Epidemiology of Endemic Bovine Viral Infections

Robert F. Kahrs, *D.V.M., Ph.D.*
Department of Preventive Medicine
College of Veterinary Medicine
University of Florida
Gainesville, Fl 32610

Epidemiology unravels the mechanisms of disease distribution in populations and relates them to disease control strategies. There are concepts of viral epidemiology which impact on the diagnosis and handling of outbreaks, vaccination decisions, and discussions of control of bovine viral diseases.

Consideration of the epidemiology of bovine viral diseases requires a temporary shift in thinking to allow control considerations to overshadow individual treatment. Control emphasis is necessary because few viral chemotherapeutic agents are available and because viral infections are acute and subtle, so effective individual treatment (if available) would likely be too late. In addition, the economic impact of viral infections frequently follows inapparent primary infection and is not observed until after the viral infection has subsided.

The Viral Disease Iceberg

Conceptionalization of viral epidemiology begins with the so-called disease iceberg. In figure 1, two stick figures (representing a veterinarian and a livestock owner) are depicted examining the consequences of viral infections. Their perception is indicated by the dotted lines. The livestock owner sees that proportion representing disease, the veterinarian is able to appreciate more. Both have their perspectives limited by the water line (clinical threshold) above which disease is detectable. The largest portion of the virus-host-environment interactions occur below the clinical threshold.

The unseen portion actually determines what happens in the economically significant area. Thus, veterinarians hoping to make effective vaccination or control decisions must consider activity below the clinical threshold and will

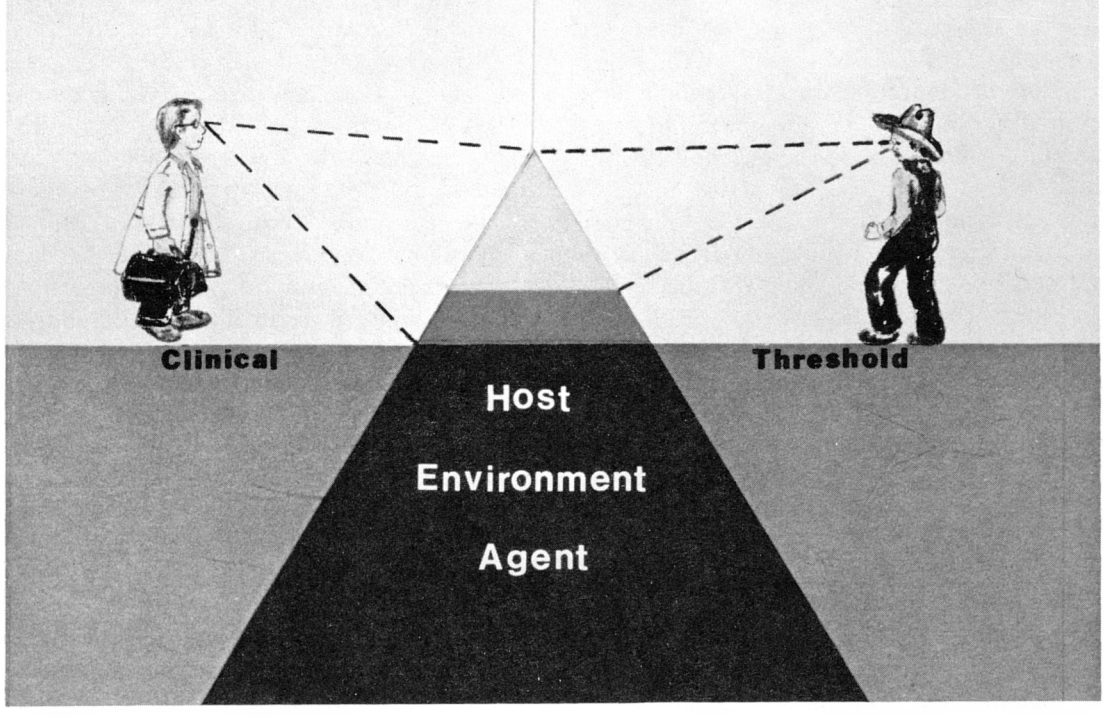

Fig. 1

encounter the following concepts.

Inapparent Infection

For most bovine viruses present in USA, primary uncomplicated infections are frequently inapparent and unnoticed by the casual observer. These are accompanied by fever and immunologic response.

