

FOOT-AND-MOUTH DISEASE

(Afta epizootica, Bek-en-klouseer, Fiebra aftosa, Fievre aphteuse, Maul-und-Klauenseuche)

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Definition [top](#)

Foot-and-mouth disease (FMD) is a highly contagious viral infection primarily of cloven-hoofed domestic animals (cattle, pigs, sheep, goats, and water buffalo) and

cloven-hoofed wild animals. The disease is characterized by fever and vesicles with subsequent erosions in the mouth, nares, muzzle, feet, or teats.

Etiology [top](#)

The FMD virus (FMDV) is a member of the genus *Aphthovirus* in the family Picornaviridae. There are seven serotypes of FMDV: A, O, C, Asia 1, and Southern African Territories (SAT) 1, 2 and 3. Within these serotypes, over 60 subtypes have been described, and new subtypes occasionally arise spontaneously. However, at a specific time, there are only a few subtypes causing disease throughout FMD endemic areas. The importance of subtypes is that a vaccine may have to be tailored to the subtype present in the area in which the vaccine is being used.

The FMD virus is pH sensitive; the virion is inactivated when exposed to pH below 6.5 or above 11. However, in milk and milk products, the virion is protected and can survive at 70° C for 15 seconds and pH 4.6. Between pH 6.7 and 9, stability increases with decreasing temperature; the virus in cell culture medium will remain viable for a year at 4° C. The virus in serum or other organic material will survive drying and can be carried on inanimate objects. In meat, the virus can survive for long periods in chilled or frozen bone marrow and lymph nodes.

Host Range [top](#)

Cloven-footed domestic and wild animals are primarily affected. Examples of other susceptible species are hedgehogs, armadillos, nutrias, elephants, capybaras, rats, and mice.

Geographic Distribution [top](#)

Foot-and-mouth disease, after World War II, was widely distributed throughout the world. In 1996, endemic areas were Asia, Africa, and parts of South America. In South America, Chile is free, and Uruguay and Argentina have not had an outbreak since April 1994. Most European countries have been recognized as free. Countries belonging to the European Union have stopped FMD vaccination. North and Central America, Australia, New Zealand, Japan, and the British Isles have been free of FMD for many years.

Geographic Serotype Prevalence of FMD [top](#)

It is interesting how certain serotypes tend to be restricted to certain areas of the

world.

Some examples are as follows:

| | |
|----------------------------------|--------------------------|
| Europe (historically) | A (5) O (1) C (1) |
| Asia | |
| Near East | A (22) O (1) |
| Middle East | A (22) O (1) C Asia (1) |
| Far East | A O (1) C Asia (1) |
| Africa | |
| Central East to West | A O |
| Northeast Central and South | SAT 1 and 2 |
| South | SAT 3 |
| Serotype C is uncommon in Africa | |
| South America | A (24), (27) O (1) C (3) |

Transmission [top](#)

The FMD virus can be introduced into a free area by the following means:

1. Direct or indirect contact with infected animals.
2. Spread of aerosol from infected animals (requires proper humidity and temperature). Aerosol from bulk milk trucks spread FMD in England. A person in

contact with infected animals can have sufficient FMDV in his or her respiratory tract for 24 hours to serve as a source of infection for susceptible animals.

3. Feeding contaminated garbage (meat, milk, blood, glands, bones, cheese, etc.)
4. Contact with contaminated objects (hands, footwear, clothing).
5. Artificial insemination.
6. Contaminated biologicals such as hormones (extraction procedure may not inactivate the virus).

After an animal becomes infected by any means, the primary mode of spread is then via respiratory aerosols. Other important means of spread are direct and indirect contact. In an outbreak of FMD, the roles of the three primary hosts in transmission are as follows:

Sheep act as maintenance hosts,
Pigs act as amplifiers,
Cattle act as indicators.

When sheep or goats become infected with FMDV, the disease may not be diagnosed for a considerable time because signs and lesions can be very mild. However, during this time, the animals will be producing infectious aerosols, contaminating fomites, and spreading the virus by contact.

Foot-and-mouth disease in pigs spreads very rapidly, for they produce 30 to 100 times more virus in aerosols than sheep or cattle. An infected pig can produce a hundred million infectious doses per day.

