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Camelid Herd Health

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KEYWORDS

• Llama • Alpaca • Herd health • Vaccination
• Biosecurity • Husbandry

ROUTINE HUSBANDRY

Facilities and Environmental Management

Camelids are adapted to the high plains of South America, with cool, dry winters and mild, dry summers. This makes parts of North America challenging for their survival. Depending on area, considerations for shelter should include provision of air flow in the summer with wind breaks in the winter, shade, and dry ground.[1] The hierarchy within camelid herds makes it imperative that shelters be sufficiently large, with large enough openings that all animals, especially the young, old, or thin, are able to enter without harassment. It is easy to design and provide adequate pasture and shelter for the healthy population of animals on the farm. On the other hand, hospital, maternity, and quarantine facilities should be well designed and constructed to be separate from each other and from the main herd groups.

Shelter that provides shade, ventilation, and wind protection is a must for camelids. Heat stress is a major health concern in the southern United States, and handling and housing of animals in consideration of the Heat Stress Index (HSI) is important. The formula and interpretation guidelines for the HSI are:

HSI = humidity (%) + temperature (°F)
HSI = less than 120, handling is considered safe
HSI = 120–150, unnecessary handling should be avoided
HSI = greater than 160, handling is considered dangerous and animals should be closely monitored

In areas where high HSI occurs throughout the year, air-flow and shade provision are of utmost importance. In cold winters, straw bedding and wind-breaks should be provided. In summer, however, straw bedding closes the thermal window, which in camelids is the ventral thorax and abdomen, and does not allow for heat dissipation.

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In the summer, sand, concrete or open pasture under shade and with fans or misting devices make good housing.

Stocking density is generally recommended to be five to seven camelids per acre full-time[2] to allow for parasite control and meeting nutritional needs. Quality and quantity of forage and dung-pile management are factors to include in stocking density recommendations. In general, camelids should be supplied approximately 2% of their body weight in dry matter for maintenance, with pregnant, lactating, or growing animals consuming 1.5 to 2 times that amount.[3] Fresh hay should be offered daily and feeders should be monitored for feed sorting, with feeding amounts adjusted accordingly. Palatable camelid- or sheep-labeled mineral mixes should be offered in every herd and actively monitored for consumption. Cattle, goat, or horse mineral should not be offered to camelids because of the risk of copper toxicity. Pasture rotation or intensive grazing can be a useful tool from a nutritional and parasite standpoint, improving land usage and reducing larval burdens across land. It is recommended that pasture rotation or housing changes not be made after 8 months of gestation in pregnant females. This is the time of gestation where uterine torsion occurs most commonly.[4] This environment change often leads to animals exhibiting rolling behavior, which is believed to be a cause of uterine torsion in this species.[5]

When providing supplemental feeds, it is important that feeds be measured and that label directions be followed. While attending a camelid conference at Ohio State University, veterinarians, owners, breeders, and other attendees were asked to measure out 1.0 lb of a commercial camelid pellet. Less than one-third of attendees were accurate to within 0.25 lb. Veterinarians turned in an average of 0.67 lb of feed (range, 0.25–1.25, standard deviation 0.34), while owners and breeders turned in a mean of 0.71 lb (range, 0.13–1.75, standard deviation 0.40).[6] This demonstration of the inaccuracy of ''eyeballing'' feed weight reinforces the need for measurement.

Environmental management is an important component in parasite control in all species. The establishment of dung piles by camelids provides some resistance to internal parasite transmission. In many herds, however, this pile is created near feeders or inside the shelter. When near feeders, smaller animals, who often sustain themselves on orts from the feeder, will have increased exposure to infective larvae. Sheltered dung piles are protected from the elements (sun and freezing), which provide some killing of larvae. Dung piles should be cleared at least weekly or biweekly, and more often when they occur around feeders or are sheltered.

It is not currently recommended that deworming take place at routine intervals because of the development of anthelminthic resistance. When an intestinal parasite problem is encountered, through diagnosis of clinical disease or demonstration of high egg counts on fecal screening, stocking density and dung-pile management should be evaluated and fecal flotations should be performed on 10% or 10 animals (whichever is greater) in the herd monthly. Both quantitative and qualitative fecal examinations should be performed by technicians or veterinarians with training and experience in reading camelid fecal preparations. It is strongly recommended in herds with parasite burdens and apparent poor response to drugs to do fecal egg count reduction tests, in which an initial fecal flotation (quantitative) is performed, a dewormer is given, and a fecal examination is repeated in 2 weeks. The dewormer is considered effective if there is a greater than 90% reduction in fecal egg count. When the monthly fecal flotation findings show negative or negligible counts, parasite monitoring can then be continued quarterly.

In areas where white-tailed deer and meningeal worm are endemic, meningeal worm prophylaxis with monthly, parenteral administration of avermectins has been recommended.[7] Documentation of the development of anthelminthic resistance

because of meningeal worm prophylaxis has led some farms to pursue drug-free meningeal worm prophylaxis, which may be instituted when designing housing and husbandry recommendations. Meningeal worm is transmitted from white-tailed deer to camelids through arboreal snails.[7–9] As such, deer-proof fencing, introduction of guinea fowl, and the use of molluscicides can minimize transmission. Removal of organic matter, in the form of leaf or wood piles, and establishment of pasture perimeters using limestone or gravel also inhibits snail and slug habitation in camelid pastures.[10] More complete assessments of parasite control measures are covered in the articles "Gastrointestinal Parasitology" by Ballweber and "Neurological Diseases" by Whitehead and Bedenice elsewhere in this issue.

Maintenance, Animal Care, and Monitoring

The single most effective time for husbandry intervention is in the spring, when shearing should occur in all camelid herds. This provides a time of temporary handling and restraint, when animals can be observed closely and most care, including vaccinations, can be provided for the year.

Shearing (**Fig. 1**) provides protection of the animal against heat stress, along with harvest of fiber. Heat stress directly affects health, productivity, and male and female fertility.[11] Because the thermal window for heat dissipation in the camelid is the ventral thorax and abdomen, a "barrel clip" or shear of only the trunk of the animal, is an acceptable means of preventing heat stress, although full-body clipping is preferred. Many llama producers prefer the barrel clip in exhibition animals, while most alpacas receive full-body clips. It is recommended that this be completed before May 1 in the southern areas and June 1 in the northern areas of North America. Shearing should not be delayed until later in the summer in northern climates, to provide adequate time for blanket regrowth before the fall and winter.

In one study involving sheared and nonsheared alpacas residing in Alabama, rectal temperatures were above the normal range in nonsheared alpacas during five sampling periods, 2 weeks apart, as compared with only one sampling period for sheared alpacas.[12] In another study, whole-body sheared alpacas had a lower body temperature compared with nonsheared alpacas, and thermography of the scrotum and medial thighs revealed lower surface temperatures in sheared alpacas.[13]

At the time of shearing, the feet and teeth should be examined and trimmed as needed. Camelids have a toenail around a soft footpad, rather than a hoof, and this toenail should be trimmed flush with the soft pad using small shear-type foot-trimming

Fig. 1. Alpaca being sheared on a raised shearing table. This method provides safe, low-stress restraint for most routine husbandry procedures.

