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Clinical Management of Captive Cheetahs

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INTRODUCTION

As wild cheetah populations continue to decline, captive populations in zoological institutions, breeding and conservation centers grow in importance. Though similar in many aspects to other species in the felid family, cheetahs exhibit unique adaptations that can make their captive care more challenging. They are more susceptible to stress induced diseases than other species (Chapter 25), and in particular captive cheetahs appear to be more susceptible to

infectious diseases, some of which was initially attributed to their lack of genetic variability (Heeney et al., 1990; Munson et al., 2005; O'Brien et al., 1985; Chapters 6 and 25). Management requires a comprehensive program to maintain a healthy population of captive cheetahs, including veterinary care, nutrition, housing, exercise, and enrichment. Initial information can be found through the cheetah Animal Care Manual. The manual, published by the cheetah Species Survival Plan® (SSP) and the North American captive cheetah specialists, provides general

guidelines for the care of cheetahs, and has been shared with the international cheetah community. These guidelines may need to be adjusted based on each institution's local and regional needs. This chapter covers the aspects of housing, stress management, restraint/handling, anesthesia, preventative medicine (including vaccination, health examinations, preshipment and quarantine examinations, and diagnostics), necropsy, and cub care. Protocols and forms that are relevant to this chapter can be found at <https://www.elsevier.com/books-and-journals/book-companion/9780128040881>.

SPECIAL HOUSING REQUIREMENTS

Facility design is critical for effective management of the cheetah. Size, barriers, substrate, shelter, transfer chutes, training, and animal management should be carefully considered. How a facility is built and what management practices are undertaken, should depend on the social groupings (single or in groups) and purpose (breeding, display, ambassador) of the cheetahs to be housed in it. Facilities should incorporate enclosures for isolation or separation, as well as having some yards interconnected to allow for ease of transfer. It is also recommended to have a chute or restraint cage so that individuals can be safely handled for procedures without the need for anesthesia (Ziegler-Meeks, 2009). By taking into account management challenges and risk factors, such as disease transmission, fence-line aggression, and ability to separate groups into their housing needs, the well-being and health of captive cheetahs can be greatly improved (Terio and Munson, 2005).

Indoor facilities should have easy access to the outdoor areas. Flooring should provide good traction and be easily disinfected. Adequate platforms should be in place so that the cheetah can be off the floor, with bedding hay or shavings for the cheetah(s) to lay on, especially during the winter months. Proper ventilation

is also needed to prevent accumulation of substances like ammonia from urine, which can result in respiratory problems (Ziegler-Meeks, 2009). The SSP recommends that cheetahs should not be confined indoors, unless it is necessary for medical management or due to inclement weather conditions. Outdoor enclosures for all cheetahs should be as large as possible. The SSP guidelines recommend a minimum enclosure size of ~750 m² for up to 2 cheetahs.

Cheetahs can be housed in open-topped enclosures behind moats, chain-link or wire mesh, solid walls, glass windows, or a combination of these materials (Ziegler-Meeks, 2009). Certain states or countries have more specific regulations for cheetah enclosures, and they should be consulted before the enclosure is constructed. Typically, wire mesh is used for the enclosure and should be no lighter than 25-cm gauge and have spaces no larger than 5 by 10 cm.

Several considerations should be taken when constructing the outdoor enclosure to prevent injury or escapes. Adult cheetahs are generally considered to be poor climbers. However, they have been reported to climb over 3 m of solid wall when no overhang was present (Marker and Schumann 1998), and they are good climbers when immature and are able to jump over a 3.5-m moat (Ziegler-Meeks, 2009). To prevent an escape, a fence made of either solid vertical walls or wire mesh should be at least 2.5 m tall with an additional 60 cm mesh overhang into the enclosure at a 45-degree angle. Overhangs are a critical part of containment and should be made of chain-link or wire mesh. Strands of wire, barbed wire, or hot wire should not be used for the overhang, as cheetahs can easily go through these and get injured in the process (Cheetah SSP manual, in preparation). Fences should be sunk around the perimeter and corners should not be tighter than 90 degrees or contain small spaces that facilitate climbing. If needed, electrified wire can be used as a supplemental deterrent to climbing.

