anecdotal, and repeated from source to source without the backing of research or clinical data. In some cases, research and clinical data simply does not exist, a situation common in any emerging field. Practitioners must evaluate sources of information critically and take the time to examine a writer or speaker's reference material in order to distinguish between information presented as anecdotal or experience based, and that which can be considered more "evidence based."

Every year, researchers and others publish research and case reports of interest and benefit to exotic mammal practitioners. However, almost none are published in journals typically read and accessed by practitioners. During research for a paper on hedgehog diseases, the author discovered 18 relevant papers on hedgehog neoplasia and other diseases. Not one was published in a journal typically read by practitioners. Articles were found in the *Journal of Comparative Pathology*, *Journal of Zoo and Wildlife Medicine*, *Veterinary Clinical Pathology*, and the *Journal of Parasitology*.

An enormous amount of data is generated by the laboratory animal community, and much of it is of benefit to the exotic mammal practitioner. However, not all information is applicable, as there are often significant differences between common diseases in pet mammals and those seen in laboratory animals.⁸

Solutions to the information barrier include encouraging practitioners to write and publish well-documented clinical case reports, and encouraging those in research and academia to publish in journals likely to be read by practitioners. Practitioners must also consider accessing research-based journals either through direct subscription or through a journal abstract service or on-line resource such as PubMed (www.pubmedcentral.nih.gov). Several exotic animal-oriented publications such as the *Journal of Exotic Pet Medicine* (www.elsevier.com/wps/find/journaldescription.cws_home/707222/description#description) review abstracts from the literature that are of benefit to practitioners.

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Anatomy and Physiology of the Rabbit and Rodent Gastrointestinal System

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Session #110

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Abstract: Rabbits, guinea pigs, and chinchillas are all classified as hindgut fermenters, depending on primarily cecal microflora for nutrient composition. The rabbit has some unique anatomical features including the sacculus rotundus and the vermiform appendix. Gastrointestinal disorders in these animals can be a challenge to clinicians as not only the motility of the hindgut must be maintained, but the microflora as well. Dysbiosis, or changes in the microflora can release toxins and further alter the pH, microflora and motility. The clinician must also be aware of gastrointestinal pain and hydration status accompanying most gastrointestinal disease.

The Rabbit Gastrointestinal System

Although dental health and thorough examination of the teeth should always be included in the physical examination of a rabbit presented with suspected digestive system disease, this discussion will concentrate on the gastrointestinal system. Nutrition plays an important role in the functioning of the rabbit digestive system and will be discussed as it pertains to the gastrointestinal anatomy, physiology, and major disease syndromes.

Rabbits are true non-ruminant herbivores. Their digestive reservoir permits and increases the efficiency of utilization of fibrous diets. They have a large stomach and well-developed cecum relative to other non-ruminant herbivores such as the horse.

Stomach

The stomach of the rabbit holds approximately 15% of the volume of the entire gastrointestinal tract.¹ It is thin-walled, J-shaped, and lies to the left of the midline.² The well-developed cardiac sphincter is lined with non-glandular stratified squamous epithelium and prevents vomiting. The fundus contains parietal cells that secrete acid and intrinsic factor as well as chief cells that secrete pepsinogen. The pylorus has a well-developed, muscled sphincter.² The adult rabbit stomach has a pH of 1–2. The rabbit feeds frequently—up to 30 times per day of 2–8 g of food over 4–6 minute periods. The stomach normally will contain a mixture of food, hair, and fluid even after 24 hours of fasting.² The stomach pH of rabbits up until the time of weaning falls into the range of 5.0–6.5. Bacteria is kept in check during the first 3 weeks of life by the production of milk oil containing octanoic and decanoic fatty acids produced by the enzymatic reaction of the suckling rabbit's own digestive enzymes on the doe's milk.² Young rabbits acquire gut flora by consumption of the doe's cecotrophs beginning at 2 weeks of age. Milk oil production ceases at 4–6 weeks of age. By this time, some ingested organisms have colonized the cecum and hindgut fermentation can begin as the bunny weans.² Gastric transit time is approximately 3–6 hours.¹ The bulk in the stomach effects intestinal passage of digesta. The high voluntary feed intake (VFI) is at least 4 times higher pro rata than a 250-kg steer. It is also associated with a low gut retention time of 17.1 hours in the rabbit compared with 68.8 hours in the bovine. High VFI together with re-utilization of gut content by reingestion of

cecal material supports the rabbit's high nutrient requirement per unit of body weight and improves feed utilization for the rabbit.³ The bovine's main volatile fatty acid (VFA) produced by rumen fermentation is propionic acid while the rabbit's main VFA is acetic acid with cecal fermentation. The primary microflora of the rabbit is *Bacteroides* species while *Lactobacillus* species is the primary microflora of the bovid.²

Small intestine

The small intestine is approximately 12% of the gastrointestinal volume in the rabbit.² The bile duct enters into the proximal duodenum. The right lobe of the pancreas is situated in the mesoduodenum of the duodenal loop. The left lobe lies between the stomach and transverse colon. There is a single pancreatic duct that opens at the junction of the transverse and ascending loops of the duodenum. The duct drains both pancreatic lobes. Technically this is the accessory pancreatic duct as the main pancreatic duct connection to the duodenum disappears during embryonic development.¹ The jejunum is the longest section of small bowel and appears convoluted. Aggregates of lymphoid tissue (Peyers patches) are present in the lamina propria with increasing prominence distally. The distal end of the ileum has a spherical thick-walled enlargement known as the sacculus rotundus. This marks the junction between the ileum, cecum, and colon. The sacculus rotundus is often called the "cecal tonsil" because of its lymphoid tissue and macrophage composition. This organ is unique to rabbits. An ileocolic valve controls movement of ingesta from the ileum into the sacculus and prevents reverse movement of ingesta back up into the ileum. The ileocolic valve opens into the ampulla coli at the junction of the ileum, colon, and cecum. There is a weak ileocecal valve that allows chyme to pass into the cecum.²

Gastrointestinal smooth muscle is stimulated by motilin, a polypeptide hormone that is secreted by enterochromaffin cells of the duodenum and jejunum. Motilin is released in response to fat while carbohydrates inhibit release. Motilin activity is not present in the cecum, but is present and stimulates smooth muscle in the colon and rectum.¹ The stomach and small intestine in the rabbit function similarly to other monogastric animals.¹ Cecotroph digestion and some fermentation takes place during the 6–8 hours they remain in the gastric fundus. Cecotrophs contain microorganisms and products of microbial fermentation including amino acids, volatile fatty acids, and vitamins. A gelatinous mucous coating protects them from some of the stomach acid. As the cecotrophs passed through the colon, lysozyme was incorporated. The lysozyme has bacteriolytic activity that degrades microbial proteins for absorption in the small intestine. Bacteria within the cecotroph produce amylase that converts glucose to carbon dioxide and lactic acid. These products along with amino acids and vitamins are absorbed primarily in the small intestine. Digestion in the stomach begins with hydrochloric acid and pepsin and continues into the proximal small intestine. Amylase from the pancreas is added, although amylase is also present from saliva and cecotrophs. The pancreas also contributes proteolytic enzymes and chymotrypsin through the accessory duct as well as most likely through small ducts connecting directly to the duodenum. Bicarbonate is secreted by the proximal duodenum to neutralize the acidity of ingesta leaving the stomach. The bicarbonate is absorbed in the jejunum. Transit time through the jejunum is 10–20 minutes and 30–60 minutes through the ileum.¹

Hindgut

The hindgut consists of the cecum and colon. The cecum of the rabbit is large and may contain 40% of intestinal content. It has 10 times the capacity of the stomach.² The cecum is thin-walled and coiled in 3 gyral folds. It ends in a blind-ended tube called the vermiform appendix. This appendix contains lymphoid tissue and secretes bicarbonate that buffers the cecal acids, and water to form the cecal paste. In addition to *Bacteroides* species, there may also be ciliated protozoa, yeasts, and small numbers of *E coli* and clostridia species in the cecal flora.² The fermentation process in the cecum results in volatile fatty acids that are absorbed across the cecal epithelium. Cecal contents have an alkaline pH in the morning and an acid pH in the mid afternoon, termed a "transfaunation" as types of microorganisms fluctuate. In addition the predominant VFA of acetate, butyrate, and propionate are

also produced.² The ascending colon is divided into 4 sections.¹ The ampulla coli opens into the first section, approximately 10 cm long and having 3 longitudinal flat bands of muscular tissue (taeniae) that separate rows of haustra or sacculations.¹ The mucosa of this section has small protrusions approximately 0.5 mm in diameter that are termed “warzen” or warts. These are unique to lagomorphs and greatly increase the surface area of the colon for absorption. The warts may also aid in mechanical separation of ingesta.¹ The taeniae are innervated with autonomic fibers from the myenteric plexus.¹ The second section of colon has a single taenia and fewer, smaller haustra.¹ There are segmental and haustral contractions that mechanically separate the ingesta into indigestible particles and liquid contents. As the large pellets pass down the middle of the lumen, water is re-absorbed and they are excreted as hard dry pellets. The third section is the fusus coli. It is a muscular area about 4 cm long, highly innervated, and vascular. Its mucosal surface has prominent longitudinal folds and goblet cells. It opens into the fourth section of ascending colon that is indistinguishable histologically from the transverse and descending colon.¹ The distal colon (sections distal to the fusus coli) ends at the rectum. Its mucosa has short crypts with abundant goblet cells. It is thin-walled and usually contains hard fecal pellets.¹

Cecotrophy, not coprophagy

Cecotrophs are formed in the proximal colon and cecum. Rabbits begin consuming them between 2 and 3 weeks of age as they begin to eat solid food. Fiber material greater than 0.5 mm does not enter the cecum but transits to be formed and passed as hard fecal pellets. The smaller particles and fluid remain in the cecum or are returned to the cecum via antiperistalsis to form high nutrient particles that become coated with mucus as they pass through the colon. They are usually passed 8 hours or so after feeding, which coincides usually to nighttime. This mechanism requires high fiber diets to function properly. Low fiber diets increase cecal retention time and promote hypomotility of the entire gut, which further reduces the cecotrophs produced. Fiber in the diet should be indigestible and at least 15%.² A low protein diet increases a rabbit’s cecotroph ingestion. A high protein diet and low in fiber reduces consumption.² In crude fiber terms, diets that are less than 150 g/kg of feed will almost always result in digestive upset while diets with greater than 200 g/kg crude fiber result in increased incidence of cecal impaction and mucoid enteritis. A diet devoid of fiber has a coefficient of apparent digestibility of organic matter of 0.90. This declines in a linear fashion to 0.40 when the diet contains 350 g crude fiber per kilogram of feed. Increased crude fiber of the diet increases the crude fiber of the cecal contents. This decreases the protein content. Compounded, pelleted diets require the addition of hay in order to supply a complete diet. In general, the recommendation that hay be supplied on a free-choice basis as a rule of good husbandry of the pet rabbit should be emphasized.³

High carbohydrate diets cause several problems. Excessive glucose allows *Clostridium spiroforme* and *E coli* to colonize.² Excess VFAs produced drop the cecal pH, that inhibits normal flora and allows pathogens to proliferate and colonize. Gas and toxins can be produced by pathogenic bacteria, and motility and nutrient production and absorption are interrupted. Fats such as full-fat soybeans, oilseeds can be used as a source of energy without causing cecal hyperfermentation.² However, feeding of vegetable fats and seeds decrease the fiber content of the diet, and lead to motility and functional depression.

It is interesting to note that rabbits have a gall bladder and secrete about 7 times the amount of bile as a dog of similar weight. They secrete mainly biliverdin rather than bilirubin. Rabbits have low levels of bilirubin reductase.²

Rabbits should be fed in a quiet place, preferably early in the morning and in the evening. Rabbits do not like dusty food. A rabbit will selectively take concentrates if the palatability of roughage is variable. This may result in diarrhea from consumption of too much protein relative to hay. A well-fed rabbit masticates its food extensively whereas when the rabbit is hungry, it doesn’t chew to any great extent. The mastication of the fiber is necessary for dental health and normal tooth wear.

Diet recommendations

The recommended diet for a mature rabbit consists of unlimited grass hay; ¼ to ½ cup (timothy/oat if rabbit is hypercalcemic, older or obese; alfalfa only if underweight, normocalcemic) pellets per 5–6 lbs (2.5–3 kg) of body weight. Fresh foods can be 1–2 cups of chopped vegetables (preferably a mix: beet greens, broccoli, carrot and carrot tops, collard greens, mustard greens, parsley, pea pods (flat edible kind), romaine lettuce, watercress, wheat grass. Other acceptable vegetables, but less Vitamin A content: alfalfa, basil, bok choy, brussel sprouts, celery, cilantro, clover, dandelion greens and flowers (not sprayed), endive, escarole/kale, green peppers, mint, peppermint leaves, raddichio, radish tops, radish and clover sprouts, raspberry/blackberry leaves, and spinach. Table 1 lists calcium contents of some common rabbit foods. For treats and only if the rabbit is not overweight and the owner is insistent on some sort of “sweet treat,” the following fruits are high in fiber and can be provided at 2 TBSP/3 kg (30 ml/3 kg) body weight daily: apple, melon, peach, plum, strawberry, blueberry, papaya, pineapple, and raspberry. Remember that rabbits evolved eating grass and herbs, not rich grains, alfalfa, and fruits. Supplementation with vitamins and other treats is not necessary. Pellets are fed as a larger portion of the diet to does in kindle starting approximately 10 days prior to delivery, as well as to growing, young rabbits up to 10 weeks of age, then the amount of pellets is scaled down to the adult amount. After weaning of the kits, the amount of pellets for the doe is decreased until a non-breeding level of appetite is established. Hypercalcemia and obesity are 2 very commonly seen diseases with dietary etiologies.

Table 1. Mean calcium and phosphorus contents (g/100 g dry matter) of feedstuffs used for pet rabbits.

Food	Calcium	Phosphorus	Dry Matter (%)
Alfalfa Hay	1.35	0.27	90
Apple	0.06	0.06	21
Barley	0.07	0.39	89
Cabbage	0.64	0.35	12
Clover (fresh) red	1.80	0.40	20
Clover (fresh) white	1.40	0.51	19
Grass	0.54	0.30	20
Corn	0.01	0.32	87
Oats	0.03	0.03	90
Peas	0.12	0.41	89
Wheat	0.07	0.39	89

Gastrointestinal illness

Rabbits that are presented with or without malocclusion but with painful abdomens, anorexia, diarrhea or lack of stool need treatment prior to correction of the oral problems. Immediate administration of analgesics and fluids often results in the rabbit beginning to eat and the gastrointestinal tract beginning to move. Table 2 can be used as a guideline for diagnosing and treating gastrointestinal disease. A detailed history and physical examination including auscultation of the abdomen may allow the practitioner to evaluate the stage of gastrointestinal distress the rabbit is in. Radiographs are useful to determine ileus. Contrast series may be utilized to determine an impaction, although barium introduced into cecums is problematic for function. The author prefers to utilize endoscopy and/or ultrasound, or an iodine-based contrast agent rather than a barium series. Most trichobezoars will move once hydration is corrected and sufficient roughage is available. Use of motility enhancers may be tried if no impaction is present. Once pain is alleviated and hydration corrected, the rabbit may begin to walk around and nibble hay, which will encourage gastrointestinal motility. While not proven, probiotics are often administered per os or intrarectally. Remember that these are usually primarily lactobacillus spp. which are not the primary microflora of the rabbit. Vitamin B complex may be given to stimulate appetite. As hepatic lipidosis may be present and playing a role in anorexia, it is advantageous to get some food into the anorexic rabbit as soon as possible. If the rabbit does not immediately start eating hay, a gavage of diluted Critical Care (Oxbow Pet Products, Murdock, NE, USA) is given. This commercial formulation can be mixed with apple juice or flavored electrolyte solution to give directly orally. Many rabbits will take hand feeding of this formula.

Rarely is surgery necessary to relieve an impaction, but if a necrotic or ischemic section of the gut is suspected, surgery may be necessary to resect the bowel. Prognosis is guarded primarily because of endotoxins produced by *Clostridium* species present in most herbivore gastrointestinal tracts. The anesthesia further decreases gastrointestinal motility, again setting up the microflora to be altered and toxins produced. It may be necessary to install an intraosseous or jugular intravenous catheter to administer antibiotics and fluids perioperatively and postoperatively for several days in these cases. Restoration of gut microbial flora and motility and postsurgery are priorities. Antibiotic choices in these cases are a balancing act as a broad spectrum antibiotic with primarily gram negative and efficacy against anaerobes should be used. Antimicrobials that primarily have a gram-positive spectrum or that do not kill anaerobes are not recommended.

Table 2. Guidelines for evaluating rabbit gastrointestinal disease.^{4,5}

Parameter	Level 1 Outpatient	Level 2 Watch Closely	Level 3 Hospitalize
Appetite	Will eat greens & treats, indifferent to pellets, reluctant with hay	Refusing most greens and treat foods	Refusing everything
Activity & attitude	Normal, frisky; hiding, just not acting right	Depressed, not moving much, not grooming	Reluctant/refuses to move, dull, head down; unresponsive
Pain (abdominal) (note: teeth grinding can occur at any level)	Does not tense abdomen on palpation, but acts slightly uncomfortable. NSAID may be adequate	Tenses on abdominal palpation, shifts stance, reacts by movement or biting: moderate pain: NSAID may eliminate	“Bunny brick” – abdomen is so tense it’s hard, rabbit sits with feet tucked underneath, reluctant to move. Opiate and NSAID recommended: severe pain
Stool	Normal or slightly abnormal consistency: soft-formed, very small & dry. Less quantity	Scant to none: small misshapen. May have had no stool X 24 hr	Fluid diarrhea; mucoid diarrhea; or no stool in several days. Perineum may be stained
Palpation	Normal; fluidy but non-painful; may palpate material in gut, stomach	Painful abdomen, may be hard, gassy, tensing makes it difficult to palpate	Gastric tympany; cecal tympany; mass effect; generalized painful abdomen
Cardiovascular	Mucous membranes pink, ears warm	Mucous membranes usually still pink, usually ears still warm	Pale mucous membranes; ears cool, poor peripheral blood pressure
Gut sounds	Normal or hyperactive	Decreased or none	No gut sounds
Urine	Volume & color normal; may have brown tinge	May be decreased volume, increased odor; may have brown tinge. Still alkaline	Decreased volume, increased odor, acidic, clear urine.
Body temperature	101-104°F	<101°F or >104°F	<100°F or >105 °F
Hydration	Normal or slight dehydration	Mild dehydration	Usually marked dehydration
Treatment	Diet corrections: hay, hay, and more hay! Fluids prn SC; Vitamin B inj. NSAID. Encourage exercise.	Analgesics; fluids SC and supportive care including high fiber force feeding with probiotics. Motility enhancer, antimicrobials, Vitamin B complex injection. Encourage to walk.	IV fluids to start, SC to follow. Analgesics (opiate and NSAID), antimicrobials, motility enhancer if no obstruction. Force feeding or gavage, probiotics. Supportive care (warmth, quiet).

The Guinea Pig Gastrointestinal System

Cavies are strict herbivores and are cecotrophic. Dental disease with resulting malocclusions are common and beyond the scope of this presentation. A full dental examination should be included if any gastrointestinal disorder is encountered. Cavies are monogastric with completely glandular stomachs. The lesser curvature of the stomach is small and forms an angle with the esophagus termed “the angular notch.”² The small intestine lies in the right side of the abdomen and is approximately 125 cm in length in an adult. The small intestine is without distinguishing sections and lymphoid tissue (Peyer patches) in the lamina propria are found throughout. The large intestine begins at the ileocecal valve.