Fig. 2. A well-trimmed camelid foot. The "V"-shaped nail has been trimmed flush with the weight-bearing surface of the foot.

instruments (**Fig. 2**). After this yearly trim, owners should examine feet periodically, as some animals, particularly those on soft ground or with a corkscrew nail conformation (**Fig. 3**), may need to be trimmed two to three times per year.

The teeth of all animals should be examined at shearing. The lower incisors grow continuously and inferior prognathism, or underbite, occurs commonly in camelids. The lower incisors should just meet the rostral end of the superior dental pad (**Fig. 4**) and may be trimmed to this length using a diamond dremel-type bit and tool (**Fig. 5**), or powered incisor trimmers designed for camelids, or obstetric wire. Next, the three pairs of fighting teeth, or upper fourth incisor and upper and lower canine teeth, should be evaluated. These erupt around 2 to 2.5 years of age in most animals and should be trimmed, particularly in males, to prevent camelids from injuring human beings and other animals. These may be trimmed using diamond Dremel bits or obstetric wire, removing the sharp point and leaving 2 mm to 4 mm of the crown above the gumline to prevent tooth abscessation. Side cutters or other manual cutting tools are strongly discouraged because of the high risk of tooth fracture. Forced extraction of these teeth is also discouraged, particularly of the mandibular canine, because of its

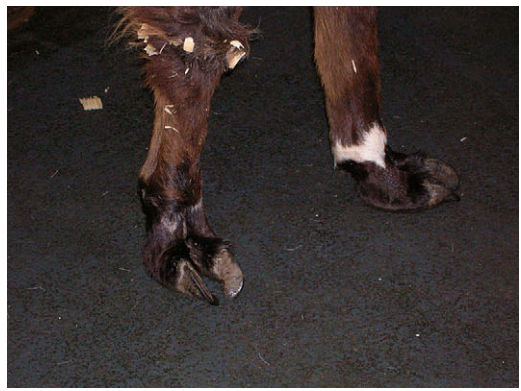

Fig. 3. A llama with deviation of the nails. This conformation generally requires more frequent trimming because of lack of normal wear.

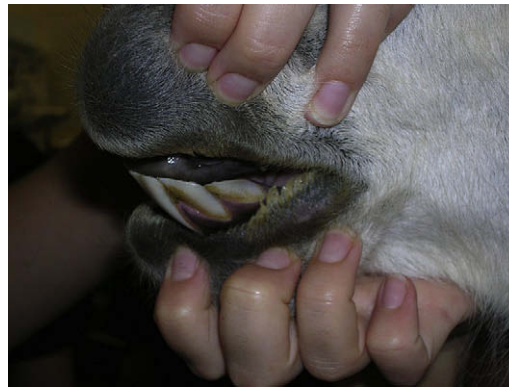

Fig. 4. Normal incisor conformation. The lower incisors meet with the dental pad. Efforts should be made to achieve this incisor height during trimming.

proximity to the mental nerve and third incisor and risk of mandibular fracture.[14] In geriatric animals, the molars should be examined for abnormal wear and the development of points or wavemouth. If noticed, this wear should be recorded along with the animal's body condition score (BCS), and a physical examination and feeding history obtained. Molar teeth should not be floated in camelids as in horses unless abnormal wear is seen, accompanied by weight loss, and a history of dropping feed or dysphagia. It is common for geriatric camelids to experience wear of molars down to the gumline, frequently resulting in severe weight loss and death. Routine or over-aggressive floating of molars contributes to the development of this condition.

Once weaning has occurred at approximately 4 to 6 months,[15] BCS becomes more important than body weight. Animal weighing should be a routine procedure for all South American camelid (SAC) owners and done when using anthelmintics or other pharmaceuticals to ensure accurate dosing. BCS should be performed on all animals within a herd monthly throughout the year to ensure timely intervention. The authors use a 1 to 10 scale,[3] with 1 being emaciated, 10 being obese, and 5 being ideal. It is imperative that BCS be performed by palpation of the animal, not visual

Fig. 5. An alpaca with significantly overgrown incisors being trimmed with a dremel-style tool and diamond-cutting plate. The use of a mouth speculum prevents potential injury to the dental pad.

examination, because of the thick fiber coat. The first area to be palpated is the lumbar region (loin). The muscle and fat in this region should slope down directly from the tip of the vertebral spinous process to the tip of the transverse process. A concavity of this slope would put the BCS of the animal below 5, while a convexity places the animal above (**Fig. 6**). Next, the ribs are palpated in the fiberless area behind the elbow. Difficulty in palpation of the ribs in combination with a convex loin places that animal at a BCS greater than 6. Obese animals may also be further classified by evaluation of fat deposits in the brisket and inguinal regions. Beyond these guidelines, BCS is a subjective scoring system, making it preferable to have the same person perform BCS each month so that there is consistency between measures. Records of BCS should be maintained for individuals in the herd along with the date of examination. A sudden change in BCS or the observation of a trend on any animal should be brought to the attention of the attending veterinarian.

Routine Care of the Healthy Newborn Cria

Assuming normal delivery of a term cria in a clean environment, management of the newborn consists in two stages: first observational, then hands-on. The breeder must be patient and first observe the cria at a distance to ensure that he is fully developed, has adjusted to extra-uterine life, is behaving normally[16] and bonding with the dam. A brief period of nostrils flaring or perhaps open-mouth breathing may be present within the first few minutes after birth, but should not be accompanied by obvious distress or audible stertor.[17] Healthy crias usually stand within 1 hour, walk within 2 hours, and nurse successfully within 2 to 4 hours after birth. Nursing is more frequent (one to four times per hour) during daylight and may last from 30 seconds to several minutes at a time.[18] Meconium is typically passed around 18 to 24 hours of age.[17] Meconium impaction often occurs in dehydrated or hypothermic crias who show decreased to absent nursing and persistent tenesmus in the face of normal urination. A warm soapy water enema (10 mL–12 mL for alpaca cria, 12 mL–24 mL for llama cria) should be administered using a soft, flexible, small-diameter catheter.[19] It can be repeated if meconium is not passed within 30 to 60 minutes after the first enema. Although infrequent, refractory cases involving impaction within the spiral colon may require oral administration of corn syrup (10 mL–20 mL by mouth, every 12 hours: osmotic laxative) or intravenous fluids. The use of Fleet enemas available in human pharmacies is not recommended. The author (MB) has seen several cases of peritonitis-induced proctitis and hyperphosphatemia associated with repeated administration of this product in newborn SACs. In healthy crias, rectal

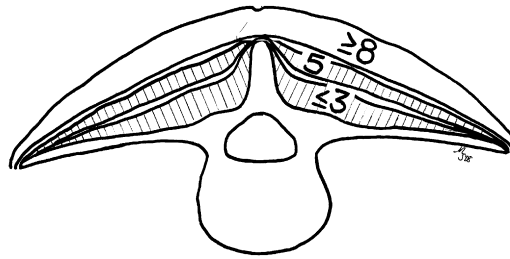

Fig. 6. Schematic of the mid-lumbar epaxial musculature in camelids. BCS values correspond to degree of muscle and fat cover. BCS scale: 1–10.

temperature, heart rate, and respiratory rate range from 100°F to 102°F, 80 to 120 beats per minute, and 10 to 30 breaths per minute. Most crias born in the early spring or late fall are at risk for hypothermia; therefore, wearing a fitted coat at least for the first 24 to 72 hours of life is advisable.

