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Biosecurity for gastrointestinal diseases of adult dairy cattle

Scott J. Wells, DVM, PhD*, Scott Dee, DVM, PhD,
Sandra Godden, BSC, DVM, DVSc

*Department of Clinical and Population Sciences, University of Minnesota,
College of Veterinary Medicine, 1365 Gortner Avenue, St. Paul, MN 55108, USA*

Perhaps no one single factor has the ability to affect the performance of animal populations as severely as infectious disease. Exposure to bacterial and viral pathogens occurs frequently in the life of an individual animal and can spread laterally throughout large populations at a rapid rate. Depending on the level of immunity within the population and the degree of management under which the animals are raised, the effect can be quite severe, particularly if concurrent infection of multiple pathogens should occur. The need to prevent the introduction of and to mitigate the effects of such pathogens has resulted in the evolution of disease-control strategies and biosecurity programs. It is a misconception that only large production units can afford to take advantage of advanced principles of disease control. The practice of biosecurity and the application of disease detection techniques are important to all producers.

The preceding paragraph is entirely appropriate for cattle herds, but it is also applicable (and was originally written) for swine farms. As biosecurity management strategies are developed and implemented to prevent introduction and spread of infectious diseases in cattle populations, it is informative to review principles of biosecurity from another livestock species in which these issues have been considered (e.g., swine) and compare these perspectives to the current situation for cattle. Should cattle biosecurity programs of the future adapt parts of the swine biosecurity model? To address this question, the authors follow a biosecurity risk-assessment model to identify important health hazards, evaluate risks, and present principles for implementing a cattle biosecurity program for important gastrointestinal health hazards of adult dairy cattle, after consideration of a swine biosecurity model.

* Corresponding author.

E-mail address: wells023@tc.umn.edu (S.J. Wells).

Use of a risk-assessment approach to evaluate biosecurity risks for cattle populations

Biosecurity can be defined as a strategy to control and prevent animal and public health-related losses. Development of a biosecurity management plan on dairy operations using a risk-assessment process has been described previously [26], categorizing the microbial risk assessment process into components of hazard identification, exposure assessment, dose-response assessment, and risk characterization [3]. Available information dictates the validity and precision of the risk estimates generated.

Hazard identification

A prioritization process for important diseases and health conditions of dairy cattle has recently been described [29], considering hazards with associated production losses, zoonotic potential, international trade implications, and animal welfare concerns. A similar process should be evaluated from the individual perspective of each cattle operation, considering the most important hazards to sustainable profitability of the enterprise. Primary pathogens of concern may differ from herd to herd, depending on factors such as sale of breeding stock. For many dairy cattle producers, the adult cow gastrointestinal pathogens of highest concern include *Mycobacterium paratuberculosis* (*M. avium* subsp. *paratuberculosis*, the cause of Johne's disease) and *Salmonella* spp. These pathogens therefore form the basis for much of the biosecurity discussion that follows.

Johne's disease and salmonellosis are of increasing concern as cattle become more concentrated within herds of large cow numbers. Animal movements from farm to farm, especially herd expansions, create special pathogen risks owing to increased exposures of cattle to multiple pathogens at times of reduced immune function related to stresses of transportation and animal re-sorting. Also, dairy cattle in the United States have become more genetically homogeneous [10], leading to risks of lack of hybrid vigor and associated lack of resistance to diseases to which these cattle are exposed. The authors begin by evaluating the disease effect, epidemiology (reservoirs of infection, primary methods of transmission), and primary control measures of these two cattle diseases. More complete understanding of the epidemiology of disease can lead to the development and implementation of more effective control strategies through the interruption of transmission between and within farms.

Economic losses from Johne's disease primarily are related to impaired animal health in affected herds (reduced milk production and premature involuntary culling in affected cattle, with resulting losses of over \$200 per cow in heavily infected herds) [16] but also may include loss of livestock sales due to buyer concerns about the disease and potential future concerns about uncertain public health risks. Cattle serve as a primary reservoir of infection for *M. paratuberculosis*, the pathogen causing Johne's disease,

along with other ruminant species and potentially, other animals. *M. paratuberculosis* is an intracellular bacterium that survives well but does not replicate outside infected animals for extended periods [5]. Transmission to uninfected cattle occurs primarily through fecal-oral routes and also through consumption of contaminated or infected milk, colostrum, or water [22]. Young calves are at highest risk of becoming infected. A long incubation period of 3 to 6 years precedes development of clinical signs. Factors predisposing to transmission of Johne's disease include introduction of cattle to the herd and use of management practices that expose young replacement heifers to the pathogen (use of multiple-cow maternity areas, lack of segregation of calves from dams after birth, and feeding of contaminated colostrum and milk to calves) [8,27]. Because of the epidemiology of Johne's disease (highest susceptibility of youngest cattle and long incubation period before clinical disease), reduction of exposure of youngstock to the pathogen is of primary importance in dairy herd control programs.

Economic losses from *Salmonella* spp. occur because of clinical disease and mortality in cattle of all ages, but an even larger potential effect is the growing public health concern about *Salmonella* spp. as a critical and costly food-borne pathogen of humans. Recently, concern has arisen from the public health community about the emergence of antibiotic-resistant strains of *Salmonella* spp. One of these strains (*Salmonella* Typhimurium DT104) was recognized in the 1990s in the United States and elsewhere as characteristically resistant to five different antimicrobics and associated with disease outbreaks in humans and cattle [1]. Salmonellosis is caused by the bacterium *Salmonella enterica*, with more than 2200 serotypes identified. The reservoir of infection includes all species of animals and birds [17]. These pathogens also can replicate in the environment under certain temperature and moisture conditions out of direct sunlight and can survive for several months [14,18]. Transmission occurs primarily through fecal-oral routes, often through contaminated feed, water, or the environment. The epidemiology of *Salmonella* spp. transmission can be complex, however, with transmission cycling through multiple species of animals in a geographic area, as demonstrated by Kinde et al. [12]. Risk factors for dairy cattle include introduction of infected cattle, grouping and housing of cattle, contaminated feed and water, and transfer of the pathogen by movement of vehicles, people, rodents, birds, and other animals [18,25]. Control of *Salmonella* spp. transmission is especially challenging because the organism can persist in cattle environments [7].