The percentage of exposures causing inapparent infection varies among viruses and probably between strains of the same virus. Most naturally occurring bovine infections with bovine viral diarrhea (BVD), parainfluena 3, bluetongue, papular stomatitis, enteroviruses, adenoviruses, rhinoviruses, parvoviruses, and reoviruses are inapparent. Inapparent infection is less common with infectious bovine rhinotracheitis (IBR).

Viral Infection of Individuals

Following exposure, some cattle are infected and others aren't. This outcome is determined by the immune status of the individual, the virulence and dose of virus, the route of inoculation, and many other factors.

Following infection, one or more cycles of viral replication occur and viral antigen is acquired by immunocompetent cells which initiate immunologic responses. The clinical consequences of exposure are determined by virus-host-environment interaction. Immune and nonimmune mechanisms result in clearing of the virus from the cow. The aftermath is immunity which may be relatively solid (as in BVD), relatively fleeting (as in parainfluenza-3), or intermediate as in IBR. If the clearing mechanism acts promptly, the infection is aborted, no disease occurs, and the result is an inapparent infection.

If viral replication and pathogenicity are adequate, cell damage occurs and clinical disease results. Ideally, following inapparent infection or clinical disease, the individual eliminates the virus and is immune. The magnitude and duration of immunity is determined by viral characteristics and host capabilities.

If all infected cattle subsequently eliminated virus and were refractive to infection, they would not infect other cattle. However, persistent infections upset this scheme.

Persistent Infections

Following primary infection, viral genetic information can remain in some cattle for prolonged periods, often a lifetime. During this time the viral genome may remain latent and inactive, or may express itself by initiating viral synthesis. Viral excretion may occur in normal cattle or in unthrifty cattle like those with chronic BVD. The mechanisms are complex. Active persistent infections are sometimes associated with immunologic deficits.

Latent persistent infections differ from active persistent infections. After primary IBR infection, viral replication and excretion cease, but virus is not permanently eliminated. Instead sequestration of the genome occurs.

This results in latent infections which are capable of subsequent reactivation, sometimes many years after primary infection. Generally reactivations are associated with stress. They can be induced experimentally with steroids (Davies and Duncan, 1974). The disease (if any) associated with reactivations is generally milder than occurs with primary infections, but cattle experiencing these "recrudescenses" constitute a reservoir of virus and a source of infection for herdmates.

The existence of persistent infections limits the value of the 30 day isolation period frequently imposed on new cattle entering herds. Isolation permits detection of acute clinical disease and 30 days is adequate for clearing of most primary infections. However, the persistently infected individual is a potential source of infection and can initiate new herd infections years after initially acquiring the virus. Therefore, introduction of new cattle is not required to start outbreaks and using the interval between introduction of new cattle and the onset of disease among contacts as an estimate of crude incubation periods can be misleading.

Viral Infections of Herds

Totally susceptible herds are infected through introduction of cattle with active primary infections, active persistent infections, recurrent latent infections, or through introduction of virus carried on animate or inanimate objects.

Infected cattle excrete virus and if there is close contact and if transmissibility of the virus is adequate and the herd small enough, all cattle are exposed and infected and the population of susceptibles is replaced by a population of partially immune individuals. When this occurs, new infections cease and unless persistent infections develop, the virus is cleared from the herd.

A solidly immune herd rarely exists because individual immunity is usually partial. Herd immunity is transient because immune individuals are replaced continually by susceptibles through diminuation of immunity in individuals, and through immigration by birth or purchase. The percentage of partially immune individuals is reduced by culling cattle present during the original exposure. The time required for a totally immune herd to revert to total susceptibility is related to the duration of immunity in individual animals, to the rate of culling of immune animals, and to the rate of introduction of susceptibles (Kahrs *et al.*, 1966). In a dairy where 25% of the total population is culled annually, time required for reversion to herd susceptibility is about 4 years unless waning of immunity in individual cattle makes the time shorter or reinfection prolongs it.

Perpetuation Of Viruses

Viruses survive in populations through cow to cow transmission of active infections and by intermittent reactivation of latent persistent infections which add to the probability of exposure and the unpredictability of outbreaks.

