Part 1: Herd Health

CHAPTER 1

Biosecurity

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Biosecurity involves efforts designed to prevent introduction and spread of disease within populations, herds, or groups of animals.[1] These efforts may be further divided into those directed at the prevention of entry of new diseases into a group (external biosecurity) and those directed at preventing spread of disease within a group (biocontainment or internal biosecurity).[2] Furthermore, biosecurity may be implemented at various levels, from the farm level to the regional or national level. To be effective, a minimum biosecurity plan should address (1) isolating new animals, (2) isolating animals returning to the herd, (3) regulation of animal, human and equipment movement, and (4) the design and implementation of cleaning and disinfection procedures directed at the reduction of pathogen loads. Although much of the following may be applicable to various animal systems, special camelid situations will be addressed, when appropriate.

General Principles

Clearly, our ability to control disease has been, and will continue to be, enhanced through technologic advances in vaccines, therapeutic agents, and diagnostic techniques. However, overdependence on these technologies may blur the importance of, and encourage indifference toward management components of disease control such as biosecurity.[3] Management, including directed input from qualified veterinarians, should strive to incorporate the breadth of available tools including risk assessment, computerized record keeping, implementation of modern diagnostic technologies and the practice of optimal husbandry techniques, including biosecurity and biocontainment.[4]

Biosecurity practices should be prioritized to address those factors that pose the greatest risk of disease introduction. The most common means by which contagious diseases are introduced to a herd involves introduction of new animals or the return to the herd of animals that had been on other premises or locations. Obviously, introduction of animals displaying any clinical signs of disease must be avoided. Importantly, producers must be educated that mere exclusion of clinically ill animals is unlikely to prevent introduction of disease. Often, animals that appear clinically normal may be incubating disease or be subclinically affected. It is well documented that in a given population of animals, only a fraction of those infected typically exhibit clinical disease, the larger proportion being subclinically affected. Consequently, appropriate and effective efforts in biosecurity must focus on the entire population of animals, rather than simply concentrating on those that are clinically affected.

External Biosecurity

The basic tenets of external biosecurity include isolation of new animals, quarantine procedures, disease testing, preventive measures, and hygiene. As mentioned earlier, the most prevalent means of introducing disease into a group of animals is via addition of new animals into the herd. The concept of a "new animal" must include animals that have never resided on a farm as well as those returning after travel to offsite facilities (e.g., shows, fairs, breeding facilities).

Animals commingled at other facilities undergo an increased risk exposure and infection. Producers must be made aware that many pathogens do not necessarily require direct contact between animals for transmission to occur. Some pathogens are efficiently transmitted via air, water, fomites (e.g., equipment, tack), pests (e.g., flies, rodents), or personnel. Some pathogens can survive in soil or organic material for weeks or even months.[5]

To lessen the risk of disease introduction, producers must be knowledgeable about health status of a new animal's herd of origin. This obviously requires communication between parties long before any animal movement. Ideally, purchasers should be familiar with both current and past health status of the seller's herd. Conditions of concern may include evidence of diarrhea, respiratory diseases, ill thrift, failure of passive transfer, abortion, and herd-based diseases. Buyers must also be knowledgeable about fundamental biosecurity practices of the seller's herd. Specific areas should include information regarding animal movement, quarantine practices, disease testing practices, vaccination practices, deworming schedules, hygiene practices, and so on. Finally, prospective buyers should minimize the number of source-herds from which newly acquired animals are purchased.

During public sales, shows, and auctions, animals from different sources are brought into varying levels of proximity. Some animals may have travelled long distances, and on arrival, they must adapt to new environments, which can serve as an additional source of stress and potential immunosuppression. Environmental changes are numerous and include temperature and humidity, ventilation, lighting, bedding, water, feed, and personnel. Numerous risk factors for disease transmission include recrudescence of latent infections and increased shedding of organisms.