All cattle producers should consider prevention of unusual disease outbreaks, including those diseases classified as foreign to their country. Foreign animal diseases with gastrointestinal clinical signs include such diseases as rinderpest, which is internationally reportable as an Office International des Epizooties List A disease based on the potential for serious socioeconomic or public health consequences. The risk of rinderpest due to movement of cattle is low in North America because of the geographic isolation of North America from much of the rest of the world, strict

regulation of animal movements from infected countries, and lack of carrier state in recovered cattle [24]. Other foreign animal diseases, however, pose higher risks of transmission through the international movement of animals, people, animal products, or semen and embryos.

Exposure assessment

Risk of exposure to pathogens is related to prevalence of the pathogens in various cattle populations and the probability of exposure to those cattle populations. Both Johne's disease and salmonellosis are endemic to North America and commonly identified in dairy herds. The National Animal Health Monitoring System (NAHMS) has estimated that at least 22% of US dairy herds and 8% of US beef cow–calf herds are infected with *M. paratuberculosis* [6,27]. Cow-level estimates of infection are conservative because of a lack of sensitivity of current diagnostic tests early in the course of infection, but the NAHMS estimates that 2% to 4% of US dairy cattle are infected as well as 0.4% of US beef cattle [4].

From the 1996 NAHMS Dairy Study [28], milk cows on 21% of dairies were shedding *Salmonella* spp. in feces at detectable levels using fecal culture at a single visit, including 5% of milk cows. From this study, in herds with at least 100 milk cows, nearly 9% of cows were shedding *Salmonella* spp. at detectable levels compared with 0.6% of cows from herds with less than 100 milk cows. These estimates are expected to be conservative estimates of the true prevalence of infection, because cows on 75% of large California dairies have been shown to have serologic evidence of exposure to *Salmonella* [21].

From recent NAHMS national studies, estimates of use of certain biosecurity practices for dairy and beef cattle can be obtained. A summarization of some practices used in the US dairy cattle population (Table 1) clearly indicates the potential risk of disease introduction through widespread lapses in between-herd biosecurity. Depending on herd size, 41% to 66% of US dairy operations introduce cattle to their operations each year, with little use of isolation or quarantine before introduction and little testing for exposure to certain pathogens before introduction. Isolation of incoming cattle before introduction to the herd is not an effective control measure for diseases of long incubation like Johne's disease, but it can be effective for diseases with shorter incubation periods, including salmonellosis. Although many cattle producers identify animals for herd management purposes, no universal animal identification exists to track the movement of cattle from farm to farm. Such systems have been adopted in Canada and parts of Europe, and tracking movements could facilitate control of certain diseases.

Likewise, risks of pathogen spread from older to younger naive cattle within a herd are generally high in US dairy herds (Table 2). Use of multiple-cow maternity housing systems is common and presents an ideal mechanism for transmission of infection with *M. paratuberculosis* and *Salmonella* spp. (and many other pathogens) from cows to susceptible calves.

Table 1

Use of between-herd management practices related to between-herd control of infectious disease by herd size

Management practices	Operations (%)		
	No. of milking cows		
	<100	100–200	>200
Introduce the following cattle onto the operation in previous year			
Bred dairy heifers	15	26	48
Lactating dairy cows	19	23	26
Bulls (weaned)	7	13	23
Any dairy or beef cattle	41	52	66
Operation average percent of cow inventory brought on the operation in the previous year (of operations that brought cattle onto the operation)			
Cows	19	16	12
Heifers	17	13	20
No quarantine of cattle for at least 7 days (of operations that brought the following cattle onto the operation in previous year)			
Bred dairy heifers	89	87	82
Lactating dairy cows	96	99	89
Bulls (weaned)	89	93	88
Not normally required before bringing cattle on farm (of operations that brought cattle onto the operation in previous year)			
<i>M. paratuberculosis</i> test	91	85	95
BVD virus test	85	78	86
BVD virus vaccination	57	41	41
Cattle left the operation for fairs and shows and returned to the operation in previous year	16	24	26

From Wells SJ. Biosecurity on dairy operations: hazards and risks. J Dairy Sci 2000;83:1–7; with permission.

Maternity pens are often used as housing for sick and lame cattle, increasing risks of calf exposure. Equipment is sometimes used for cattle feed and manure handling, potentially contaminating feed before consumption, and some operations use recycled water to flush cow alleyways, both practices potentially perpetuating the cycle of fecal-oral pathogens in cattle environments.

US dairy herds are currently managed in a manner that presents multiple opportunities for introduction of pathogens, including *M. paratuberculosis* and *Salmonella* spp. A few of these risks have been estimated previously. Introduction of 40 cows to a dairy herd from herds of unknown Johne's disease health status leads to a 65% probability of introducing Johne's disease

Table 2

Use of management practices related to within-herd control of infectious disease by herd size

Management Practice	Operations (%)		
	No. of milking cows		
	<100	100–200	>200
Use of multiple-cow maternity housing facilities	47	63	72
Use of maternity housing not separate from that of lactating dairy cows	61	31	13
Frequent or occasional use of calving area as a hospital area for sick cows	56	58	43
At least 25% of heifer calves born on the operation remained with their dams more than 24 hours	17	11	10
Use of multiple-calf preweaned heifer housing	50	31	33
Equipment used for manure handling also used to handle feed given to heifers <12 months of age			
At least weekly	11	19	13
Occasionally but less than weekly	10	12	14
Sick cows not separated from other cows and heifers to prevent nose-to-nose contact	86	76	53

From Wells SJ. Biosecurity on dairy operations: hazards and risks. J Dairy Sci 2000;83:1–7; with permission.

to the herd [26]. Use of flush systems for cow alleyways is associated with a 33% to 90% probability of herd infection with *Salmonella*, depending on ration and herd location [11].

Dose-response assessment

Limited information suggests that dose of pathogen plays a role in development of Johne's disease and salmonellosis. Young cattle develop more extensive lesions after experimental exposure to *M. paratuberculosis* than older cattle [13], indicating the effect of timing of exposure to *M. paratuberculosis* on infectious dose. Clinically ill cattle may shed more than 10^8 bacilli per gram of feces and up to 5×10^{12} bacilli per day [5], indicating the massive dose potentially received. The infectious dose of *Salmonella* spp. likely is dependent on serotype, virulence of strain, and the age of cattle host [17]. A single cow may shed 10^6 *S. Dublin* organisms per gram of feces and 10^9 organisms per day [18].