Breeding Facilities

Breeding facilities require additional considerations. Because cheetahs exhibit a high degree of mate selection (Chapters 9 and 27), facilities need to be able to hold a large number of potential breeding animals (four to six females and at least two groups of males) and be subdivided into multiple interconnected enclosures, to increase the chances of reproductive success (Bertschinger et al., 2008; Wielebnowski et al., 2002; Ziegler-Meeks, 2009). Cheetahs used for breeding purposes are currently not recommended to be used concurrently as educational program animals (ambassador cats). The SSP guidelines recommend that all males be maintained in their natural sibling coalitions to improve reproductive success, as well as maintain strong, healthy coalition bonds. Alternatively, captive male cheetahs can be successfully introduced at a young age, to form stable coalitions that simulate natural social groupings of wild male cheetahs (Chadwick et al., 2013; Chapter 27). Koester et al. (2015) reported improved testis function and more normal, motile spermatozoa and androgen production in males held in coalitions compared to those held singly.

The breeding facility should include several maternity enclosures, which are isolated from other enclosures and public viewing, to decrease stress to the dam. These maternity yards should still have easy access to the females' original enclosures and a minimum of two potential dens should be in place. Dens should be constructed with easy access to the cubs by keeper and veterinary staff, while minimizing stress to the dam (Ziegler-Meeks, 2009). Offspring should stay with the dam for at least 1 year and up to 18 months of age. Male and female siblings will have to be separated at around 20–22 months of age. Male siblings can stay together for life. Facilities should be prepared to hold offspring for up to 2 years after being separated from the dam.

STRESS MANAGEMENT

Several cheetah diseases, as well as poor reproductive performance have been linked to stress levels (Chapters 25 and 27); stress management is therefore an important part of clinical management. Many factors, including exhibit design, animal movements, exercise, and enrichment, need to be addressed to minimize stress. Cheetah exhibits should be located far from potential sources of stress, such as other large carnivores (e.g., lions, hyenas), and should be designed to encourage natural behavior. Limiting the need for animal handling, particularly during breeding situations, decreases acute stresses. Exercise is crucial for cheetahs, and should be facilitated through sufficient enclosure size, as well as a lure course system within the enclosure. Mechanical lure coursing equipment pulls a lure (such as a rag, feathers, or meat treat) quickly (80 kph) around the area. The running provides enrichment and health opportunities for the animals. Other enrichment opportunities, such as providing meat on the bone or carcasses (Chapter 26), novel scents and 'safe' toys, and climbing structures, should be provided for the well-being of the cheetah.

RESTRAINT AND HANDLING

Medical Training and Restraint

Cheetahs, whether captive- or wild born, adapt quickly to daily routine procedures in captive settings. Cheetahs can be trained to "station" voluntarily along a fence or in a chute for medical procedures using positive reinforcement. This type of training decreases the stress associated with procedures and allows the use of lower anesthetic drug dosages during induction. Cheetahs are amenable to being trained for multiple routine procedures, such as voluntary venipuncture (usually lateral tail vein or saphenous vein), ultrasounds, radiography, administration of medications, and subcutaneous fluids.



FIGURE 24.1 Crating a cheetah at the Cheetah Conservation Fund.

Cheetahs can also be trained to readily shift from their enclosure to a chute, restraint cage, or crate for veterinary procedures (Fig. 24.1). Once restrained, cheetahs can be injected intramuscularly (i.m.) or intravenously (i.v.) via hand- or pole-syringe. The volume of the drug combination for intramuscular injections performed on a physically restrained animal (e.g., in a squeeze crate) should be kept to a minimum, while using a relatively large luer lock syringe (e.g., 5 or 10 cc) and needle size (20 or 18 g) to facilitate administration and reduce the risk of partial drug delivery.