Newly purchased animals or those returning from events where commingling has occurred should be placed in quarantine for a minimum of 30 days. To be effective, quarantine facilities must be physically separate from the main herd, its handling facilities and housing. Although it is not practical to identify a single, defined distance for separating the quarantine facility from the main herd, it is safe to state that the farther it is, the better it is. Ideally, this would invoke a separation distance of several hundreds of yards, positioned downhill and downwind such that prevailing winds or surface drainage does not carry aerosols or contamination toward the main herd. Finally, quarantine facilities must be located such that access is not made too difficult or impractical for personnel attending to animals at the facility.

Effective quarantine practices utilize the concept of "all in—all out." That is, when multiple animals are placed in an isolation facility concurrently, all animals leave the facility at the same time. If multiple animals are placed in a facility over time, the last animals to arrive dictate the time when all the others in quarantine will be allowed to leave.[4] Animals in quarantine must be monitored on a daily basis. Basic parameters include gait, attitude, activity, appetite, water consumption, urination, and defecation. Potential signs of disease may include nasal or ocular discharge, changes in stool consistency, coughing, lameness, and so on. If body temperature is recorded, it should be consistently obtained during the same time of day. Animals showing unique changes in activity, behavior or signs of disease should be further separated from other quarantined animals and examined by a veterinarian.

Personnel attending to quarantined animals should wear protective clothing (e.g., coveralls) and boots that are devoted solely to the quarantine facility. Clothing and boots should be washable, and boots should be made of rubber or other impervious materials. All equipment and supplies used in a quarantine facility (e.g., halters, ropes, feeders, buckets) must be solely devoted to that facility and remain at the facility. Ideally, personnel working with quarantined animals should have minimal or no contact with the main herd. If dedicated personnel are not available, quarantined animals should be attended to only after animals in the main herd have been cared for.

Testing for specific diseases may be accomplished during the quarantine period. A period of 30 days is generally adequate for collecting and submitting samples as well as receiving and interpreting results. Preventive measures such as deworming and vaccinations may also be performed during the quarantine period.

Owners must be informed of the potential for disease transmission by visiting personnel. Ideally, visitor contact with herd animals should be minimized and appropriately controlled. Owners or herd managers should know the background of visitors, especially with regard to recent animal contact, including contact with camelids and other domestic and wild species. Visitors should be dressed in clean clothing and be provided with coveralls and boots. Protective clothing should be collected at the end of the visit, and all personnel should have access to a hand washing area. Uncontrolled access to a herd by the general public should be prevented.

Exporting camelids to breeding farms is a common practice within the industry. Producers must be aware that animals returning from these farms are essentially equivalent to newly imported animals. Commingling of animals from varying backgrounds and different ages at these facilities carries an extremely high risk for both exposure to and recrudescence of infectious diseases.

Owners must also be made aware that other animal species may function as mechanical or biologic vectors of infectious agents. Domestic pets and vermin (insects, rodents, birds) are of particular importance, especially if present in high numbers.

An often overlooked vector that presents a significant disease transmission risk is the common house fly *Musca domestica*.[6] These insects have physical characteristics (mouth parts, hairs, sticky foot pads) and activities (defecation, vomiting) that greatly enhance their ability to transmit large numbers of pathogens. Under the right conditions, flies may harbor certain pathogens (e.g., *Cryptosporidium parvum*) for several weeks.[7]Numerous methods have been described for controlling flies during different points in their life cycle, including the use of various chemical agents. In addition to chemical means, control must also include removal of feces and wet organic debris, since fly larvae require appropriate substrates and levels of humidity.

Rodents are also a source of disease transmission. In other livestock industries (dairy, beef, and poultry), mice have been implicated in the transmission of salmonellosis.[8–11] Mice are also significant reservoirs of *Cryptosporidium*. Importantly, significant numbers of rodents may be present long before signs of their presence (feces) become noticeable.

Biocontainment

Numerous risk factors are associated with the occurrence and propagation of diseases within and between populations. It is both logical and convenient to categorize such risk factors as they relate to host animals, the environment, or infectious agents. Recognizing both the presence and the significance of specific risk factors is necessary before implementing specific biocontainment practices that are designed to mitigate disease.