Hindgut

The cecum is the largest part of the digestive tract usually containing up to 65% of the gastrointestinal contents. It is large, thin-walled, and fills most of the left ventral abdomen.² It measures approximately 15–20 cm in length.² It has 3 white muscular longitudinal bands: the dorsal, ventral, and medial teniae coli. The saccular outpouchings between the bands are haustra. The colon appears dark green and is approximately 70 cm long. It functionally is divided into the shorter proximal section (20 cm) and the distal, longer section (50 cm). The proximal colon has mucosal folds on the mesenteric side that forms a longitudinal furrow. The furrow aids in separating high protein and smaller particles from the poorer quality material that will pass out of the colon as dry fecal pellets. Antiperistalsis transports the bacteria and higher protein particles back to the cecum for further fermentation.²

Physiology

Gastric emptying time is approximately 2 hours with a total gastrointestinal transit time averaging 20 hours (dry fecal pellets). Cecotrophy may be performed 150–200 times daily. Young cavies initially populate their intestinal tract by eating the sow’s cecotrophs and pellets. Gut flora is primarily gram-positive bacteria with anaerobic lactobacillus. Coliforms, yeasts, and clostridia may be present in small numbers.⁶ Cavies are more efficient than rabbits at digesting fiber. Satiety is determined by the distension of the gastrointestinal tract. Increasing fiber does not increase appetite.⁵ A crude protein level of 18–20% is needed for growth and lactation. A crude fiber level in the diet should be 10–16%.⁶

Gastrointestinal disorders

Two conditions involving the gastrointestinal system are seen frequently, and both may be linked. The first is anorexia. The clinician needs to determine if the anorexia is primary (refusal to eat a new brand of pellets), with subsequent malocclusions, and hindgut dysbiosis (change in microflora) and motility, or if the anorexia is secondary to a hindgut disorder or dental disease. Diarrhea is the second most common condition. It needs to be determined if it subsequent to other disease or if it is a primary disease of the gut. Changes in diet, stress, illness, anesthesia, or reproduction may alter gut motility and/or gut microflora, resulting in diarrhea. Clostridial infections secondary to antibiotic therapy that did not control anaerobes is frequently the cause. Antibiotic administration has been linked to disruption of normal gut flora. A generality is that broad-spectrum antibiotics administered subcutaneously or intramuscularly are less likely to cause problems. Chloramphenicol, enrofloxacin (fluoroquinolones), and trimethoprim/sulfonamides have rarely caused dysbiosis. In some large colonies, coccidia may cause diarrhea particularly in young guinea pigs.⁷ Fecal/rectal cultures, gram stains, and parasite evaluation along with history and complete physical examination including the teeth may be needed to determine the etiology. Diarrhea associated with an overgrowth of *Candida albicans* has been seen in cavies on prolonged antibiotic treatment.⁷

Treatment may involve analgesics and NSAIDS, probiotics, motility enhancers, antimicrobials, additional vitamin C, and almost always, fluid therapy. Assisted feeding with Carnivore Care (Oxbow) greatly increases the likelihood of recovery, but as caviae do not tolerate a lot of handling and injections while ill, the prognosis is always guarded!

Chinchilla Gastrointestinal System

Chinchillas share many similarities with guinea pigs, however are generally hardier and tolerate handling and treatment better than caviae. Dental disease is not uncommon, but discussion is beyond the scope of this presentation. The gastrointestinal tract is long, 11.5 feet for the small and large intestine combined in an adult.⁸ The cecum is large and coiled. The colon is sacculated. The cecum of the chinchilla holds approximately 23% of the dry matter content of the large intestine compared to the rabbit (57%) and the guinea pig (44%).⁸ Cecophagy is similar to the guinea pig except that cecotrophs may be passed in the day as chinchillas feed mostly at night. Fecal excretion is primarily at night. Transit time of ingesta through the gastrointestinal tract is approximately 12–15 hours. Chinchilla nutritional needs have not been studied as extensively as the needs of rabbits and other rodents. It currently is recommended that chinchillas receive grasses and hays, and pellets containing 16–20% protein, 2–5% fat, and 15–35% bulk fiber.⁸ A pellets-only diet is not sufficient for roughage and predisposes the chinchilla to enteritis. Providing 1–2 tablespoons of pellets per day, with ad lib good-quality grass hay, and 1–2 teaspoons of fresh leafy vegetables seems to be adequate for dental and gastrointestinal health for non-breeding chinchillas.

Gastrointestinal disease

Esophageal choke has been described in chinchillas that are feed raisins, fruits, and nuts, or those consuming their bedding or post-parturient females on the placentas. Bloat or gastric tympany has been associated with overeating of clover and sudden food changes, particularly to foods rich in carbohydrates. Bloat can be alleviated with decompression of the stomach, either by passing a stomach tube or trocarization through the abdominal wall. Fluid therapy and analgesics should be administered. Gastric trichobezoars have been seen in chinchillas that are chewing their fur. Trichobezoars will usually resolve with medical treatment similar to that used in rabbits: fluids, analgesics, motility enhancers, and roughage.⁹ Constipation seems to be more of a clinical problem than diarrhea. The usual cause is too much pelleted diet without sufficient roughage or fiber.⁹ Fluid therapy along with small amounts of fresh foods such as apples, carrots, or leaf lettuce, along with the owner discontinuing any treat foods such as raisins, seeds, and grains usually corrects the problem. In some, a laxative or a motility enhancer may be needed until the diet is corrected. Diarrhea frequently is the result of too much fresh vegetable intake. Infectious diarrheas are accompanied by a chinchilla that presents depressed, dehydrated, and staining of the perianal area. Rectal prolapse is seen in stressed young chinchillas, and may also be a sequellae of diarrhea. The prolapse can be reduced as in other animals, but etiology should be determined. Intestinal torsion, intussusception and impaction of the cecum and/or colon have been diagnosed in chinchillas. Animals present severely depressed and with a painful and usually distended abdomen. Surgery may be required, and the prognosis is guarded.⁹

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Gross and Surgical Anatomy of the Reproductive Tract of Selected Exotic Pet Mammals

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Abstract: Elective and therapeutic surgery of the reproductive tract of exotic pet mammals is common. Wide anatomical differences among exotic pet mammals make knowledge of comparative anatomy of the reproductive tract of critical importance. Indications for elective surgery include prevention of reproduction and undesirable reproductive behaviors, as well as disease prevention.

Introduction

Exotic companion mammals include many different species belonging to different Orders: carnivores (Carnivora); rabbits (Lagomorpha); rodents (Rodentia); Artiodactylids (Artiodactyla), and insectivores (Insectivora). Also included are some species of non-human primates (Primates) and bats (Chiroptera). Recently, some species of the mammal subclass of marsupials (Marsupialia) have also been introduced as pets.

Fortunately, time has long past when practitioners treated the first “non-conventional” species such as ferrets, rabbits, and few rodents as simply smaller dogs and cats. It is now clear why veterinarians who include exotic mammals into practice need a clear understanding of the anatomy and physiology of so many different species. Both the “standard of care” practiced by exotic animal veterinarians and the level of care demanded by exotic animal owners is increasing. Elective surgery is performed more frequently; therefore, the knowledge of the surgical anatomy is extremely important.

This presentation discusses the comparative gross and surgical anatomy of the reproductive tract of the ferret and skunk; rabbit and selected species of rodents; sugar glider and Virginia opossum; as well as the potbellied pig and hedgehog. A brief discussion of the different neutering techniques and indications for elective neutering will be discussed as well.

Ontogenesis of the Reproductive Tract

A quick review of the ontogenesis¹ of the reproductive system is often useful for a better understanding of the anatomical differences between exotic mammal species. The urinary and the reproductive system originate from the same mesodermic structure. The development of the proximal organs is independent; however, the distal tracts maintain a close relationship for the rest of their development and life. The early formation of the reproductive tract is the same for both genders.

The gonads originate from the genital crest; the genital tracts develop from the mesonephric duct (also called the Wolffian duct) and the paramesonephric duct (also called the Mullerian duct); the external genitalia develop from the primitive cloacal region.

During the undifferentiated phase, the Mullerian ducts—paired and symmetrical—lie medially to the Wolffian ducts and fuse together distally into the primitive distal urogenital sinus; the Wolffian ducts—paired and symmetrical—lie lateral to the Mullerian ducts and enter the distal urogenital sinus.

In the male, the proximal tract of the Wolffian duct becomes the epididymus, and the distal tract develops into the deferent duct. The Mullerian ducts regress almost completely, with the exception of the distal tract which becomes the prostate gland. Changes in the ligaments of the gonad and of the ventral abdominal wall lead to the descent of the testicles, which usually begins after birth.

In the female, the Mullerian ducts become the genital duct, and differentiate into the salpinges, the uterine horns, and the vagina. The Wolffian ducts regress. The primitive cloaca is divided by the formation of a septum. Dorsally, it delimits the distal tract of the intestine, and ventrally the urogenital sinus.

The external genitalia originate from 2 different structures: 1) the genital tubercle in the ventral part of the abdomen and 2) the primitive urogenital ostium. The size of the genital tubercle increases considerably in males, becoming the penis with the urethra; in the female, it remains small and becomes the clitoris. The primitive urogenital ostium becomes a groove, surrounded laterally by 2 folds. From these folds, the scrotal sacs will develop in the male, while the labia majora of the vulva will develop in the female. In most pet species, they will then regress, and remain the labia minora.

The kidney develops from the primitive pronephros (which in mammals regresses very early) in stages to stages to form the mesonephros and the metanephros. The primitive ureters of the mesonephros are the Wolffian ducts, which will develop later into the male genital ducts. From the distal part of the mesonephric ducts, the ureteric bud will develop, becoming the secondary or definitive ureter. The cranial part of the urogenital sinus, where the secondary ureters end, enlarges and becomes the urinary bladder. In this phase the primitive urinary bladder is still connected with the allantois through the allantoic pedicle. The short tract of the urogenital sinus between the opening of the mesonephric ducts and the opening of the secondary ureters becomes the definitive urethra in the female, while in the male this will form the proximal tract of the urethra. (Most of the urethra will origin from the development of the genital tubercle.)

Important modifications occur during ontogenesis of the genital system of different mammal species (especially between the more familiar placental and the marsupial species), leading to anatomical peculiarities that have significance for the practitioner considering surgery of the reproductive tract.

Marsupial Mammals

The urogenital tract of marsupials demonstrates the most significant anatomical differences compared with placental mammals.² In marsupials, final development of the ureters places them medial to the genital ducts, while in placental mammals the ureters course laterally. The presence of the ureters prevents fusion of the distal part of the genital ducts into a single uterine body in the female, as is present in most placental mammal species.^{2,3}

For this reason, the uterus is completely paired, and divided into 2 uterine horns (or uterine bodies). The 2 separate genital ducts continue distally, actually forming 2 separate vaginas, termed “lateral vaginas.” Due to the presence of the ureters on the medial aspect, the lateral vaginas cannot fuse together, but become united just ventral to the ureters, into an anatomical structure called the “median vagina.”^{2,3} In reality, the term “median vagina” is controversial, because this structure continues distally into the urogenital sinus, which is the remnant of

the primitive cloaca. The uterine horns have 2 separate cervixes, like the rabbit, and enter the median vagina. The urinary bladder is positioned ventral to the median vagina and to the urogenital sinus. The division is marked by the urethra, which opens caudoventrally, and by connective tissue between the median vagina and the urogenital sinus. In most marsupial species, the birth canal is transient, and is recreated at each birth, while in other species it remain patent after the first birth.

The distal tract of the ureters enters the urinary bladder crossing the median vagina laterally.

The urogenital sinus opens externally through the urogenital opening. Because it is very close to the anal opening, this orifice is also called the cloacal opening.

The peculiarity of the external genitalia of male marsupials (in common only with lagomorph species among placental mammals) is that the scrotal sac is well developed and located cranial to the penis, and to the urogenital opening. The tip of the penis of the sugar glider is forked.

The anatomical peculiarities described above impact surgical techniques for neutering and spaying pet marsupials. Orchiectomy is straightforward and the testicles can be easily accessed through a single scrotal incision. Nevertheless, the pendulous appearance of the scrotum suggests ablation could be indicated as well.^{4,5}

The surgical technique for neutering the female is more challenging. Anecdotally reported infections of the genital tract of female captive Virginia opossum suggest that elective neutering may be important in this species kept as a pet. As in placental mammal species, it is probably ideal to remove as much reproductive tissue as possible. Therefore, neutering of the female opossum, (and the rabbit as well) is better termed ovario(salpingo)hysterovaginectomy.

The position of the distal ureters as they cross the median vagina before entering the urinary bladder makes removal of the paired lateral vaginas together with the uterine horns impossible. Therefore, ovariohysterovaginectomy is performed in 2 steps: ovariohysterectomy followed by vaginectomy of the 2 lateral vaginas.

Placental Mammals

Anatomical peculiarities of placental mammal species following ontogenetic development have different significance in male and female animals. In males, the most important are related to the descent of the testicles. Soon after descent of the testicles into the scrotal sac, the paired distal openings of the abdominal wall—the so called “inguinal rings”—close in all species except lagomorphs and rodents. In these species, the inguinal rings are patent throughout the life of the animal, and they allow each testicle to move from the homologous scrotal sac to the caudal part of the abdominal cavity and vice versa.^{6–10}

In female species, the extent to which the primitive Mullerian ducts fuse distally and the development of the urogenital sinus determine some of the significant differences in the anatomy of the vagina, the urethra, and the uterine cervixes.

Indications for surgical alteration in rabbits and rodents

Indications for elective surgical alteration in rabbits and rodents include prevention of breeding and reduction of hormone-related aggression. Hormonal aggression appears most common in female rabbits, but is of negligible concern in female guinea pigs. Some, but not all, male rabbits display undesirable sexual behavior directed toward

owners, other pets, or objects. Undesired sexual behavior is rare in male guinea pigs and rodents, but male guinea pigs may display dominance with other males in the group. Both intact male and female rabbits may spray urine outside the litter box. Owners also report increased aggression among intact female and male rabbits, male mice, and occasionally male guinea pigs. Surgical alteration often greatly reduces unwanted sex-related behaviors, but may not eliminate them entirely.

Additional indications include prevention of uterine neoplasia in female animals, in particular rabbits, and ovarian cysts in female guinea pigs. Intact female rabbits are especially prone to neoplasia of the reproductive tract, but also pyometra, hydrometra, and reproductive cysts and abscesses. Incidence of uterine adenocarcinoma is high, with one study reporting 60% in animals over 4 years of age.¹¹ For this reason, and for elimination of hormone-related aggression, surgical alteration is highly recommended in female rabbits.

Ovarian cyst formation is a common problem in older guinea pigs, with an incidence in one examined population of 76%, mostly in pigs between 2 and 4 years of age.¹² Cyst size varies, but very large cysts can produce general debilitation, presumably due to discomfort of space-occupying mass. Some cysts are accompanied by symmetrical alopecia. Serous cyst formation is a normal component of the ovarian cycle in female guinea pigs, and can be experimentally induced with estrogen.^{13,14} A study investigating links between breeding history, age, cyst prevalence, and size showed no relationship between breeding history and cyst formation, but a significant relationship between cyst size and prevalence and age.¹⁵ FSH has been shown to have some anti-cystic effects in experimental guinea pigs.¹⁴ More data on the incidence of debilitating cysts in pet populations is needed in order to better evaluate the risk/benefit of early ovariohysterectomy for the prevention of ovarian cysts in this species.

Ovariohysterectomy has been proposed for prevention of mammary tumors in rats. The incidence of mammary tumors in specific lines of laboratory rats ranges from a low of 3.1% in males to 27% in females.^{16,17} The author was unable to find statistics on the incidence of mammary tumors in pet rat populations, or scientific data on the efficacy of ovariohysterectomy for prevention of spontaneously occurring mammary tumors in pet rats. Laboratory studies on the hormonal effects of mammary tumor development are conducted on specific laboratory strains with chemically induced tumors that are not the same as those spontaneously occurring in pet rats. Therefore, extrapolation of these studies to pet rats should be done with caution.

Rabbits: male

The urogenital anatomy of male rabbits is unique among placental mammal species, and common in marsupial species.^{6,7} The penis is located caudal to the testicles, which lie cranial to the penis in 2 separate hemiscrotal sacs. The other important anatomical peculiarity, mentioned above and in common with rodent species, is the open inguinal canal, making rabbits (and rodents) “functional cryptorchids.” Position of the testicles depends on many factors including body position, body temperature, breeding activity, gastrointestinal tract filling, and the amount of abdominal fat. The testicles of rabbits are elongated and not round. The epididymis is clearly visible at the caudal pole of the testicle, but not as developed as in rodent species. There is also significantly less peritesticular fat than in rodent species. The glans of the penis is not well developed, is tapered, and covered by a prepuce.⁷

The 2 main anatomical peculiarities of male rabbits have important implications in regard to orchietomy. Ligation of the open inguinal canals is highly recommended during the surgical procedure in order to prevent hemiscrotal herniation of abdominal viscera such as intestinal loops or the urinary bladder. The position of the penis caudal to testicles makes a prescrotal approach with a single incision on the midline possible.⁶

Different techniques have been described for orchietomy in rabbits: the traditional scrotal approach using a closed or open technique,^{6,9} the prescrotal approach,⁶ and, as the rabbit is a functional cryptorchid, the abdominal

approach.^{6,18} Each technique has practical advantages and disadvantages. The scrotal techniques are well described, most familiar to practitioners, and can be accomplished rapidly. The prescrotal approach, however, is the best technique for proper anatomical closure of the inguinal canals. Due to the position of the penis, manipulation of the delicate skin of the hemiscrotal sacs, including shaving and scrubbing, is completely avoided. In this technique, a 1.5–2 cm incision is made on the midline just cranial to the base of the hemiscrotal sacs. Blunt dissection of the subcutaneous tissue and inguinal fascia reveal the vaginal processes where they lie just before entering the abdomen through the inguinal canal. The vaginal process is bluntly dissected from the surrounding soft tissues and isolated, and 3 to 4-0 suture material passed around it and tied loosely to act as a stay suture. The vaginal process is incised to access the testicle and spermatic cord, which are gently grasped and exteriorized through the incision. The ligament between the hemiscrotal sac and the tail of the epididymis is gently dissected, and the spermatic cord containing blood vessels and nerves is clamped, ligated and removed. Ligation of the testicular blood vessels can be performed separately in larger rabbits, if desired. The preplaced stay suture is tied, which will close the vaginal process. Inguinal fascia and subcutaneous tissue are sutured.

Rodents: male

In general, the testicles of male rodents are large relative to body size, and round in shape.^{10,19–21} The epididymis is well developed, both at the caudal and the cranial pole in the rat. The surrounding fat is usually abundant. Some species of squirrel-like rodents such as the prairie dog are true functional cryptorchids, as the testicles descend into the scrotal sacs only during the breeding season. The glans of the penis is well developed, especially in porcupine-like rodents such as guinea pigs and chinchillas.

The external genitalia of the guinea pig are encompassed in a well-developed circumanal skin fold, also called the “perineal sac.”^{21,22} While this structure resembles an anal orifice, the actual anal orifice is located in the deep caudal part of the anal fold, complicating tasks such as rectal measurement of body temperature. In the deep part of the mucocutaneous area are many sebaceous scent glands (also called “grease glands”), which produce a dense, yellow, creamy and odiferous secretion. This anatomical feature predisposes the male guinea pig to impaction of the anal fold with feces, dry secretion, hay, or other bedding material.

The seminal vesicles of the male guinea pig are well developed, tubular, and long, about 10 cm in length. These structures are located in the caudal portion of the abdomen and may cause momentary confusion as they might be mistaken for uterine horns during laparotomy.²¹

As in rabbits, techniques for castration include open and closed scrotal techniques, the prescrotal approach, and the abdominal approach. The prescrotal technique is effective in rodent species,^{19,20} both for access to the testicles and an anatomic closure of the inguinal ring, which is much wider in rodents than in rabbits. As the penis is located cranially to the scrotal sacs, 2 separated parapreputial incision are required.

The abdominal approach for orchiectomy has also been reported in rodent species.²³ This technique is recommended for squirrel-like rodent species like the prairie dog, outside of breeding season, or in very young animals where it may be difficult or impossible to locate the testicles in the scrotal sac.

Rabbits: female

Like cats and ferrets, female rabbits are induced ovulators, with ovulation occurring 10–13 hours after mating. There is no estrus cycle, but rather a period of receptivity occurring every 5–6 days.

In the female rabbit, the ovaries, oviducts, and the uterus are paired organs, similar to the case in other placental mammal species.^{10,24} Ovaries are not located in a true ovarian bursa as in some carnivore and rodent species,

but are usually surrounded by fat that also surrounds the mesovarium and the mesosalpinx. The uterus is a complete paired organ (not partially paired as in most of other placental mammal species). It is bicornuate with 2 cervixes, which open directly and separately into an elongated vagina. The mesometrium (broad uterine ligament) is usually filled with fat, especially in overweight or obese rabbits. The vaginal body is a long, large, and flaccid unpaired organ. The urinary bladder is positioned ventrally to the vagina and uterine horns, and the urethra opens into the ventral aspect of the vaginal body. This marks the division between the vestibulum, which is caudal to the urethral opening, and the larger true vaginal body, which is cranial to the urethral opening.^{10,24}

Technique for ovariohysterovaginectomy in rabbits is similar to ovariohysterectomy in other species. It may be advantageous to remove as much of the vaginal body as possible, as reflux of urine from the bladder to the vagina is possible, and to prevent infection in the vaginal remnant, similar to “stump pyometra” in other species.