If shifting into a crate or stationing is not possible, and anesthesia is necessary, cheetahs can be darted by blowpipe or with CO₂ powered dart guns inside their enclosures. However, given their leaner muscle mass, care must be taken to avoid spiral fractures along the femoral bone due to penetration of the dart needle into the shaft of the bone (Meltzer, 1999).

Anesthesia

Multiple anesthesia protocols have been used in the cheetah. Selection of anesthesia protocol should be tailored to account for the temperament of the animal, pertinent clinical history, route of administration, procedure to be performed, and clinician expertise. Most protocols use tiletamine–zolazepam or ketamine

combined with an $\alpha 2$ agonist (Table 24.1). Protocols that include tiletamine–zolazepam, whether in combination with an $\alpha 2$ agonist or on its own, are often associated with prolonged recoveries and hypertension. However, these protocols are useful when small volumes of anesthetic drugs are needed (e.g., for darting). Several fully reversible anesthetic protocols have also been reported using $\alpha 2$ agonists, such as medetomidine or dexmedetomidine in combination with butorphanol and midazolam (Table 24.1). These protocols provide a fast onset of anesthesia, good muscle relaxation and rapid recovery; however, sudden arousals can be observed at the reported dosages and total injection volume can become large. Varying degrees of hypertension have been observed with $\alpha 2$ agonist combinations (LaFortune et al., 2005; Woc Colburn et al., 2017).

Intravenous anesthetic protocols have also been used in cheetahs trained to accept injections. Either a butterfly infusion set or i.v. catheter can be inserted into the lateral tail vein or medial saphenous vein for drug administration (Fig. 24.2). Alfaxalone can be intravenously titrated to effect and allows general handling of cheetahs, as well as electroejaculation (EEJ). While poikilothermia has been reported in the past (Button et al., 1981), these reports are from a time when alfaxalone was combined with alphadolone and cremophor EL as solvents, as opposed to the current combination of alfaxalone and cyclodextran in water as the solvent (Goodchild et al., 2015). Intravenous propofol–fentanyl protocols have also been reported in the cheetah. These protocols produced rapid induction and stable cardiorespiratory parameters and wore off 15–20 min from induction. Anesthesia can readily be maintained by gas inhalant anesthesia, such as isoflurane. Maintenance of anesthesia with propofol–fentanyl via total intravenous anesthesia is not recommended in cheetahs because, as in domestic cats, it can produce prolonged anesthetic recoveries and episodes of apnea (Woc Colburn et al., 2009).