Risk characterization

Although quantitative risk estimates are not available for these diseases, the morbidity and mortality caused by Johne's disease and salmonellosis indicate the relative ease of transmission. A qualitative approach to evaluate the risk of transmission has been developed for Johne's disease as outlined in the following section.

Risk-assessment approach for Johne's disease

It is important for each producer who chooses to focus on Johne's disease to evaluate the most important transmission risks within the herd and then develop a herd plan to deal with highest risk management areas. The format for a Johne's disease risk assessment was initially developed and endorsed by the National Johne's Working Group and more recently modified in Minnesota to create a working system for use on-farm by veterinarians (www.cvm.umn.edu/dairycenter/johnes). This risk assessment, continuing to be developed to improve standardization, provides a useful method of assessing the priority areas of risk of transmission to various cattle age groups with *M. paratuberculosis*. The risk assessment is weighted to focus attention on the maternity pen and young replacement heifers (such as early separation of calf from dam) because of the biology of Johne's disease. Adoption of a herd biosecurity plan to address the highest risk areas should also prevent transmission of many other diseases such as salmonellosis and rotaviral and coronaviral infections.

To expand the herd plan from Johne's disease to prevention of *Salmonella* spp infections, it is important to expand the biosecurity focus to other areas as well, although retaining the focus on exposure by cattle to fecal material. Smith and House [20] have proposed priority areas for focus in reduction of *Salmonella* transmission using a best management practice approach. Although model *Salmonella* control programs in dairy herds have not yet been demonstrated to be effective in practice, the authors expect that successful pathogen reduction programs of the future will include many of the areas emphasized by Smith and House.

Risk management: applying biosecurity principles for cattle populations

Putting these ideas into action is the risk management part of the equation. Using the outline developed in our swine biosecurity model (found in the Appendix at the end of this article), the authors consider a strategy designed to reduce the risk of pathogen introduction to and within farms in the development of a comprehensive framework of biosecurity directed especially toward the pathogens *M. paratuberculosis* and *Salmonella* spp. in dairy cattle herds.

Health status of the dairy herd

Veterinarians should work with the herd management team to develop protocols for the routine monitoring, diagnosis, and treatment of common diseases. Development of protocols in this manner ensures that planning takes place with input from all of the important players and also ensures that this plan is communicated to everyone involved. Although these services and programs are more likely to be requested by mid- and large-sized dairies, smaller dairies also can use them successfully. For Johne's disease

and salmonellosis, the first level of monitoring is the recording of clinical cases of disease. Most cows with clinical Johne's disease (diarrhea and weight loss not responsive to treatment) are culled from the herd, so a record of clinical Johne's disease as a contributing cause for culling is an efficient way to measure the incidence of Johne's disease in the herd through time. Similarly, for salmonellosis, occurrence of acute cases of enteritis and mortality in calves and older cattle should be recorded and followed up with diagnostic evaluations to determine etiology.

Routine diagnostic evaluations of clinically abnormal animals are recommended, either by the herd veterinarian or by trained and skilled herd managers using diagnostic protocols developed with the herd veterinarian. All dead animals, including youngstock and adults, should be routinely necropsied by the herd veterinarian, and appropriate samples should be submitted to the regional veterinary diagnostic laboratory. Record-keeping systems, whether paper or electronic in nature, should be in place, with all cases of morbidity and mortality routinely recorded. The management team, including the herd veterinarian, should review records of production and disease on a regular basis. Only by having such monitoring and record-keeping programs in place will producers be able to detect early occurrences of unusual disease incursions in the herd.

Monitoring of infection and exposure to Johne's disease and *Salmonella* is helpful in developing and evaluating progress with the biosecurity plan. For Johne's disease, the initial step is to confirm the presence or absence of *M. paratuberculosis* on the operation. ELISA tests can be used as herd screening tests, but they need to be followed up with fecal culture to confirm infection in the herd. Lack of confirmed infection with *M. paratuberculosis* leads biosecurity planning in a different direction (focus on prevention of infection) compared with that for herds with confirmed infection (focus on control of infection). Periodic reassessment is important to compare seroprevalence to the baseline prevalence. It is equally important for periodic evaluation of the management plan and its implementation (e.g., annual risk assessment) by an outside reviewer. For *Salmonella* spp., ongoing evaluation of exposure or fecal shedding may be warranted only if the herd experiences ongoing health problems such as calf mortality (B.P. Smith, DVM, personal communication, 2001).

Facility design and location

Location of adult herd site. Site selection and facility design, as they relate to biosecurity, are important considerations for new dairy start-ups or expanding dairies. In selecting the site and designing facilities, important considerations include drainage, exposure to prevailing winds to optimize natural ventilation, and access roads. In contrast to the swine industry, there are currently no strong recommendations as to minimum distance between dairy or beef farms. It is recommended, however, that animals do not share pasture, water sources, or have fence-line contact with animals from other farms.

Location of youngstock site. The use of segregated production, as with off-site heifer rearing or the use of custom heifer growers to raise replacement animals, is considered important in reducing the risk of exposure and infection of young calves to important pathogens in adult feces. Important pathogens include not only *M. paratuberculosis* and *Salmonella* spp. but also others that cause enteric disease in young calves (e.g., *Escherichia coli*, cryptosporidia, coccidia, rotavirus, and coronavirus; see chapter 2 by Barrington et al.). Because the newborn and young calf are considered to be the most susceptible to infection with *M. paratuberculosis*, early removal from the dam and either segregated or off-site rearing are considered to be important management techniques to reduce the risk for new infection [9,19]. If replacement cattle are raised on the same site, the location of calf hutches, barns, and pastures should be physically isolated from facilities and pastures used for the adult livestock. Manure and feed should be handled in such a way as to prevent youngstock from being exposed to fecal material from older animals, which requires consideration of the manure handling system, the direction of manure flow or drainage, and the equipment used to move feed and manure around the farm. For example, adult manure should not be pushed through or stored in areas (e.g., barnyards) where youngstock have access. Also, manure- or feed-handling equipment contaminated with adult manure should not be allowed to come in contact with youngstock facilities.