Rodents: female

In rodent species, an alternative development of the primitive urogenital sinus leads the urethra of female animals to open outside the vagina. Therefore, 3 separate openings are present: the urethral, the vaginal, and the anal orifice.¹⁰ Another difference from female rabbits is that female rodents have an unpaired cervical canal, which opens into the vagina through a single cervical opening. In reality, the length of the fused, unpaired tract is different among the rodent species: in porcupine-like rodents such as guinea pigs and chinchillas the cervical canal is easily recognized; in rat-like rodents some authors²⁵ describe a cervical canal, but 2 separate cervical openings are also reported in the female hamster. Ovariohysterectomy is similar to feline/canine technique in these species, but can be complicated by abdominal fat in older or obese animals, by the more cranial position of the ovaries that are often surrounded by abundant fat in guinea pigs, or by small patient size.

Indications for Surgical Alteration of Carnivores

Indications for reproductive surgery of carnivores include elimination of breeding and reduction of hormonal aggression. Many intact male carnivores have increased musky odor, in particular, the ferret.

Female ferrets are induced ovulators, and estrus cycles begin at about 6–9 months of age. Failure to mate results in unabated estrogen production, ultimately leading to bone marrow suppression and pancytopenia, with resulting non-regenerative anemia.²⁶ Most female ferrets in the United States are mass-produced by large commercial breeding facilities and spayed prior to arrival at pet stores. However, ferrets from private breeders are occasionally encountered, and the practitioner must educate the owner on the necessity of surgical alteration, or alternatives such as breeding or sham mating with a vasectomized male ferret. Intact female ferrets presented for ovariohysterectomy after the onset of estrus must be evaluated for non-regenerative anemia, and supportive care may be indicated, including blood transfusion.²⁷

The testicles of the ferret are similar to those of the cat, while the penis resembles that of the dog.

The body of the penis is not visible, but is easily palpable due to the J-shaped os penis (which lies dorsal to the urethra). The prepuce is the only visible part of the male external genitalia in ferrets that have been neutered prior to puberty, and for this reason it is not unusual for owners to mistake the gender of their male pet. The prostate gland of the ferret is present at the base of the urinary bladder and surrounds the urethra. It is not distinct in neutered males, but enlargement and other diseases can occur due to hormonal stimulation resulting from adrenal gland disease.²⁸

The uterine horns of female ferrets are long, and they fuse immediately in front of the cervix, forming a short body.²⁸ The ovarian bursa is not well developed. The vulva appears as a small slit a few millimeters cranial to the anal orifice. Estrus or hormonal stimulation due to adrenal disease can produce significant enlargement of the vulva. Orchiectomy and ovariohysterectomy of ferrets is straightforward, and surgical technique is similar to that performed in cats.

The reproductive cycle of the spotted skunk (*Spilogale putorius*) is well described, as this species is a common laboratory model for reproductive studies, in particular those involving delayed implantation. Much less information is available on the species most commonly encountered as a pet, the striped skunk (*Mephitis mephitis*), but which is assumed to be similar.²⁹ However, 2 references claim the striped skunk to be an induced ovulatory, while the spotted skunk is a spontaneous ovulator.^{29,30} The skunk is seasonally polyestrous with estrus cycles occurring between September and January. Pet skunk groups commonly claim that intact female skunks are extremely aggressive during estrus, and therefore recommend surgical alteration. Another commonly circulated statement is that intact, unbred female skunks have a high incidence of reproductive tract-related disease and death, and compare the need for surgical alteration to that of the ferret. The author (A. M. L.) has encountered at least 2 owners who claim their intact female skunks do not display aggressive behavior during estrus, and is unable to substantiate claims regarding medical necessity of ovariohysterectomy. However, overwhelming anecdotal reports do indicate surgically altered male and female skunks display less aggression and have better pet quality.

The anatomy of the reproductive tract of skunks is similar to that of dogs, and the surgical technique is the same. The author (A. M. L.) prefers a prescrotal castration technique in male skunks.

Miscellaneous Species

Determining the gender of hedgehogs is not difficult, as the male has a ventral prepuce located in the middle of the abdominal surface. The testicles are not visible due to lack of a true scrotal sac, and because they usually remain within the abdomen. Elective castration is most easily performed through the abdominal approach, as in squirrel-like rodents. Males possess many accessory glands: paired prostate glands, seminal vesicles, bulbourethral glands, and Cowper's-like glands.^{32,33}

The vulva appears as a small slit close to and cranial to the anal opening. The reproductive tract of the female is located in the caudal portion of the abdominal cavity. Uterine horns are short, and they open into the long vagina through a single cervix. A fan-shaped paired gland, homologous to the male Cowper's-like glands, lies laterally to the vagina.³³

Intact hedgehogs are not overtly aggressive, therefore elective surgical alteration is not commonly performed. While overall incidence in pet populations is unknown, mammary neoplasia and neoplasia of the reproductive tract appear to be common in hedgehogs. One study reported an overall incidence of neoplasia of 53% in captive hedgehogs, with the most common sites being mammary tissue, digestive tract, and the endocrine system.³⁴ Uterine neoplasia is most commonly adenosarcoma, and a common clinical feature is vaginal bleeding.³⁵ It is unknown whether preventative hysterectomy will reduce the incidence of mammary tumors, or should be considered for prevention of uterine neoplasia, as hedgehogs are prone to neoplasia of many other organ systems as well.

The anatomy of the genital system of swine is extensively described in the literature. The practitioner must keep in mind that the reproductive tract of the female pig is located more caudally than in dogs, and that the ovarian ligament and the uterus itself are more friable than in carnivores.^{36,37}

Orchiectomy in pigs is recommended to prevent development of offensive odors and aggressive behavior, typically occurring at puberty, which is typically at 3.5–4 months of age.³⁸ Surgical technique is pre-scrotal, as performed in dogs. It is not known if potbellied pigs have the same predisposition, but because the domestic pig is genetically predisposed to inguinal hernia, it may be advisable to suture the external inguinal ring.^{36,37}

Ovariohysterectomy is performed to prevent aggressive behavior in the sow. When surgery is performed prior to puberty, the uterus is much smaller but less accessible. After puberty, however, a large amount of fat can surround the ovaries and the uterine horns, making surgery more challenging.^{36,37}

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Anatomy and Physiology of the Gastrointestinal System of the Ferret and Selected Exotic Carnivores

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Abstract: The anatomy and physiology of the ferret is different than cats or dogs. Gastrointestinal disease has usually manifested by diarrhea, weight loss, and anorexia. The role of *Helicobacter mustelae* has been studied as a model for gastrointestinal disease in other species. The hedgehog and sugar glider are essentially insectivore/omnivores but have the simple stomach and intestinal tract more similar to those of carnivores. The Virginia opossum's gastrointestinal tract has served as a model for omnivorous marsupials. Gastrointestinal disease in the insectivore/omnivores is one of the most common reasons for presentation in the exotic pet practice of these species.

Introduction

Several of our common non-traditional companion pets have a “carnivore” type of gastrointestinal tract, although the actual diet may consist largely of insects rather than meat. The gastrointestinal tract of the domestic ferret, *Mustela putorius furo*, has been studied extensively as a model for several human gastrointestinal tract diseases, including spontaneous gastric and duodenal ulcers, gastro-esophageal reflux, gastric carcinoma and lymphoma, the lack of acid mucosubstances similar to humans, and *Helicobacter mustelae* infection. Hedgehogs (*Atelerix albiventris*) are classified as insectivores, but most are omnivorous/carnivorous and opportunistic, including consumption of carrion. Sugar gliders (*Petaurus breviceps*) have a simple gastrointestinal tract with the exception of a large cecum, which is used for gum fermentation.

The Ferret

The ferret has a short transit time, 148–219 minutes when fed a meat-based diet. The digestive system is under vagal and sacral innervation. The tract is spontaneously active even under anesthesia. Motility can be moderated with atropine. The stomach spontaneously produces acids and proteolytic enzymes. Histamine and vagal stimulation provoke more secretions.¹

Gut closure for antibody absorption occurs in kits between 28 and 42 days of age. Ferrets can absorb beta carotene and convert it to retinoic acid. Carbohydrases and proteolytic activity take place distally in the jejunum rather than more proximally in the duodenum.¹

Stomach

The ferret has a simple stomach, similar in shape to that of the dog. There is prominent vasculature of the stomach as well as a prominent lymph node lying in the lesser curvature. It is innervated by parasympathetic fibers from the vagus nerve and sympathetic fibers via the celiacomesenteric plexus. The stomach has considerable storage capacity (100 ml of milk in 10 minutes in an adult). Some 80% of a meal is stored in the proximal stomach.¹

The lower esophageal sphincter (LES) and the mechanisms of gastro-esophageal reflux in the ferret are being used as an animal model.^{2,3} Transient LES relaxation is the mechanism and is unassociated with swallowing in the ferret, just as in the human.⁴ Gastric infusions of glucose, lipid, and gas are all effective in provoking gastro-esophageal reflux in the ferret. Lipid and glucose stimulate acid secretion.⁴ The fundus of the stomach and the LES are coinnervated by vagal preganglionic motor neurons as these sections work in tandem: the LES must relax to accommodate food during ingestion or preceding emesis. The antrum of the stomach provides mixing and propulsion of contents for gastric emptying and are innervated by neurons responding to differing neurotransmitters.⁵⁻⁹ The ferret is used as an emetic model to test anti-emetics. Serotonin successfully blocks cisplatin at 10 mg/kg emesis.¹⁰ An anti-emetic pursued in the ferret model has been delta9-tetrahydrocannabinol (D⁹-THC), the cannabinoid that is anti-emetic in humans. Ferrets have the Cannabinoid1 receptor in the dorsal motor vagal nucleus, with cell bodies in the area postrema, nucleus tractus solitarius, and nodose ganglion. This receptor mediates the anti-emetic action of cannabinoids.^{11,12} The cannabinoid D⁹-THC was found to cause gastro-esophageal reflux due to the relaxation of the lower esophageal sphincter. This effect may have implications in the treatment of gastro-esophageal reflux and other upper gastrointestinal disorders.¹²

The ferret stomach also secretes acid in response to histamine, pentagastrin, and calcium. There is a low concentration of free histamine in the stomach. The ferret lacks the histamine-forming enzyme (L-histidine decarboxylase) in the stomach, although histamine-destroying activity is present. Histamine also stimulates secretion of proteolytic enzymes. Histamine H₂ receptor antagonists abolish the acid secretion response to exogenous histamine or exogenous stimulation with pentagastrin. Atropine only reduces acid secretion by 30%.¹

Gastrin is secreted in the gastric antrum and duodenum. Hypoglycemia induced by insulin produces a sustained stimulation of acid secretion.¹ This is particularly relevant to ferrets with insulinomas: therapy needs to include medications that decrease acid secretion.

Intestine

The ferret intestine consists of 3 sections. Villi and goblet cells are present in all sections. The duodenum is the proximal segment. The duodenum is innervated by vagal preganglionic parasympathic neurons originating in the dorsal motor nucleus of the vagal nerve in the brainstem.¹³ The major duodenal papilla contains the common opening for the bile and pancreatic ducts. This is located about 3 cm from the pylorus. The minor papilla may be absent. Brunner's glands are present in the submucosa of duodenum proximal to bile duct. The glands produce only neutral mucosubstances, as in humans.¹

The jejunal and ileal segments cannot be distinguished and may be referred to as the "jejunoileum" that ends at the ascending colon. The small intestine is innervated by the vagus nerve and the sympathetic trunks arise from the celiac and cranial mesenteric plexus.¹

Motility is affected by the hormones secretin, PZ-CCK (pancreozymin-cholecystokinin), an unidentified vasoconstrictor, VIP, and substance P. VIP inhibits jejunal motor activity due to vagal stimulation while substance P excites activity. Both increase water secretion by jejunal epithelium. The muscular layer has a higher concentration of these hormones than the epithelium. Jejunal motility mediated by hormones is not blocked by atropine. 5-hydroxytryptamine (5-HT₃) and synthetic serotonin receptor agonists induce large contraction and defecation. The basal colonic motility pattern was not changed, and the large contractions can be blocked with a receptor antagonist. The implications of this model are for testing pharmaceuticals for constipation without undesired changes in gut motility patterns.¹⁴ Cervical (mechanical) vagus stimulation will affect motility. This has significant implications for the clinician who may manipulate the neck and thorax during intubation and inadvertently stimulate the vagus nerve and intestinal motility at the beginning of surgery.

The large intestine is composed of the colon and rectum. There is no cecum and no ileocolic junction. The junction is inferred by the presence of the anastomoses of the jejunal artery with the ileocolic artery. The colon consists of the ascending, transverse, and descending colon, with the largest being the descending. The colon is innervated by autonomic fibers from the vagus, cranial, and caudal mesenteric plexus.¹

There are tubular glands and goblet cells in the colon. These secrete sulfated mucosubstances. The motility of the colon resembles that of a dog ileum. Motility is vagus-dependent and mediated by cholinergic and noncholinergic fibers. Sacral innervation is excitatory. Retroperistalsis begins in the colon which may be the genesis of vomiting in the ferret.¹

Exocrine pancreas and biliary system

The exocrine pancreas and biliary system are also under vagal stimulation. There is a trophic relationship with capillary connections between the islets and the exocrine pancreatic tissue. A bile salt-dependent lipase is produced. The adult jill mammary tissue is high in this enzyme. Ferret milk has activity 10–20 times higher than human milk. If lipase elevations are present in the blood, consider pancreatic inflammation or disease.¹

The gallbladder contracts in response to cholecystokinin. Cholecystokinin is found throughout the gastrointestinal tract. This contraction inhibits gastric emptying and stimulates small intestine and colonic motility. The contractile response directly effects smooth muscles and/or neurons, which furthers intestinal motility.¹

Diseases of the Gastrointestinal Tract

Ferrets are used as animal models for emesis as they have a low tolerance for many chemicals and the vagal reflex is strong, with a simple stomach for propulsion. They are also used as models of *Helicobacter* gastritis, gastric carcinoma, pyloric and intestinal ulceration, inflammatory bowel disease, colitis, and gastrointestinal neoplasia. As *Helicobacter mustelae* is endemic in most of the commercially-produced pet ferrets, the ferret is set up for gastrointestinal disease from this etiologic agent alone. In addition, ferrets are prone to stress-induced gastrointestinal ulcers with hemorrhage and hypermotility. All of the above conditions may result in varying degrees of diarrhea: acute, chronic or intermittent; with or without visible hemorrhage, and with or without secondary bacterial or viral involvement. Table 1 lists gastrointestinal diseases of ferrets. Table 2 lists treatments published for *H mustelae*. Table 3 lists adjunctive therapies for gastroenteritis. A detailed history is needed to determine a course of action. This includes volume, color, consistency, frequency, and duration the clients have seen diarrhea. The source of the ferret, including breeder, may play a significant role in the priority of etiologies. Other information should include how long the ferret has been in the household, whether other ferrets and pets are present, as well as human family members—are any symptomatic with diarrhea? The type of litter used and sanitation program may be of importance. Diet including treats fed, toys available, and incidental environmental information (such as access to showers or sinks) should be recorded. Ferrets are notorious for licking soaps, chewing on stuffing dug out of furniture, and chewing shoes and shoe liners, and even perfume or shampoo bottles. Correlation with activity should also be figured into the evaluation. For example, does it occur round the clock or is it only after intense playtime? Does it only occur after the vacuum cleaner is run near the ferret's cage? Tenesmus or vocalization, or accompanying borborygmus or flatulence should be recorded. Teeth grinding may indicate pain, and anorexia may be a sequellae to the pain. A full dental examination should also be done as severe dental disease may be part of the clinical presentation.

A physical examination of the ferret should be thorough and include auscultation of the abdomen and examination of the anal area. A fecal examination should include floatation and direct smear of fresh material, as well as

staining to look at bacterial levels and presence of blood cells. A rectal culture and cytology may be indicated. Blood work should include lipase, which has been shown to be elevated in many cases of inflammatory bowel disease. Anemia is not an uncommon finding and may indicate gastrointestinal hemorrhage. Fecal occult blood can be tested; however, the ferret should be placed on a diet that does not contain meat for at least 24–36 hours prior to testing as normal ferret foods contain meat and blood products that result in positive test results. Radiographs including a contrast study are frequently useful. Ultrasonography can be used to look at motility of the stomach, including the pyloric area. Ultrasonography of the abdomen may also find other pathologic conditions. Endoscopy is useful for examination of the stomach, pylorus and colon. Endoscopy can also be used abdominally. Biopsies can be taken endoscopically or via laparotomy. A PCR test for gastric *Helicobacter mustelae* is available from Research Associates Laboratory, R.A.L., Inc, Dallas, TX, USA (www.vetdna.com). The author uses a sterile length of infusion set tubing measured for the particular ferret. Using a sterile hemostat, the culturette swab can be inserted into the tubing and pushed in until it is firmly seated. The tube is then passed into the sedated ferret's stomach and the stomach manually massaged around the culturette.¹⁵⁻¹⁸

Inflammatory bowel disease (usually lymphoplasmic) probably has multiple causes and may have an underlying genetic component, particularly considering its progression to neoplasia in many ferrets. Food allergies have yet to be explored other than some clinical trials in some cases to alternate protein feline diets. The grain carbohydrates used in commercial food formulations may be a problem: allergy testing as done in dogs and cats should be pursued. Immunomodulating medications such as prednisone (prednisone USP, Roxane Laboratories, Columbus, OH, USA), azathioprine (Imuran, GlaxoSmithKline, Research Triangle Park, NC, USA), and metronidazole (Metronidazole USP, Watson Laboratories, Inc, Corona, CA, USA) have been used based on therapies for other species. Table 3 lists dosages.

Although *H mustelae* is found in most adult ferrets, it is not always implicated in clinical gastritis or ulcers. It does play a role as an opportunist and exacerbates ulceration of the stomach and intestines. It appears to play a role in the development of gastric neoplasia, and it may play a role in inflammatory bowel disease and colitis. As *H mustelae* is a model for human *H pylori* infection, further improvements in clinical implications, diagnosis, and treatment will be forthcoming.

In summary, the ferret gastrointestinal tract is designed to be excitatory, have rapid motility, and be highly secretory. Exogenous stressors and chemical and neurologic stimulations further increase motility and secretion. During any hypoglycemic episode, the clinician needs to be aware of the pancreatic and gastric physiology and treat the nausea and secretions in addition to the hypoglycemia. It may also be prudent to administer medication to inhibit acid secretions prior to surgeries and in any stressed, ill ferrets.

Table 1. Etiologies of gastrointestinal disease. Diarrhea is most common clinical sign in ferrets.¹⁵⁻¹⁸

Disease	Diagnosis	Treatment	Age grouping
Bacterial, primary or secondary	Culture and Sensitivity	Appropriate antimicrobial therapy, adjunctive	Any. #2 – usually younger
1. <i>Helicobacter mustelae</i>	1. <i>Helicobacter</i> PCR, histopathology		
2. Lawsoni/Desulfovibrio	2. Biopsy and Histopathology		
3. <i>Campylobacter jejuni</i>	3. Culture difficult, human labs		
Bacterial, uncommon Mycobacteriosis	Histopathology PCR	Zoonotic risks?	> 2 years
Viral:	Coronavirus isolation PCR	Supportive care	#1. Any, usually following stressful event, ferret gathering
1. Ferret Enteric Coronavirus (FEVC)			#2. baby, weanlings
2. Rotavirus	PCR		#3. Ferrets who did not complete their baby series of vax
3. Canine Distemper Virus	PCR		
Coccidiosis	Fecal floatation, direct smear	Anti-coccidial drugs	Usually < 1 year
Giardiasis			
Inflammatory bowel disease	Histopathology	Some suggest anti-inflammatory drugs; caution in ferrets with possible <i>Helicobacter</i>	Usually > 2 years, history of intermittent diarrhea
Gastrointestinal neoplasia	Histopathology	Surgical excision Chemotherapy	Usually > 3 years
Foreign body ingestion	PE, radiographs, exploratory surgery	Surgery	Usually < 2 years
Stress-medical or psychological	History Detection of underlying medical condition	Correction of underlying medical disorder or psychological stress	Any
Idiopathic megaesophagus	Radiology	Unrewarding	Any

Table 2. Treatment regimens for *Helicobacter mustelae* based on clinical trials.^{17,18}

Effective combinations	Unsuccessful medications
Amoxicillin (30 mg/kg q8h X 21–28d; Metronidazole (20 mg/kg q8h X 21–28d; bismuth subsalicylate (7.5 mg/kg q8h X 21– 28d)	Amoxicillin alone. May not be effective at q12h even in combinations Metronidazole alone. May not be effective with Amoxi if given at 12-h intervals Chloramphenicol alone Enrofloxacin alone
Enrofloxacin (8.5 mg/kg/day divided q12h) X 14d; bismuth subcitrate* (12 mg/kg divided q12h) X 14d	Tetracycline Bismuth subsalicylate alone Omeprazole and amoxicillin
Clarithromycin (12.5 mg/kg q12h X 14d Ranitidine bismuth citrate*(24 mg/kg q12h X 14d)	Omeprazole alone
Clarithromycin (12.5 mg/kg q8h X 14d; Ranitidine bismuth citrate* (24 mg/kg q8h X 14d) This is also a published dosage.	