TABLE 24.1 Previously reported anesthesia protocols in the cheetah

Generic Name	Dosage	Route	Reversal Agents and Dosage	Comment
Tiletamine-Zolazepam	2–4 mg/kg	i.m.		Higher doses may cause apnea
Tiletamine-Zolazepam	4.2 mg/kg	i.m.	Flumazenil 0.031 mg/kg or Sarmazenil 0.1 mg/kg	Improved recovery
Tiletamine-Zolazepam	1.9–2.6 mg/kg	i.m.		
Ketamine	1.38–3.38 mg/kg			
Tiletamine-Zolazepam	1.0–1.4 mg/kg	i.m.	Atipamezole 5×	
Ketamine	1.0–1.4 mg/kg		Medetomidine	
Medetomidine	0.010–0.014 mg/kg			
Tiletamine-Zolazepam	1.5–1.7 mg/kg	i.m.	Atipamezole 7×	
Ketamine	1.5–1.7 mg/kg		Dexmedetomidine	
Dexmedetomidine	0.01 mg/kg			
Tiletamine-Zolazepam	1.5 mg/kg	i.m.	Atipamezole 0.15 mg/kg	Hypertension
Medetomidine	0.030 mg/kg			
Tiletamine-Zolazepam	2.9 mg/kg	i.m.	Atipamezole 5×	Hypertension
Medetomidine	0.027 mg/kg		Medetomidine	
Tiletamine-Zolazepam	1.15 mg/kg	i.m.	Yohimbine 0.1–0.2 mg/kg	Prolonged recovery
Ketamine	1.84 mg/kg			
Xylazine	0.46 mg/kg			
Ketamine	6.9 mg/kg	i.m.	Atipamezole 5×	Transient seizures, hypertension
Medetomidine	0.027 mg/kg		Medetomidine	
Ketamine	2.5 mg/kg	i.m.	Atipamezole 0.3mg/kg	
Medetomidine	0.04–0.07 mg/kg			
Ketamine	6.9 mg/kg	i.m.		Hypertension
Midazolam	0.4 mg/kg			
Ketamine	5.0 mg/kg	i.m.	Atipamezole 10×	Fast and smooth induction, excellent sedation level
Dexmedetomidine	0.017 mg/kg		Dexmedetomidine	Cardiovascular parameters similar to medetomidine and ketamine
Medetomidine	0.035 mg/kg	i.m.	Atipamezole 0.0175 mg/kg	Rapid induction and recovery
Butorphanol	0.2 mg/kg		+ Flumazenil 0.006 mg/kg	Hypertension
Midazolam	0.15 mg/kg		+ Naltrexone 0.25mg/kg	
Dexmedetomidine	0.0158 mg/kg	i.m.	Atipamezole 0.125 mg/kg	Rapid induction
Butorphanol	0.22 mg/kg		+ Naltrexone 0.1 mg/kg	Less hypertension than with other protocols
Midazolam	0.18 mg/kg			
Alfaxalone	54–90 mg	i.v.		Initial bolus, then add to effect
Alfadolone acetate	18–30 mg			Poikilothermia
Alfaxalone	2 mg/kg	i.v.		Used for EEJ
Propofol	5–6.5 mg/kg	i.v.		Smooth induction.
Fentanyl	0.002 mg/kg			CRI caused prolonged recovery

CRI, Constant rate of infusion; EEJ, electroejaculation; i.m., intramuscularly; i.v., intravenously.
Modified from Woc Colburn, et al., 2017



FIGURE 24.2 Administration of Propofol intravenously through an i.v. catheter placed in the lateral tail vein of a cheetah at Smithsonian Institution National Zoological Park.

Anesthesia Monitoring

While under general anesthesia, the cheetah's heart rate, respiratory rate, body temperature, oxygen saturation, systemic blood pressure, and end-tidal CO_2 , should be monitored closely. Frequency is determined based on the patient and anesthetic protocol, but ideally should be recorded minimally every 5 min. An anesthetized cheetah's heart rate and respiratory rate can vary depending on the anesthetic drug combination used. Lower heart rates are seen with α_2 agonists, such as medetomidine and dexmedetomidine. Lower respiratory rates are observed with respiratory depressant anesthetics, such as butorphanol and propofol. Body temperature should be monitored closely. If

hyperthermia ($>40^\circ\text{C}/104^\circ\text{F}$) is present, the body should be cooled down in a controlled manner to prevent a rapid drop of body temperature. Hypothermia ($<37^\circ\text{C}/98^\circ\text{F}$) should be addressed aggressively to prevent hemodynamic changes. Both direct and indirect blood pressure monitoring during anesthesia have been performed in the cheetah (Sadler et al., 2013; Sant Cassia et al., 2015), and measurement of blood pressure is recommended as part of overall anesthesia monitoring. Intravenous or subcutaneous fluids should be provided throughout the anesthesia.

The cheetah's eyes will remain open and should be lubricated with tear gel as soon as an ophthalmic examination has been performed. A blindfold or eye cover should be placed. The positions of the eye and pupil size are dependent on the depth of anesthesia, as well as anesthetic agents used.

Recovery

Recovery from anesthesia should be provided in a quiet, dark space. The head should be placed straight, making sure that the throat is not kinked and that the airway is clear. Cheetahs can be given access to water and then food once they are able to stand and walk normally.

