CHAPTER 2

THE EPIDEMIOLOGY OF FMD

FMD virus is an aphtovirus within the *picornaviridae* family. The most important characteristics in the epidemiology of the disease include the rapid growth of the virus, its stability under a variety of conditions and the occurrence of serotypes (Donaldson, 1991). There are seven serotypes and several subtypes within each. The infections caused by different serotypes are clinically indistinguishable. The animals that survive a FMD infection become permanently infected to the particular strain that cause the infection; however, there is no cross-protection between serotypes.

FMD attacks all cloven-hoofed animals. In the U.S. this includes cattle, sheep, goats, pigs, camels, deer and bison. Cattle are the most susceptible animal species. Cattle, in particular, are important in the epidemiology of FMD because of their high susceptibility to airborne virus, because they may excrete the virus for at least four days before the first symptoms appear, and because of their economic importance. Even though sheep and goats can also be infected, their symptoms are often less severe or are subclinical. Pigs are the most important source of air dissemination of the virus; once infected, they excrete vast quantities of the virus. They also have a high susceptibility to infection by the oral route (Donaldson and Doel, 1994). Thus pigs can be described as amplifying hosts and cattle as indicators. Sheep can be described as maintenance hosts because they quite often have mild or even inapparent signs that can easily be missed (Donaldson, 1994a). In spite of its infectivity, FMD may infect some susceptible species and spare others in the same area (Dunn and Donaldson, 1997).

Several factors affect the spread of the disease. The most important are the species infected, the number of direct and indirect contacts among animals (mainly movements of animals and humans), animal density in the area, husbandry methods, environmental conditions, and delays in identifying the disease and applying control measures. Recent epidemics in Taiwan (1997) and Italy (1993), described in detail in Appendix E, illustrate the extreme contagiousness of the FMD virus.

The primary methods of FMD transmission are aerosol, direct contact and ingestion. It is generally accepted that the virus most commonly infects via the respiratory route, especially in ruminant species where very small doses can initiate infection (Donaldson, 1994a). Cattle, sheep and pigs can be infected by inhaling doses in the range of 10 to 25 infectious units. In contrast, the dose required to infect cattle by the oral route is almost 1 million infectious units. (Donaldson, 1991).

Of all mechanisms of transmission of FMD, movements of infected animals are by far the most important, followed by movement of contaminated animal products (Donaldson, 1994a). Once one or more animals in a herd have been infected, the quantity of virus in the environment will be greatly amplified, and transmission by different routes will be possible. The virus can be spread over long

distances by incubating or asymptomatic carrier animals; by vehicles such as feed trucks; by birds, coyotes, domestic animals such as dogs and cats, rodents and arthropods; by mechanical vectors; and by fomites.[1] Garbage containing uncooked meat scraps and bones from infected animals has been a source of infection in pigs. Humans may inhale and harbor the virus in the respiratory tract for as long as 24 hours, and may serve as a source of infection to animals (APHIS, 1991).

An important feature of FMD is that virus excretion occurs before infected animals manifest clinical signs. The length of the incubation period is variable and depends mainly on the virus strain, dose of exposure and the route of entry. With natural routes and high exposure doses the period can be as short as two to three days but could take up to 10 to 14 days with very low doses (Donaldson, 1994a). The airborne virus is emitted over a four to five day period by an animal infected with FMD and the excretion of the virus may start up to four days before the onset of the first clinical signs. The peak of excretion in a pig may reach 100 million infectious units per 24 hours, whereas the same peak is only 100 thousand in a cow, a sheep or a goat.

Even though there is large body of literature that has shown the possibility of airborne dissemination, this has not been proved.[2] Airborne spread over a distance of 60 km over land and 200 km over sea is believed to have occurred (Moutou and Durand, 1994; Donaldson, 1991). The factors which are believed to favor airborne spread of FMD virus are low to moderate wind spread; high humidity, since airborne virus survives optimally above 60% relative humidity; stable atmosphere, particularly a temperature inversion; absence of heavy precipitation which could cause a wash-out of virus; and high stocking density of cattle downwind (Donaldson, 1994a).

Apart from the respiratory route, less frequent routes of infection could be breaks in an animal's integument, i.e., the skin or mucous membrane. Thus the injection of faulty FMD vaccines, foot-rot in sheep, the feeding of rough fodder, harsh use of milking machines, surgical procedures and damage caused by fingernails during nose restraint of cattle can all provide entry points for the virus.

A high stocking density will facilitate spread as the crowding together of infected and susceptible animals will maintain a high level of challenge from both infected animals and the environment. On the other hand, under extensive beef rearing systems such as found in South America and Africa, the spread of the disease is generally more insidious (Donaldson, 1994a).

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[1] Fomite: an inanimate object that can harbor pathogenic microorganisms and thus serve as an agent of transmission of an infection.

[2] Some veterinarians are skeptical about airborne transmission, believing that in most infections attributed to this vector, the virus was actually carried by unidentified mechanical means.

Period of infectiousness

The infectious period depends on the type and size of a herd, on husbandry practices, and on whether the disease is allowed to run its course, or controls are applied. In the 1951-1952 Canadian outbreak, the disease was allowed to pass through before slaughter of infected animals. Thus it was possible to determine the natural duration of the disease in the farms, based on the periods over which lesions developed. The mean period of infectivity was around 20 days for cattle herds (range nine to 66 days) and 13 days (range 10 to 17 days) for pigs, although herd sizes were relatively small (Sellers and Daggupaty, 1990).

During the acute phase of the disease, which generally lasts three to four days, all excretions, secretions and tissues contain virus. Such animals are very potent spreaders of virus. Their products will contain high quantities of virus, and must be decontaminated or destroyed. Matured and deboned meat has been shown to be free from the virus, which is inactivated by the drop in pH during rigor mortis. The virus, however, survives in the bone marrow and lymph nodes (Donaldson and Doel, 1994).