Facility design. Whether designing a new facility or retrofitting an old one, careful planning must determine where different groups of animals will be housed; how to achieve adequate ventilation; how to ensure cow and operator comfort and safety; which animal handling and restraint systems to use; and how to determine systems for the flows of vehicles, labor, animals, manure, and feed on the farm. All of these considerations will affect the risk of introduction or transmission of disease on the dairy. The herd veterinarian can become a valuable contributor to the process of helping producers in designing these facilities and in developing written standard operating procedures that determine how various systems function (e.g., traffic, labor, manure, feed, animal flow) and how various tasks are to be performed on the facility.

Facility design for preweaned calves and replacement heifers. Newborn calves should be removed from the dam's environment as soon as possible after birth to prevent exposure to *M. paratuberculosis* and *Salmonella* spp. and other pathogens (cryptosporidia, rotavirus, coronavirus, *E. coli*, and coccidia) in the maternity pen environment. Calves should be processed immediately (colostrum, dip navels, vitamin injections, and so forth) and then quickly placed in calf housing that is physically removed from the adult herd. In the winter months in cold environments, calves may need to be placed first in a calf-warming box or warm room and allowed to dry before placement in hutches or a cold barn. Note that appropriate cleaning and disinfection of these calf-processing and calf-feeding areas need careful attention.

Preweaned calves should be housed individually to minimize opportunities for nose-to-nose contact with pathogens in respiratory secretions and manure from other calves and from older animals. Hutches are ideally suited to this purpose but must be managed to prevent disease transmission between neighboring or successive calves. This management includes selecting or creating a well-drained and well-ventilated site and leaving enough space between hutches to prevent nose-to-nose contact. Hutch placement should be rotated (or alternated) to a new piece of ground between successive calves. The bedding is removed from the old ground, and it is put out to sit, exposed to the sun, for 7 to 14 days. Additionally, hutches should be pressure washed and scrubbed with disinfectant between successive calves. Laying the hutches on their sides with interiors exposed to the sun for 3 to 4 days also helps to kill pathogens. Hutches may not provide sufficient protection for calves against heat stress during the summer. Providing shade over hutches may be necessary to prevent heat stress in particularly hot and humid climates.

Although greenhouse barns and warm barns offer improved operator comfort compared with hutches during the winter months, they are less ideal for the control of infectious disease because ventilation usually is reduced and there is often greater opportunity for direct contact between calves. The postweaning facilities should be designed to allow for easy removal of manure and easy cleaning and disinfecting of both the ground and partitions between successive calves. After weaning, calves should initially be placed in small groups (e.g., 6–10 per pen). In addition to allowing easy delivery of feed, fresh water, and excellent ventilation, these facilities should be designed to allow for easy regular removal of manure and application of fresh bedding as well as easy movement and handling of cattle (e.g., with either a chute or headlock system in place).

Regardless of the housing style selected, producers should look for opportunities to set up the facilities so that calves and youngstock can be moved through different areas (or different age groups) on an “all-in–all-out” basis, similar to that used so successfully in the swine industry. This method allows for complete cleaning and disinfection of facilities before new groups move into the facility, breaking the cycle of disease from old to young. It also minimizes the spread of disease that comes from the “mixing” that occurs when new animals are constantly introduced to an existing group. An all in–all out management system is currently being adopted for calves and replacement heifers by some larger dairies and heifer growers.

Facility design for the adult herd. Whether for a tie-stall or free-stall operation, similar considerations must go into the design of facilities for the adult herd. Areas must be designed for quarantine and processing of new arrivals, far-off dry cows, close-up dry cows, fresh cows, treated and sick cows, and the rest of the milking herd. Sick cows should be housed separately from the rest of the dairy herd (i.e., no nose-to-nose contact or sharing of feed or water). Maternity and fresh cow pens should not be used for sick or lame cows. Drug

storage, treatment facilities, and record-keeping systems should be located close to the hospital pen area. All facilities should be designed to allow for the safe and convenient movement, restraint, and treatment of animals, whether a chute system, headlocks, or a management rail system is used.

Maternity pen design and management are of special significance in preventing disease transmission among cows and to the newborn calves. To minimize exposure of the cow and the calf to pathogenic bacteria, the goal must be for the cow to calve into a clean, dry, and well-bedded environment. Because of labor and facility constraints, many herds, both small and large, house and calve dry cows in a group pen and on a bedded pack. Successful management of bedded packs can be achieved only by frequently removing contaminated bedding with liberal and frequent application of fresh bedding. If not extremely well managed, the result is a moist, dirty environment that predisposes cows to infectious diseases such as metritis and mastitis and the newborn calves to umbilical infections and fecal-oral transmission of *M. paratuberculosis*, *Salmonella* spp., and other pathogens (cryptosporidia, rotavirus, coronavirus, *E. coli*, and coccidia). The lack of continuous sunlight exposure in these housing environments prevents ultraviolet light inactivation of pathogens. Not only is the highly susceptible newborn calf exposed to the pathogens from its own dam but also to the pathogens excreted in the manure from all of the dams that have previously been or are currently housed in the same pen.

An alternative to group housing and calving on a bedded pack is the creation of individual maternity pens that are cleaned, disinfected, and rebedded between individual calvings. This model comes closer to the model for farrowing sows, wherein sows farrow in individual crates that are cleaned and disinfected between uses. The system requires herd workers to monitor close-up cows frequently and move individual cows into an individual maternity pen when calving is imminent. The calf and the dam are removed from the pen shortly after delivery, and the area is cleaned, disinfected, and prepared for the next cow. Calves should not be allowed to nurse, and the cow's udder should be cleaned before removal of colostrum for calf feeding. Although this maternity system should be most successful in meeting the objective of delivering the calf into a clean, dry environment (and preventing the transmission of Johne's disease and salmonellosis), it requires resources such as sufficient available labor to allow for frequent observation and timely movement of close-up cows, a gate system that allows for the safe and easy transfer of these cows into the maternity pen by a single person, and a manure-handling system that allows for the quick and convenient removal of contaminated bedding.

Introduction of replacement stock

As is the case with swine, the introduction of new cattle into the herd offers the greatest risk for introducing pathogens onto the dairy. This risk can be minimized in herds with stable herd sizes by rearing replacement heifers within a closed-herd system and using semen from reputable firms with

good disease control programs to breed all heifers and cows. Even if heifers are reared at a separate facility, preventing their exposure to cattle from other herds during this period maintains a closed-herd system. Maintaining a closed herd also prevents purchasing, boarding, or loaning of calves, cows, or bulls; sharing pastures or fence lines with ruminants from other farms; returning animals to the herd after shows; and transporting cattle in someone else's vehicle without first cleaning and disinfecting it. Although a truly closed herd may not be practical in today's climate of expanding dairies, farms should ultimately try to move toward a closed-herd system as soon as that option becomes feasible.