PREVENTATIVE MEDICINE

A complete, consistent preventative medicine program should be instituted in all cheetah facilities. The recommendations for cheetah are very similar to those for other exotic felids. Specific testing recommendations exist for health examinations, quarantine, and preshipment protocols (Table 24.2).

Health examination and preventative medicine protocol

Health examinations are performed as part of a complete preventative medicine program. The program should be based on each institution's needs and disease risks, as well as the

TABLE 24.2 Required and Recommended Medical Procedures as Part of the Quarantine, Routine, and Preshipment Examinations for Cheetah

Procedure	Quarantine	Routine exam	Preshipment
SSP REQUIRED MEDICAL PROCEDURES			
Physical exam	X	X	X
CBC, serum chemistry	X	X	X
FeCOV, FIV, FeLV serology	X	X	X
Heartworm testing			X
Serum bank	X	X	X
Urinalysis	X	X	X
Survey radiographs			X
Fecal ova and parasite screening	X	X	X
Fecal FeCoV PCR	X		X
Immunization	If needed	If needed	If needed
Dental prophylaxis	If needed	If needed	If needed
Body weight	X	X	X
Permanent ID	X	X	X
SSP RECOMMENDED MEDICAL PROCEDURES			
FPV, FHV, FCV, Toxoplasma serology	X	X	X
Survey radiographs	X	X	
Heartworm testing	X	X	
Fecal Culture for enteric pathogens	X		X
Fecal FeCoV PCR		X	
Gastroscopy and gastric biopsies	X	X	X
Abdominal ultrasound	X	X	X
Approved research requests	X	X	X

CBC, Complete blood count; FCV, feline calicivirus; FeCoV, feline enteric coronavirus; FeLV, feline leukemia virus; FHV, feline herpesvirus; FIV, Feline immunodeficiency virus; FPV, feline parvovirus/panleukopenia; PCR, polymerase chain reaction, SSP, Species Survival Plan® (SSP) for cheetahs. Data based on Citino, S., Haefele, H., Junge, R., Lamberski, N., McClean, M., Sanchez, C., 2009. Cheetah SSP Health Chapter. In: Ziegler-Meeks, K. (Ed.), *Husbandry Manual for the Cheetah (Acinonyx jubatus)*, White Oak Conservation Center, Yulee, Florida pp. 242–277.

overall health of the animal collection. Health examinations include a complete physical examination, body weight, body condition score (Dierfeld et al., 2007), complete blood count, serum biochemistry, urinalysis, viral serology, and fecal screening (Citino et al., 2009) (Table 24.2). Other recommended procedures are based on each institution's preventative medicine program. These may include survey radiographs, abdominal

ultrasonography, gastric endoscopy for baseline evaluation, and testing for heartworm (antigen and antibody test) or specific infectious disease (Table 24.2).

Normal hematology and serum biochemistry values for both captive and free ranging cheetahs have been reported in the literature (Depauw et al., 2012; Hudson-Lamb et al. 2016; ISIS, 2013; Munson and Marker, 1997). Feces should be

examined for ova and parasites, and appropriate deworming and ectoparasitic treatment should be administered. Routine viral screening should include serology tests for feline immunodeficiency virus (FIV), feline leukemia virus (FeLV), and feline enteric coronavirus (FeCoV), as well as fecal FeCoV PCR (Gaffney et al., 2012) should be performed. Screening tests should be performed by a standardized laboratory that is familiar with analyzing sera and fecal samples from non-domestic species.