Similarly to other large animal neonates, a cria's umbilicus should be dipped with a disinfectant soon after birth. Consensus on dipping solution, frequency, and dilution factor, however, is lacking. Suggestions vary among investigators and include 2% to 3%[18,20] or 7% iodine tincture,[16,19,21] 0.5% chlorhexidine solution,[17–19] povidone-iodine solution,[16,21] 1:1 povidone-iodine and glycerin,[21] and Lugol's solution.[21] Recommended dipping frequency varies from one[16] to three times daily within the first 24 hours[19] and up to 72 hours after birth.[17] In accordance to the most preferred dipping solution used in most large animal veterinary hospitals, the authors favor thorough immersion of the umbilical cord in 0.5% chlorhexidine solution twice within the first day of life.

Birth weight should be taken using an electronic scale and recorded. Alpaca crias should weigh at least 12 lbs (most range from 14 lbs–18 lbs) at birth and gain 0.25 lb to 0.50 lb per day thereafter.[19] Newborn llama crias typically weigh 20 lbs (most range from 24 lbs–36 lbs). Their expected growth rate is slightly higher than alpaca crias at 0.5 lb to 1.0 lb per day.[19] In selenium-deficient areas, crias should receive Bo-Se (0.5 mL for alpaca cria, 1 mL for llama crias, subcutaneously).[17] To prevent hypophosphatemic rickets, vitamin D (usually in vitamin A, D, and E mixture) should be administered at a dosage of 1,000 IU/kg subcutaneously, twice at 3-month intervals, especially for dark-coated fall-born crias.[22,23]

BIOSECURITY IN SOUTH AMERICAN CAMELID OPERATIONS

The concept of biosecurity or biocontainment is not new but has been the subject of many recent scientific articles devoted to various domestic species,[24] including swine,[25,26] poultry,[27] horses,[28,29] dairy cattle,[30–32] and beef cattle.[33–36] International disease outbreaks of foot-and-mouth disease, bovine spongiform encephalopathy, as well as recent loss of turberculosis-free status in certain states in North America has spurred a global interest for biosecurity, including veterinary practices[37,38] and teaching hospitals.[29,39,40] While most of the review articles currently available on this topic in the veterinary literature share common features throughout, only three have been centered on alpaca operations.[41–43] Optimizing care and production of SACs through herd-health programs truly rely on implementation of customized biosecurity protocol tailored for the control of specific diseases. Biosecurity represents the management practices designed to prevent the introduction of new diseases or pathogens into a group of animals.[44] Biocontainment corresponds to strategies directed at preventing the occurrence and propagation of diseases within a herd.[33]

The Hazard Analysis and Critical Control Point program generally applied to food safety can be appropriate to design a biosecurity program[30] for SAC operations. To be effective, such a program should include (1) hazard identification (ie, a prioritized list of common infectious diseases of llamas and alpacas), (2) exposure assessment (likely routes by which the animals would be exposed), (3) risk characterization (individual susceptibility and risk areas for disease exposure), and (4) risk management (creation, implementation, and supervision of specific biosecurity and biocontainment practices for the operation). The biosecurity plan should also take into account the epidemiologic triad for disease occurrence: individual animal involved, disease agent, and current environmental conditions.[33]

Hazard Identification: Identify Infectious Diseases of Concern

SACs are known to suffer bacterial, viral, protozoal, and parasitic diseases similar to other domestic livestock. The primary risk factors associated with infectious agents include virulence factors, size of inoculum or exposure dose, strain variation, and whether one or several infections exist concomitantly.[45] The size of inoculum (pathogen concentration) represents the major factor determining the severity of clinical disease and the rapidity of its onset.[45] It is also important to remember that nonpathogens can become pathogenic, given the right circumstances.[44] Pathogenic microorganisms differ in virulence, contagiousness, and modes of transmission.[37] In the case of bacterial diseases, virulence factors associated include surface pili or fimbriae, which allow for attachment to the host, and production of various toxins or enzymes, which enhance host cell damage or promote bacterial survival despite cell-mediated or humoral response of the host. Plasmid or integron-mediated antimicrobial resistance is also considered an important virulence factor, especially for enteric bacteria in calves.[45] Virulence factors associated with viruses, protozoa, and nematodes has been less-well described. Undoubtedly, they will vary upon the pathogen in cause. A detailed list of infectious disease agents identified in alpacas has been published.[41] From this list, Bovine Viral Diarrhea Virus (BVDV), neonatal diarrhea complex, gastrointestinal parasites, *Streptococcus equi* ssp *zooepidemicus, Brucella melitensis*, and *Mycobacterium tuberculosis* are of primary concern for North American SACs.

Several reports of acute,[46–48] experimental,[49] and persistent infection[50,51] with BVDV in SACs have been published within the last decade. Although still considered an uncommon disease agent, this pestivirus has the potential to spread between herds via transportation and commingling of healthy with acutely or persistently infected animals, or through inappropriate to nonexistent quarantine protocol for new or returning llamas or alpacas boarded on other farms. Current BVDV testing and recommendations from the Alpaca Research Foundation and Alpaca Owners and Breeders Association include testing each animal attending shows, all existing and new alpacas before their arrival to the farm, stillborn fetuses, and poor-doer or newborn crias whose dam may have been exposed to BVDV during gestation. Testing methods of choice include polymerase chain reaction or virus isolation on whole blood.

Neonatal diarrhea is an important cause of morbidity and mortality in the preweaning period. Current management of llama and alpacas in North America resembles sheep and goat flocks that have led to increased stocking densities, exposing young crias to greater pathogen load.[52] In one study, potential pathogens recovered in feces of 45 unweaned crias with diarrhea included coronavirus (45%), *Giardia* spp (18%), *Eimeria* spp (13%), *Cryptosporidium* spp (9%), rotavirus (2%), and nematodes (2%).[52] Another comprehensive review on the subject added *Escherichia coli* to the list of common pathogens associated with neonatal cria diarrhea.[53]

Diagnosis, treatment, and control of gastrointestinal parasites are important components of camelid herd health and special attention should be made to coccidial infestation. To this date, four different species of coccidia have been described in the United States, and include *Eimeria alpacae, E. lamae, E. macusaniensis*, and *E. punoensis*.[54,55] *E. macusaniensis* is considered to be a major pathogen not only for juvenile but also adult llamas or alpacas.[56–59] Clinical presentations may vary, ranging from subclinical shedding or mild nonhemorrhagic diarrhea to severe acute enteritis associated with protein loss, chronic weight loss, or acute death.[56,57,59] Despite using appropriate fecal floatation technique, coccidial oocysts may not be detected, making the diagnosis and control

of this protozoal disease particularly challenging.[57] The authors refer the reader to the article by Ballweber elsewhere in this issue for more in depth information on coccidia and other gastrointestinal parasites of importance in SACs.