If new animals are to be introduced to the herd, steps can still be taken to minimize the risks of introducing new diseases. Veterinarians should assist their clientele in developing protocols for selection of cattle to be introduced into the herd and describing the method of introduction. Although this article focuses on gastrointestinal diseases of adult cattle, most of these recommendations are nonspecific and apply to many other diseases of cattle.

Know the herd of origin. The buyer and seller, or their respective veterinarians, should discuss the current (actual, not hypothetical) herd vaccination program, general herd health status, and specific disease history of the herd of origin and of individual cattle considered for purchase. Buyers also should learn about udder health (i.e., somatic cell count data, bulk tank culture results, clinical mastitis records and culture results, examination and palpation of udders and teat ends), other clinical disease records (e.g., diagnosis of salmonellosis or clinical Johne's disease), and the biosecurity, vaccination, and testing program for the herd of origin. Prospective buyers should avoid purchasing replacement animals from unknown sources or those that have been mixed with other cattle before sale. If possible, producers should purchase heifers rather than mature cows because they are easier to quarantine if not yet milking, and because they are less likely to have contagious mastitis infection. For Johne's disease, there is large benefit to selection of cattle from herds enrolled in a status program (Voluntary Johne's Disease Herd Status Program, to be discussed in more detail in the next section).

Testing purchased cattle. When deciding whether to test for a specific disease, one must consider such factors as the risk of disease introduction, the potential economic and health consequences if the disease is introduced, the accuracy of the diagnostic test being considered, the cost of testing, convenience and potential risks associated with testing, timeliness of test results, how the disease is transmitted, and whether there are other effective ways to manage or control the disease if it is introduced (e.g., vaccination or treatment). Although there is no universal consensus on which diseases to test for, those worth considering and that veterinarians should at least discuss with their clientele include bovine viral diarrhea virus (persistent infection), contagious

mastitis (i.e., *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma bovis*), *Neospora caninum*, bovine leukosis virus, *Salmonella* spp., and *M. paratuberculosis*. Because it takes 3 to 4 weeks to obtain some test results, samples should be collected and submitted on arrival of the animal into the quarantine area. Alternately, animals may be isolated and tested while they are still on the seller's property, before transport.

For Johne's disease, testing individual cattle is of marginal value and may not be a cost-effective activity (see chapter 9 by Smith). Because of the biology of this disease and the imperfect diagnostic tests currently available, ELISA tests only detect approximately 15% of 24-month old-heifers that are infected with *M. paratuberculosis* but still in the early stages of the disease [23]. Under these circumstances, testing individual heifers will not prevent the introduction of Johne's disease; however, by use of herd screening programs, the infection status of the herd of origin can be determined far more accurately than the infection status of a single individual animal. Producers can dramatically lower the risk of introducing a Johne's disease-infected animal by purchasing animals from herds that have screened the herd and are known to be either negative or have a low disease prevalence. Many states have developed herd status programs to document herd infection status (e.g., Voluntary Johne's Disease Herd Status Program for Cattle).

There may be specific cases, such as in an ongoing herd outbreak, when management changes are ineffective, when testing for *Salmonella* spp. is indicated. In most circumstances, however, the authors do not recommend that producers should routinely test new cattle purchases for *Salmonella* spp., unless concerns exist about *S. Dublin*, which is host-adapted for cattle infection with resultant carrier cattle. The routine culturing of feces is time consuming and expensive. Because carriers are relatively uncommon and shedding is intermittent, the value of screening new purchases by fecal culture is questionable. As for serum antibody testing, B.P. Smith (personal communication, 2001) recommends that persistently high antibody titers must be found on two tests performed 60 to 90 days apart to consider a cow as a carrier. This testing schedule may be impractical for most dairy producers. Ultimately, salmonellosis is a disease best controlled through sanitation and other management practices.

General recommendations for introducing new cattle arrivals are as follows:

1. Purchased animals should be transported in a manner that minimizes stress and injury.
2. Animals should be transported in the buyer's own vehicle, which should be cleaned and disinfected before and after transporting cattle. If someone else's vehicle is used, one should be certain it is cleaned and disinfected before use.
3. New arrivals should be housed in a designated quarantine area for 30 days before allowing contact with resident cattle. The quarantine

period serves to protect both populations of cattle. The resident cattle are protected from exposure to new infections until the quarantined new arrivals can be properly tested, vaccinated, and monitored daily for signs of clinical disease. The new arrivals are protected from exposure to diseases present in the resident herd until they are properly vaccinated and have improved specific immunity to those diseases.

4. Quarantine facilities would, ideally, be located on a separate site. Although less ideal, animals may still be successfully quarantined in a different barn on the same site or even in a separate pen in the same barn as resident cattle. Regardless of the facility constraints, the ultimate goal is for quarantined animals not to share the same air space, waterers, or feeders, or have nose-to-nose contact with resident cattle.
5. The practitioner should collect the necessary samples to test for infectious disease status.
6. Cattle should be treated with a medicated footbath on arrival. The feet should be trimmed and examined by a professional hoof trimmer. Trimming equipment should be disinfected between animals.
7. New arrivals should be dewormed and vaccinated while in quarantine, so that their immune status is similar to that of the resident herd.
8. Daily monitoring should be conducted to evaluate the animal's attitude, appetite, fecal consistency, and rectal temperature for signs of clinical disease.
9. The preceding measures may not be possible when purchasing lactating animals. In this situation, it may be possible to quarantine, test, and vaccinate the group of lactating cows while still on the seller's property. On introduction, the newly purchased animals should be grouped separately from the resident milking herd. The possible spread of contagious mastitis should be prevented by using proper milking hygiene, sanitation of milking equipment, and milking the newly purchased cattle last.

On-farm biosecurity programs

Animal management system. Clinically ill cattle pose a major reservoir of infection from *M. paratuberculosis* and *Salmonella* spp. (especially *Salmonella* Typhimurium). It is important to house these cattle away from high-risk cattle (youngstock and recently fresh cattle) and other healthy cattle if possible. It is especially important not to house these clinically ill cattle in or near the maternity pen to avoid exposure of newborn calves to these pathogens.