During the physical examination, attention should be paid to lesions caused by viruses, such as feline calicivirus (FCV) and feline herpesvirus (FHV), as cheetahs are highly susceptible to these viruses. Similarly, given the propensity for a wide variety of hepatic, gastric, and renal diseases, special attention should be given to those organ systems (Chapter 25). The oral cavity should be evaluated for lesions, such as papillomatous plaques under the tongue or oral ulcerations. A thorough dental examination should be conducted. Crowding of incisors and palatal depressions are common in captive and wild cheetahs (Marker and Dickman, 2004; Steenkamp et al., 2017; Chapter 7). Palatal depressions can become pathological (focal palatine erosion, FPE; Chapter 25); these crypts can get impacted and infected, leading to abscessations and oronasal fistulas. Gently removing the points from the mandibular M1 (using a Dremel or similar tool) prevents further trauma to the crypts. Tooth abrasions and fractures, particularly those of the canine teeth, are commonly found on oral examination in captive cheetahs (Steenkamp and Boy, 2009). Resorptive lesions have also been documented in both captive and wild Namibian cheetah skulls (Roux et al., 2009).

Vaccinations

Cheetahs are susceptible to similar infectious diseases as seen in domestic cats (Chapter 25) and they should be vaccinated appropriately.

The current recommendation by the Cheetah Veterinary Scientific Advisory Group of the American Association of Zoos and Aquariums (AZA), the SSP, and the European Endangered Species Programme (EEP) are broken down between core vaccines and those that are supplemental, based on each institution's disease risk assessment.

Core vaccines include: rabies, feline parvovirus/panleukopenia (FPV), FHV, and FCV. FHV, FPV, and FCV should be given as a killed vaccine (e.g., Fel-O-Vax from Boehringer Ingelheim, Fevaxyn Pentofel from Zoetis) at 6, 9, 12, and 15–16 weeks and a booster at 6 months (Citino et al., 2009). Rabies vaccine should either be a killed (Imrab 3, Merial) or a canary-pox vectored subunit vaccine, and should be administered at 4–6 months of age and boosted at 1 year of age. Adults should be vaccinated ever 1–3 years for FPV, FHV, FCV, and Rabies. Serum antibody titers can be monitored to evaluate response to the vaccination. Pregnant females are recommended to be revaccinated for FHV, FPV, and FCV with a killed virus vaccine 3 weeks prepartum.

For breeding institutions that have had herpesvirus infections associated with severe and recurrent lesions in their young cheetah cubs (<3 weeks of age), a modified-live virus (MLV) vaccine against FHV (Merial PureVax Feline 3, Merial) has been trialed as a booster. This MLV vaccine is under current investigation and should only be used as a booster in adult females that are going to be bred and that have already received a killed FPV, FHV, FCV vaccine 3 weeks prior, as the calicivirus component could cause the development of pad vesicles (Citino, unpublished data). The MLV herpes vaccine should not be used in kittens, juveniles, or in those not deemed healthy, as disease may be induced (Citino, unpublished data). When using the MLV herpes vaccine, there is a potential for shedding of the vaccine strain virus, therefore recently vaccinated cats should only be in proximity (e.g., sharing fence-lines) with

low-risk cheetahs for approximately 3 weeks after vaccination. A thorough risk-based analysis should be performed prior to making the decision to use modified-live vaccines in cheetahs and precautions to prevent disease transmission to other cheetahs should be taken. Vaccinations for FeCoV, FeLV, FIV are not recommended at this time. A risk-based analysis should also be performed before deciding to vaccinate for the Canine Distemper Virus (CDV) at the institution.

Quarantine and preshipment protocol

Any newly acquired animal should undergo a quarantine period before being introduced into an existing collection, for both the safety of the individual animal, as well as the collection. Quarantine period and examinations vary among institutions. Factors that affect timing and duration include, but are not limited to, health and disease status of the individual, place of origin, outcome of examination performed prior to its transfer, and history of infectious disease in both the sending and receiving institution. The quarantine period is typically 30 days. During that time period, and depending on preshipment testing, similar procedures to those required for routine health examinations should be completed.

Advanced diagnostics technique

Diagnostics used in domestic cats can readily be applied to the cheetah. Radiographs, ultrasonography, and gastric endoscopy with biopsies, can provide additional information about the health status of the animal. Physiological findings specific to the cheetah are briefly described in Chapter 7. Baseline two-view thoracic and abdominal radiographs are routinely taken by some institutions.