* not commercially available in the US, can be compounded

Sources:

Amoxicillin: Amoxil, GlaxoSmithKline, Research Triangle Park, NC, USA

Metronidazole USP: Watson Laboratories, Inc, Corona, CA, USA

Bismuth subsalicylate: Pepto-Bismol, Proctor & Gamble, Cincinnati, OH, USA

Enrofloxacin: Baytril, Bayer, West Haven, CT, USA

Clarithromycin: Biaxin, Abbott Laboratories, Abbott Park, IL, USA

Omeprazole: Prilosec, AstraZeneca Pharmaceuticals LP, Wilmington, DE, USA

Table 3. Medications used as adjunctive therapy of gastroenteritis.^{17,18}

Drug	Dosage	Comments
Azathioprine	0.9 mg/kg PO q24–72h	Used in IBD if other tx ineffective. Immunosuppressive
Famotidine	0.25-0.5 mg/kg PO, IM, IV q24h	Histamine antagonist; available over the counter; decreases gastric acid; provides pain relief. Oral OTC can be crushed, mixed with flavor gel, palatable
Metronidazole	50 mg/kg PO q24h	IBD, some immunosuppressive effects
Omeprazole	0.7 mg/kg PO q24h	Protein pump inhibitor, short-term usage only
Prednisone	1-2.5 mg/kg PO q24h	Anti-inflammatory. Used in eosinophilic gastroenteritis, IBD, palliative in LSA
Ranitidine USP	24 mg/kg PO q8h X 14d	Histamine inhibitor; decreases gastric acid; provides pain relief. Tablet form available over the counter, must be compounded as human formulation unpalatable
Sucralfate	25 mg/kg PO q8h	Coats esophageal and gastric mucosa, local effect only. Syrup palatable

Sources:

Azathioprine: Imuran, GlaxoSmithKline, Research Triangle Park, NC, USA

Famotidine: Famotidine tablets USP, Zenith Goldline Pharmaceuticals, Inc, Miami, FL, USA

Metronidazole: Metronidazole USP, Watson Laboratories, Inc, Corona, CA, USA

Omeprazole: Prilosec, AstraZeneca Pharmaceuticals LP, Wilmington, DE, USA

Prednisone: Prednisone USP, Roxane Laboratories, Columbus, OH, USA

Ranitidine USP: Ranitidine Tablet USP, Perrigo Co, Allegan, MI, USA

Sucralfate: Carafate Aventis Pharmaceuticals, Inc, Kansas City, MO, USA

The Hedgehog

The African pygmy hedgehog's (*Atelerix albiventris*) gastrointestinal system is similar to most carnivore gastrointestinal tracts. It has a simple stomach, and a smooth non-complex colon. It does not have a cecum and has a poorly defined ileo-colonic junction. Gut transit time in one study was reported as 12–16 hours.¹⁹

Disease etiologies and clinical manifestations of disease are similar to those of other carnivores. Treatment with oral medications may be more difficult in those that are not used to having the owner manipulate its head and mouth. *Salmonella* serotype Tilene has been identified from pet hedgehogs in the United States. Table 4 lists diseases, diagnoses, and therapies of gastrointestinal disease in pet hedgehogs. A complete workup with hematology, serum chemistries, imaging, and fecal parasite examination are recommended for any hedgehog presenting with gastrointestinal disease. Diagnostics listed in Table 4 are specific to those etiologies.

Table 4. Gastrointestinal diseases of pet hedgehogs.²⁰

Etiology	Signs	Diagnostics	Treatments
<i>Salmonella</i> sp, other bacteria	Clinically asymptomatic or diarrhea, weight loss, anorexia, dehydration, lethargy, death	Fecal culture and sensitivity, <i>Salmonella</i> special media	<i>Salmonella</i> : supportive care primarily, discuss zoonotic potential. Other bacterial: per sensitivity; supportive care
Candidiasis, alimentary	Weight loss, depression, blood in stool	Fecal cytology and culture and sensitivity	Appropriate antifungal per sensitivity, supportive care, decrease sugars in diet?
Cryptosporidiosis of ileum, jejunum, colon	Severe enteritis, wasting, death	Fecal cytology, biopsy, histology	No effective treatment.
Endoparasites	Unthriftiness, diarrhea	Fecal floatation, wetmount, history of exposure to wild-caught hedgehogs	Anthelmintics per parasite identified. Not seen much anymore with captive reared
Obstructions (foreign bodies)	Vomiting, diarrhea, non-specific weight loss, abdominal pain, lethargy, acute collapse	Radiology, contrast needed sometimes, laparotomy, exploratory	Surgical enterotomy or gastrotomy as indicated. Analgesics
Non-specific enteritis, gastrointestinal inflammation, ulcerations	Tenesmus, diarrhea, melena or frank blood, anorexia, weight loss, lethargy, dehydration	Radiology, contrast, ultrasonography, laparotomy, biopsy	Non-specific, antibiotics, supportive, antiinflammatories, gastrointestinal protectives
Diet-induced	Diarrhea	History of treat foods, milk, diet changes	Discontinue offending foods, stabilize diet, symptomatic antidiarrheals
Neoplasia	Diarrhea, weight loss, unthriftiness, non-specific pain, lethargy	Imaging, laparotomy with biopsy	Palliative or can try neoplasia therapies as in felids for specific diagnosis

The Sugar Glider and Virginia Opossum

The sugar glider is considered an omnivore, although its gastrointestinal morphology and dentition share features with carnivorous mammals. Teeth have limited shearing action and can only compress insects, not break them down into small pieces like a true carnivore. They can extract the hemolymph and soft tissues of insects through compression, then discard the exoskeleton. An interesting functional difference between eutherians and marsupials concern the Brunner's glands of the duodenum. In eutherians, Brunner's glands are usually confined to the submucosa and the ducts empty into intestinal crypts of Lieberkuhn. In American marsupials, they drain into large mucosal depressions that are surrounded by more glands. In Australian marsupials, the ducts empty directly into the duodenal lumen. No Australian marsupial carnivore has a cecum. The sugar glider has a well-developed cecum, needed for the fermentation of ingested gums and a short colon. Otherwise, their gastrointestinal tract is similar to the Virginia opossum. There are well developed salivary glands that include large mandibular and smaller parotid and sublingual glands. The distal esophagus mucosa has raised transverse rugae. The stomach is simple and rather globular in form. The gastric mucosa is mostly fundic glands. There are some pyloric glands, and there is a narrow zone of cardiac glands at the cardiac sphincter. Enterendocrine cells, along with endocrine cells in the pancreas control digestive functions. Secretions include gastric acid, gastrin, gastric-inhibitory polypeptide, secretin, cholecystokinin, and pancreaticozym. ²¹

The small intestine is about 3 times the length of the large intestine. The mesenteric attachments to the colon are loose. Just distal to the pylorus is the "collar" of Brunner's glands in the submucosa. These secrete alkaline fluid and mucus. ²¹

Gastrointestinal disease in omnivorous/insectivorous marsupials clinically presents most frequently with diarrhea and some degree of anorexia, weight loss, dehydration, lethargy, and collapse. Vomiting may be seen in predominantly upper gastrointestinal illnesses. Bacterial, protozoal, and toxic etiologies have been found. Malnutrition or dietary changes may also play a role. Diagnostics and treatments follow regimens similar to that of other essentially carnivorous mammals.

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Practical Exotic Mammal Vaccine Strategies

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Session #126

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Abstract: Few guidelines exist for vaccination of exotic pet mammals. Practitioners must have a clear understanding of individual disease susceptibility, product availability, and consider vaccine risk vs. benefit.

Introduction

Vaccination against infectious disease is a proven preventative therapy in domestic species. Vaccination is also practiced in non-traditional and exotic pet species, at the practitioner's discretion and without benefit of trials demonstrating safety and efficacy.

The goal of vaccination of exotic species is to derive the benefit of protection from disease. Disadvantages of vaccination include unproven efficacy, lack of trials demonstrating safety, and the possibility of vaccine-induced disease. A number of commercial vaccine products are available for use in veterinary medicine, including single or multiple agent vaccines, killed or deactivated vaccines, and recombinant subunit vaccines containing DNA segments.

Legalities of Vaccine Use in Exotic Pet Medicine

Vaccines are approved for use in only one common exotic pet species, the ferret.

Vaccines are regulated by the Animal Plant and Health Inspection Service-United States Department of Agriculture (APHIS-USDA), which "regulates veterinary biologics (vaccines, bacterins, antisera, diagnostic kits, and other products of biologic origin) to ensure that the veterinary biologics available for the diagnosis, prevention and treatment of animal diseases are pure, safe, potent and effective."¹

APHIS-USDA does not regulate veterinary use of these products; therefore, veterinarians can legally use vaccines in a discretionary manner. This does not even fall under the heading "off-label" usage, as this term specifically applies to animal drugs, which are regulated by the Food and Drug Administration's Center for Veterinary Medicine (FDA-CVM).²

The Centers for Disease Control Morbidity and Mortality Weekly Report (CDC-MMMR) publishes the Compendium of Animal Rabies Prevention and Control, 2005, prepared by the National Association of State Public Health Veterinarians. The bulletin gives up-to-date recommendations for prevention and control of rabies virus. The only statement referring to use of rabies vaccine in exotic animals reads, "No parenteral rabies vaccines are licensed for use in wild animals or hybrids. Wild animals or hybrids should not be kept as pets."³

The American Veterinary Medical Association (AVMA) does not specifically recommend against vaccination of exotic pet mammals, but neither does it endorse it. The official AVMA position can be summed up in

recommendations for the use of rabies vaccine in wildlife and hybrid animals: “The safety and efficacy of parenteral rabies vaccination of wildlife and hybrids have not been established, and no rabies vaccines are licensed for these animals.” AVMA goes on to encourage zoos and research institutions to establish rabies vaccination programs in order to protect valuable animals, with the caution that vaccination must not “replace appropriate public health activities that protect humans.”⁴

Liability may be a concern when using a vaccine on a non-approved species. In a position paper on the vaccination of wolf hybrids, AVMA Professional Liability Insurance Trust (PLIT) recommends first checking on the legal status of the animal in question. If the animal were legal as a pet, the trust would consider vaccination of the animal as a “discretionary use of a biologic by the veterinarian, an act which the policy does not specifically exclude.” However, if a veterinarian vaccinates an animal kept illegally, vaccination is considered an illegal act, and likely not covered under the AVMA professional liability act.⁵

AVMA-PLIT specifically recommends the following when considering vaccination of a non-approved species: (Linda Ellis, DVM, Trust Representative, AVMA-PLIT, March 2006)

1. Confirm that possession of the animal is legal per state, community, and other applicable laws.
2. Obtain informed consent from the owner, and note this consent in the medical record. Informed consent assures that the owner understands there are no safety and efficacy trials associated with the use of the vaccine in their pet.
3. Use products and vaccination procedures with some “track record” of success, for example vaccines and protocols used by zoos, even if use is non-published or anecdotal.

Using products with some history of success allows support of vaccination as following the current “standard of care.” The trust representative cautioned against being the first to try a new product in an unapproved species as successful legal defense in the case of death or adverse effect will be much more difficult.

Determining Vaccination Protocols

The principles of determining what vaccines are beneficial in any single exotic species include:

1. Determination of individual susceptibility of the species in question for the diseases for which vaccines are available
2. Determination of the likelihood of that particular animal encountering a particular disease
3. Determination of potential products that might be useful
4. Acquisition of information regarding reported or anecdotal benefits and dangers of the use of each particular vaccine in a particular species
5. Determination of zoonotic potential of the particular disease

Determining Vaccine Protocols: Individual Susceptibility and Likelihood of Encountering Disease

Most information on the susceptibility of non-traditional pet species to infectious diseases comes from studies in wildlife, and is generally reported in wildlife journal and textbooks. Information on susceptibility and natural transmission can be useful to determine the probability a specific animal will encounter and become sick from a specific disease. Outbreaks of disease in exotic mammals kept as pets are occasionally reported in the literature as well. Table 1 is a summary of domestic and wildlife species and their reported susceptibility to viral diseases for which commercial vaccines are available (Table 1). The author was unable to find information on feline herpesvirus in exotic mammals.

Canine Distemper Virus (CDV)

All members of the taxon Carnivora are thought to be susceptible to CDV. This includes raccoons, foxes, skunks, ferrets, coatimundi, kinkajou, and certain exotic felids as well.⁶ CDV outbreaks have been documented to occur in free-living raccoons, and varying levels of morbidity and mortality are linked to variable virulence of the CDV strain.⁷ The striped skunk is thought to be moderately resistant to CDV,⁶ but the author is aware of several confirmed cases.

Rabies

All mammals are considered susceptible to rabies virus infection.⁵ Raccoon-variant rabies virus was confirmed in 1 guinea pig and 7 pet rabbits in New York State, necessitating post exposure treatment in several adults and children. 4 animals were exposed to raccoons, one exposed to a skunk, and exposure of the 3 remaining animals was unknown.⁷ In the United States, significant reservoirs appear to be bats, skunks, raccoons, coyotes, and foxes.⁵

Parvovirus

The susceptibility of exotic animals to canine parvovirus (CPV) and/or feline parvovirus (FPV) varies.⁵ CPV is mostly a disease of canids, while FPV is reported in felids, raccoons, and mink. Skunks appear resistant to both feline and canine parvovirus. Raccoons, however, are susceptible to disease produced by FPV but not CPV. (Note: the most important infectious diseases of raccoons appear to be rabies virus, CDV, and FPV.⁵ Numerous studies of free-living wildlife indicate antibodies for CPV are present in species such as foxes and martens.^{8,9} While mink are susceptible to FPV, ferrets are not, except when inoculated in utero or within several days of birth.⁵

Infectious canine hepatitis

This disease was first described in the silver fox, and many members of Canidae, Mustelidae and Ursidae family are susceptible, including skunks, raccoons, mink, ferrets, wolves, and bears.⁵

Canine coronavirus

Infection of exotic mammals is considered rare, but possible. There are many species-specific strains of coronavirus, and each appears limited only to closely related species only, for example canine coronavirus between dogs and cats, and porcine coronavirus from pigs, to dogs to foxes.⁵

Table 1. Susceptibility of domestic and exotic mammals to selected viral diseases for which commercial vaccines are readily available in the United States. From: Williams S, Barker IK. *Infectious Diseases of Wild Mammals*. Ames, IA: Blackwell; 2001, unless otherwise indicated.

Disease	Viral Class	Natural Infection	Reservoir Range in US	Transmission, Incubation	Zoonosis
Rabies	Rhabdovirus Lyssavirus	Carnivores Fennec fox Skunk Wild gerbils Wild rats Raccoon Coati Guinea pig ⁶ Rabbit	Skunk, raccoon, coyote, fox, bat	Bite, saliva 1–3 months, but could be days to several years	Yes
Canine Distemper CDV	Paramyxovirus Morbivirus	All Carnivora: Canidae Mustelidae, Procyonidae Hyaenidae Ursidae, Viverridae Felidae Marine mammals Peccary ²⁴	Raccoon Black Bear Coyote Wolves Fox	Close association with many secretions, aerosol; 1–2 weeks	No; Controversial connection with Paget's disease
Western Equine Encephalitis WEE	Arbovirus	Squirrel Opossum Mice Vole Wild rabbits	Birds Jackrabbit	Mosquito vector	Rare
Eastern Equine Encephalitis EEE	Arbovirus	Opossum Mice Rats Other rodents Monkey Bats	Birds	Mosquito vector	Rare
Feline Panleukopenia FPV	Parvovirus	Felidae Canidae, Procyonidae Mustelidae Suspected: Ursidae Viverridae	Felidae	Contact with feces and fecal contaminated environment	No
Canine Parvovirus CPV	Parvovirus	Canidae	Coyote, wolves	Same	No

Table 1 cont'd.

Disease	Viral Class	Natural Infection	Reservoir Range in US	Transmission, Incubation	Zoonosis
Infectious Canine Hepatitis CAV-1	Adenovirus	Canidae, Mustelidae, Ursidae, raccoon	Fox, wolves, coyote, skunk, raccoon, mink, ferret, bears	Direct contact, infected fomites	No
Feline Leukemia Virus (FELV)	Retrovirus	Domestic Felids, rare non-domestic felids: cougar leopard cheetah bobcat ¹⁰	Domestic felids	Excretions, secretions	No
Feline Immunodeficiency Virus (FIV)	Retrovirus	Domestic felids, rare in non-domestic felids: Puma, lion, cheetah, leopard	Domestic felids	Saliva-bite	No
Canine Coronavirus	Coronavirus	Rare in wildlife, but considered possible	Domestic canids	Upper respiratory or GI mucosal secretions	No
Feline Calicivirus	Calicivirus	Domestic felids, wild felids probably susceptible: cheetah, lion, tiger, panther, bobcat ⁹	Domestic felids	Direct contact, aerosol	No
Feline Infectious Peritonitis	Coronavirus	Domestic felines, many exotic felids			No

Feline Leukemia Virus (FeLV) and Feline Immunodeficiency Virus (FIV)

FeLV and FIV are predominantly a disease of domestic cats.⁵ However, rare cases have been reported in exotic felids, including a case of fatal FeLV in a captive bobcat.¹⁰ The source was presumed to be a domestic cat that served as a surrogate nurse.

Feline Calicivirus (FCV)

Feline Calicivirus is primarily a disease of domestic cats.⁵ Antibodies against FCV have been detected in wild bobcats in California.⁹

Feline Infectious Peritonitis (FIP)

FIP is emerging as a potential pathogen in exotic felids, and may be concern for endangered populations. Multiple surveys of wild and captive exotic felids demonstrated positive animals by one or more detection methods. Some wild felids had evidence of infection as well.^{11,12}

Eastern Equine Encephalitis (EEE) and Western Equine Encephalitis (WEE)

These viruses are not considered significant pathogens of exotic animals. Both viruses have been occasionally isolated from a number of wild mammals including squirrels and Virginia opossums. Experimental infection of several rodent species did not produce mortality.⁵

Bacterial Diseases

Leptospirosis

Leptospirosis appears to be a re-emerging infection in domestic dogs, and surveys in wildlife indicate the presence of one or more serovars in wild raccoons, skunk, and squirrels, but not in tested opossums. Results of this study suggested wildlife might be a source of infection in domestic dogs.¹³

All mammal species can be reservoirs of leptospirosis, which is transmitted directly via urine, or through contaminated surfaces. In most cases, the organism exists in a stable host-parasite relationship without evidence of clinical disease. However, disease can be severe to fatal. Multiple serovars exist, and have different levels of pathogenicity and likelihood of apparent infection in different hosts. For example, *L. gryppotyphosa* is maintained in raccoons, skunks, and rodents, *L. icterohaemorrhagiae* in rodents, and *L. pomona* in ungulates.⁵ Leptospirosis has potential zoonotic potential, including documentation of transmission from raccoon and rat to human. Most cases of Leptospirosis in humans are linked to exposure to contaminated water.¹⁴

Bordetella bronchiseptica

Bordetellosis is a disease problem in dogs, cats, rabbits, rats, monkeys, humans, pigs, and guinea pigs. In rabbits, *B. bronchiseptica* is primarily an opportunistic organism, often acting as a co-pathogen with another organism, for example, *Pasteurella multocida*. As the organism is commonly present but seldom causes disease in rabbits, attempts to eradicate the bacterium is seldom attempted.¹⁶

B bronchiseptica can be a significant cause of morbidity and mortality in guinea pigs, with younger pigs most severely affected. Older pigs are often inapparent carriers, and outbreaks are often related to stress. Most pigs will eventually develop immunity and clear the organisms.¹⁶ Most references make the assumption that interspecies transmission can occur.

Comments on Ferrets and CDV

Ferrets are often used as a model for distemper studies, as mortality in this species approaches 100%. They are apparently susceptible to several related strains, including 2 separate strains of lion morbillivirus.¹⁶ As ferrets with distemper often do not survive long enough to spread the disease to other ferrets, most ferret disease is likely due to exposure to sick dogs. Distemper in dogs appears to be mainly clustered in areas with high numbers of immigrant populations and unvaccinated pets, for example Tucson and Phoenix, Arizona, as well as shelters in large cities (Chicago, Illinois, and Dallas, Texas) (Rich Ford, oral communication, February 2006). However, there is a paucity of data on the current incidence of CDV in dogs, as this is not a reportable disease.

An informal survey of veterinary colleagues treating exotic pet revealed that confirmed CDV is uncommon in ferrets. Most reported only sporadic cases, averaging one case per 5–6 years. The respondent with the highest reported incidence (1–2 per year) practices in a CDV endemic area, with several confirmed cases of the disease in dogs per month.