Manure management system. Because fecal-oral transmission is the most common route of infection for the gastrointestinal diseases of interest discussed herein (*M. paratuberculosis* and *Salmonella* spp.), manure systems must be designed to provide minimal opportunity for fecal contamination of feed and water sources. Regardless of the system in place, manure should be removed regularly and in the direction away from the most susceptible

animals (i.e., calves, youngstock, maternity pens). Equipment (e.g., buckets) used to handle manure should not be used to deliver or push up feed to animals. Because *M. paratuberculosis* can survive in the environment (on pastures or in water) for many months, it is recommended that adult cow manure not be spread on pastures where youngstock are allowed to graze. Using manure-handling systems that recycle flush water (e.g., flush freestall barns) represents a risk for exposing the adult herd to pathogens found in feces [11].

Feed management systems. Careful consideration should be given to the types of feeds provided, as well as systems for feed storage, feed delivery, feed bunk design, and feeding management. One feed-related concern is that many wet byproduct and commodity feeds are often contaminated with *Salmonella*. Practices such as pelleting, steam flaking, and roasting can reduce bacterial numbers. *Salmonella* bacteria are killed by heat processing at temperatures of 55°C (131°F) for 1 hour or 60°C (140°F) for 15 to 20 minutes [2].

Commodity loads should be inspected on delivery for visible evidence of spoilage or mold and the presence of animal droppings (e.g., rodents). Purchasing these feeds fresh, on a frequent basis, and mixing feed immediately before feeding may reduce the risk of using contaminated feed. One should rotate stocks, always feeding the oldest feed out first. A new load of feed should not be dumped on top of the remains of the last load. Feed storage bins, silos, commodity sheds, and other feed storage areas should be cleaned out between batches of feed by pressure washing to remove old feed, dust, bird manure and other contaminants, and then allowing ample time to dry before refilling. All feed delivery equipment should be cleaned between deliveries and farms.

All feeds should be inspected routinely for molds or spoiled material, and if spoiled matter is present, the feed should be discarded and not fed to animals. Feed bunks should be cleaned out daily. Rough, porous feed bunks that can harbor pathogens should be resurfaced to make them smooth. Refusals should not be stored more than 24 hours to prevent spoilage. In general, it is not recommended to feed refusals to youngstock. If refusals are fed to youngstock, they should be fed to the oldest heifers to minimize disease transmission to the more susceptible younger cattle [2]. Similarly, forages and concentrates may be contaminated with *Salmonella* spp. by rodents, cats, dogs, birds, or flies. Rodent, bird, and fly control programs should be implemented in feed storage and handling areas and animal housing areas. Access by cats and dogs should not be allowed in feed storage and handling areas.

The location of feed bunks should be such that feed is easily delivered, refusals are easily removed, and the potential for fecal contamination is minimal. For example, as feed is pushed up to cows or heifers in drive-by feeding systems, care should be taken not to use the same blade for pushing

up feed as was used for scraping manure, to avoid pushing the feed or the blade through manure in cow transfer alleys, and not to drive on feed with manure-contaminated wheels. Manure-handling equipment should not be used to handle feed.

Water quality and management. Water odor, taste, mineral content, and bacterial content are determined by testing water sources. Water cups, troughs, and tanks should be designed and positioned to minimize opportunities for fecal contamination and to allow for easy and regular cleaning. Similarly, wells, ponds and streams should be protected from fecal contamination. Youngstock should not have access to barnyards, pasture areas, or water sources where adult cattle have access, where adult manure is stored, or where run-off from adult manure may occur [2].

Control traffic onto and within the farm. Infectious disease can be introduced to the farm by fomites such as transport vehicles, rendering vehicles, and visitors' boots and clothing. Additionally, visitors or farm staff can carry disease from diseased to susceptible animals within the facilities. As with the swine industry, visitors should be instructed to make appointments in advance to visit the farm. Additionally, signs should be posted restricting access to livestock and instructing visitors to go directly to the main office on arrival. All visitors should sign a logbook to allow future evaluation of transfer of pathogens in the case of a disease outbreak.

On larger dairies, farm staff may be designated to work only in one area and with one group of animals (e.g., susceptible calves or fresh cows) and do not work in or travel through areas where diseased animals are housed. If employees are required to work with all groups of animals, as is the case on small and mid-sized dairies, they should work with diseased animals only after handling susceptible animals (e.g., young calves, close-up, fresh, and lactating cows). Alternately, they should wash hands, change clothing, and disinfect boots after having handled sick animals before moving to work with groups of healthy or susceptible groups of animals.

The farm management should provide clean boots and coveralls to all visitors who will access animal facilities or feed storage areas. Dressing should occur in an area designed to prevent cross-contamination. Footbaths should be provided for visitors and farm staff members who are moving between different areas of the farm (e.g., sick-cow area, calf area), with adequate fresh water and scrub brushes available to remove organic material from boots before disinfection. Visitors should have access only to those facilities that concern them (e.g., feed delivery, dead stock, milk pick-up) and should be restricted from parlors and barns.

Veterinarians play a critical role in on-farm biosecurity programs. First, a practicing veterinarian is a potential fomite for disease transmission, with particular risk because of movement from farm to farm after exposure to diseased and infectious animals. Second, a veterinarian should serve as a

role model for biosecurity on the farm and a catalyst for positive change among herd managers and workers. The veterinarian should arrive on the farm with clean coveralls and boots, generally move from most susceptible cattle groups to diseased cattle groups (evaluating sick cattle last), wash and disinfect boots between cattle groups, and avoid contaminating feedbunks and feed storage areas with boots. Although the potential role of the veterinarian as a fomite for within-herd transmission of disease among groups of cattle may seem small compared with the everyday flow of people and vehicles on the farm, attention to these details may help to motivate biosecure practices by others.

Vehicles and equipment also should have restricted entry to farms. For example, dead stock trucks, dead stock cables, or dead stock truck drivers should not have access close to or within animal housing facilities or feed storage areas. Carcasses should be removed from these facilities as soon as possible and stored in a remote location that has separate access and is not visible to the public. Drivers of rendering or dead stock vehicles picking up carcasses should be educated to travel directly to this area, through a separate access route if possible [2]. All vehicles and equipment (such as foot-trimming equipment) should be washed, disinfected, and dried before arriving on the farm. No vehicles carrying live animals should be allowed on the farm unless the animals are from an approved source. External vehicles removing manure should be washed and disinfected before being allowed on the farm. All vehicles removing manure from the farm should be restricted from animal housing and feed storage or handling areas.