FMD in adult livestock does not usually result in a mortality rate above 5% except in rare circumstances. However, in young animals, especially under conditions of dense stocking, a rate of up to 90% may result (Donaldson, 1994a). After a relatively short period (between two to three weeks), most adult animals recover from the lesions and become productive again. In some cases, a permanent reduction in productivity has been observed. Healing of the erosions caused by the vesicles on the tongue and other parts of cattle takes place rapidly (within about 10 days) unless secondary bacterial infection occurs. Tongue lesions in pigs are much less dramatic and heal much more rapidly (Donaldson, 1991).

In certain cases, the virus has affected some susceptible species and spared others. During the epidemic in Morocco in 1989-91 there was a high morbidity rate in sheep and mortality in lambs, with only a few outbreaks in cattle (Donaldson, 1994a). Only pigs were infected in the 1997 epidemic in Taiwan. The preliminary results of transmission experiments done by the WRL revealed that the Taiwan outbreak strain failed to cause disease in cattle and goats mixed with diseased pigs which were artificially infected (Shieh, 1997; Dunn and Donaldson, 1997).

Sometimes more than one serotype can be found in a single infected animal. This phenomenon has been found only with samples submitted from countries where the disease is endemic (Donaldson, 1994a). This feature is important in relation to vaccine selection.

The stability of the FMD virus varies according to the medium in which it is present, particularly the pH and the temperature. The virus is inactivated by a low or high pH (pH below 6 or above 8), low relative humidity, sunlight and high temperatures. It may survive for extended periods outside the host in certain protected locations (APHIS, 1991). A comprehensive list of survival periods of the

FMD virus in different environments, animal parts and products is published in APHIS (1991).

The FMD virus can spread to the wildlife population. In the 1924 California infection the disease established itself in white-tailed deer. The initial investigation used poison to obtain a sample of deer; some 30% of the carcasses exhibited lesions of FMD. An intensive campaign followed in which 22,214 deer were killed and their carcasses examined by veterinarians. Of these, a little more than 10% exhibited lesions of FMD. It took until mid-1925 to eradicate the disease from the wild deer population (Sanson, 1994).

After recovery from FMD, up to 80% of ruminant species may become persistently infected. It is believed that these carriers can initiate fresh outbreaks when brought into contact with fully susceptible animals. Vaccinated or immune animals exposed to infection may also become carriers. The duration of the carrier state varies according to the species involved, the strain of the virus and probably other unidentified factors. The maximum recorded periods of carriage for different species are: over three years for cattle, nine months for sheep, four months for goats, five years for the African buffalo and two months for water buffalo (Donaldson, 1994a).

The carriers are particularly important in non-vaccinating countries that are normally free of the disease and fail to eliminate all carriers after suffering an outbreak. Even though the spread of FMD from carriers to susceptible animals has not been demonstrated (Donaldson, 1991; Callis, 1996), it is recommended that carriers not be mixed with susceptible animals.

Diagnosis of FMD

The symptoms of FMD are similar to those of other diseases occasionally occurring in the U.S. (e.g., vesicular stomatitis). Because of these similarities, the field diagnosis always has to be complemented by a laboratory test. Before a FMD outbreak, the only laboratory authorized to perform those tests is the FADDL at Plum Island.

In the presence of a vesicular disease, a producer has two alternatives. Either he/she assumes that it may be FMD, reports the disease (as current regulations require) and has the farm quarantined (with the consequent economic losses), or he/she assumes that it is a less severe disease, does not report it and waits until the symptoms disappear. The information collected during this research showed contradictory opinions among animal health officials and private practitioners on which of the two alternatives producers are more likely to chose. Due to the potential consequences of this behavior, prevention policies aimed at informing producers about the nature of FMD should be considered.

COMMENT: OTHER FMD EPIDEMICS

Hans Riemann

Professor Emeritus

UC School of Veterinary Medicine

Information on other epidemics provides useful information to California. There are publications on the FMD epidemics in other industrialized countries such as Denmark (1982), Austria (1973) and England (1966-67). The Danish epidemic of March and April, 1982, has been well documented, and it is worthwhile to compare its data with the assumptions and simulations in the study reported here. There were 1,700 herds within a radius of 15 miles from the first affected (index) herd, which was initially misdiagnosed.

A "cordon sanitaire" of 750 feet radius was established around each clinically affected herd, with controlled movements of people and no movement of animals. A control area of 6.25 miles radius was also established around clinically affected herds, with no movement of animals among farms and controlled movement to slaughter. Only clinically affected herds, not "latent" herds, were quarantined and eventually slaughtered. Public media such as TV and radio were used extensively to keep the farmers appraised of the FMD situation, and the eradication efforts were kept highly "transparent." In four weeks the dissemination rate dropped from an initial level of about eight to less than one. The epidemic was "stamped out" in less than two months with only 20 (i.e., 1.2%) of the herds in the area affected. The sharp decline in the dissemination rate (which was also observed in the English and Austrian epidemics) was mainly due to precautions taken by the farmers themselves. This illustrates that the success of an eradication program first and foremost depended on farmers' actions; it did not succeed as a "command and control" activity.

The weather conditions in Denmark were favorable for windborne spread, but an attempt to simulate windborne spread failed. This type of spread was also contradicted by the sharp drop in dissemination rate. (Most virus is excreted early in the disease before there is any chance of depopulation; for this reason, prompt quarantine is more important than depopulation.) Windborne spread of FMD has not been documented empirically and is supported only by theory and by some epidemiological studies of diseases other than FMD. Experience from previous cases suggests that long distance spread of FMD is mainly due to transport of animals or their products.