Most reported cases of confirmed CDV seems to occur in stray animals brought into animal shelters, presumably in contact with dogs.

An exotic animal pathology services reported about 5 suspected or confirmed cases per year (Michael Garner, Northwest ZooPath, oral communication, February 2006).

Another exotic animal pathologist reported a cluster of suggestive cases in 1998, all coming from a single retail source that also sold large numbers of puppies (D. Reavill, Zoo/Exotic Pathology Service, oral communication, February 2006).

Determining Vaccine Protocols: Finding Products that Might be Useful, and Information Regarding Use of these Products in Pet Exotic Mammals

A number of manufacturers produce vaccines for domestic animals. Only 3 are licensed for use in an exotic pet mammal, the ferret (Table 2). Adverse reactions to vaccination of exotic species occur, and are mostly anecdotally reported. An example of an exception is a report on morbidity and mortality associated with the use of live attenuated CDV vaccine in mink.¹⁸ Others include reports of mortality from the use of modified live CDV vaccines in ferrets, fennec foxes, and kinkajous.⁶ There are even fewer reports of limited vaccine challenge trials, with the exception of the ferret. Since most anecdotal reports of vaccine-induced illness are related to the use of live attenuated vaccine products, most vaccine protocols suggest use of killed or DNA subunit products in exotic species.

Table 2. Vaccine products of potential use in exotic mammal species.

Product and Manufacturer	Vaccine Type	Approved Species
Purevax Merial	Modified live canary pox vector with DNA segment of CDV	Ferret
Imrab 3 Rhône-Mérieux	Killed rabies virus	Dog, cat, ferret, horse, cattle, sheep
Fervac United Vaccine	Modified live CDV	Ferret
Felovax Fort Dodge	Killed feline panleukopenia feline herpes virus and calicivirus	Cat
Leptovax Fort Dodge	Modified live <i>L. grippotyphosa</i> , <i>L. pomona</i> , <i>L. icterohaemorrhagiae</i> , <i>L. canicola</i>	Dog
Fel-O-Vax Lv-K Fort Dodge	Killed Feline Leukemia Virus	Cat

The American Zoo and Aquarium Association is creating standardized husbandry guidelines for multiple species, and information from these guidelines can be useful to practitioners dealing with these species kept as pets. At this time, husbandry guideline drafts have been proposed for a number of mammalian and avian species, with the goal to have all zoo species covered in the coming years. Access to husbandry guidelines requires membership, which is inexpensive and worthwhile for veterinarians treating a significant number of exotic pets.¹⁹

An example includes recommendation for vaccination taken from the Felid Taxon Advisory Group (TAG) Husbandry Manual for Small Felids, which recommends vaccination of valuable exotic felids with 1 ml of Fel-o-vax (Fort Dodge Laboratories Inc, Fort Dodge, IA, USA). Cubs are vaccinated once every 2 weeks from 8–16 weeks of age, or a single vaccine for adult animals.¹⁹ Also recommended in rabies endemic areas is vaccination against rabies with Imrab (Rhône-Mérieux, Inc, Athens GA, USA). The TAG does not recommend vaccination against FeLV or any other feline disease, but suggests vaccine against Leptospirosis in endemic areas.¹⁹ Similar recommendations are being developed for other species.

Some practitioners advocate vaccination of guinea pigs against *B. bronchiseptica*. Many commercial vaccines, including *B. pertussis* vaccine for humans, and commercial porcine and canine vaccines have been shown to afford protection due to the close relationship among strains of *B. bronchiseptica* and substantial antigenic cross-reactivity. In most cases vaccination prevented disease but did not completely eliminate the organism from the respiratory tract.^{20,21} In the author's experience, most cultures of guinea pigs with respiratory disease reveal a wide range of organisms, and only occasionally *B. bronchiseptica*. Practitioners noting high morbidity and mortality due to *B. bronchiseptica* might consider vaccination of at-risk guinea pigs.

Commercial ferret distemper vaccines have been tested for safety and efficacy. Commercial vaccines appear protective against a number of related strains, including 2 strains of lion CDV.¹⁶ Reaction in ferrets after administration of vaccines is high. In one study comparing vaccine reaction rates in 143 ferrets after administration of a modified live avian cell culture canine distemper virus vaccine alone, an inactivated rabies vaccine alone or

both together were 5.9%, 5.6%, and 5.6%.²² Another study of 3578 animals indicated a much lower vaccine reaction rate. Rates were 0.51% for rabies vaccine administered alone, 1.0% for one of either approved distemper vaccine for ferrets alone, and 0.85% for both products administered simultaneously.²³ It is unclear why reaction rates were so different in these 2 studies.

Zoonosis

Occasionally vaccination decisions are made with consideration of the zoonotic potential of the disease in question, in particular vaccination against rabies virus. While all mammals are susceptible, probability of exposure to rabies is minimal in many exotic mammals caged and maintained indoors.

Of the diseases mentioned in this paper, rabies virus, EEE, and WEE are considered by CDC to be reportable.³

Future of Vaccinations in Exotic Mammals

Among the most valuable advances for exotic mammal vaccines would be successful safety and efficacy trials in these species, which is unfortunately unlikely to happen due to the lower economic value of sales of vaccines for unusual species. Vaccination trials in endangered species may involve measurement of antibody titers, but are unlikely to involve challenge studies.

Measurement of post vaccination antibody titers may be useful in exotic mammals, and several reference laboratories offer measurement of titers for CDV, CPV, FPV, and other viral diseases. However, interpretation of test results is problematic in exotic mammal species.

Development of additional DNA subunit or killed vaccines may prove useful in the prevention of vaccine-induced disease. In January 2006, Dow AgroSciences announced registration for the first plant-made vaccines, where antigen DNA is inserted into plant cells, with no possibility of vaccine-induced disease or post-vaccine viral shedding.²⁵ It remains to be seen whether this technology may one day prove beneficial for exotic mammals.

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Practical Marsupial Medicine

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Session #130

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Abstract: There are a number of species of marsupials that are being kept as companion animals. These are the sugar glider (*Petaurus breviceps*), the South American short-tailed opossum (*Monodelphis domestica*), the Virginia opossum (*Didelphis virginiana*), and the wallabies (Tamar, *Macropus eugenii*; Bennett's, *Macropus rufogriseus rufogriseus*). Marsupials differ from placental mammals in many anatomical and physiological ways, but can be compared to other common companion animals for purposes of medical therapy. Appropriate diet and husbandry plays a large role in disease. The most common problems presented to the practitioner include metabolic bone disease, obesity, dental disease, urogenital tract and cloacal glandular infections, cardiac disease, and trauma.

Introduction

Companion marsupials commonly seen in exotic pet practice include the sugar glider (*Petaurus breviceps*), the South American short-tailed opossum (*Monodelphis domestica*), the Virginia opossum (*Didelphis virginiana*) and the wallabies (Tamar, *Macropus eugenii*; Bennett's, *Macropus rufogriseus rufogriseus*). The brush tail possum (*Trichosurus vulpecula*) is occasionally found as a pet, although the USDA banned them from importation from New Zealand due to the high infection rate with *Mycobacterium bovis*. However, a number are still found, although called "phalangiers" to escape confiscation. The practitioner is encouraged to search the literature and build a reference collection to adequately provide diet and husbandry information, medical and surgical therapy, and care.

General Characteristics of Marsupials

Marsupials get their name from the presence of the marsupial bones, or ossa marsupialia, which serve as attachment surfaces for several abdominal muscles. They rest on and articulate with, the pelvic and pubic bones. They generally are boot-shaped, flattened, and varied in size. They have been referred to as "Eupubic bones" and may be considered comparable to abdominal ribs in reptiles. Once thought to support the pouch, this has generally been found not to be true as they are present in males (no pouch) and are atrophied or absent in marsupial moles and the *Petaurus* species (the gliders).¹

The marsupium or pouch is found in a variety of degrees of enclosure. It is well developed and forward facing in the macropods (kangaroos and wallabies), backward facing in koalas and wombats, and absent in the South American short-tailed opossum, considered to be a more primitive marsupial. It develops from annular skin creasing around each teat (primal pouch), to a common marsupial wall surrounding all teats, to finally a closed marsupium.

The shoulder girdle of newborns consists of a continuous cartilaginous arc of primal elements found otherwise only in reptiles and egg-laying mammals. This provides adequate support for forelimbs and shoulders so that the newborn can make its way to the pouch. The most important role is played by the metacoracoid. Immediately

following birth, the arc breaks up, and the shoulder girdle assumes the usual association with the sternum as in adult marsupials and placental mammals. The metacoracoid becomes the coracoid process of the shoulder blade.

Marsupial coats are generally woolly. Forelimbs are often foreshortened with hindlimbs elongated, with the best examples exhibited in the macropods. In several families, the second and third toes of the hind feet have grown out into grooming claws. The first toe is always clawless (except in the shrew opossum and marsupial mole). Olfactory, tactile senses and hearing are well-developed; vision is poorly developed. The skull has palatal windows. Unique features of the endocrine system include the facts that adrenals of females are twice the size of male adrenals on the basis of mg per kg body weight. During lactation, this discrepancy increases because of an enlargement in the "X" zone of the cortex, and an increase in a testosterone-like steroid has been detected. Cortisol is the most abundant corticosteroid. The kidneys in the desert-adapted animals have enlarged medullas and an increased ability to concentrate urine. The cloaca is a common terminal opening for rectum, urinary ducts, and genital ducts. Metabolism of marsupials in general are considered to be about two-thirds that of eutherian (placental) mammals. Heart rates are usually about half the rate of that seen in equivalent-sized eutherians.²⁻⁴

The urogenital tract of marsupials is significantly different from that of eutherian mammals. In all marsupials the urinary ducts pass mesially to the genital ducts, and in all eutherians they pass laterally. This results in male eutherians having the vas deferens loops around the inside of the ureter to reach the testes, and in male marsupials this loop is absent. In female eutherians, the 2 oviducts fuse together in the midline to form a single vagina and uterus. In female marsupials, this fusion cannot occur because of the presence of the ureters. The 2 lateral vaginas become united anterior to the ureters, where a median vagina is formed. At parturition, a birth canal is formed in the connective tissue between the median vagina and the urogenital sinus, through which the fetus passes. In most marsupials, this birth canal is transient and reforms at each birth. In most kangaroos and wallabies, it becomes lined with epithelium and remains patent after the first birth.⁶

Temperature regulation

Marsupials are born without the ability to regulate body temperature. During the first half of pouch life, body temperature of the young will closely approximate ambient temperature if they are removed from the pouch. At about halfway through pouch life, young marsupials begin to regulate body temperature. This timing coincides with the start of thyroid function. Species from humid tropical climates such as some of the *Phalanger* species are not capable of compensating for evaporative water loss and cannot survive dry heat. Macropods exposed to high temperatures seek the shade of trees or cool caves. Most marsupials avoid activity in the heat of the day. Cloacal temperatures are lower than actual body temperature, therefore ear (tympanic) temperature readings are more likely accurate for core body temperature; however, ear temperature readings may be difficult to get in the very small marsupials. Studies done in the brush tail possum and rabbit that looked at chloramphenicol metabolism measured liver temperature and found that they were essentially equal and the pharmacokinetic/dynamic study showed that CHPC dosage was 50 mg/kg q12h for both.⁵

Metabolic rates of marsupials: impact on diet

Basal metabolic rates have been studied in a number of marsupial species.⁴ It has been found that despite a lower metabolic rate, marsupials can increase their metabolism in times of high rates of heat loss or reproductive needs. These adaptations allow energy reserves to last longer in adverse conditions, have lower food requirements, and have more environmental tolerance. So in actuality, marsupials can do more with less. In captivity, energy requirements are less than in the wild.⁴ Dietary-related disease is frequently seen and obesity is common. Appropriate diets and quantity must be stressed to the owners. Heterothermy is common in insectivorous animals, both marsupial and eutherian, because a constant supply of insects is unlikely in the wild. Because they cannot cache food like

granivores, they enter into a torpor to conserve energy. The Didelphids, Monodelphids, and Australian Petaurids and the Tarsipedidae (honey possum) can have torporous states lasting up to 11 hours. Sugar gliders have a basal metabolic rate similar to the macropods. Part of their endogenous nitrogen is retained and recycled to the digestive tract to increase protein availability. Sugar gliders have a larger cecum than most omnivores to ferment ingested gums. Herbivorous marsupials recycle urea and have resident flora to degrade and resynthesize protein. The bottom line for clinicians is that there is enough information available from captive and field studies of the major species of marsupials (metabolic rates, affects of food habits, activity levels) to develop appropriate diets. Micronutrient components still need to be studied in many; however, little should be left to guesswork, and diets should not be fed simply because the animal prefers certain food items. It is easy to over-feed captive marsupials.

Sugar Gliders (*Petaurus breviceps*)

The sugar glider (Marsupaialia, Phalangerioidea, Phalangeriae, Phalangerinae, *Petaurus breviceps*, 4 subspecies from New Guinea, 3 from Australia: *P.b.breviceps*, New South Wales, Victoria, Tasmania; *P.b. longicaudatus*, Queensland; *P.b. ariel*, Northern Territory) is native to New Guinea and Australia, with at least 7 recognized subspecies. The habitats are primarily open forests, either tropical or coastal forests, or dry inland sclerophyll tropical forest. They are nocturnal, arboreal, and nest in leaf-lined tree holes with up to 6 other adults and young. Predators include owls, feral cats, kookaburras, foxes, and goannas. The gliding membrane (patagium) extends from the fifth digit of forepaws to the ankles. Gliding distance can be up to 50 m. The tail is well-furred and weakly prehensile. The first and second digit of the hind feet are partially fused (syndactylous). The average awake body temperature is 32°C (89.6°F). Sugar gliders are quite vocal, with a whole series of alarm yaps and screams. The natural diet in the wet season (winter) is primarily gums of eucalypts and acacias with nectar from flowers of same trees. The rest of year they are mainly insectivorous. They have specialized incisors for gouging the bark of trees. The head/body length is 120–132 mm, tail length is 150–480 mm. Average adult weights vary for the different subspecies, with the larger subspecies ranging from 115–160 g for males, 95–135 g for females. In captivity, they will breed throughout year and produce 2 litters per year on average. The pouch contains 2 teats and 2 offspring are common. Gestation is brief, about 16 days, then the fetus migrates to the pouch. The joeys begin to leave the pouch at 70 days and are independent at 17 weeks, but may remain in parental nest.

Sexual maturity is reached at 8 months to 1 year of age for females, and usually at 12–14 months of age for the males. The female has the typical marsupial bilobed uterus with lateral vaginas and central birth canal. Males have a forked penis, and mid-ventral scrotum. Males also develop a scent gland on the forehead which they may also rub on the female's chest. Males also have scent glands on the chest, and anal glands. Both sexes scent mark territory. The female just urine marks. Her scent glands are within the pouch. She will secrete and increase marking to indicate breeding readiness to the male. Life span in the wild is usually only 4–5 years, but ages of up to 9 years have been recorded. In captivity, with optimum nectar/insectivore diet and husbandry, they may live 12–14 years. The maximum recorded lifespan is 14 years. One of the main things to remember about our pet population is that the sugar glider is an extremely social animal and should not be kept as a solitary animal. Sugar gliders become almost torporous during the day (their night) and can be extremely difficult to rouse. The same thing happens if they are too cold. Home temperatures are at the low end on their comfort zone. Supplemental heating is usually necessary for a healthy glider. The housing enclosure size minimum is 2 m wide by 2 m long and at least 1.8 m high.

The natural diet of sugar gliders includes the “sugary sap or gum” of the eucalypts in which small insects are also trapped and consumed (wattle or acacia gum tree which has a carbohydrate-rich sap), insects, arachnids, small vertebrates, and the nectar from blossoms of eucalypts, banksias, acacias, and several types of native apple.

Favorite types of trees are ones that the Australian's call "bloodwood" as the sap runs red, crystallizes, mixes with the decaying pulp of the tree, and attracts more termite and ant activity. Other types of trees have a yellowish sap, which leaves "manna," a deposit of white encrusting sugars left where it has flowered from a wound produced by sap-sucking insects, birds, squirrel gliders or possums in a tree trunk or branch. The glider has been observed to eat honeydew, an excess sugar secreted by sap-sucking insects. The name "sugar" glider does not relate to "sugar as in fruits," although the glider may "like" those foods. It also does not rely on nuts, grains, or seeds despite the books published by breeders and much information on the Internet. Australians keeping gliders in captivity put up outdoor lights to catch insects and moths for their gliders as the major portion of the diet, with an artificial nectar (either Leadbeater's Mix or one designed for honey-eating possums) as the other major portion, with only occasional small pieces of fruit as treats.

Diseases of sugar gliders

A number of disease problems are being seen in pet gliders with the greatest number being attributed to malnutrition, and its consequences including encephalomalacia, osteomalacia, cardiac failure, hind quarters paresis, paralysis, weakness, ataxia, myonecrosis, and cataracts. Also seen are injuries and fractures from trauma, pneumonia (chilling, malnutrition), diarrhea (various bacterial) or enteropathy (may be diet-related), and intestinal *Capillaria* species. Poor hair coat and dermatitis have been seen. Pouch infections are not uncommon, with bacterial and/or candida as causative agents. Obesity is seen in many overfed, underexercised, and malnourished gliders. *C. piliformis*, giardia and possibly cryptosporidia have been diagnosed. *Giardia* has been diagnosed as a suspected causative agent of chronic diarrhea. So far, treatment based on other carnivore species has not seemed to clear the organism. Pharmacology studies need to be performed using metronidazole, fenbendazole, and paromomycin, which have been efficacious in other species to clear the organism. A self-mutilation syndrome with CNS signs attributable to Baylisascaris, Toxoplasmosis, and, in one colony, Listeriosis, has been diagnosed. Another colony experienced what was most likely a pentastomid infestation: the adult parasite was found in the duodenum in both the adult and juvenile gliders (as young as 5 weeks after pouch emergence). Aberrant migration may be the cause of the CNS signs. Therapies and diagnostics for sugar gliders follows parameters used in other insectivores and carnivores. Clinically, the ferret dosage of medications seems to work per kilogram basis. The author has not encountered drug adverse or toxic reactions following ferret-based medication therapy. Clinicians need to continue to get diagnostic samples for blood, microbiology, cytology, parasitology, and histology samples to build more information about our captive gliders. Our experience with them as indoor pets in North America does not seem to correlate well with problems found in wild populations in Australia.

Gastrointestinal obstruction has been seen due to inappropriate food or foreign body obstructions. Urinary tract disease is being diagnosed including cystitis, nephritis, urinary obstruction with subsequent bladder rupture. Cloacal and para-cloacal gland enlargement, impaction and abscessation is seen particularly in neutered marsupials. Males presented with dry or necrotic penises may be septicemic. Amputation does not impair urination. Neoplasia is seen in older gliders and primarily has been lymphatic or hepatic, although as more gliders reach geriatric age, we may encounter more types of neoplasia.

Gliders are frequently presented due to either aggression towards their owners or other gliders, or for self-mutilation. Whereas aggression may be part of normal social behavior particularly with territory marking and reproductive activity, self-mutilation is a problem of captivity. The practitioner needs to develop a history-gathering and trouble-shooting system similar to that used with feather-picking birds. Self-mutilation is usually seen in solitary sugar gliders. Sugar gliders have been used in laboratory animal medicine as models of serotonin-deficiency depression. To clinically depress a sugar glider, the researchers found one only has to house them as single animals. Many of our pet gliders are solitary. And unfortunately, because they were removed from glider families prior to puberty, they do not know how to properly integrate into glider society. Gliders should not be housed as solitary animals.

Introduction to another glider later in life, particularly after neutering, may make stress and problems worse. Therapy needs to be aimed at maximizing the diet and habitat, and in many cases will require medical intervention. Many of the tri-cyclic antidepressants and newer serotonin-enhancer drugs may be useful. The author has used Prozac (2–5 mg/kg PO q12h; Lilly, Indianapolis, IN, USA) in sugar gliders successfully to stop mutilation while correcting dietary and husbandry conditions. Dosage may be increased slowly over time. It takes 4–8 weeks before blood/brain levels are fully maximized, so clients need to be cautioned as to timeline for improvement.

Surgical techniques follow the same guidelines as with other small mammals. Orchiectomy is slightly different, because of the different marsupial anatomy. The testicles in the scrotum are attached via a short stalk to the body wall. Make an incision longitudinal and parallel to and running along the stalk, then use blunt dissection to expose the blood supply and vas deferens. Bury the sutures! Sugar gliders are very adept at suture removal unless adequate analgesic is provided, and the sutures are buried. Of a disturbing note is that the International Sugar Glider Society on its website is recommending breeders do castration by using a rubber band around the scrotal stalk. This is resulting in necrosis, self-mutilation, and septicemia. It is not recommended as a humane procedure!