When cattle are infected with FMDV, signs and lesions usually develop more rapidly and are more severe than in pigs, sheep, or goats. If cattle, sheep, and pigs are exposed together, cattle will usually get sick first. This may result from increased exposure due to a greater pulmonary tidal volume.

Some animals can be carriers of FMDV. Most ruminant species can harbor the virus in their pharyngeal tissues for a long period. Recovered cattle or vaccinated cattle exposed to diseased animals can become healthy carriers for 6-24 months. Sheep can be carriers for 4-6 months. Although under experimental conditions it has been difficult to demonstrate transmission of FMD from carriers to susceptible livestock, there is strong circumstantial field evidence that carriers may have been the occasional cause of outbreaks. Also it has been shown that the virus was

maintained for many years in a relatively small, isolated group of African buffaloes without the appearance of clinical signs.

Some strains of FMDV seem to have a predilection for certain species. There have been strains that affect pigs but not cattle. In South America, mature cattle have had clinical signs of FMD, when sheep in an adjacent pasture were normal.

Incubation Period [top](#)

After experimental exposure, signs may develop as early as 12 hours. The usual interval is 24 to 48 hours.

When susceptible animals are in contact with clinically infected animals (peak time of transmission is generally when vesicles rupture), clinical signs usually develop in 3 to 5 days.

Pigs fed infected garbage usually develop signs in 1 to 3 days. Intact oral epithelium is resistant to infection, but during the process of ingesting food there may be injury, and the virus may also enter through the tonsils.

Clinical Signs [top](#)

Cattle [top](#)

Initial signs are fever of 103-105° F (39.4-40.6° C), dullness, anorexia, and fall in milk production. These signs are followed by excessive salivation; drooling (Fig. 111), serous nasal discharge; shaking, kicking of the feet or lameness; and vesicle (blister) formation. Sites of predilection for vesicles are the tongue (Figs. 115, 117), dental pad, gums, soft palate, nostrils, muzzle, interdigital space (Fig.112), coronary band, and teats (Fig.116.). Vesicles may be difficult to see. The animal may need to be tranquilized to facilitate a thorough examination.

After vesicle formation, drooling may be more marked, and nasal discharge, lameness or both may increase. Pregnant cows may abort, and young calves may die without developing any vesicle.

The course of an FMD infection is 2 to 3 weeks. Secondary infection may delay recovery. A lactating animal may not recover to preinfection production because of damage to the secretory tissue.

Sequelae to FMD in Cattle [top](#)

Secondary infection — mouth, nose, feet
Hoof deformation
Low milk production
Mastitis
Unthriftiness — failure to gain weight
Breeding problems
Panting — associated with pituitary gland damage
Diabetes mellitus

Swine [top](#)

Initial signs are fever of 104-105° F (40-40.6° C), anorexia, reluctance to move (Fig. 113), and squeal when forced to move. These signs are followed by vesicles on the coronary band (Figs. 114, 119), vesicles on the heels, vesicles in the interdigital space (foot involvement is usually severe), and vesicles on the snout (Fig. 114). Mouth lesions are not too common and when they occur are smaller and of shorter duration than in cattle and tend to be a "dry"-type lesion (Fig. 118). There is no drooling. Sows may abort. Piglets may die without showing any clinical sign.

Sheep and Goats [top](#)

Clinical signs, if they occur, tend to be very mild, and may include dullness; fever; and small vesicles or erosions on the dental pad, lips, gums, and tongue. Mild lameness may be the only sign. In lame animals there may be vesicles or erosion on the coronary band or in the interdigital space. Infected animals may abort. Nursing lambs may die without showing any clinical sign.

Gross Lesions [top](#)

Cattle [top](#)

The diagnostic lesions are single or multiple vesicles ranging from 2 mm to 10 cm. These can occur at all sites of predilection. Gross lesions on the tongue usually progress in the following manner:

1. A small blanched whitish area develops in the epithelium.
2. Fluid fills the area, and a vesicle (blister) is formed.
3. Vesicle enlarges and may coalesce with adjacent ones.