Streptococcosis, also know as ''alpaca fever'' in Peru, has been isolated from North American SACs.[60,61] Exposure to *Streptococcus equi* ssp *zooepidemicus* result in high fever, depression, anorexia, and recumbency.[62] In the chronic form, systemic infection involves lungs and serosal surfaces of thoracic and abdominal cavities. Death may occur within 4 to 8 days of the onset of clinical signs. Suggested risk factors for this disease include weather or transport stress and exposure of SACs to carrier horses or other carrier species.[41]

Brucellosis (*Brucella abortus* and *Brucella melitensis*) is endemic in bactrian and dromedary camel populations, particularly in herds that commingle with other domestic ruminants.[42,63] SACs are susceptible to *Brucella melitensis* type 1, which manifest as abortion within the last trimester of gestation.[62] In Peru, contact with infected sheep was deemed responsible for the outbreak of brucellosis in a large alpaca herd.[60] Standard laboratory serologic screening tests for cattle brucellosis, such as the card test, buffered acidified plate antigen, or standard plate test, provided consistent results in SACs experimentally infected with *Brucella abortus*.[60] Brucellosis-infected lamoids should be reported to appropriate state and federal agencies. The disease can be treated with broad-spectrum antibiotics to eliminate development of the carrier state in the female. However, euthanasia of positive reactors may be required in certified brucellosis-free states.

SACs are not particularly susceptible to tuberculosis, but both natural and experimental infections have been reported.[60] Similarly to brucellosis, tuberculosis has been through an intensive eradication program in other domestic livestock residing in United States. Recommended screening-test methods for SACs consists of intradermal administration of purified protein derivatives of *Mycobacterium bovis* or *Mycobacterium avium* (0.1 mL) in the fiberless area of the axillary region.[60] Reaction is read 72 plus or minus 6 hours after injection. All suspects or reactors should be reported to appropriate state and federal agencies.

Exposure Assessment: Consider Different Modes of Disease Transmission

As with other domestic livestock, disease agents can be transmitted between camelids by direct contact with feces, nasal or ocular discharge, saliva, urine, blood, uterine fluids, placenta, semen, and exudate and tissues of diseased, subclinical carrier, or dead animals. Direct transmission may occur by ingestion (particularly for enteric pathogens), through nose-to-nose contact between infected and noninfected animals housed in closed proximity, or inhalation of aerosols produced by coughing, urination, or defecation.[45] Pathogens can also be transmitted indirectly by contact with contaminated soil, bedding, water or feed supplies, or equipment used for oral administration of treatment,[64] with pathogenic microorganisms capable of surviving in the environment.[45] Prevailing winds and air flow entering or exiting farm buildings and premises are carriers as well.[44] Other important mechanical vectors to consider include contaminated personal hands, protective clothing, and footwear, feeding and manure handling equipment, fomite (shovels, feed buckets, halters, blankets, and so forth), and vehicles used to accomplish daily tasks.

Rodents, insects, birds, and domestic pets (dogs, cats) can also represent important biologic and mechanical vectors of diseases in veterinary patients. Arthropod-borne pathogens of SACs include West Nile virus[65] and eperythrozoonosis (*Mycoplasma hemolama*) infection.[66,67] Toxplasmosis-induced blindness was

diagnosed by the author (MB) in a female alpaca housed on a 2-acre pasture to which three infected outdoor domestic cats had access. In other livestock species, flies have shown to play an important role in movement of different pathogens. One day after exposure to house flies (*Musca domestica*) experimentally inoculated with *Escherichia coli* O157:H7, the bacteria was recovered in 100% (8 out of 8) of fecal samples and 62.5% (5 out of 8) of drinking water of calves exposed.[68] Approximately 56% and 8% of synanthropic flies (n = 4,544) trapped in a multispecies agricultural complex comprising a sheep flock, dairy and beef cattle herd, horse ranch, and wildlife areas populated with white-tailed deer and Canadian geese were infected with *Cryptosoridium parvum* oocysts and *Giardia lamblia* cysts, respectively.[69] In human hospitals, house flies have been involved in mechanical transmission of nosocomial infections with multiple antibiotic-resistant bacteria.[70] The role of rodents in the transmission of salmonellosis in chicken layer farms and sheep flocks has been established.[71,72]

Risk Characterization: Recognize Individual Susceptibility and Risk Areas for Disease Exposure

Herd immunity is characterized by the level of resistance that is sufficient to prevent the entry of a particular disease into, or its spread within the herd. Specific immunity may be acquired as a result of previous exposure to a specific pathogen, either through natural infection or vaccination.[37] Innate immunity is more than genetically based; it is also directly correlated with overall health and nutritional status of each individual animal comprising the herd. In case of severe disease outbreak, inadequate levels of dietary energy, protein, vitamins, or mineral may represent the difference between subclinical, clinical but recovering, chronic poor-doer, and dead animals. Any additional stressors, such as overcrowding, change in feedstuff, inclement weather, transportation, shearing, poor housing conditions, or presence of concurrent diseases contribute further to immunosupression[37] and thus increased susceptibility to infectious agents.

It is well known that periparturient cows, ewes, and does experience various degrees of immunosuppression because of redistribution of circulating immunoglobulins in the colostrum. In fact, many experience a rise in fecal egg counts as well during this period. Although periparturient females are at greater risk for diseases when compared with nonpregnant females and castrated or intact males present on the premises, younger stock are typically more immunologically naive than mature animals, thus more susceptible to infectious agents.[41] The most important risk factor for diseases in young crias beyond congenital (cleft palate, choanal atresia), developmental (rickets), or heritable defects is failure of passive transfer (FPT) of maternal antibodies. Predisposing factors for FPT include unsupervised delivery, which may result in neonatal maladjustment syndrome (hypoxia during stage II labor) or hypothermia from misadventure at pasture following birth. Musculoskeletal injuries can limit mobility and ability to nurse: it should be suspected in neonates born with assistance who cannot stand within 4 hours of birth. For experienced dams, maternal factors leading to FPT include teats or mammary gland abnormalities including retained wax plugs, mastitis,[42] agalactia, or conditions leading to recumbency.[41] Clearly, inexperienced dams may not allow the cria to nurse, which may also result in FPT.

The type of environmental conditions in which the animals are managed can become a risk area for disease exposure and spread within the herd. Fortunately, environmental risk factors are often amenable to the implementation of specific biosecurity practices, mainly centered on improving animal comfort.[41] These risk factors include atmospheric conditions (temperature hot or cold, percent of humidity, wind

chill, natural or artificial ventilation, and other such factors); housing (pasture, dry lot, barns, for example); physical environment (bedding, cleaning and disinfection protocols, including fecal pellets removal and disposal, and so forth); stocking density; general hygiene and hygiene related to feeding practices; and miscellaneous stress resulting from handling and transportation.[41] Access to clean, fresh drinking water at all times is essential. During cold seasons of the year, animals should be provided adequate bedding, shelter, and diet with sufficient energy density, protein, and mineral content. During warm, hot, and humid seasons, management conditions should be centered on heat stress prevention (see ''Routine husbandry'' section, above). Barns or other buildings housing animals indoors, regardless of the time of the year, should be adequately ventilated. Consistent removal of fecal pellets, soiled bedding material, uneaten feed, well as proper drainage of stalls and soils will aid in minimizing local pathogen accumulation[41] and potential insect breeding sites.[34] This is further facilitated by the unique behavior of SACs, who urinate and defecate in one specific area of a stall, lot, or pasture. Feeding practices and water sources should be designed to prevent fecal contamination from herd mates, other domestic animals (dogs, cats, and so forth), rodents, and birds.[41] Handling, shearing, transportation, out-of-farm boarding, and hospitalization are common stressful events that should be managed to alleviate unnecessary tension or distress. Stress of transportation can be minimized by providing good footing, feed, water, and hauling of a companion. For hospitalized patients, close proximity of a familiar herd mate should be considered. If this is not possible, placement of mirror in the stall of such patient mimic the presence of a very familiar herd mate.