South American (Brazilian) Short-tailed Opossum (*Monodelphis domestica*)

The short-tailed opossum is from eastern and central Brazil, Bolivia, and Paraguay. It has been used extensively as a laboratory animal. Males weigh 90–150 g, females between 80–100 g. Head, body length is 110–200 mm and tail length is 45–80 mm. The tail is about half as long as the head and body, but always shorter than the body alone, and sparsely haired. It is prehensile, and used by the opossum to carry bedding and other items to be dragged back into its nest. The pouch is not developed. The mammae are arranged in a circle on the abdomen and number 8–14. They usually dwell on the ground, but can climb. Nests are usually built in hollow logs. They are basically nocturnal, but as pets, do spend time interacting with owners during the day. They will use rat wheels for exercise. In South America, they live in human dwellings where they are welcome as they destroy rodents, insects, and arachnids such as scorpions. Individuals are highly intolerant of each other, though conflicts rarely result in serious injury. Breeding occurs throughout the year in tropical ranges, with young numbering 5–12. Newborn cling to the nipples of the mother, later they ride on the back and flanks. *M domestica* may have up to 4 litters annually. Gestation period is 14–15 days. Postpartum dependence lasts about 50 days. Sexual maturity is attained at 4–5 months. Breeding has occurred at up to 39 months of age in males, 28 months in females. Estrus lasts 3–12 days, but may vary up to 1 month. Diet fed in laboratory facilities: pelleted fox diet (National Complete Fox Food Pellets, Reproduction Diet, Milk Specialties Co, New Holstein, WI, USA), (Mazuri Exotic Canine Diet 5M52, Mazuri Carnivore Diet 5636, Reiserstown, MD, USA), insects, and pinkie mice. They are prone to atherosclerosis following hyperlipidemia and hypercholesterolemia. Fasting plasma cholesterol on National Fox Food (3.1 % fat dry weight): 85 ± 22 mg/100 ml. 17.7% fat diets (equivalent to 40% calories from fat) produce elevated cholesterols of 1000–1900 mg/100 ml after eating that for 8 weeks. There are high responders and some genetically lower responders (304–593 mg/100 ml). They are also used as models for UV induced sarcomas and melanomas. Blood samples may be drawn from the ventral tail artery. In the laboratory, cardiocentesis is usually done, although this is not recommended in pets as it occasionally leads to acute hemorrhage and death.⁷

The principal spontaneous disease problems of the short-tailed opossum occur in the digestive system and most diagnoses were lesions of the liver. The most common cause of death from digestive system disease was rectal prolapse. Neoplasia is found most frequently in the digestive system—in the liver—followed by the pancreas. Another frequent disease is enteritis of the small intestine with gaseous distention. The second most common system in which lesions were diagnosed was the urogenital system, and the kidney most frequently affected, with

nephritis. The most common neoplasm found is pituitary adenoma (prolactinoma), followed by uterine leiomyoma, skin lipomas, adrenal gland pheochromocytomas, and liver carcinomas. Most of these are found in opossums older than 22 months. Cardiovascular disease is fairly common, with congestive heart failure developing in males more frequently than in females. Heart disease was generally found in animals averaging 37 months of age.⁸

In general, *M domestica* is fairly hardy. In pet short-taileds, malnutrition, obesity, chilling, injury from falling or handling, and a mange mite have been seen.

Tammar or “Dama” Wallaby (*Macropus eugenii*)

Tammar wallabies originate in the southwest coastal area of Western Australia (south of Perth). The forked penis of the male is found in the ventrum of the cloaca. Testes are external. The cloacal temperature may be lower than actual body temperature; the tympanic temperature reading is probably more accurate. Cloacal temp: 35–36.0°C (95–96.9°F). Heart rate is 125–150 bpm. Gestation period is 25–28 days. Estrus cycle is 30 days. Pouch life is 250 days. Birth weight is less than 0.03 oz (1 gram). Weaning is at 10–11 months of age. Blood samples can be collected from the cephalic vein or lateral caudal vein (just dorsal to lateral of the vertebral processes on either side of the tail). Intramuscular injections can be made into the thigh or tail muscles. Subcutaneous injections should be done in the intrascapular space. Housing: Tammar wallabies must be kept above 16°C (60°F), with a large area to run without obstacles. They need to have escape routes and shade. They need a dry bedding area. They can be group-housed with several males per group. Captive diet: alfalfa hay, and 50:50 mix of horse and rabbit pellets. Timothy hay may be provided ad lib and also used as bedding. In the wild, the diet is grasses and forbs. Most commonly seen problems: injuries, “lumpy jaw” (various organisms, *Actinomyces bovis*, *Bacteroides* species, etc.) This is often a chronic problem with the tooth eruption process. Without sufficient roughage, the teeth which erupt posteriorly in the jaw and migrate anteriorly before being lost adjacent to the diastema, may not migrate properly. Lost premolars may leave openings for bacteria to get into the jaw. Coarse, sharp feeds such as oat awns should be avoided, since they can cause trauma to the mouth and the tissues can be invaded by the bacteria mentioned above. Provision of materials such as long dry grass or fibrous tree bark for the animals to chew on appears to reduce the incidence of the disease. Chewing on these presumably toughens the oral mucosa. It may also be important in providing the molar teeth with sufficient work to enable them to be properly shed. Body weights range from 3.55–5.30 kg.

Bennett’s Wallaby (*Macropus rufogriseus rufogriseus*)

Bennett’s wallaby is a subspecies of wide ranging red-necked wallaby and is found in Tasmania. It is mainly crepuscular and nocturnal. Groups may be seen at feeding areas and water holes, but it is not a cohesive social group. Adolescent males stay with mothers beyond weaning and into the following year. Daughters wean sooner than sons. Related females form “clans” with common feeding areas. Large dominant males reserve certain areas of their territory for their own use and have exclusive mating rights in those areas. Weights: Males are 15–26.8 kg, females are 11–15.5 kg. Life span is considered to be 12–15 years. Sexual maturity in females is at 14 months of age, males 19 months of age. Breeding is strictly seasonal. Bennett’s wallaby gestation period is 30 days with a pouch period of 7–8 months, Birth weight is less than 0.03 oz (1 gram). Weaning is at 12–17 months. Table 1 provides a list of common infectious diseases of companion marsupials.

Table 1. Common infectious diseases of marsupials.¹⁰

Disease	Pathogen	Species/ susceptibility	Clinical Signs	Diagnosis	Treatment
Salmonellosis	<i>Salmonella</i> spp.	All, especially young	Diarrhea, depression, enteritis, septicemia	Fecal/oral c&s	Parenteral antibiotics, electrolytes, fluid therapy
Lumpy Jaw (Necrobacillosis, Actinomycosis)	<i>Bacteroides</i> sp, <i>Fusobacterium necrophorum</i> , <i>Actinomyces</i> sp, <i>Corynebacterium</i> sp	Macropods in captivity, rare in wild	Swelling of mandible or maxilla, poor prehension, cellulitis/osteitis, pus production, depression	Odor, culture, radiographs	Debridement parenteral antibiotics, local disinfection, husbandry measures to reduce crowding, cleanup environment, proper diet
Mycobacteriosis	<i>Mycobacterium tuberculosis</i> , <i>M bovis</i>	Probably all, esp. brushtail possum. Common in New Zealand brushtails	Weight loss, cachexia, tubercles in viscera, skin, bones	Clin signs, culture, radiology, not responsive to treatment, unknown if intradermal skin test effective in diagnosis.	Not responsive to treatment, cull. Public health significance
	<i>M avium</i> , <i>M intracellularis</i> , <i>M scrofulaceum</i>	Wallabies	Abscesses of skin, bone, visceral organs may be involved, purulent arthritis	Acid-fast stains, culture	None, isolate, cull. Non-responsive to treatment
Pasteurellosis	<i>Pasteurella multocida</i> , <i>P haemolytica</i>	All, esp. possums	Cellulitis, hemorrhagic septicemia, bronchopneumonia	Clinical signs Culture	Parenteral antibiotics, reduce stress, fighting
Pneumonia in Macropods	<i>P multocida</i> , <i>Klebsiella</i> spp, various organisms	Macropods—all species; more common in winter or in wild-caught animals; chilled	Dyspnea, coughing, frothy nasal or oral discharge, death	Clinical signs, auscultation, radiology	Parenteral antibiotics, supportive therapy

Table 1 cont'd. Common infectious diseases of marsupials.¹⁰

Disease	Pathogen	Species/ susceptibility	Clinical Signs	Diagnosis	Treatment
Pouch infections	<i>Pseudomonas aeruginosa</i>	Macropods	Dirty pouch, odor, brown, thick discharge	Clinical signs, culture	Disinfection, cleaning, topical and systemic antibiotics
Herpesviruses	Herpesvirus	Wallabies (Parma, Tammar), potoroos, quokka	Transient infertility, eye/nasal discharge, lingual ulcers, depression, anorexia, death	Titers, histopath, virus isolation, virology	No therapy yet. May try acyclovir?
Candidiasis	<i>Candida albicans</i>	Artificially reared pouch young. Act hungry, won't suckle.	White curdlike encrustations in mouth, lips, gums, tongue margins. Depression, painful mouth	Cytology, culture	Clean out, oral nystatin, antifungals, supportive care
Infectious dermatitis	<i>Pseudomonas pyocyanea</i>	Brushtail possums, Virginia opossum	Localized form, skin in and around pouch. Generalized form can cause dehydration toxemia, death	Culture	Antibiotics as indicated by sensitivity, clean up
	<i>Staphylococcus</i> species, <i>Actinomyces dermatonomus</i>	Brushtail possums, Virginia opossum	As above	As above	As sensitivity
"Crispy ear"	<i>Strep</i> species	Virginia opossum	Edges of the ears become necrotic, can become systemic	Culture	Aggressive antibiotic therapy, debride, NSAIDS, Aloe vera. Prognosis is guarded to poor
Dermatophytosis	<i>Trichophyton mentagrophytes</i>	Brushtail possum, Virginia opossum	Sparse, scaly lesions, generalized over skin	Culture	Antifungals as in other species, zoonotic public health significance

Specific problems seen with house wallabies include lumpy jaw, gastrointestinal obstruction due to ingestion of foreign material such as carpet or towels, obesity, genital-urinary tract infections, diarrhea due to improper diet, injuries from running into walls and furniture, and attacks from other pets. Clinicians need to be familiar with proper handling in the office environment. It is usually advantageous to immediately administer diazepam at 0.5–1 mg/kg IM to decrease the anxiety of the animal and potential for future muscle necrosis. Restraint is best done by first securing a firm hold on the base of the tail, then supporting the rest of the body much like one does with a fractious cat. Wallabies can do considerable damage with the nails of their hind feet. They may also bite. Vocalizations of stress and anger include a loud hissing, accompanied by thumbing and whacking the floor with feet and tail.

Virginia Opossum (*Didelphis virginiana*)

This is the only marsupial native to North America, and if hand-raised from a rescued infant (mother is usually road-kill), they make wonderful pets. They learn to come when called, and as latrine animals, will readily use newspapers in specific places to urinate and defecate. Other than nibbling some houseplants, they are generally non-destructive and docile. They also like to be held and cuddled.

As pets, the biggest challenge may be to prevent obesity by providing sufficient exercise and limiting food quantity. Diet must be carefully regulated. Metabolic bone disease is probably the second most common problem seen in pet opossums. All opossums brought in from the wild are heavily parasitized and need to be repeatedly treated with levamisole (levamisole injectable 13.65%, Agri Laboratories, Ltd, St. Joseph, MO, USA) at 6–10 mg/kg PO or SC every 3–4 weeks for several months. Repeated fecal exams should also be done, although many will not shed ova after the opossum is a few months old. Cardiac disease is a major problem after 2 years of age. Cardiomyopathies may be diagnosed using ECG, echocardiograms and radiographs. Dilatative as well as hypertrophic forms have been found. Treatment is based on feline disease parameters.⁹

Chronic urogenital tract infections are common in unspayed females. It is recommended that companion opossums be spayed. An unspayed female will be very restless, pace, and will slobber on many household objects. This behavior stops after removal of the ovaries and uterus.

New diet information

An Action-Alert was issued in March 2005 by the National Opossum Society, Inc. Available at: <http://www.opossum.org>. Accessed February 28, 2006, concerning different dry cat foods composition. The current recommendation is for owners to find the cat food that list the cat foods that have the following major nutrient percentages: Protein 31.5%, Fat 11%, Calcium 1.1%, Phosphorous 0.9%, and Vitamin A at 10,000 IU/kg. Avoid products that use soy as a major component. An example of an adult opossum's diet: 70% "Peter's Food" (1 part cat food, 1 part blended vegetables, ¼ part yogurt), 20% fruit variety, and 10% mixed protein (which can be canned salmon, hard-boiled eggs with shell, chicken livers cooked, yogurt). Treat foods include calcium-gut loaded crickets or other dusted adult insects. The volume will vary depending on the size and activity of the opossum, but in general consider 1–2 cups total volume for a 3-kg opossum for the evening meal, and about ½ to 1 cup of food for the morning/day meal.

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Emerging Diseases—Hype or Reality

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Abstract: The scientific and lay press report “emerging diseases” with regularity, and there are concerns of a regression to the standard of the previous century. Antibiotic resistance, modernization of society, and varied other factors likely have a synergistic action in the “creation” of some emerging diseases, some of which can jump from animal to man. A few of the reported diseases in rodents, rabbits, and bats, as well as the actual types of conditions seen in a specialty diagnostic practice, are reviewed in this discussion. While some emerging diseases from the headlines may yet impact pets, zoological collections, wildlife, and man, more mundane conditions are most prevalent in our clinical experience. More rodents, rabbits, and bats are likely seen by veterinarians, and as a result, there is more opportunity to see what was likely there all along. A number of more common conditions need research efforts and data collection in order to better understand why these particular conditions are “emerging” as problems.

Introduction

There is a new era in human and veterinary public health as a continual increase in “emerging diseases” is routinely reported in the scientific and lay press. This presentation will mention some of the conditions considered “emerging diseases” in small mammals, and compare/contrast the reports with a few of those conditions that seem to be increasingly seen in a diagnostic pathology practice that specializes in “exotic” animals.

The question that should be answered is: What is an “emerging” disease? According to Lederberg, ““Emergence is in fact regression, a return to the standard that prevailed universally in the previous century.”¹ For instance, common microbes like *Staphylococcus aureus*, which used to be easily treatable by penicillin, have evolved to be antibiotic-resistant.

In addition, exposure to infectious diseases that pass from animals to humans is accelerating because of the modernization of our society. Humans are encroaching upon the environment and coming into contact with microbes, which can jump from animals, sometimes with fatal consequences. The factors responsible for new diseases are varied but probably have a synergistic action.

Most of these conditions have only been recognized in the last several years, and it is not clear if they are truly emergent, just more readily recognized. An example would be rodent *Helicobacter*. This paper will briefly discuss a few of the reported diseases in rodents, rabbits, and bats, as well as the actual types of conditions seen in a specialty diagnostic practice.

Rodents

In rodents, the following diseases have been identified, primarily by the laboratory animal community, as “emerging.”

1. *Helicobacter* infections of mice, rats, and hamsters.
2. Beta hemolytic *Streptococcus* infections of mice.
3. *Staphylococcus aureus* infections of athymic (nude) mice.
4. *Corynebacterium bovis* (Hyperkeratosis-associated coryneform or HAC) infections of athymic (nude) mice.
5. Atypical parvovirus infections (MPV and RPV) of mice and rats.
6. Atypical reovirus and paramyxovirus (parainfluenza) virus infections of guinea pigs.
7. Atypical mouse hepatitis virus (MHV) infections of mice.
8. Atypical mouse rotavirus (EDIM) infections of mice.
9. Rat respiratory virus (RRV) infections of rats.

Most of these infections seem to be clinically mild or inapparent. Many have not been associated with lesions or physiologic changes, and several may only be recognized by seroconversion.² These statements are based on experience with laboratory rodents, which often is different than what is happening with pet rodents.

Based on submissions to our diagnostic service, there appears to be an increase in the number of cases of central nervous system disease in rodents. Explanations for this include expansion of the pet rodent base, greater awareness by owners, and more concern for the possibility of a zoonotic disease, particularly lymphocytic choriomeningitis.

Lymphocytic choriomeningitis virus (LCMV) is a rodent-borne virus belonging to the family Arenaviridae, genus *Arenavirus*, which causes a wide spectrum of human disease. The virus is often considered a problem in hamsters, but can occur in a wide variety of rodents. Although it can affect humans, cases are seen infrequently.

We have seen sporadic cases of presumed viral encephalitis in chinchillas and a woodchuck and encephalomalacia of undetermined cause in a guinea pig. The largest number of cases, however, is of purulent meningoencephalitis due to bacteria. In these cases the organisms have been seen and/or cultured. This condition has been diagnosed in mice, rats, gerbils, hamsters, and guinea pigs. In addition cases of probable toxoplasma-induced encephalitis have been seen in rats and a prairie dog.

Rabbits

In rabbits, “emerging” diseases include rabbit hemorrhagic disease due to Calicivirus. It has been increasingly reported since being found in China in 1984. The disease has an unusually high death rate and hemorrhage. In addition, *Borellia burgdorferi* has been documented in rabbit ticks. Rabbits developed a rash similar to

the typical Lyme disease rash as well as the same type of immune response generated after being bitten by ticks infected with *B burgdorferi*.

We have seen occasional cases of hemorrhagic disease but have not documented Lyme disease in pet rabbits. We have seen an increasing number of cases of renal disease in pet rabbits, however. The primary condition is interstitial nephritis with lymphocytes and plasma cells, or occasionally heterophils. There may be fibrosis and mineralization. Tubular casts are occasionally present. In some animals, there is variable glomerulitis and glomerular sclerosis. A few cases are associated with a bacterial infection, but in most the cause is not apparent. Because the lesion is morphologically similar to renal lesions caused by *Encephalitozoon*, this protozoa is a primary etiologic candidate. This is true even though organisms are not seen. These organisms can be difficult to demonstrate, and they may not be present even though there is an ongoing immune-mediated inflammatory response.

Bats

Bats are being incriminated as carriers and possible reservoirs of several viral diseases, including Hendra and Nipah viruses, as well as lyssavirus.³ Some bats have also been considered possible carriers of the coronavirus that causes SARS, although there is some controversy concerning this assumption.

No documented cases of these infections have been seen in material presented for diagnosis. In most cases, the cause of the conditions submitted is not determined, but bacterial disease, probable nutritional/metabolic disorders, and neoplasia are seen. Organs most commonly involved include the lung, liver, and urinary tract (kidney and urinary bladder). Morphologically, both inflammatory and noninflammatory lesions are seen.

Discussion

Given the recent arrival, or at least, recent recognition of many of the reported conditions, particularly in rodents, there is minimal literature to give guidance as to their biology or importance. The biology of these infections is not well understood, but anecdotal reports and data suggest they may not be highly infectious, particularly the rodent diseases.

In the case of the conditions seen by our diagnostic service, it is probable that much of the increase is due to more animals being seen by veterinarians rather than newly emergent diseases. It would also appear that these more mundane conditions are the most prevalent in our real-world situation, even though they do not generate the headlines. It's not impossible that conditions now widely reported, and in some cases feared, will impact pets or zoologic collections in the future and they must be kept in mind as potential differential diagnoses. From the standpoint of the animal populations we have contact with, there are a number of more common conditions that need research efforts and data collection in order to better understand why these particular conditions are "emerging" as problems.

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Idiopathic Myofasciitis in the Domestic Ferret

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Session #132

Summary Style Manuscript

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Introduction

Spontaneous inflammatory polymyopathies are well documented, especially in humans¹ and dogs.² Experimentally or iatrogenically-induced inflammatory myopathies also occur in animals.³ The domestic ferret (*Mustela putorius*) is a popular house pet in the United States. During an 11-year span (1994–2005), Northwest ZooPath (NZZP) has received 2040 domestic ferret biopsy or necropsy submissions, most of which were privately owned as pets. Since late 2003, a previously unrecognized inflammatory disease process involving muscle and fascia has been diagnosed in several ferrets at NZZP.⁴

Signalment and Clinical Signs

Affected ferrets ranged in age from 5–24 months of age with an average age of 10 months. There is no gender bias. Clinical signs include high fever, lethargy, recumbency, ataxia, posterior paresis or pain when moving, inappetance or anorexia, and abnormal stools. Blood work reveals mild to marked leukocytosis with mature neutrophilia, and mild to moderate, usually nonregenerative, anemia. Common serum abnormalities include mild to moderate elevation of ALT, mild hyperglycemia, and hypoalbuminemia. Treatment, which has included various antibiotics, anti-inflammatory drugs, glucocorticoids, antipyretics, pain killers, interferon, and cyclophosphamide, has been ultimately unsuccessful in all cases and the patients have either died or were humanely euthanized.