Ubiquity of Viruses

Serologic and virologic evidence indicates widespread distributionof BVD (Mills and Luginbuhl, 1965), IBR (Kahrs, 1978), adenoviruses (Mattson, 1973), rhinoviruses (Rosenquist, 1971), reoviruses (Lamont, 1968), picornaviruses (Mattson and Reed, 1974), and parainfluenza-3 (Woods, 1968). Unlike foot and mouth disease, ephemeral fever, and rinderpest, these viruses rarely cause devastating epizootics because they are less virulent and are endemic throughout the world. These infections are frequently inapparent and their mechanisms for perpetuation are highly developed. Thus, they are virtually ubiquitous and exposure of assembled cattle or cattle kept for breeding purposes is inevitable. The probability of individual cattle or individual herds being exposed to each virus differs and is less than the probability of an area exposure. These probabilities are estimated from antibody prevalence surveys. The probability of exposure of individual herds is influenced by the amount of immigration, and by movement of men and equipment recently contacting cattle.

The likelihood of clinical disease following infection is largely determined by environmental factors.

The Role Of Environment

Clincial disease attributable to the endemic viruses is caused by dynamic interaction between the virus, the bovine host, and the environment. Of these, the environment imposed by the total production-management system is most influential in determining the outcome of infection. The total production-management system alters the opportunity for exposure, the likelihood of infection, and the likelihood of clinical disease or death. Thus, intensive production-management systems can trigger serious economic losses with infections which would be inapparent in cattle on open range wth adequate space, feed, and water, and in ecological balance with endemic viruses. In this steady state, the economic impact of these viruses is largely through abortion and early neonatal infections.

When population density increases, detrimental influences appear, multiple infections occur, stress reactions are activated, and herds have problems. In the most intensive cattle production-management systems (feedlots and veal operations), intermingling of cattle infected with multiple microbiologic flora under extreme pressures of socialization occurs simultaneously with imposition of unnatural diets. Here, otherwise mild viral infections are associated with serious clinical disease. Economics and tradition dictate livestock production-management systems, and threat of the endemic viral infection is only one consideration producers face. The mind-boggling complexity of bovine viral disease epidemiology helps us appreciate the temptation to seek simple solutions in vaccines.

The Vaccine Solution

The epidemiologic interactions described are consistently predicated on assumptions of susceptibility and immunity. The overriding implication is that altering susceptibility or inducing immunity could eliminate economic concern over viral infections. This solution has major short-comings in the imperfection of the bovine immune system and the limitations of vaccines.

Partial Immunity

Specific immunity to most viral infections involves humoral and cellular components of the immune system. The relative importance of each differs with viruses. For example, BVD immunity, like that of other systemically disseminated viruses, is highly correlated with humoral antibody (Shope, 1978). Resistance to IBR seems to be more related to locally deployed elements of the cell mediated immune system (Rouse and Babuik, 1974).

As the role of different classes of immunoglobulins functioning in respiratory, reproductive or alimentary tract secretions unfolds, it becomes evident that absolute or solid immunity is rare in cattle. Therefore, natural infection or vaccination should be regarded as rendering cattle partially immune at best, and any assumptions about the duration of this partial immunity must be evaluated carefully (Heuschele, 1978).

Vaccine Limitations

The multifactorial etiology of clinical signs associated with viral infections and the shortcomings of the bovine immune system suggest vaccines offer only partial protection.

There are many potential pathogens for which vaccines are not available. Among these are bovine respiratory syncytinal virus (Lehmkuhl *et al.,* 1979), rhinoviruses (Rosenquist, 1971), adenoviruses (Mattson, 1973), and possibly papular stomatitis (Irwin *et al.,* 1976).

Existing vaccines need continual development to improve efficacy means of administration, and safety. Reliance on modified live virus (MLV) vaccines invokes concern about persistent vaccine infections and potential for pathogenicity in immunologically deficient cattle. Lastly, assuming MLV vaccines are the best disease control alternatives, then improved systems of vaccine delivery are needed for each production-management system (Kahrs, 1976).

Summary

Many endemic viruses are ubiquitous among cattle populations. They frequently cause inapparent infections, and are perpetuated by cow to cow transmission of active or persistent infections.

The extent of clinical disease attributable to these viruses is dependent largely on environmental factors imposed by production-management systems.

Vaccinations is a reasonable control alternative, but has severe shortcomings which must be addressed in coming decades.

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