The most common means by which contagious diseases are introduced in the herd involves the introduction of a new, purchased animal, or transient breeder that has not resided on the farm, or reintroduction of those who have been temporarily boarded on another farm for daily care or breeding purposes. The latter also include all SACs returning from shows or auctions, activities extremely common in the alpaca and llama industry. As mentioned previously, the likelihood of disease transmission is exacerbated by stress caused by loading, mixing, and transportation,[25] and this appears particularly true with most pathogens. When numerous animals of various ages and originating from different sources are commingled together, especially after long-distance travel, risk of disease transmission is extremely high.[73] Furthermore, one must assume that changes in the environment, such as different climatic and lighting conditions, bedding material, feed or water sources, and closer contacts to visitors with various provenance during such events, can pose a significant source of stress on the animals.

Clearly, SACs showing clinical signs of disease should not be introduced to the herd.[41] And yet, animals may be apparently normal but incubating a disease: convalescent carriers or long-term pathogen shedders. This ''iceberg effect'' disease phenomenon is well recognized within various populations or group of animals; that is, only a small portion of the animals exhibit clinical disease whereas a larger percentage remain subclinical.[45] Consequently, disease-control strategy must be applied to all exposed animals and not just those that demonstrate clinical disease.[45]

Risk Management: Biosecurity Program Recommendations for Sac Operations

In recent years, modern science and research have produced a wide variety of products, ranging from antibiotics, antifungal, antiviral, as well as killed, modified live, or bacterin vaccines to treat and prevent clinical diseases. Antimicrobials and vaccines are often perceived as solutions to all disease problems, which often results in poor perception of potential benefits related to implementation of

appropriate biosecurity and biocontainment practices.[44] A sound biosecurity program for SAC operations should focus on management principles that reduce exposure to pathogens, enhance protection against disease agents, oversee and control the movement of all personnel in charge, as well as visitors, and corroborate all activities through record keeping.

Reducing pathogen exposure

Ensuring good perimeter control using appropriate fencing and identifying designated access routes to the farm premises and buildings should reduce the opportunity for exposure to disease.[74] Biologic waste build-up on farm premises may be a source of disease agents and, under most favorable environmental conditions, favor insect breeding sites that in return can serve as mechanical vectors.[34] The key mitigation for waste management is regular removal of fecal material (dung piles), thorough removal of bedding material followed by cleaning and disinfection of indoor stalls after each use, and proper surface drainage both indoors and outdoors.[74] Lastly, feed residues should also be removed and composted or spread on fields and not refed.[74] Newborn crias should be isolated with their dams in a clean, dry, previously disinfected and well-bedded maternity pen for at least 5 to 7 days after birth. The maternity pen should be located in a building designed for maternity use only, not to isolate sick animals.[31,32,44]

When purchasing new SACs, prospective buyers must know the overall health, management, and immune status of the herd of origin.[30] This is most efficiently accomplished when open communication and trust exists between the buyer and seller.[41] A prepurchase history should include current housing conditions; date and types of vaccines, anthelmintics, and insecticides used on the farm; current screening protocol for gastrointestinal parasites; shearing and toenail trimming dates; feeding practices, including water sources and amount and type of hay, grain, pellets, and mineral offered; previous diseases encountered, such as gastrointestinal problems (diarrhea), respiratory disease, abortion, weight loss, poor growth in crias, or unexplained death; current biosecurity practices (including quarantine) and whether or not the farm of origin participates in shows or houses transient breeders and boarders on a regular basis.

Specific information to be requested before purchase of females of breeding age include age, breeding dates, male used for service, method and date of pregnancy diagnosis, and past problems encountered at breeding (infertility, uterine infection), during gestation (early embryonic death, abortion), or at parturition (dystocia, retained placenta),[42] poor lactation capacity, past cria history (prematurity, congenital defects, FPT), and overall health history. A complete gynecologic evaluation, including uterine culture and cytology, should be performed before purchasing a breeding female with a history of infertility, dystocia involving obstetric manipulations, or postpartum complications.[42] Age, health history, musculoskeletal soundness, libido, and past progeny records are important aspects to scrutinize for breeding males. Of course a veterinary health certificate verifying the current health status of the animals should be provided by the seller at the time of purchase. If appropriate, the buyer may request the animals to be tested negative for BVDV, eperythrozoonosis (*Mycoplasma haemolamae*), gastrointestinal parasites, and brucellosis or tuberculosis, as determined by regulatory authorities, before purchase.

Quarantine protocol for South American camelids Any diseased animals should be isolated from the remainder of the herd and managed separately,[74] either through quarantine or other designated facility. Furthermore, all animals leaving the premises and

coming in contact with other mammals should be placed in quarantine. This includes new additions to the herd, transient breeders or boarders that leave the farm, and returning show animals.[43] In general, recommended quarantine periods for domestic livestock range from 15 to 60 days,[24,25,30,32,41–43,45,74] with the exception of the swine industry, which recommends up to 90 days of isolation.[25] Most investigators recommend a period of at least 21 to 30 days for new arrivals to be housed in a designated quarantine facility before allowing contact with resident animals.[24,30,32,42,43,45,74] A 30-day period is preferable, as it appears to allow enough time for manifestation of most infectious diseases, as well as completing the prepatent period for many common parasites.[43] Regardless of the housing style selected for quarantine, producers should organize the facility so that the animals can be moved through on an ''all-in-all-out'' basis, similar to that used so successfully in the swine industry.[25,32] Biosecurity procedures to be followed when entering and leaving contaminated areas should be used by owners, herd managers (if applicable), personnel, and veterinarians.[75] The last animal being quarantined should dictate the time whereby the whole group can be released to the main herd.

Quarantine provides an opportunity for clinical inspection, laboratory testing, and vaccination. Thorough physical examination findings, body weight or BCS should be recorded for each animals entering quarantine.[43] At this time, gastrointestinal parasite screening, fecal culture, specific-disease testing, and complete blood count and serum chemistry should be performed, if deemed appropriate. In case of parasite infestation, appropriate anthelmintics should be administered and fecal examinations should be repeated 2 weeks later. Affected animals should have at least two consecutive negative-fecal examinations before being released from quarantine.[43] While in quarantine, each lamoid should be inspected daily. Periodic recording of temperature and body weight can be useful monitoring parameters. Furthermore, owners and personnel should be instructed on potential clinical signs of disease to anticipate. Clearly, any abnormalities should be recorded. If signs of disease are present, affected animals must be separated from other quarantined herd mates, examined, and treated by a veterinarian.[41]

Handling and housing quarantine facilities should be physically separate from the main herd by several hundred yards, and should be located such that predominant winds or surface runoff do not carry airborne or terrestrial pathogens toward the main herd.[41] Its access must be limited only to designated personnel. If total separation from the main herd area is not feasible, a solid fence or double-fencing system with a minimum of 4 feet between fence lines should be built to prevent direct contact between quarantined and main-herd animals.[43] The type of fencing material used should be such that it prevents introduction of biologic or mechanical vectors as well as native wildlife.[43]