Cheetahs are prone to several renal and hepatic conditions including hepatic veno-occlusive disease, glomerulosclerosis, medullary

amyloidosis, pyelonephritis, and suppurative nephritis (Chapter 25) making abdominal ultrasonography a useful diagnostic tool. In normal ultrasound of the liver and the spleen, myelolipomas are commonly seen and are an incidental finding (Chapter 25). Ultrasonography, particularly transrectal ultrasonography, is a useful tool to monitor the reproductive organs and ovarian status in cheetahs (Goeritz et al., 1999; Schulman et al., 2015; Chapter 27).

Gastritis is prevalent in the North American, European, and South African captive cheetah population and is commonly associated with *Helicobacter* infection. The high prevalence was attributed to stress responses (Chapter 25). The only current, definitive antemortem diagnostic test is gastroscopy with gastric biopsies. C-urea breath test can be utilized to see if *Helicobacter* is present, however, this cannot identify the degree of gastritis (Chatfield et al., 2004).

Newer methods for early detection of chronic renal disease are being researched: Glomerular filtration rate, renal plasma flow, endogenous creatinine clearance, and fractional excretion studies have been performed in healthy captive cheetahs (Holder et al., 2004; Sanchez et al., 2007; Terio and Citino, 1997). The use of urine protein-creatinine ratio can be useful for the confirmation of proteinuria. Serum symmetric dimethylarginine, a renal biomarker, can also be used to detect early renal disease. This test appears to be promising, however to date there are no reference values for non-domestic felids, including cheetahs. Newer research into renal biomarkers are being conducted in several exotic felids and can potentially be applied to cheetahs. Serum and acute phase proteins are being used to detect early stages of inflammation, secondary to gastrointestinal and renal diseases. Baseline serum and acute phase proteins are described in captive cheetahs (Depauw et al., 2012). These can be used in nonhealthy cheetahs to aid in the early diagnosis of a variety of gastrointestinal and renal diseases.

POSTMORTEM

In the event of a death, a complete necropsy should be performed following available guidelines (e.g., produced by Cheetah SSP and EEP programs). A complete set of tissues should be submitted in formalin for histopathology and pertinent tissues should be stored frozen (-80°C) for potential additional testing. Findings should be reported to the appropriate stud-book keeper and veterinary advisors so that ongoing and emerging disease issues can be identified and researched.

HAND-REARING

Cheetahs have a gestation length of approximately 92 days (Chapter 27). During parturition and cub rearing, it is important to decrease potential stress and disturbance to the dam to prevent potential neglect or trauma to the cubs (Ziegler-Meeks, 2009). Prior to the birth of the cubs, a hand-rearing protocol should be in place along with equipment and supplies, in case they are needed. Every effort should be made to allow the dam to rear the cubs on her own. However, if illness, maternal neglect, abandonment, or trauma occurs, or if only 1 cub is born, a decision to hand-rear has to be made rapidly. Fostering should always be done for single cubs (when another litter is available) as the single cub does not stimulate the dam enough for adequate milk production. Fostering on to a similar aged litter has been successful with cubs that differ by as much as 3 weeks in age.

When cubs are pulled for hand-rearing, they should be evaluated by the veterinary team to assess for health problems, hydration status, and congenital defects. Cubs with failure of passive transfer of antibodies due to the lack of adequate intake of colostrum, are more susceptible to infectious diseases due to their decreased immunity. If failure of passive transfer is present, a plasma transfusion from the dam or another cheetah may be needed. Plasma can be given to

the cubs subcutaneously or by mouth for the first 1–2 weeks to ensure that full amount is received. Approximately 19% of hand-reared cubs do not survive, with a large percentage of deaths occurring before 30 days of age (Lombardi et al., 2009). Gastrointestinal disorders, pneumonia, and upper respiratory diseases are common causes of mortality with a variety of potential etiologies (Bell, 2005). To prevent exposure to infectious diseases, hand-rearing should be performed in an isolated room and proper personal protective equipment, such as gloves, gowns, masks, and boots, should be worn. Deworming with pyrantel pamoate should begin at 6 weeks and be administered every 2 weeks until cubs are 16 weeks of age. Facilities in geographic locations that are endemic for heartworm disease (*Dirofilaria immitis* infection) should start prophylactic heartworm prevention as early as 6 weeks of age, when the first set of vaccines is given.