4. Vesicle ruptures.
5. Vesicular covering sloughs leaving an eroded (red) area (Figs. 117, 120).
6. Gray fibrinous coating forms over the eroded area.
7. Coating becomes yellow, brown or green.
8. Epithelium is restored, but line of demarcation remains; line then gradually fades.

Occasionally "dry" FMD lesions develop. Instead of forming a vesicle, the fluid is apparently lost as it forms and the upper layers of the epithelium become necrotic and discolored. The lesion therefore appears necrotic rather than vesicular.

Gross Lesions on the Feet [top](#)

The vesicle in the interdigital space is usually large because of the stress on the epithelium caused by movement and weight. The lesion at the coronary band at first appears blanched; then there is separation of the skin and horn. When healing occurs, new horn is formed, but a line resulting from the coronitis is seen on the wall of the hoof.

Gross Cardiac and Skeletal Lesions [top](#)

Animals that die may have grayish or yellowish streaking in the myocardium - degeneration and necrosis. These findings are known as "tiger heart" (Fig. 121). Skeletal muscle lesions occur but are rare.

Swine [top](#)

Vesicles on the snout can be large and filled with clear or bloody fluid. Mouth lesions are usually the "dry" type and appear as necrotic epithelium. Feet lesions are usually severe, and the hoof can become detached. Animals that die may have grayish or yellowish streaking in the myocardium with degeneration and necrosis ("tiger heart").

Sheep [top](#)

Lesions in the mouth and vesicles on the coronary band may be few, small, and

difficult to find. Animals that die may have grayish or yellowish streaking in the myocardium with degeneration and necrosis ("tiger heart").

Morbidity and Mortality [top](#)

The morbidity rate is essentially 100 percent in a susceptible population of domestic animals. Mortality is usually less than 1 percent, but in young animals and with certain isolates mortality can be high. In an FMD outbreak in Israel, there was a high mortality (at least 50 percent) in wild mountain gazelles. The same virus caused typical low mortality in cattle. In the gazelles, there was a severe viral pancreatitis that accounted for the high mortality.

Diagnosis [top](#)

Field Diagnosis [top](#)

In cattle, FMD should be considered whenever salivation and lameness occur simultaneously and a vesicular lesion is seen or suspected. Fever often precedes other clinical signs; therefore, febrile animals should be carefully examined. Early diagnostic lesions may be found before animals start to salivate, have a nasal discharge, or become lame. To avoid missing a diagnosis, examine the mouth of a lame animal and the feet of any animal with signs or lesions involving the mouth or nostrils. Typically, FMD spreads rapidly and there is a high clinical attack rate; however, this cannot be counted upon, for a relatively avirulent strain could appear, or more resistant animals (sheep) could be affected.

In pigs, sheep, and goats, FMD should be considered when animals have sore feet, vesicular lesion is suspected, or both.

Specimens for the Laboratory [top](#)

Because the various vesicular diseases have similar clinical signs, a laboratory diagnosis is mandatory. Oral, nasal, foot, or mammary lesions are good sources of specimens. The following should be collected from each of two or three animals:

1. Vesicular fluid (as much as possible).
2. Epithelium covering a vesicle.
3. Flaps of epithelial tissue still attached.

(For 2 and 3 above, try to collect about 0.5 gm.)

Old necrotic or fibrinous material that is difficult to remove is undesirable and often is highly contaminated with bacteria.

4. About 5 ml of blood with anticoagulant (viremia ends about 5 days after the onset of disease).

5. Esophageal—pharyngeal (OP) fluid from convalescent cattle, sheep, or goats.

This should immediately be diluted with an equal volume of cell culture fluid (e.g., Hanks balanced salt solution with lactalbumin hydolysate) and shaken vigorously for about 1 minute. If the solution turns yellow, the pH is low and the virus could be inactivated; discard and collect another sample.

6. Blood for serum (10 ml of serum).

7. From dead animals, collect samples of epithelial lesions, lymph nodes, thyroid, adrenal gland, kidney, and heart (about 10 gm).