Within the quarantine area, animals should be housed on a nonslip surface, ideally brushed concrete that allows for easy and thorough cleaning and disinfection. Sand and dirt are acceptable, but should be totally removed and replaced between animals.[43] Grass paddock should not be used as it is not possible to thoroughly be cleaned or disinfected appropriately.[43] Water and feed containers, scale, handling, and treating equipment, as well as cleaning devices, should be solely devoted to the quarantine facility and must be easy to clean and disinfect. Specific attire (plastic or rubber boots, coveralls, and gloves) should always be worn by all personnel attending the quarantine area.[41,43] This applies to workers, and other visitors (veterinarians, shearers). Footbaths should be strategically placed at all entrance points, and well maintained. Finally, the facility should be cleaned and disinfected on a daily basis and at the completion of each quarantine period.[43]

Enhancing protection against disease agents

Vaccination in support of management No vaccines are currently labeled for use in camelids, placing the responsibility for use of vaccines with the veterinarian. This, combined with the paucity of information regarding efficacy and safety of vaccines in camelids, and the unknown prevalence of certain infectious diseases, make vaccination recommendations difficult. Vaccination in SACs should only be performed as a means of supporting management decisions that reduce exposure and susceptibility to pathogens. Vaccination recommendations for camelid herds should be made from risk assessments based on diagnostic information and theoretic risk for each herd in each geographic region.

Toxoid vaccination against *Clostridium perfringens* types C and D and *Clostridium tetani* is the current ''core'' vaccine recommended for SACs. Crias are immunocompetent at birth[76] and, therefore, active immunization may be attempted during the neonatal period. Vaccination of the healthy cria against *C. perfringens* types C and D and *C. tetani* (CDT), using full dosages of toxoid vaccines, should occur at 48 to 72 hours after birth, with a booster administered 2 weeks later. Llamas have shown the ability to develop antitoxin responses to *C. perfringens* Types C and D[77] and *C. tetani*.[78] The duration of immunity for CDT vaccines is not known, but annual vaccination is recommended. It may be advisable to administer this vaccine 4 to 6 weeks before expected parturition to provide tetanus protection for birth-associated trauma and to increase colostral immunity for these pathogens. The author (MJ) recommends that, if a husbandry procedure (ie, castration) or injury occurs that would place an animal at risk for tetanus, a tetanus toxoid booster should be given at the time of the procedure if the animal's last tetanus toxoid has occurred more than 6 months previously. If that animal's tetanus toxoid was more than a year previously or is not known, a tetanus antitoxin should be administered at the time of injury. In general, CDT trivalent vaccines are sufficient and should be the preferred product to avoid adverse reactions and injection site reactions. In regions where snakebite or liver flukes are common, which predispose to other serious clostridial infections (*C. septicum, C. novyi* and *C. haemolyticum*), a seven- or eight-way *Clostridium* vaccination may be considered. If they are used, it is recommended to recheck the injection site 1 week after vaccination for a local adverse reaction.

Rabies virus is a concern in most areas of North America and the spitting behavior of camelids increases the concern of zoonotic transmission of this disease. There have been sporadic cases of camelid rabies encephalitis in North America,[60] with outbreaks in Peru reported.[60] Transmission from alpaca-to-alpaca via biting has been demonstrated.[60] The use of a large-animal-labeled rabies vaccine should be performed at full dose annually. Given the case fatality rate of this disease and zoonotic potential, it is important to recognize that vaccinated animals may not be fully protected from infection.

Early embryonic deaths, abortions, and stillbirths occur in camelids, but infectious causes are rarely identified. When abortions occur in a herd, all fetal materials should be submitted, along with maternal blood, to a veterinary diagnostic laboratory for infectious disease testing. The dam should be isolated from the herd, as for a newly added animal, and monitored for further clinical signs of disease. If an infectious agent is identified, vaccination against that agent may be considered as part of a comprehensive herd health-preventive program to minimize risk. Leptospirosis has been diagnosed in SACs[79] and causes both reproductive and renal disease. In herds or areas where leptospirosis is an endemic disease, vaccination with multivalent bovine vaccines may be performed. Alpacas have been vaccinated experimentally and measured-antibody response has occurred.[80] There is evidence of short-lived

immunity in alpacas vaccinated against *Leptospira*[80] and it is recommended that high-risk farms vaccinate females before breeding and again at mid-gestation.[76] This vaccine may need to be given up to four times annually in endemic areas where wildlife and contaminated water-source exposure cannot be controlled.[42] Another potential abortive agent, *Chlamydiophila* (formerly *Chlamydia*), isolated from infected fetal materials, may be vaccinated against, with good serologic responses to sheep-labeled vaccines.[76] In 2007, Dubovi reported on the testing of 12,000 alpaca samples submitted to Cornell University for BVDV testing.[81] These samples revealed a 0.15% prevalence of persistent infection with serum-neutralizing antibodies present in 14% of 268 samples submitted for serology. Persistent infection, pyrexia, ill thrift, abortions, and stillbirths have been associated with BVDV infection in camelids.[47,50,51] Although disease has not been successfully created experimentally,[49] it is believed that persistently infected crias are the greatest source of infection and, as such, should be euthanized. The study of 43 strains of BVDV isolated from alpacas in a large geographic area showed that 42 of 43 were genetically similar, falling into one of two groups. That these strains could potentially be traced to a common origin makes testing and elimination of persistently infected animals the highest priority for control.[81] Vaccination of camelids against BVDV is not currently recommended because of potential interference with diagnostic testing[81] and lack of efficacy or safety information.

Camelids housed near domestic and exotic equids are at risk for encephalomyelopathy caused by equine herpesvirus-1 and Eastern Equine Encephalitis virus.[82] This risk is greatest in the presence of exotic equids, and in such situations, killed EHV-1 vaccination should be considered quarterly[76] and in high-risk areas for Eastern Equine Encephalitis, killed vaccines may be advisable.

West Nile Virus has been reported in camelids,[65,83,84] however the relative risk appears to be low. In a serologic survey of camelids in northern Colorado in 2003, 73% (27 of 37) were seropositive, with a morbidity rate of 8.2%. The overall rate of mortality was 5.5%, with a case fatality rate of 66.7%.[85] The use of equine-labeled vaccines in SACs has yielded mixed results. Ramsey and colleagues[86] performed serologic testing on llamas and alpacas, administering doses every 3 weeks. No antibody responses were noted after one dose, but 75% of animals had a marked antibody response after the second and third doses. Duration of antibody, however, was short-lived, with significant decreases in titers by 10 weeks after the initial vaccine dose. In another study,[87] vaccination of 84 llamas and alpacas with equine-labeled vaccine was determined to be safe and that three vaccinations at 3-week intervals resulted in virus-neutralizing titers similar to horses receiving two doses, with titers persisting for greater than 40 weeks. Combining the information gathered between these two studies, vaccination against West Nile virus should begin 2 to 3 months before the start of vector season, and boosters every 2 to 3 months should be considered. Because of this intense and expensive vaccination schedule, many farms have elected not to vaccinate the entire herd against West Nile virus, or have chosen to only vaccinate highly valuable individuals in endemic areas. It is not known how annual revaccination should be scheduled, but it should probably occur 3 to 6 weeks before peak exposure.[87]

Vaccination with regards to control of diarrhea in crias is frequently discussed as an important aspect of a preventive herd-health program. Primary etiologies of cria diarrhea include enterotoxigenic *Escherichia coli* (K99), *C. perfringens* Types A, C, and D, *Salmonella* spp, viruses including rotavirus and coronavirus, and parasites, including *Cryptosporidium*, *Giardia*, and coccidian parasites.[52,53,56] When encountering an outbreak of diarrhea in crias, it is important first to focus on determining an etiology and identifying potential sources.