Host Animal Risk Factors

Congenital, developmental, or heritable abnormalities may be risk factors for disease, depending on the anatomic location and the tissue or organ affected. Any abnormality that prevents a *cria* (baby camelid) from behaving normally (e.g., nursing, ambulating) will likely increase risk of disease.

Failure of passive transfer (FPT) of maternal immunity is a major risk factor for the development of neonatal infectious diseases such as diarrhea.[12] To obtain adequate passive transfer, crias must consume and absorb an adequate mass of colostral immunoglobulin in a timely manner. In general, camelid colostrum contains a relatively high concentration of immunoglobulin; therefore, FPT rarely occurs as a result of poor colostrum quality. Instead, FPT in crias generally results from a failure to nurse appropriately within the first hours of life. Factors associated with crias that do not nurse appropriately include neonatal maladjustment (cerebral hypoxia), cleft palate, choanal atresia, fractures or other conditions that limit mobility or nursing. Hypothermia or misadventure may result if crias are born unsupervised or at pasture. Maternal factors associated with FPT include mismothering, teat or udder abnormalities, agalactia, or conditions causing recumbency of the dam. Although the degree of intervention necessary during and after parturition is debatable, producers should strive to visually monitor the birthing process and initial nursing.

The general nutritional status of both neonates and mature animals may influence the occurrence of disease. Underconditioned or malnourished animals are more prone to infectious diseases, since metabolic demands required for appropriate immunity are typically compromised. The thick fiber coat of camelids may easily mask thin animals or those that have lost significant condition. Owners should be instructed to routinely weigh their animals or at least palpate to determine body condition scores. If animals are discovered to be thin or losing body condition, a veterinarian should be consulted to determine the cause. Overfeeding and overconditioning of camelids may also occur. Obese animals are more likely to be infertile and develop hyperthermia. Overconditioning may also exacerbate primary diseases, both noninfectious and infectious. Overconditioned camelids are prone to developing hepatic lipidosis as a complication of other systemic primary diseases.

In addition to dietary issues involving protein or energy, inappropriate levels of macronutrients (calcium, phosphorous), trace minerals (cobalt, copper, selenium, zinc, iodine, iron) or vitamins (B complex, A, D, E, K) may result in either primary disease or exacerbation of secondary disease states.[13] Camelids should always be provided access to fresh, clean water. This is especially important in areas where high ambient temperatures are combined with high relative humidity.

Infectious Agent Risk Factors

Principal risk factors associated with infectious agents include specific virulence factors, size of inoculum or pathogen load, and presence of single or multiple infections.[4]

Virulence factors may include mechanisms that enhance pathogen survival, including attachment or invasion and drug resistance. In general, the effect of virulence mechanisms and how they relate to disease in camelids is similar to that in other domestic livestock. For example, crias exposed to enteroinvasive strains of *Escherichia coli* are more likely to suffer bacteremia compared with those exposed to noninvasive strains. Exposure to drug resistant strains of bacteria (e.g., *Salmonella)* may be associated with herd outbreaks of disease. The pathogens that affect camelids are often similar to those that affect other domestic species and include bacteria, viruses, protozoa, and various parasites. These agents have been reviewed and are listed in Box 1-1.[14–17]

Although camelids are known to suffer diseases similar to other domestic livestock, no camelid-specific vaccines have been produced or approved for use in the United States. Many products are, therefore, used in an extra-label manner. Owners and managers should be informed that extra-label use carries no assurance of efficacy or safety. The basic foundation for immunizing camelids is, therefore, limited and includes immunization against *Clostridia* organisms such as *Clostridium perfringens* types C and D and *C. tetani* toxoids. A killed rabies vaccine and a leptospirosis bacterin may be used if either disease is endemic. Although other vaccines have been administered to camelids, it is recommended that any modified-live virus vaccine or live bacteria product be used with caution in