Gross Lesions

Gross lesions include red and white mottling and dilatation of the esophagus, and white streaks in the heart, diaphragm, and intercostal muscles. Generalized muscle atrophy may be prominent even in animals with adequate fat stores. Fat may have red mottling. Lungs are sometimes congested. The spleen is usually markedly enlarged and pale.

Histologic Lesions

Histologic changes include moderate to severe suppurative to pyogranulomatous inflammation involving the skeletal muscle and blood vessels at multiple sites, particularly the esophagus, heart, and muscles of the hind limbs and lumbar region. Myleoid hyperplasia of spleen and/or bone marrow, hepatitis, pneumonia, and mediastinitis are also prominent features.

Ancillary Procedures

Bacterial and viral cultures have been negative for pathogens. Electron microscopy, PCR, and immunohistochemistry have been negative for various infectious agents.

Conclusions

The etiopathogenesis of polymyositis in ferrets is not known. It is a fatal disease of young adult ferrets characterized by rapid onset of clinical signs, high fever, neutrophilic leukocytosis, treatment failure, and death (or euthanasia). The distribution of histologic lesions, particularly in the esophagus, suggests that this is likely a single distinct entity. Cultures and extensive microscopic examination have failed to detect infectious agents. The only commonality in affected ferrets is administration of a particular brand of canine distemper vaccine, which is no longer available. Interestingly, the disease has been inadvertently reproduced during an experimental vaccine trial by one of the authors (N. J. S.).

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Wobbly Hedgehog Syndrome: A Neurodegenerative Disease of African and European Hedgehogs

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Session #133

Summary Style Manuscript

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Introduction

Hedgehogs are popular pets in the United States and occasionally are used as experimental animals.¹ Wobbly hedgehog syndrome (WHS, degenerative myelopathy, spongiform leukoencephalopathy, progressive paralysis) is a neurodegenerative disease affect the brain and spinal cord of African pygmy (*Atelerix* sp) and European (*Erinaceus europaeus*) hedgehogs.²⁻⁵ The prevalence of this disease in pet African hedgehogs in the United States approaches 10%. Cluster patterns in defined family lineages are apparent, suggesting this is a heritable disease. Reported age range for onset of clinical signs is 1–36 months, and average age is 18 months, with no gender bias. Most cases become immobile within 18 months of onset. All treatments have been unsuccessful in reversing this disease or slowing the onset of signs. In an owner survey, no dietary correlation was noted for affected animals.²⁻⁵

Clinical Signs

Hedgehogs with WHS have clinical signs that may include falling consistently to one side, tremors, exophthalmos, scoliosis, seizures, muscle atrophy, dysphagia, wasting, ascending paresis or tetraparesis, and rarely self-mutilation. These signs are not specific and differentials should include other common hedgehog diseases such degenerative disc disease, brain tumor, or septic meningoencephalitis.

Gross Lesions

Gross findings include emaciation, generalized muscle atrophy, scoliosis, abrasions on the dorsal aspect of the feet, and large pale liver. No gross lesions are observed in the central nervous system.

Histopathology

Microscopic lesions include spongiform change in the white matter of the cerebrum, cerebellum, and brain stem, and in the white matter tracts of the spinal cord at all levels. Demyelination, axon degeneration, and occasional neuronal necrosis are also seen, the latter especially in the ventral horns of the spinal cord, with axonal changes

also occurring in the ventral nerve rootlets. Gliosis accompanies chronic lesions, but no inflammation is seen. Clear inclusions are seen routinely in the renal tubular epithelial cells of affected animals, and the significance of these relative to the CNS lesions is being investigated.

Conclusion

Wobbly hedgehog syndrome is an idiopathic neurodegenerative disease. Cluster patterns in family lineages are apparent, but the occurrence of the disease in different species of hedgehogs suggests that heritability may be influenced by dietary or environmental factors or infectious agents.

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Update of Ferret Adrenal Disease: Etiology, Diagnosis, and Treatment

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Session #135

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Abstract: Ferret adrenal disease or hyperadrenalcorticism is a common disorder in ferrets, characterized by marked sex steroidogenesis and neoplasia. Control mechanisms and etiology of the disease have established initial stimulation and mechanisms of stimulation, active LH receptors in diseased adrenal tissue, and correlation with time of gonadal removal. A genetic or familial predisposition appears to exist and is currently being studied as a possible homologous genetic disorder with the Multiple Endocrine Neoplasia (MEN) syndrome in humans. Therapeutics aimed at controlling the stimulation to the adrenals, suppressing sex steroidogenesis, blocking peripheral hormonal effects, and debulking of the tissue are currently used to manage the disease.

Introduction

Ferret adrenal disease or ferret hyperadrenalcorticism is one of the most common clinical presentations of ferrets. Unlike Cushing's disease, the primary hormones elevated are sex steroids. Within the past few years, a number of studies have been done looking at the different aspects of the disease, developing the model of what is occurring, and developing management strategies to enable affected ferrets to live out their lifespan.

Endocrine Controls and Neoplasia

It is well known that domestic ferrets are seasonal breeders, with copulatory ovulation and subject to a complex hormonal stimulation and feedback system that was studied as a model of reproductive controls in the 1970s and 1980s. Examination of these systems established a number of factors that have importance in the development of adrenal disease. It was established that in the ferret, in the absence of the gonads, the adrenal gland can respond similarly to a gonad for sex steroidogenesis. A first step in connecting the basic research and the disease was to look for active hormonal receptors that would result in sex steroid production. It had been determined that there were significant elevations of estradiol, androstenedione, and 17 OH progesterone rather than cortisol in ferrets with hyperadrenalcorticism. It was determined that the adrenal gland has luteinizing hormone (LH) receptors that are active in affected ferrets.¹

Basic endocrine research in the ferret determined that at puberty and consequently at breeding, sex hormone levels achieve peaks then "set the gonadostat" in the brain regulation areas (hypothalamus, pituitary). Neutering at puberty or at breeding-age in adult ferrets causes an LH surge which then acts similarly to breeding itself. This LH surge followed by subsequent increased gonadotropin releasing hormone (GnRH) without gonadal response serves to downregulate sex steroid production. This action seems contradictory, but prolonged elevated levels of GnRH is a negative feedback mechanism for sex steroid production. A study was that examined the pituitary glands of intact or neutered ferrets, and 10 neutered ferrets with hyperadrenocorticism. The ferret pituitary gland

histologically was similar to the dog pituitary. In 2/10, a tumor was detected in the pituitary gland, although these had characteristics of clinically non-functional gonadotrophic tumors seen in man. In some of the ferrets, there was low pituitary immunoreactivity for gonadotrophic hormones, which was considered to be due to the feedback of autonomous steroid secretion by the neoplastic transformation of the adrenal cortex. This study concluded that the initially high concentrations of gonadotrophins resulting from castration initiated the hyperactivity of the adrenal cortex. The conclusion of this study was that because of the low incidence of pituitary tumors and the low density of gonadotropin-positive cells in non-affected pituitary tissue suggested that persistent hyperadrenocorticism was not dependent on persistent gonadotrophic stimulation.² This finding contradicts the clinical finding that a medication sustaining gonadotrophin releasing hormone levels with a synthetic GnRH analog, recognized by the pituitary depresses the production of sex steroids in the ferret. This finding does explain the initial stimulation to the gland, and possibly why as the tumor progresses as it is not responsive to pituitary control. It would then follow that progression of anaplasia may be under a tumor suppressor gene control, rather than continuous pituitary stimulation. Episodic pituitary stimulation does explain why some ferrets will exhibit “rat tail” and pre-hyperadrenocorticism seasonally, before they are considered “adrenal disease.” In intact animals, coitus triggers an LH surge, with subsequent ovulation or intromission. In males, the hormone feedback causes downregulation so the male goes out of season. In the female, pregnancy ensues in most cases. Hormonal feedback from the gonads is necessary to conclude the breeding season. The author noted in her study using intact ferrets, 1–2 weeks of hot weather (over 80°F with no air conditioning) caused both the males and females to go out of season spontaneously. In the 3 years we followed intact ferrets, all would cycle-out of season by late August, and none of the females developed estrogen-toxicity and anemia, despite monthly blood draws of 2-3 mLs.³ (C. A. J. D., J. Oliver, unpublished data, February 2006).

Early spay/neutered (ES/N) animals have levels of sex steroid production seasonally similar to their intact counterparts. This was not anticipated when the longitudinal study began. The longitudinal study was comprised of 6 ES/N animals (3 males, 3 females) and age and sex-matched locally bred intact ferrets, followed with monthly hormone analysis from 4 months of age through 12 months of age, and then periodically (30 days post-neuter/spay for the intact ferrets), and twice annually for the ES/N ferrets. A number of the original study ferrets have been adopted and lost to the study, several remain available for periodic sampling. The 6 ES/N animals reside with the author. Unlike intact animals that have gonadal production of sex steroids, and breed, which then downregulates the system, the ES/N animals’ adrenals respond and produce sex steroids, but no “breeding” occurs to shut the system down. The sex steroid levels continue to be produced throughout the year at a level appropriate to the breeding season level.

Post-puberty spayed/neutered ferrets have a markedly lessened hormonal cycle throughout the year, but it is still present. Sex steroids in all ferrets (altered or intact) rise at what can be considered the start of breeding season (late December/January for males; January–March for females). Levels are lowest for males in late summer, early fall, and for females September–November. Females lag behind the males’ sex steroid level elevation by 1–2 months. Keeping ferrets on artificial light cycles, or supplying melatonin may suppress the sex steroid seasonal responses for awhile, but eventually the cycle continues. It may be out-of-synch with the calendar.

There is a correlation between the timing of removing the gonads and the onset of “adrenal disease.”³ A study was done that explored some of the possible endocrine pathways for control (ACTH or alpha-MSH) by examining plasma levels of the hormones in neutered animals and intact animals. It was concluded that ferrets with hyperadrenocorticism did not have detectable abnormalities in plasma concentrations of ACTH or alpha-MSH.⁴

The working hypothesis proposed by the author for the etiology of adrenal disease is that stimulation via the pineal, pituitary and secretion from the hypothalamus of GnRH and LH up-regulates sex steroid production in the adrenal tissue which then responds without a set-point for “shut-off”: the tissue responds initially with hyperplasia.

Elevations of estradiol, androstenedione, and 17 OH progesterone can be measured by validated hormonal assays performed at the University of Tennessee's Clinical Endocrinology Laboratory, Knoxville, TN, USA.

The second hypothesis is that if an aberrant tumor suppressor gene is present, hyperplastic tissue with stimulation progresses to adenoma, then eventually adenocarcinoma, following models in other animals and humans. A completed study looked at tumor markers in ferrets, based on the work in gonadectomized DBA/2J mice that develop adrenocortical tumors expressing transcription factor GATA-4. 86% of the ferret adrenocortical carcinomas, particularly in areas of myxoid differentiation expressed GATA-4. Normal adrenocortical cells lacked GATA-4 expression. Two other markers of adrenocortical tumors in gonadectomized mice that are co-expressed with GATA-4 are inhibin-alpha and LH receptor. These were co-expressed in some of the ferret tumors. No GATA-4 expression was observed in 3 cases of nodular hyperplasia; however, patches of anaplastic cells expressed GATA-4 in 50% of the tumors classified as adenomas. The conclusion was that GATA-4 does function as a marker of anaplasia in ferret adrenocortical tumors.⁵ The relevance of this shows that there may be a way of tracking and marking the tumors (prognostication for the practitioner when advising the client), and pathways of cancer development in the ferrets is similar to that of other species. This also is suggestive of a genetic root to the development of the disease, as GATA-4 is a protein marker.

A point of management of the disease is to depress or suppress the stimulation to the adrenal gland, thereby stopping sex steroid production. Blocking sex steroids from affecting other tissues can also be done, thereby decreasing clinical signs, but none of these medical therapeutic agents may halt the progression of hyperplasia to adenoma to adenocarcinoma, if the possibility of an aberrant tumor suppressor gene is involved. Central (brain level) suppressive drugs such as leuprolide acetate depot formulations (Lupron 3.75 mg, 7.5 mg 30 day Depot; TAP Pharmaceuticals, Lake Forest, IL, USA) have been proven to down-regulate sex steroid production and decrease clinical symptoms. Melatonin implants (Ferretonin, Melatek, LLC, Fort Collins, CO, USA) in some ferrets have short-term suppressive effects. There are additional medications used for humans that work in ferrets for either central or peripheral sex steroid downregulation, blocking peripheral hormone receptor sites or interruption in the enzymatic pathways of sex steroidogenesis.⁶⁻⁹

Genetic Research

Because of the high incidence of neoplasia in ferrets, the search for the possibility of genetic or chromosomal aberrations is being studied in domestic ferrets. In humans, the appearance of benign or malignant proliferations within 2 or more endocrine glands is nearly always genetically determined and is termed multiple endocrine neoplasia (MEN) syndromes. There are 3 currently accepted human familial syndromes in which there is a progression from hyperplasia to neoplasia in endocrine tissues; these include MEN types 1 (MEN1), 2a (MEN2a), and 2b (MEN2b). MEN1 syndrome usually is characterized by parathyroid hyperplasia, pancreatic islet cell, and/or pituitary tumors. Up to 40% of MEN1 patients also develop adrenal, thyroid, or thymic tissue tumors. MEN2a and MEN2b syndromes are characterized primarily as medullary thyroid cancer (MTC) with or without pheochromocytomas and parathyroid adenomas. MEN1 and MEN2 are inherited as autosomal-dominant genetic traits. The MEN1 gene is ubiquitously expressed and is not limited to organs affected by the syndrome. A number of different mutations have been described for the MEN1 gene in humans. As there seems to be a similarity between the endocrine neoplasm patterns in the ferret and the human MEN1 syndrome, research being conducted by Dr. Michelle Hawkins at the University of California at Davis is first looking for a homologous gene in the ferret to the human MEN1 gene. At this time, a homologue has been identified. The sequence of the normal ferret MEN1 gene must be completed, then it can be determined in which tissues the normal gene is expressed. The next step will be to test neoplastic tissues from affected animals for mutations within these genes to determine whether an association can be made with the human MEN syndromes. (M. Hawkins, written communication, January 2006).

Therapeutic Regimens

Lupron 30 day depot formulation (TAP Pharmaceuticals) was effective in downregulating sex steroid production in intact ferrets in-season. Effects lasted 30 days. Lupron 3 month depot formulation (TAP Pharmaceuticals) was effective in the intact males for 75–90 days (January through April); but 2 females in one study returned to estrus by 60–75 days, so it is doubtful that the 3-month formulation will truly last for the full 3 months (C. A. J. D., J. Oliver, unpublished data, February 2006).

Melatonin implants (Melatek LLC) in one controlled study in intact males in season did not effectively decrease sex steroids.¹⁰ Others have reported clinical effects of regression of outward signs.⁹

Surgery to debulk the glands may slow the progress by decreasing the tissue producing the sex steroids. A clinical study has shown that without additional suppression of the hormone stimulation, ferrets who have surgery as the only treatment did not live as long as those that had lupron 30-day treatment alone. Surgery to debulk along with hormone suppression appears to have a slight edge over Lupron 30 day depot (TAP Pharmaceuticals) alone (C. A. J. D., J. Oliver, unpublished data, February 2006).

Data suggests that ES/N is detrimental for at least 2 reasons: 1) the set point in the sex steroid production feedback loop is not set—the ferret comes into puberty and its first breeding season similarly to intact ferrets, but the system does not shut down and 2) time for onset of adrenal disease is shortened so that younger ferrets are affected. Adrenal disease has been documented by hormone level, ultrasound, and histopathology in ES/N ferrets as young as 8 months of age (C. A. J. D., J. Oliver, unpublished data, February 2006).

Clinical Recommendations 2006

Until Dr. Hawkin's genetic work to seek a tumor suppressor gene is completed, as clinicians we may consider the following based on data collected so far:

1. ES/N is not advantageous to the ferret as the hormonal feedback system responds similarly to intact ferrets at puberty and into the breeding season.
2. In ES/N ferrets, the author is trying a “chemical breeding” at the time of puberty or their first breeding season. There may be a specific window of opportunity, but without weekly hormone panels, the author is using the calendar and the weather/light levels for timing: January for the males, mid-February to mid March for the females: males receive 200 µg of Lupron 30 day (TAP Pharmaceuticals); females 100 µg. Data from the longitudinal study of ES/N and intact, age-matched counterparts supports this. (C. A. J. D., J. Oliver, unpublished data, February 2006).
3. All ES/N ferrets should probably be given a “chemical breeding” every breeding season annually to cause the LH surge, then maintain a plateau long enough to keep them out of cycle for the whole season. It may be advantageous to use the 3-month formulation for subsequent years. As this longitudinal study is on-going, this is still a hypothesis based on the data collected to date. This should block that “initiating stimulation.”
4. If ferrets are to be spayed or neutered, as late in life as possible, and towards the end of breeding season their first year (puberty) is likely ideal. The question that has not been answered for these is should they

be “chemically bred” each subsequent year like the ES/N ferrets. Preliminary data shows that the following year, these ferrets have hormonal rises to match the onset of breeding season, just not as elevated as intact ferrets. (C. A. J. D., J. Oliver, unpublished data, February 2006).

5. The goal of all therapy is to enable the ferret to have a good life for the 5–7 years of its lifespan. A management program, like vaccination programs as annual visits, can be formulated. Owners then need to be educated about the importance of annual veterinary attention for their ferrets, and perhaps twice a year for ferrets as they age. With further data analysis and publication of the data gathered, a goal may be to stop the early spay/neuter practice in this seasonal, copulatory ovulator animal.

And in conclusion, if an aberrant tumor suppressor gene or genes are discovered and a commercial assay developed to enable screening of all ferrets, we as veterinarians need to give considerable thought now to issues this will cause. The first group of ferrets to be tested by an assay would be the breeders.

1. If we try to eliminate the gene through a breeding program, will we create further genetic problems?
2. What will happen to all the breeder ferrets that test positive, yet may never have the disease? (Phenotype expression is not an absolute.) If baby ferrets are tested at the breeding facility and show positive, will these all be killed?
3. In all pet ferrets that are screened, what will happen to any that test positive?
4. This could lead to very large numbers of euthanasias of perfectly healthy ferrets that may or may/not ever show a neoplastic disease. Ferrets already owned and then tested and shown to be positive: what do you tell the owner? The author anticipates that many ferrets will be killed or dumped at shelters.

We need to consider the implications on the ferret population and the animal’s desirability as a pet. I believe that based on the data and pathophysiology of this disease, a first step would be to halt the early spay/neuter practice. Second would be to consider essentially a “chemical breeding” for all ES/N ferrets annually for life, starting at puberty. Thirdly, we need to get this information out to pet shops, veterinarians, and the owners. Most veterinarians are conditioned to think about an annual vaccine – not much different than an annual anti-hormone shot, but it may be a better preventative injection for the ferret than that vaccination.

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Novel Diagnostics for Exotic Mammals

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Session #140

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Abstract: Specialized testing for exotic mammals is available but often unknown to most practitioners. It is important to understand the principle behind the test and the limits of the technique, as well as the validation process, in order to best use them in clinical cases. These concepts will be reviewed in conjunction with a presentation and discussion of testing available for rabbits, ferrets, and rodents.

Introduction

Traditional testing methods and new and improved assays have greatly revolutionized veterinary diagnostics over the past 20 years. ELISA-based immunoassays have become commonplace not only at the laboratory levels but at the point of care for many companion animal species. PCR tests for the detection of RNA and DNA have been developed for many viruses and bacteria and are available at a growing number of laboratories. Test options for diseases of exotic animals are available, but their wide use is still retarded by the lack of information in regards to clinical applicability. The goal of this summary is to provide a general review the current diagnostic tests and how they may be used in the exotic veterinary practice.

Diagnostic Tools

Laboratory infectious disease diagnostics rely upon the following principles: detection by culture, detection of seroconversion (antibodies), detection of antigen (by serology), and detection of DNA/RNA (by PCR).^{1,2} Culture continues to be limited by issues related to the infectious agents themselves. Bacterial culture has not greatly changed over the past 10 years with the exception of the addition of molecular technology. Growth from specialized cultures (ie, for *Mycobacterium* species) can now be screened using PCR to improve both sensitivity and specificity. Adaptations to virus isolation can similarly be made.