When diarrhea in crias is a significant issue on a farm, stocking density, season of birth, and birth order should be evaluated. Spring-born crias have the lowest morbidity rate, while fall-born crias have the highest.[88] Furthermore, regardless of the time of the year, crias born late in the season have greater exposure to pathogens amplified by early-born crias. For this reason, controlling the season of birth and separating dams because of delivery late versus early in the season may have protective effects on their crias. Passive immunity may be attained in camelid neonates by the use of active dam immunization or cria monoclonal antibody administration at birth against *E. coli*, rotavirus, and coronavirus. These products have unknown efficacy in camelids and should be considered useless in the absence of management changes. In herds with endemic enterotoxemia, 20 mL of *C. perfringens* types C and D antitoxin may be administered subcutaneously at birth.[76]

In general, vaccinations should be administered subcutaneously wherever possible because of the very small muscle mass of camelids. Intramuscular and subcutaneous injections are most commonly done low in the neck, in front of the shoulder (**Fig. 7**), but subcutaneous injections can also be administered over the lateral thoracic wall (**Fig. 8**). Intramuscular injections may also be administered in the triceps muscles. It is always recommended that needles only be used once to prevent injection-site abscesses and the possible transmission of the blood parasite *Mycoplasma* (*Eperythrozoon*) *haemolamae*.[89]

When making vaccine recommendations to camelid owners, veterinarians must remember that they are using these products in an extra-label manner, without manufacturer liability. Additionally, all of the studies presented here demonstrate only serologic responses to vaccines, providing no known protective antibody level or challenge data. It is advisable to discuss risks and potential benefits of all biologics and pharmaceutics thoroughly with owners when designing herd-health protocols. With the exception of CDT and perhaps rabies, all vaccines listed here are only recommended when there is documented evidence of that disease etiology in the herd and where vaccine is relied upon only to support management controls.

Fig. 7. Intramuscular injection being administered into the caudal cervical epaxial muscles.

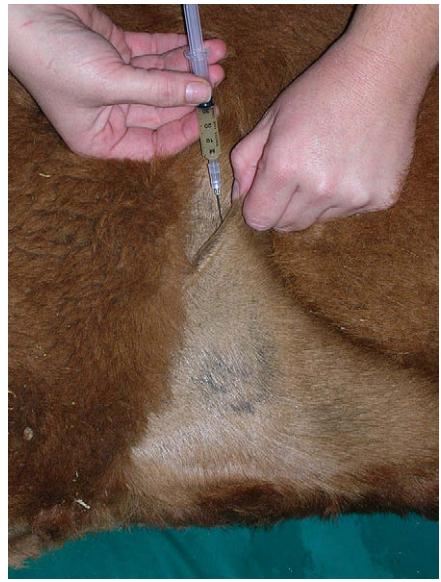

Fig. 8. Subcutaneous injection being administered over the thoracic wall, behind the elbow.

Laboratory testing Routine on-farm surveillance (beyond quarantined animals) is best used to determine current immune status of the animals and defines which infectious agents are circulating through the herd.[74] The extent of laboratory testing may vary based upon the current biosecurity program, management practices, and ongoing diseases encountered on each farm. Situations where laboratory testing may be important include assessment of passive transfer of maternal antibodies in neonates; investigation of a diarrhea outbreak in juveniles through fecal flotation, culture, and electron microscopy; or submission of aborted fetus, placenta, and maternal blood to veterinary diagnostic laboratory for diagnosis confirmation. Complete necropsy of all animals that die is strongly recommended, as it allows confirmation of diseases and conditions occurring in the herd.[74]

Cleaning and disinfection Appropriate cleaning and disinfection procedures are vital to breaking transmission cycles of disease agents that contaminate the animal environment, handling, feeding, treatment, and cleaning equipment, directly or indirectly.[38,41,45] It represents an important line of defense in good biosecurity program, but should be considered as an adjunct measure rather than a stand-alone procedure.[25] Personal hygiene is critical to prevent iatrogenic dissemination of disease-causing organisms between animals[28] and decrease likelihood of zoonosis. It includes frequent hand washing with hot water and antibacterial soap, cleaning and disinfection of boots or other protective shoe covers, and washing work clothes with bleach followed by hot-air drying.[41,45] The Centers for Disease Control and Prevention consider hand washing as the most important step in preventing transmission of infectious diseases.[39]

The most relevant first step to cleaning is thorough removal of all organic debris from surfaces, boots, or equipment coming into contact with the animals.[41,45,90–92] Vigorous scrubbing, scraping, and rinsing must be performed before application of disinfectant.[92–94] High-pressure washing may not be as effective at removing bacterial

contamination as hand-scrubbing, but can be an efficient method for cleaning large areas.[38] A power washer used on concrete floors and farrowing crates can reduce the bacterial load close to 100 %, regardless of water temperature or the use of a detergent.[91] However, it may aerosolize surface contaminants to distant sites during the cleaning process and may make the operator at risk of disease if zoonotic pathogens are involved.[28,38,45]

The producer must take full advantage of natural disinfectants available in the environment, such as sunlight, heat, cold, and dessication from fresh air and wind.[32,74,91] Sunlight is the most potent natural disinfectant because of its ultraviolet range of wavelength.[91] However, it has little penetrating power through glass or translucent roofing sheets; therefore, the value of sunlight in animal buildings is totally unreliable. Appropriate ventilation of farm buildings is also important to consider in a biosecurity program. Under-ventilated building builds up stagnant air with dust and gases (ammonia), and gradually becomes warmer and more humid. In these circumstances, airborne concentration of pathogenic microorganisms that the animals may be carrying may also be increased.[91] On the other hand, over-ventilation may be synonymous with draft and results in chilling of the animals. Recommendations for appropriate ventilation in domestic animal buildings has been published.[91]

Several products are commercially available for disinfection of equipment, farm buildings, and premises. Product chemical characteristics, concentration, contact-time, temperature, pH, water content and hardness, and the amount of organic debris present are essential determinants to the success of disinfection procedures.[41] Sodium hypochlorite (household bleach, NaOCl, readily available as 5.25% or 12.75%) at a sufficient concentration, contact time, and temperature combination is effective against bacterial and viral agents, but not cryptosporidium oocysts.[45] Sodium hypochlorite is cost effective and environmentally safe; however, it is rapidly inactivated by the presence of organic debris.[38] Because of its acidity (pH = 6), it is usually corrosive to metals.[45] At room temperature, recommended concentrations of this product in human environments range from 500 ppm (1:100 of 5.25% household bleach), with a 10-minute contact time, to 5,000 ppm (1:32 dilution of 5.25% bleach), with a 1-minute contact time.[45] For viruses in veterinary hospitals and kennels, a recommended dilution of household bleach is 1:32 (0.175% NaOCl) at room temperature, with a 10-minute contact time.[93] Other chemical disinfectants, such as quaternary ammonium, are effective against a wide range of bacteria, including *Salmonella* spp, some viruses, and fungi, and have a high long-lasting surface activity, even in the presence of organic material.[28,91] Peroxygen disinfectants are bactericidal, virucidal, and fungicidal and have minimal adverse effects on the animals and their environment. In one study investigating the effectiveness of directed misting application of 4% peroxymonosulfate disinfectant in a large animal veterinary hospital, effective disinfection of surface areas was obtained as bacterial counts (*Staphylococcus aureus* and *Salmonella typhimurium*) were reduced by more than 99.9999%.[94] Phenolic disinfectants have prolonged antibacterial and antiviral activity, especially on porous surfaces. However, because of its toxicity to human beings and animals,[91] its use is not recommended on SAC operations.