BOX 1-1 Disease Agents of Camelids

BACTERIA
Brucella abortus
Hemoplasmas—(hemotropic mycoplasmas)
Leptospirosis spp.
Mycobacterium avium subsp. *paratuberculosis*
Mycobacterium tuberculosis
Salmonella spp.
Streptococcus zooepidemicus
Bacillus anthracis
Clostridium spp.
Corynebacterium pseudotuberculosis

FUNGAL
Coccidioidomycosis

VIRUSES
Adenovirus
Bluetongue virus
Rotavirus
Bovine viral diarrhea virus
Contagious echthyma (Orf)
Coronavirus
Eastern Equine Encephalitis
Equine herpes virus 1
Equine viral arteritis virus
Foot and mouth disease virus
Influenza A virus
Papillomavirus
Parainfluenza virus 3
Rabies
Respiratory syncytial virus
Vesicular stomatitis virus
West Nile virus

PROTOZOA
Coccidia
Cryptosporidium
Giardia

PARASITES
Haemonchus
Lice
Liver flukes
Mites
Ostertagia
Paralaphostrongylus tenuis
Trichostrongylus
Nematodirus
Trichuris
Ticks

an extra-label manner. Finally, information concerning the scheduling of vaccination in camelids is limited at this time. In general, immunization schedules similar to those of other domestic livestock species may be recommended.

A unique condition termed "alpaca fever" involves alpacas' exposure to *Streptococcus equi.* subspecies *zooepidemicus.* The organism was first described as a pathogen of alpacas in Peru and has since been implicated as an important pathogen in North America.[17,18] Alpaca fever may occur in acute, subacute, or chronic forms, with high fever and anorexia usually present in the acute and subacute manifestations. Systemic infection, usually involving the lungs or serosal surfaces of the thoracic or abdominal cavities, may follow ingestion of the organism, and death may occur within 4 to 8 days of onset of clinical signs. Although the origin of the organism is often not determined, it is presumed that risk factors include exposure of alpacas or llamas to carrier-horses or other species harboring the organism.

Coccidiosis is largely a parasite problem causing diarrhea in crias less than 1 year old, often accompanying the stress of weaning, and also in previously unexposed or immunosuppressed adults. Infection occurs via the fecal–oral route; therefore, housing, feeding practices, and pasture management are important in reducing exposure to susceptible animals. Importantly, oocysts can survive for several weeks in warm, dry environments, but they can persist for months to years in cool, damp environments. The prepatent period (time from ingestion of infective oocysts to shedding in feces) varies between coccidia species and may range from approximately 10 days for *Eimaria punoensis* to 33 days for *E. macusaniensis.* Cross-protection between coccidia species does not appear to occur; therefore, even adult camelids may become infected and develop clinical disease after exposure to a new species.

Camelids should also be monitored and examined for external parasite infestations including pediculosis (lice), acariasis (mites and ticks) as well as fungal infections such as dermatophytosis (ringworm).

Environmental Risk Factors

New World camelids were domesticated while residing in areas with low population density and wide-open grazing in the mountains of South America. This environment lessened the risk of pathogen exposure and disease propagation, since direct contact between animals was minimized and pathogens were frequently exposed to unfavorable environmental conditions (freezing or thawing and desiccation). Today, camelids commonly reside in environments varying from pasture settings with low population density to dry lots with barns or enclosures with high population density. Specific risk factors include housing (e.g., barns, pastures); physical environment (e.g., bedding, animal exposure, cleaning and disinfection); general hygiene; miscellaneous stresses such as transportation and handling, and atmospheric conditions (e.g., temperature, humidity, ventilation). Fortunately, many of the risk factors associated with environmental conditions can be controlled with implementation of specific biosecurity measures.

Although it is not possible to alter general atmospheric conditions, management changes that provide shelter and improve comfort can be implemented. In cold environments, camelids should have adequate bedding and shelter from excessive moisture and wind. Adequate access to diets with sufficient energy and protein content should be provided during extreme hot and cold conditions. To maintain appropriate hydration, camelids should have free access to clean fresh water sources that do not freeze.