There have been considerable improvements in immunoassays. Examples of serological assays include ELISA, virus neutralization, complement fixation, indirect immunofluorescence, and gel immunodiffusion. The use of recombinant antigens (vs crude antigen preparations) has aided in the development of more sensitive and specific assays. Western blot testing, often regarded as to technically difficult for use as a routine test is now more readily available as a primary test option or for confirmatory testing. In specific regard to exotic diagnostics, the “older” techniques of agglutination, immunodiffusion, and neutralization continue to provide an important base for testing as they do not require species specific reagents that are often needed for ELISA testing. However, with added pressure to produce good exotic tests, more monoclonal antibodies will likely become available to improve the existing serodiagnostic test options.

Decision Analysis and Test Validation

Decision analysis is a process for analyzed test choices by the use of a flowchart or decision tree.³ This perhaps is a fancy way of going through a diagnostic rule-out list, but it forces an acknowledgement of an action to be taken for any positive or negative result. That is, by formulating such an analysis for a clinical case, it questions the value of each diagnostic test in making a treatment plan or final diagnosis.

Sensitivity and specificity are very relative terms. They are extremely useful for comparing different tests for the same agent but do not have direct use in clinical practice. They are often based on ideal cases—sometimes with experimental infection—with animals at a particular timepoint along infection or disease. They do not address a large uncertainty about diagnostic parameters such as the following.⁴

1. Test properties and performance. There is no or very little standardization in veterinary diagnostics. Techniques, cut-off values (for positive vs. negative results), and controls will all vary between laboratories.
2. Clinical context. In some cases, the likelihood of receiving a positive result is greater in a clinically ill patient. However, complicating issues maybe present that may affect results, including other concurrent diseases, previous treatments, and poor immune status.
3. Prevalence of the disease. Antibody-based testing in an area or population with higher prevalence will be complicated in terms of determining possible infection vs exposure or post treatment re-exposure.
4. Multiple testing. In general, paired or serial testing is considered to be helpful but in particular disease processes, increases in titers are not always seen during infection.

Assay validation is complicated by similar criteria whereby validation cannot be limited to a few reference samples and ideal cases.⁵ Validation is truly an experimental process involving the optimization of a technique to detect an analyte with accuracy and precision. Reference samples can then be employed to determine an initial sensitivity and specificity. Importantly, this must be extended by what is referred to as conditional, incremental, and continuous processes. As a group, these analyses refer to changes relative to assay that should improve the ability to interpret the test results. For instance, validity may increase with use of additional confirmed reference samples over time, sensitivity and specificity for a test may be variable dependent on the phase of infection, and the assay must be continuously monitored through statistical verification. Test validation and design improvements do not end with the publication or presentation of a new test. It continues through a repetitive process to assess test performance for each population of animals to which it is applied.

Your Role in Diagnostic Testing

It is important to recognize that analytical errors can occur while the sample is still at the clinic or in transit to the lab. Thus, in addition to choosing a lab that you feel is competent, you must minimize any sample issues that could result in pre-analytical errors. A fundamental part of this process is having the most current lab information to ensure that the proper sample is collected—not only proper sample volume but proper sample type (ie, correct anticoagulant, swab type). This continues with storing and shipping the sample by the preferred method. Ideally, a standard operating procedure should be available and periodically reviewed to have the most accurate information. Keep a list of contact names, numbers, and websites to update this information and expedite answering of questions on sample collection and test interpretation.

Diagnostic for Exotic Mammals

Excellent general reference materials on this subject are readily available including the *VCNA Exotic Animal Practice publication*, *Exotic DVM*, the *Journal of Exotic Pet Medicine*, and others.⁶⁻⁷ The current review will state available testing options and issues relevant to the particular disease agent. Table 1 presents a non-comprehensive list of laboratories which offer specialized testing that would be of use to the exotic veterinary practitioner.

1. *Fungal diseases*. Serologic options remain limited for the diagnosis of various fungal diseases.⁸ Agglutination-based assays for antibody can be applied to any species as they depend only on a final read out of precipitation of antibody-antigen complexes. Similarly, antigen-based assays for *Cryptococcus* and *Aspergillus* species can also be employed. However, specific application of these tests to many exotic animals has not been described in the literature.
2. *Cryptosporidium* and *Giardia* species. Traditional light microscopy has been supplanted by test options including ELISA, immunofluorescence, and PCR. *Giardia* ELISA and PCR testing has been reported to have similar sensitivity and specificity in humans, although PCR was able to detect positive samples earlier in infection.⁹ ELISA antigens are believed to be conserved among *Giardia* species. *Cryptosporidium* ELISA has been applied with success in animal samples with a good sensitivity for potentially zoonotic *C parvum* isolates but less sensitivity for non-zoonotic species.¹⁰ To this reviewer's knowledge, there have been no publications regarding the application of PCR to routine diagnostic animal samples for these parasites, although test services are available.
3. *Pasteurella multocida*. Two test options are available and should be considered to be used in conjunction. An ELISA using purified specific antigen has been described in the literature and found to give highly reproducible data and significant titer differences between negative and positive experimentally infected animals.¹¹ Significant antibody differences were also described in naturally infected animals.¹² PCR has been applied in human medicine but this reviewer could not find any description in veterinary medicine, although PCR has been described as a monitoring tool in *P pneumotropica* in lab animals. The value of the test is likely high as the reliability of nasal cultures is not great. The extra sensitivity and specificity of the molecular technique should aid in detection.
4. *Tyzzer's disease/Clostridium piliforme*. Serological testing for this agent in rabbits (and rodent species) is available through most rodent clinical pathology labs. PCR testing has been described in the literature using feces of rodents.¹³ PCR services are available commercially (through lab animal labs) but this reviewer could find no comprehensive description of the application to rabbits.
5. *Rodent serology and PCR testing*. A wide host of test services are available for all species of rodents due to their need in lab animal medicine. All the diagnostic centers listed in Table 1 are receptive to samples from private practitioners. Serological assays are IgG based so care must be taken in test interpretation in acutely ill animals. PCR tests have been well documented in lab animals and if samples are prepared and shipping properly, results will be reliable.
6. *Rabbit rotavirus*. ELISA techniques are described in the literature but could not be found for use in veterinary diagnostics by this reviewer. Notably, in experimental infection, rabbits were found to strongly seroconvert and remain positive through 2 years postinoculation.¹⁴ PCR analysis was recently described in lab rabbits and demonstrated that a human PCR kit provided ample cross reaction.¹⁵ This test is available for fecal samples at Michigan State University (MSU).

7. *Rabbit hemorrhagic disease virus*. Antigen detection tests are the primary screening test for this virus and involves the use of liver or spleen homogenates in an ELISA technique.¹⁶ More recently, a more sensitive PCR test has been described.¹⁷ This test is available for postmortem use at MSU.
8. *Encephalitozoon cuniculi*. Diagnosis of *E cuniculi* is troublesome. Seropositive animals can be found in the absence of clinical signs. Most serostudies that have been published are from non-U.S. locations which does not aid in understanding the prevalence of this agent in routine exotic practice. In the United Kingdom, 23% of asymptomatic rabbits were found to be seropositive vs. 69% of symptomatic animals. Titers were found to be detectable 3–4 weeks after exposure.¹⁸ In an experimental model of infection, antibody was not found to correlate with disease.¹⁹ Thus IgG seropositive status may reflect chronic infection, clearance but seroconversion, incidental exposure, or possible cross reaction. There are 2 prospective studies that may have some worth in furthering ECUN diagnostics. First, IgM titers were found in experimentally infected animals from day 17 through 38.²⁰ Additionally, ECUN spores can be recovered in the urine of some infected animals. One study found spores present between week 4 and 12 post exposure.²¹ Relative insensitive techniques have been used thus far but PCR should prove to enhance both sensitivity and specificity. Rodent laboratories offer PCR testing, but practitioners should note that no controlled studies have been conducted using IgM titers or PCR in rabbits with natural infection.
9. *Ferret epizootic catarrhal enteritis (ECE)*. Detection of this agent is the key to diagnosis. Molecular techniques using tissues, saliva, and feces have been published.²² MSU offers PCR testing on feces.
10. *Ferret influenza*. Ferrets can be naturally infected by (human) influenza A and B. No specific or ferret-validated tests for the virus have been described, but the virus is known to induce seroconversion in experimental models of disease. PCR testing is available at most human laboratories and, if accessible, could be considered for use in ferret cases.
11. *Ferret (canine) distemper virus*. Standards known to canine clinical pathology can be applied to ferret infection. Seroconversion can be monitored by serum virus neutralization assays with the use of paired samples. In experimental infection, blood was found to carry viral antigen from day 2 to 6 postinfection and conjunctival scrapings were found to be positive after day 9.²³ Direct fluorescent testing of these samples as well as the use of PCR would be of diagnostic value. PCR has been described in the literature where over 50% of clinically ill dogs and one ferret were found positive.²⁴
12. *Helicobacter mustelae*. A limited study comparing immunohistochemistry and PCR was performed and showed a good sensitivity of the molecular technique with the final recommendation of submitting swabs from oral mucosa, stomach, and rectum whenever possible.²⁵ Antibody ELISA techniques have also been described but are not commercially available.²⁶ Seroconversion was found to increase with age but the titer was found to decrease with a positive response to treatment. Practitioners should note that other *Helicobacter* species are prevalent in rodents and PCR testing at most rodent labs is readily available.
13. *Aleutian disease virus*. Three types of tests have been presented for ADV testing: serum protein electrophoresis, serology, and PCR. Protein electrophoresis allows for the quantitation of specific acute phase protein fractions and immunoglobulins (gamma fraction). There are several literature citations including Porter and colleagues who reported that naturally infected ferrets have a significantly higher gamma globulin levels (0.49g/dl vs 1.06g/dl).²⁷ In experimentally infected animals, increases were found by day 63 postinfection and were present throughout the termination of the experiment at day 182.²⁷ Palley reported more marked increases (up to 54% of the total protein) in 2 naturally infected ferrets.²⁸ As protein electrophoresis is more commonplace in diagnostic labs, the practitioner should take care to submit non-hemolyzed, non-lipemic samples to a lab that has in-house established reference ranges.

The application of serological testing for antibody was first documented for application to infection in mink species. Counter immunoelectrophoresis (CEP or CIEP) involves the use of an agarose gel medium and an electric current. Antibody-antigen complexes are formed when the sample has ADV antibody and read out as a precipitin. Serum samples are not diluted for analysis and there is no quantitation of titer normally given in this test. The antigen used in this test is a tissue culture preparation of whole virus lysate representing a spectrum of ADV antigens. Two ELISA tests have been produced using recombinant antigen. In general, the use of specific recombinant antigens in ELISA tests greatly eliminates any potential false cross reaction that may be present in tissue culture prepared antigen. However, as the normal antibody response is polyclonal during infection, the use of specific antigen(s) may not fully gauge the humoral immune response and result in lower overall sensitivity. Avecon uses combination of capsid (VP) and non structural (NS) recombinant antigens (B. Stephon, personal communication, April 2006). UGA-IDL uses a capsid ELISA (K. Pennick, personal communication, April 2006). Notably, the application of the tests to ferrets in controlled studies (including the CEP) have not been described in the literature. Also, although anti-ferret IgM and IgG are commercially available, the test services do not report specific titers. Quantitation of such may not be clinically helpful (B. Stephon, personal communication, April 2006).

There has been very little information published regarding ADV serology in ferrets and little more in mink. What has been documented is as follows and does support perhaps questioning titers for NS vs VP antigens in clinical cases:

- a. CEP, immunofluorescence, and complement fixation have been found to be reliable and specific in detecting mink antibody to ADV.²⁹
- b. By Western blot analysis in minks, when the hypergammaglobulinemia was exhibited, 10/12 animals reacted preferentially with VP antigens and 2/12 reacted preferentially to NS antigen.³⁰ Seroconversion by indirect immunofluorescence and increases in gamma globulins were present by day 30 postinfection.
- c. In mink species, vaccination with VP proteins enhanced the disease whereas the use of NS antigens in the vaccines promoted partial protection.³¹ Hypothetically, if the same is true in ferrets, the titers to nonstructural antigens during infection may shed some light on the severity of disease.
- d. Porter et al reported that 28/71 ferrets with ADV showed equal titers to VP and NS antigens, whereas 42/71 reacted preferentially with NS antigens and 1/71 reacted only with VP antigens.³² Furthermore, low antibody titer animals were found to be more reactive to NS antigens versus high titer animals which were more reactive to VP antigens.

The application of PCR testing has been proposed in the literature. Jackson et al found that after initial infection of mink species, ADV DNA was initially found high levels in the blood but decreased when the animals seroconverted.³³ The amount of DNA was also found to correlate with the severity of the lesions. The PCR technique was applied to formalin-fixed tissues by Une in a fatal case of ADV in a ferret.³⁴ More recently, Pennick reported the presence of ADV DNA in serum, urine, feces, and blood of an antibody-positive ferret over a 1.5-year period.³⁵ Necropsy tissues were later analyzed by in situ hybridization and found positive for ADV. Thus, PCR will likely be a viable technique to complement antibody testing. More detailed reports of natural and experimental infection of ferrets should be completed to understand the time course of positive results for both assays.

Table 1. List of laboratories with exotic mammal test services.

Laboratory	Test Services
Avecon www.avecon.com (610) 837-8400	ELISA for ADV
Avian Biotech www.avianbiotech.com (800) 514-9672	PCR for <i>Mycobacterium</i> , <i>Candida</i> , <i>Cryptosporidium</i> , <i>Giardia</i> , <i>Salmonella</i>
Bioreliance www.bioreliance.com (800) 553-5372	Rodent and rabbit serology, rodent PCR
Blue Cross Animal Hospital (208) 678-5553 Contact: Dr. Blau	CEP for ADV
Charles River Labs www.criver.com (877) CRIVER1	Serology and PCR for rodents
Cornell University http://www.diaglab.vet.cornell.edu/ (607) 253-3900	Serum neutralization and direct fluorescence for CDV, <i>Giardia</i> and <i>Cryptosporidium</i> antigen ELISA, fungal serology
Infectious Disease Lab-University of Georgia (706) 542-8092	PCR for <i>Salmonella</i> , <i>Pasteurella</i> (also serology), Anticipates ADV ELISA and PCR for summer 06
MSU www.animalhealth.msu.edu/ (517) 353-1683 Contact: Dr. Maes (maes@dcpah.msu.edu)	PCR for CDV, ferret enteric coronavirus, ferret rotavirus A and C, rabbit rotavirus, rabbit hemorrhagic disease virus, Aleutian disease virus
RADIL-University of Missouri http://www.radil.missouri.edu/ (800) 669-0825	Serology and PCR testing for rodents and serology for rodents and rabbits
RAL, Inc. www.vetdna.com (972) 960-2221	PCR for <i>Helicobacter</i> , <i>Cryptosporidium</i> , <i>Giardia</i> , <i>Salmonella</i> , interests in receiving samples for ADV and ECUN
Taconic Anmed www.taconic.com (301) 762-0366	Serology for rodents and rabbits, PCR for rodents and also <i>Helicobacter</i>
University of Miami – Comparative Pathology http://pathology.med.miami.edu/cpl/ (800) 596-7390	Serology for rodents, interested in receiving samples for rabbit ECUN testing, <i>Giardia</i> and <i>Cryptosporidium</i> antigen ELISA
Veterinary Molecular Diagnostics www.vmdlabs.com (513) 576-1808	PCR for <i>Helicobacter</i> , <i>Cryptosporidium</i> , interest in receiving samples for <i>Salmonella</i> , <i>Giardia</i> , <i>Mycobacterium</i> , and ADV
Zoologix www.zoologix.com (818) 717-8880	Extensive menu of avian, primate, wildlife and rodent PCR tests

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Update on the ABVP–Exotic Companion Mammal Specialty Status

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Abstract: An update is provided on current work by the Association of Exotic Mammal Veterinarians (AEMV) to gain Specialty Board Certification under the auspices of the American Board of Veterinary Practitioners (ABVP). The blueprint of the credential process and examination is being established now and is in review by the ABVP. The general blueprint for ABVP–Exotic Companion Mammal will mimic the other ABVP specialties. To apply for the specialty, an applicant will submit a credential package, which must be accepted by the ABVP before the candidate is allowed to sit for examination. We are hoping to sit the first applicants for the examination in November 2007, pending approval by the American Board of Veterinary Specialties (ABVS), the governing body for specialties by the AVMA. More information on the ABVP process can be found at <http://www.abvp.com>.

Since its inception in 1999, the Association of Exotic Mammal Veterinarians (AEMV) has had the goal of gaining specialty recognition for exotic companion mammals. This group is defined as ferrets, rabbits, guinea pigs, small rodents, and a miscellaneous grouping.

The AEMV approached both the American Board of Veterinary Practitioners (ABVP) and the American College of Zoological Medicine (ACZM) as parent organizations for this specialty. The ACZM was not receptive to the concept, whereas ABVP was.

In developing the specialty, AEMV is operating under guidelines supplied both by ABVP and the American Board of Veterinary Specialties (ABVS). The latter organization is the governing body for specialties by the AVMA. The AEMV is going through a multistage process for recognition.

Stage 1 involved making a presentation stating the case for the uniqueness and vitality of exotic companion mammal medicine. A formal proposal was developed by members of AEMV and presented to the ABVP. The proposal outlined the number and type of exotic companion mammals seen, the knowledge base available, and other resources. Surveys of AEMV members revealed that numerous veterinarians would be interested in obtaining specialty status. ABVP granted us that approval in 2004.

Stage 2 was the formation of an organizing committee of 20 veterinarians recognized as leaders in exotic companion mammal medicine. During the Stage 1 process, many individuals were identified as interested in helping with the ABVP process. These individuals were then contacted after Stage 1 approval. Individuals with varying backgrounds were sought. Preference was given to board-certified specialists in both private practice and academia. Approval of the organizing committee occurred during 2005.

Stage 3 is the stage during which the blueprint of the credential process and examination is established. This includes the creation of examination questions. ABVP is unique in that what defines the specialty is based on a survey of experienced veterinarians. In our case, veterinarians with exotic companion mammal expertise are identified through membership with AEMV and subscription with various exotic journals. At this time, all paperwork dealing with Stage 3 is being reviewed by the ABVP.

Stage 4 is when final approval is granted by ABVP.

Stage 5 is approval by ABVS. It is anticipated that an ABVS presentation by the AEMV and ABVP will occur during the November 2006 meeting.

The general blueprint for ABVP–Exotic Companion Mammal will mimic the other ABVP specialties.

To apply for the specialty, an applicant will submit a credential package, which must be accepted by the ABVP before the candidate is allowed to sit for examination. This package will consist of:

1. Six years experience in a practice where the applicant has seen at least 25% exotic companion mammals (ECM).
2. Ninety hours of continuing education (CE) over the last 5 years in exotic and companion mammal topics. There is an approved CE listing that is available on <http://www.abvp.com>. Most international, national, and regional CE programs that are offered will comply with the approved list.
3. Three letters of recommendation from veterinarians who are acquainted with your skills. One of these letters needs to be from a board-certified specialist. The forms are standardized and available at <http://www.abvp.com>.
4. Two case reports on different species (species groupings include ferrets, rabbits, hamsters, hedgehogs, guinea pigs, and sugar gliders), plus one published report. The published report can be a case report (must include signalment, diagnostics, differentials, and a review of prior literature) or original research (must include review of prior literature and significance to the practicing veterinarian).

Publication of the published report should be in a peer-reviewed scientific journal (defined by ranking in *Indicus Medicus*, which essentially requires the review process by specialists to be rigorous, and that the review process is independent from the editorial board and editorial processes). This requirement excludes several publications, including *Proceedings of the North American Veterinary Conference*, *Small Animal and Exotic Practice Medicine*, and *Compendium*. The *Journal of the American Veterinary Medical Association*, the *American Journal of Veterinary Research*, the *Journal of Zoological and Wildlife Medicine*, and various lab animal journals would be included. Because the publishing world for exotics is small, we would accept publication in *ExoticDVM* and *Seminars in Avian and Exotic Pet Medicine* (this journal is working toward inclusion in the approved *Indicus Medicus* journals).

5. A self-evaluation form. This is one form still being reviewed by ABVP.
6. A current curriculum vitae and proof of graduation from veterinary college.

Your credential package is due at the ABVP by January 15 of the year of the exam. If your credential package is found to be deficient, you have 2 years to correct the deficiency (extra fees are required for repeat credential evaluation).

Once an applicant passes credentialing, then they would sit for the examination. The 3-day examination would consist of multiple choice questions and would have a practical part that would include pictures and video. All questions will be from referenced sources currently available to the private practitioner. A reading list is available at <http://www.abvp.com>.

You have 3 years to pass all 3 parts of the examination (extra fees are required for repeat examinations).

Once you have passed the examination, you are credentialed as a specialist for 10 years. Your specialty status needs to be recertified by then or it will expire. You can recertify in years 8, 9, or 10 before expiration.

More information on the ABVP process can be found at <http://www.abvp.com>.

We are hoping to sit the first applicants for the examination in November 2007, pending ABVS approval.