Cubs should be weighed every day at the same time prior to being fed. The average birth weight of cubs is approximately 474 g. Lombardi et al. (2009) reported that the average growth rate in a healthy hand-reared cheetah cub averaged 48 g/day. Those that did not survive averaged much lower daily gains (~ 5 g/day). Mean growth rate was affected by the type of first solid food given, with ground beef having the lowest growth rate. Cheetah milk is lower in carbohydrates than domestic cat milk and milk replacers; therefore Lombardi et al. (2009) recommends diluting commercial milk formula with distilled water to help decrease carbohydrate load and diminish frequency of diarrhea. Formulas, such as Kitten Milk Replacer (KMR) have been used successfully, mixed either at a 1:2 or 1:3 ratio, and lead to higher survival rates than dog formulas (Esbilac; Lombardi et al., 2009). Zoologic formulas 42/52, 33/40, and 30/55 contain less carbohydrates compared to KMR, and are less frequently associated with diarrhea. Different institutions have added supplemental vitamins, protein sources, or have combined milk replacers to bring the milk composition closer to natural cheetah milk,

the constituents of which have been well documented (Lombardi et al., 2009). It is recommended for the first feedings to consist of 5% dextrose mixed with distilled water or pedialyte, and then introduce the formula gradually once cubs are stable and taking several feedings well. Frequency of bottle-feeding depends on the cub's age, and is gradually decreased from every 2 h for newborns to approximately six feedings per day by week 4. Amount of formula usually starts around 10%–12% of body weight per day and is gradually increased to 15%–20%. Feedings greater than 20% have led to loose stool and other gastrointestinal disturbances (Lombardi et al., 2009). Cheetah cubs should be adequately hydrated to prevent impactions. During feeding, care should be taken to prevent aspiration pneumonia.

Meat-based baby foods can be added at 3 weeks of age. If doing well, cooked meat is added to the diet, followed by raw meat, around 4–5 weeks of age. Cubs can then be weaned by 6–7 weeks of age (Citino, unpublished data). Weaning at a younger age leads to less carpal valgal abnormalities, which are commonly seen in hand-reared cheetahs (Bell et al., 2011; Chapter 25).

Diets fed to captive cheetahs, especially supplemented meat, can vary significantly in vitamin and mineral content. These dietary differences alter blood mineral and vitamin levels, and may predispose cheetahs to nutritional disease, such as metabolic bone disease (Beckmann et al., 2013; Depauw et al., 2012). For this reason, diets should be carefully evaluated, particularly in growing cheetahs, to ensure that they not only meet dietary recommendations for felids, but also that circulating levels of nutrients are adequate.

CONCLUSIONS

Cheetahs pose many husbandry and veterinary challenges, in part due to their unique anatomy, physiology (Chapter 7), and

propensity to develop disease in the captive setting (Chapter 25). Maintaining the cheetahs' health by providing the proper care in captivity is essential for successful captive propagation, which will become more important as wild populations continue to decline. Providing proper care in captivity depends on a good understanding of their clinical and management needs. The topics of enclosure set-up, stress management and exercise, as well as clinical care are especially pertinent to ensure increased welfare and long-term sustainability of the captive population. Significant progress has been seen over the past decades and management will continue to improve as additional insight is gained from *in situ* and *ex situ* studies, as well as from substantial management experience. Global management programs, such as the SSP, EEP, Japanese Association of Zoos and Aquariums (JAZA), and Australasian Zoo and Aquarium Association (ZAA) continue to work within their regions to promote best-practice guidelines for the captive care of cheetahs.

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