Vaccination. A conditionally approved killed Johne's disease vaccine is available in certain states with state veterinarian approval. Although the efficacy of this vaccine has not been well demonstrated, it is thought to reduce development of clinical Johne's disease (and reduce fecal shedding) but not to prevent infection. Chronic vaccine-site swellings (i.e., brisket) are a frequent side effect, and accidental inoculation of humans can similarly result in disfiguring lesions. Because the vaccine can be given to calves only up to 35 days of age, vaccination does not lead to immediate herd immunity. Killed *Salmonella* calf vaccines have not proven efficacious [18], but a modified live *S. Dublin* vaccine has been shown to be beneficial when given to young calves (B.P. Smith, DVM, personal communication, 2001). Some benefit may result from vaccination against Johne's disease and salmonellosis in certain situations, but only as an adjunct to the more important biosecurity system in place.

Risk communication

A biosecurity management plan is only as good as its implementation, and any biosecurity system designed for a specific purpose is only as effective as the people who control and manage it. The best management systems can be

overwhelmed by human error. All farm workers involved in implementation of the biosecurity plan need to understand its importance to ensure follow-through of the program. Acceptance by the farm's vendors and suppliers, as well as family members and friends, is necessary. For these reasons, it is critical that the herd biosecurity plan be communicated to these individuals clearly, frequently, and consistently.

Biosecurity conclusions

The inability to control diseases such as Johne's disease relying solely on testing and culling has been frustrating. The development of management-related biosecurity programs and systems while evaluating effects on production must be considered. As new research into the diagnosis and control of infectious diseases of cattle is developed, the system will have to adapt as well. It is imperative that cattle producers be forward thinking and open to perspectives from other livestock species (e.g., swine) and implement specific strategies when warranted. Bovine practitioners are in the ideal position to lead the process of re-educating the cattle industry concerning the importance of animal and public health. In so doing, veterinarians must continue to develop novel creative strategies to understand the disease process, to control its spread, and ultimately, to minimize its effect.

References

- [1] Akkina J, Angulo F, Hogue, A, et al. *Salmonella typhimurium* DT104 situation assessment. Ft. Collins (CO): USDA-APHIS and USDA-FSIS; 1997. p. 3–7.
- [2] Bovine Alliance for Management and Nutrition. Biosecurity of dairy farm feedstuffs. Arlington (VA): BAMN Publications; 2000. p. 1–5.
- [3] Buchanan R. Principles of risk assessment for illness caused by foodborne biological agents. *Journal of Food Protection* 1998;61:1071–74.
- [4] Centers for Epidemiology and Animal Health, USDA. Animal and Plant Health Inspection Service: Veterinary Services: Johne's disease on U.S. dairy operations. Publication no. n245.1097. Fort Collins (CO): National Animal Health Monitoring System, 1997. p. 1–52.
- [5] Chiodini RJ, Van Kruiningen HJ, Merkal RS. Ruminant paratuberculosis (Johne's disease): the current status and future prospects. *Cornell Vet* 1984;74:218–62.
- [6] Dargatz DA, Byrum BA, Hennager SG, et al. Prevalence of antibodies against *Mycobacterium avium* subsp. *paratuberculosis* among beef cow-calf herds. *J Am Vet Med Assoc* 2001;219:497–501.
- [7] Gay JM, Hunsaker ME. Isolation of multiple *Salmonella* serovars from a dairy two years after a clinical salmonellosis outbreak. *J Am Vet Med Assoc* 1993;203:1314–20.
- [8] Goodger WJ, Collins MT, Nordlund KV, Eisele C, Pelletier J, Thomas CB, et al. Epidemiologic study of on-farm management practices associated with prevalence of *Mycobacterium paratuberculosis* infections in dairy cattle. *J Am Vet Med Assoc* 1996;208:1877–81.
- [9] Groenendaal H, Galligan D. Economical consequences of Johne's disease control programs [doctoral thesis]. New Bolton Center, University of Pennsylvania, Center of Animal Health and Productivity, School of Veterinary Medicine; 1999. p. 1–53.
- [10] Hansen LB. Consequences of selection for milk yield from a geneticist's viewpoint. *J Dairy Sci* 2000;83:1145–50.