8. Full set of tissues in formalin.

If the specimens can be delivered to a laboratory within 24 hours, they should be placed on ice. If delivery will take longer, quickfreeze the specimens, and do not allow them to thaw during transit. If dry ice is used, be sure that the vials are tightly sealed with stopper and tape so that no carbon dioxide enters the vial. The carbon dioxide will lower the pH and inactivate FMDV. Epithelium can also be placed in buffered glycerin and kept at 39° F (4° C) or -4° F (-20° C). Ratio of epithelium to glycerin should not exceed 1:10.

Laboratory Diagnosis [top](#)

To confirm the initial case of FMD, the virus has to be isolated and identified. After confirmation of the initial case, diagnosis can be made by antigen or nucleic acid detection, or both.

Serological tests are available to detect antibody and differentiate infected and vaccinated animals.

Differential Diagnosis [top](#)

Differential diagnosis for FMD should include vesicular stomatitis, swine vesicular disease, vesicular exanthema of swine, foot rot, and chemical and thermal burns. In cattle, oral lesions caused by rinderpest, infectious bovine rhinopneumonitis, bovine virus diarrhea, malignant catarrhal fever, and bluetongue can be similar to the later lesions in FMD. In sheep, lesions caused by bluetongue, contagious ecthyma, and lip and leg ulceration can be similar to the later lesions of FMD.

Treatment [top](#)

Starting about 1951, FMD vaccine was produced by the Frenkel method. Normal tongue epithelium was removed, minced, placed in a nutrient broth, and inoculated with FMDV. After replication of

FMDV, the virus was inactivated with formalin, and aluminum hydroxide was added as an adjuvant. This method as well as virus propagation in cell culture is being used today to produce FMD vaccine.

Outbreaks of FMD have been traced to use of formalin-inactivated vaccine. Apparently, in some cases, vaccine contained viable virus. Today (1996) the classical FMD vaccines are prepared using binary-ethyleneimine (BEI) inactivated virus and aluminum hydroxide-saponin or oil as an adjuvant. Double emulsion oil vaccines have been shown to produce an immunity of longer duration than aluminum hydroxide-saponin vaccine.

To date, molecular-engineered vaccines have not been as effective or as economical as the cell culture vaccines.

When vaccinating animals, it is important that the vaccine contain the same subtype of virus as is in the area. This necessitates frequent checking of the serotype and subtype during an outbreak because FMD virus frequently changes during natural passage through various species.

Protection induced by a good aluminum hydroxide vaccine decreases rapidly in 4-6 months. A double emulsion oil vaccine can protect for up to 1 year.

Vaccinated animals that are not completely protected can be a source of infection. The virus may replicate and be shed, but the animals may not show any clinical sign of infection.

Control and Eradication [top](#)

The official attitude of a country regarding control of a disease depends on how

seriously the disease affects the country, the financial and technical ability of the country, and what its neighbors are doing. The degree of control of FMD varies as follows:

1. Virtually no control in some Asian and African countries where FMD is enzootic.
2. Protection of valuable or accessible animals or vaccination along a border to provide a buffer zone. (May vaccinate cattle because of severity of the disease but not sheep and goats.)
3. Large-scale vaccination and quarantine with or without slaughter of infected animals.
4. Regulatory measures to prevent entry of FMD virus and quarantine and implementation of an eradication program.

A country where FMD is endemic should be as concerned about introduction of FMD virus as a country that is free of FMD because the introduced virus may be a serotype to which the native animals have no immunity.

The following are the essential features of a control and eradication program:

1. Stop movement of animals and animal products in the area affected.
2. Slaughter infected animals (and known contact animals).
3. Destroy carcasses.
4. Disinfect vehicles leaving the infected area.
5. Perform vaccination.

If eradication by slaughter fails, vaccination may be used to control the outbreak. There are experimental results indicating that potent vaccine may induce significant immunity in 4 days to protect exposed cattle to FMD.

6. Inform and educate the community.

Most developed countries have detailed plans to deal with an outbreak of FMD.

Public Health [top](#)

In a review of the zoonotic aspects of FMD by K. Bauer in 1997, he reported that, since 1921, FMD virus has been isolated and typed from slightly over 40 human cases (4). The cases occurred on three continents: Europe, Africa, and South America. Type O predominated, followed by C, and rarely A. Because infection is uncommon, FMD is not considered to be a public health problem.

GUIDE TO THE LITERATURE [top](#)

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