In hot and humid environments such as those found in the southeastern and western United States, heat stress is prevalent. Prevention of heat stress should involve management practices that facilitate a camelid's ability to cool itself.[19] Shearing practices should be adjusted to coincide with seasons of high environmental temperature. Camelids should always have access to sufficient shade and be housed with damp, sandy soils, which facilitate thermoregulation. Sprinkling systems that spray the camelids' ventrum and wading ponds may be effective. In severe conditions, air-conditioned stalls may be necessary. Importantly, any time animals are housed in confined areas (either during hot or cold weather), attention must be paid to adequate ventilation. As a general rule, if individuals inspecting a facility are not reasonably comfortable because of excessive heat, cold, wind, moisture, humidity, odors, and so on, it is likely that animals will be similarly uncomfortable.

Frequent manure removal and provision of well-drained soils or bedding material will aide in minimizing pathogen buildup. Feeding practices should be centered on preventing fecal contamination and include the use of hay feeders, hay nets, and raised mangers. Water systems should also be designed to prevent fecal contamination as well as contamination by pests, rodents, or other domestic or wild animals.

Handling, holding, and transportation facilities should be designed and managed to alleviate undue tension or distress. Appropriate ventilation, temperature, and footing should be considered. When appropriate, animals should have access to fresh water and feed during these periods.

General Cleaning and Disinfection

Concepts of appropriate cleaning and disinfection that are critical to breaking disease transmission have been reviewed by several authors.[4,20] Cleaning must be recognized as a multiple-step process. The critical first step in the cleaning process involves thorough removal of all visible organic debris (e.g., soil, feces, urine, milk, sputum). The cleaning process includes physical areas such as pens or stalls, feeding and other equipment, and soiled hands and cloths. Vigorous cleaning should precede application of disinfectants for these substances to attain maximum effect.

Many products are available for disinfecting equipment or premises. In addition to their chemical characteristics, other variables will determine a product's effectiveness. These include the product concentration, contact time, temperature, pH, water content, water hardness, as well as the amount of organic debris present. Sodium hypochlorite is generally available as a 5.25% solution (household bleach) and is both cost effective and environmentally safe. At sufficient concentrations, contact time, and temperature it is effective against most bacterial and viral pathogens, although not all (e.g., *Cryptosporidium* oocysts). Recommended concentrations of sodium hypochlorite for use in human environments range from 500 parts per million (ppm) (1 : 100 dilution) and 10 minutes contact time at room temperature to 5000 ppm (1 : 10

dilution) and 1 minute contact time at room temperature, the higher concentrations being used in more critical areas.[4] For viruses in veterinary hospitals, a 0.175% solution (1 : 32 dilution) with a 10-minute contact time at room temperature has been recommended.[21]

The characteristics of environmental surfaces of animal facilities and equipment will influence success or failure of cleaning and disinfection protocols.[22] For example, unfinished plywood retains approximately 15-fold more microorganisms compared with painted or varnished plywood. Varnished plywood retains approximately 15-fold more microorganisms compared with plastic surfaces. On smooth impervious surfaces such as metal or plastic, washing with soap and water to remove visible contamination will result in the elimination of approximately 99% of the microbial load. Similar washing of typical household surfaces removes approximately 90% of the microbial load. It can be presumed that washing of rough lumber will remove even less microorganisms. This knowledge may be used to recommend cleaning and disinfection protocols, in designing facilities, and choosing construction materials and equipment. Finally, basic knowledge about the survival of pathogens on various substrates may be useful in both the management and the investigation of disease outbreaks.

Personal hygiene of animal handlers and farm personnel is critical in impeding the transmission of pathogens between animals or from animals to humans. Basic steps should include frequent hand washing with hot water and soap, cleaning and disinfection of foot wear, and thorough washing of clothing.

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