Use of designated boots for specific farm areas combined with use of footbaths is recommended in SACs farms, although its efficacy may be debatable. In swine facilities, one study demonstrated that boot disinfection using footbaths was accomplished only after manure-free boots were soaked in disinfectant (didecyl dimethyl ammonium chloride; Roccal-D) for 5 minutes.[92] A field trial evaluating the effects of footwear-hygiene protocols on nonspecific bacterial contamination of floor surfaces in an equine hospital did not show any significant decrease in the number of bacteria

with use of rubber overboots and footbaths/footmats filled with quaternary ammonium or peroxygen disinfectant.[95] Other perhaps more practical and efficacious alternatives of footbaths include the use of disposable plastic boots for personnel assigned to the quarantine areas and for visitors who spend short periods of time on the farm.

The characteristics of environmental surfaces in farm equipment influence the success or failure of a cleaning and disinfection protocol.[90] Unfinished plywood retains 15-fold more bacteria than painted or varnished plywood, while varnished plywood retains approximately 115-fold more bacteria than plastic surfaces. Washing impervious surfaces, such as metal or plastic, with soap and water from visible gross contamination can decreased the microorganism load by 99 %.[41] Washing other less impervious surfaces or very porous surfaces will remove a significantly fewer number of organisms. Sealing or painting exposed wood and other porous surfaces (rubber) may improve cleanability.[38]

Concrete stall flooring allows for very effective disinfection between animals.[28] Litter or bedding material should first be removed and may be burned or buried so there is no possible contact with livestock.[91] Stalls bedded with dirt, sand, or clay cannot be thoroughly disinfected. Dirt-floored areas should be scraped a few inches to hard surface, especially around a heavily contaminated area.[28,91] Water tanks and feed troughs should be cleaned on a regular basis and transportation equipment should be cleaned and disinfected before and after each use.[74]

Oversee personnel in charge and control movement of visitors

The potential for disease transmission by employees, owners, and visitors should not be underestimated.[41] Knowledge of the current premises biosecurity program should be mandatory for all personnel.[74] Complete understanding of what actions are generally used to protect the animals, when and how exceptions to standard procedures should be made, and who to refer to in case of concerns or questions is critical for the success of the program.[38] Access to written biosecurity procedures and appropriate and regular training sessions should be provided for all employees.[74] Education of all personnel on the biology (mode of transmission, contagious nature of disease agent, persistence in the environment, zoonotic potential, most appropriate cleaning and disinfection methods) of common diseases is strongly encouraged.[38]

Access by the general public with the main herd should not be permitted.[41] As mentioned previously, visitors including farm neighbors, prospective buyers, shearers, or curious tourists can contribute to introduction of disease agents in SAC operations. Contact between such visitors with herd animals is strongly discouraged if not prohibited.[41] However, if allowed, a thorough investigation focusing on current and past contact with SACs or other livestock species should be obtained from the visitors. Herd visits should be scheduled in such manner that visitors are aware and compliant with current biosecurity measures in place. The visitors should be provided disposable or nondisposable protective clothing (clean coveralls, boots, and gloves) before close interaction with herd animals and farm premises. Upon completion of the visit, protective clothing should be recovered or disposed of and visitors should have access to a water source and antibacterial soap to wash their hands.[41]

Importance of record keeping

Record keeping is a key component of managing any efficient animal operation.[96] Records are needed not only for legal, financial, and taxation purposes but also for maintaining a permanent documentation of the farm business, monitoring and analyzing day-to-day activities, facilitating disease control and eradication, and formulating future plans. All animals present on the farm, including newborn crias, should

have a unique identification. Electronic identification using an intradermic microchip has gained significant popularity over the last decade. Moreover, llamas and alpacas can be officially registered either through the International Lama Registry (ILR) or the Alpaca Registry Incorporated (ARI). Using DNA technology, ARI and ILR validate the parentage of animals submitted for pedigree registration. Once an alpaca's or a llama's parentage has been validated, the respective registry issues a registration certificate that provides known lineage and assigns a unique number to each animal. Most regional and national shows, sales, and other events require that participating alpacas and llamas be registered. Registered animals have enhanced value, as their pedigrees are recorded and more informed breeding choices can be made because their lineage can be traced. Although currently on a voluntary basis, SACs are also eligible for registration through the National Animal Identification System.

Once all the animals have a unique identification, the breeder is ready to start collecting data on each individual animal. Production, husbandry, health, and financial data recorded should be easy to retrieve once imported in the record-keeping system selected, whether paper or electronic in nature. Computers are rapidly becoming the preferred and most efficient form of record-keeping system. Production records should include periodic weighing and BCSs, breeding dates, pregnancy diagnosis date and method, problems encountered at (dystocia) or after parturition (retained fetal membranes, poor milk production, and so forth), and health status of the newborn cria (term, premature/dysmature, congenital defects, and other issues). Common husbandry procedures, such as shearing, toenails, and fighting teeth-trimming dates should be also recorded. Health records should include veterinary care and comprise the following information: before- or after-purchase examination findings (including health certificate), including results of any laboratory test performed (ie, BVDV), fecal flotation date and results, type of dewormer used; dosage, frequency, and day of administration, vaccination protocol, diseases diagnosed; diagnostic tests performed, treatment instituted and outcome, other medication administered, and postmortem examination reports of dead animals and aborted fetuses. Any travel to shows, auctions, or temporary boarding to outside breeding farms should be noted as well.

Aside from each individual animal record, the breeder should keep a main-farm diary and include personnel in charge, as well as their respective assignments, detailed biosecurity procedures, quarantine protocol, and maintenance of a visitor log. Information to be recorded in a visitor's book should include current date, name and address of the visitors, purpose of the visit, date of last contact with SACs or other livestock, time of arrival and departure, and signature to confirm that biosecurity precautions have been observed.[25] Written protocols for special circumstances, such as dystocia, care of the healthy, premature or dysmature newborn cria, or evacuation in the event of a disaster (ie, fire, flood) are also desirable.[97]

SUMMARY

Most herd-health catastrophes in SACs occur as the result of oversight in the biosecurity and management procedures. It takes such an instance to bring about awareness of camelid owners to the need of designing a herd-health program. Veterinarians, however, have unique training and qualifications in population medicine, which make them more than qualified to assist farms in the design and execution of preventative medicine plans. It is therefore recommended that camelid owners, in conjunction with their veterinarians, implement herd-health and biosecurity plans tailored for their operations. This may mean changing some existing practices and perhaps adding to the farm with quarantine or hospital facilities. The benefits of avoiding the introduction

of disease far outweigh any short- or long-term cost and inconveniences of implementing such a program and changes.

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