- [11] Kabagambe EK, Wells SJ, Garber LP, Salman MD, Wagner B, Fedorka-Cray PJ. Risk factors for fecal shedding of *Salmonella* in 91 US dairy herds in 1996. *Prev Vet Med* 2000;43:177–94.
- [12] Kinde H, Read DH, Ardans A, Breitmeyer RE, Willoughby D, Little HE, et al. Sewage effluent: Likely source of *Salmonella enteritidis*, phage type 4 infection in a commercial chicken layer flock in Southern California. *Avian Dis* 1996;40:672–76.
- [13] Larson AB, Merkal RS, Cutlip RC. Age of cattle as related to resistance to infection with *Mycobacterium paratuberculosis*. *Am J Vet Res* 1975;36:255–57.
- [14] Mitscherlich E, Martin EH. *Mycobacterium paratuberculosis*: Microbial survival in the environment. New York: Springer-Verlag; 1984. p. 248–50.
- [15] Moore C. Biosecurity and minimal disease. *Vet Clin North Am Food Anim Pract* 1992;8: 461–74.
- [16] Ott SL, Wells SJ, Wagner BA. Herd-level economic losses associated with Johne's disease on U.S. dairy operations. *Prev Vet Med* 1999;40:179–92.
- [17] Radostits OM, Gay CC, Blood DC, Hinchcliff KW. Diseases caused by *Salmonella* spp. In: *Veterinary medicine: a textbook of the diseases of cattle, sheep, pigs, goats, and horses*, 9th edition. London: WB Saunders; 2000. p. 809–27.
- [18] Smith BP. Salmonellosis in ruminants. In: *Large animal internal medicine*, 3rd edition. St. Louis: Mosby; 2002. p. 775–9.
- [19] Smith DR. Biosecurity risk management to improve heifer health and value. In: *Proceedings of the Third Annual Professional Dairy Heifer Grower's Association National Conference*. March 1999. Bloomington (MN): Professional Dairy Grower's Association; 1999. p. 87–92.
- [20] Smith BP, House J. Prospects for *Salmonella* control in cattle. In: *Proceedings of the 25th Annual Meeting of the American Association of Bovine Practitioners*. St. Paul (MN): AABP; 1992. p. 67–73.
- [21] Smith BP, DaRoden L, Thurmond MC, Dilling GW, Konrad H, Patten JA, et al. Prevalence of salmonellae in cattle and in the environment on California dairies. *J Am Vet Med Assoc* 1994;205:467–71.
- [22] Sweeney RW. Transmission of paratuberculosis. *Vet Clin North Am Food Anim Pract* 1996;12:305–12.
- [23] Sweeney RW, Whitlock RH, Buckley CL, Spencer PA. Evaluation of a commercial enzyme-linked immunosorbant assay for the diagnosis of paratuberculosis in dairy cattle. *J Vet Diagn Invest* 1995;7:488–93.
- [24] US Animal Health Association. *Foreign animal diseases*. Richmond (VA): Committee on Foreign Animal Diseases of the US Animal Health Association, 1998.
- [25] Warnick LD, Crofton LM, Pelzer KD, Hawkins MJ. Risk factors for clinical salmonellosis in Virginia, USA cattle herds. *Prev Vet Med* 2001;49:259–75.
- [26] Wells SJ. Biosecurity on dairy operations: Hazards and risks. *J Dairy Sci* 2000;83:1–7.
- [27] Wells SJ, Wagner BA. Herd-level risk factors for infection with *Mycobacterium paratuberculosis* in U.S. dairies and association between familiarity of the herd manager with the disease or prior diagnosis of the disease in the herd and use of preventive measures. *J Am Vet Med Assoc* 2000;216:1450–57.
- [28] Wells SJ, Fedorka-Cray PJ, Dargatz DA, Ferris K, Green A. Fecal shedding of *Salmonella* spp. by dairy cows on-farm and at cull cow markets. *J Food Prot* 2001;64:3–11.
- [29] Wells SJ, Ott SL, Seitzinger AH. Key health concerns for dairy cattle—new and old. *J Dairy Sci* 1998;81:3029–35.

Appendix

Biosecurity principles for swine populations (Scott Dee, DVM, PhD)

Several important principles are designed to reduce the risk of pathogen introduction to and among naive swine farms: (1) the health status of breeding

stock, (2) facility design and location, (3) replacement stock introduction, and (4) on-farm biosecurity programs.

Health status of breeding stock

A proper start to any swine project consists of selecting a breeding stock source that commands the highest level of health. In today's modern swine industry, breeding stock should be free of the following pathogens: porcine reproductive and respiratory syndrome virus, pseudorabies virus, transmissible gastroenteritis virus, swine influenza virus H1N1/H3N2, porcine circovirus type 2, *Brucella suis*, *Mycoplasma hyopneumoniae*, *Actinobacillus pleuropneumoniae*, toxigenic *Pasteurella multocida* type D, *Serpulina hyodysenteriae*, *Salmonella choleraesuis*, and *Sarcoptes suis*. Selection of the source herd should follow a careful review of diagnostic and production data and communication with a staff veterinarian. A monitoring program should be in place within the source herd, and testing should take place monthly by the collection of a representative sample of each pig population using both antibody and antigen tests when available. Proper sample sizes should be calculated according to population size, the desired level of confidence of the sampling protocol, and the sensitivity and specificity of each test used. Diagnostic evaluation of tissues collected from clinically abnormal pigs should be conducted on a routine basis, and records made available at all times. A thorough understanding of the health status of the seedstock source minimizes the risk of introducing unwanted pathogens into a herd. Proper planning includes communication and sharing of diagnostic data between veterinarians and producers before purchase.

Facility design and location

The risks of contracting an infectious disease are much higher in extremely hog-dense areas, so construction of new facilities should always initially focus on site location. A minimum of 2 miles (3.2 km) is suggested between farms, although little scientific data are available to support this claim. The use of segregated production is also important to minimize the spread of pathogens between animal populations and to interrupt the cycle of pathogens that occur from older to younger pigs. Segregated production involves the rearing of weaned and growing pigs on sites separate from the sow herd. Segregated production techniques, although ideally requiring separate sites, can be practiced on a single site, so long as the weaned-pig facility is separate from the sow herd. Functional distances for on-site segregation range from 50 to 100 yards (Scott Dee, DVM, PhD, personal experience, 1993–2001).

Replacement stock introduction

The largest risk of pathogen entry to a swine farm is through the introduction of replacement breeding stock, so many producers have adapted

programs to raise their replacement females using a closed-herd system. Internal multiplication of breeding stock is an effective way to minimize the risk of pathogen introduction to a farm and often results in consistent exposure of growing pigs to farm-specific microflora, a practice which frequently improves overall herd immunity. If such a practice is not possible, all incoming replacement gilts from an external source should be quarantined, blood-tested to ensure the proper health status, and then acclimated to farm-specific microflora before entry. The quarantine facility should ideally be located on a separate site, away from the sow herd. The facility should use all in–all out animal flow, and producers should care for these animals after leaving the sow herd for the day. Animals should be blood-tested on arrival and 1 week before entry to the sow farm to ensure that the desired health status has been maintained throughout the quarantine period.

On-farm biosecurity programs

Moore [15] has written a comprehensive review on the biosecurity of swine units, and readers should refer to it for additional detail. To minimize disease transmission, breeding should be done by artificial insemination (AI). Semen should be purchased from a reputable AI center with a documented high-quality health status monitored on a monthly basis. Semen should be distributed by a courier service to neutral delivery points located at the perimeter of the farm. Other biosecurity measures include a minimum of 48 hours free of swine contact and shower facilities for all personnel before entry into the sow and boar centers. Fumigation rooms are an excellent way to disinfect inanimate objects, such as tools and feed bags, before their entry into the animal airspace. For personnel movement between on-site facilities, personnel should change boots and coveralls and wash their hands before entering each facility. Professional exterminators should be hired on a contract basis to visit farms monthly. All openings to facilities should be bird-proofed, using bird screen, particularly over the sidewall openings to naturally ventilated finishing facilities. Other important components of a sound biosecurity program include incineration of carcasses, washing and disinfecting transport vehicles when marketing animals, and perimeter fencing.