CHAPTER 3.10

Foot-and-mouth disease

Fast facts

Foot-and-mouth disease (FMD) is a highly contagious, exotic viral vesicular disease of cloven-hoofed animals.

Organism

FMD virus (FMDV):

- primarily replicates in epithelial cells in the pharynx and dorsal soft palate and then spreads via the blood to secondary sites
- can remain infective in the environment for several weeks and possibly longer in the presence of organic matter
- is inactivated by high and low pH and many disinfectants.

Susceptible species

All cloven-hoofed animals are susceptible, including cattle, sheep, pigs, goats and deer. Of domestic livestock, the disease is most severe in cattle and pigs.

Economic impact

There is potential for significant economic loss associated with eradication, production losses and restrictions on international trade.

Epidemiology

FMD:

- has an incubation period of 2–14 days, depending on the dose and route of exposure
- causes morbidity of up to 100 per cent in domestic livestock
- causes mortality in <5 per cent adult animals, higher in young animals
- virus can persistently infect a number of animals for varying periods.

Transmission

Transmission occurs via:

- aerosol transmission
- direct contact, usually oronasal
- swill feeding
- fomites
- artificial insemination.

Clinical signs

Clinical signs include:

- vesicles and ulcers in the mouth, feet and teats
- lameness
- pyrexia
- unwillingness to eat
- excessive salivation
- abortion
- drop in milk production
- sudden death in young animals.

Post-mortem

At post-mortem, vesicles may be present in ruminal pillars and 'tiger heart' striping of cardiac muscle in young animals.

Samples

Also refer to the detailed section on sampling for animals with vesicular disease.

- blood (EDTA and plain tubes)
- vesicular fluid, oropharyngeal fluid, oral, nasal and tonsillar swabs, epithelium, and epithelial tags (in buffer or virus transport medium).

Actions to take

If you suspect a case of FMD:

- call the Emergency Animal Disease Watch Hotline (1800 675 888) immediately or contact a government veterinarian in your state or territory
- isolate suspected cases and implement biocontainment protocols (including farm movement controls) until advised by government veterinary authorities.

Introduction

Foot-and-mouth disease (FMD) is a highly contagious viral vesicular disease of cloven-hoofed animals. The most significant risk for entry of FMD into Australia is through illegal importation of meat and dairy products from infected animals fed to pigs as swill (swill feeding).

Disease agent and susceptible species

FMD virus (FMDV):

- is a member of the genus *Aphthovirus* within the family *Picornaviridae*
- is a single-stranded RNA virus with no envelope
- is differentiated into seven serotypes (A, O, C, Asia 1, SAT 1, SAT 2 and SAT 3) by various serological tests. There is no cross-protection between serotypes. Serotypes have been further classified into genotypes and topotypes based on genetic similarity and their geographical origin and occurrence
- has numerous antigenic variants and studies are required to assist with the selection of the most appropriate vaccine strains
- can infect all wild and domestic cloven-hoofed animals (of the domestic livestock species, cattle, buffalo, pigs, sheep, goats and deer are susceptible to FMD, with the disease most severe in cattle and pigs)
- has some strains which may affect Bactrian camels and camelids, and the Asian elephant
- infection of humans has been reported but is extremely rare, and infections were minor and self-limiting. FMD is not a public health concern.

Distribution

FMD:

- is endemic in the Middle East, South Asia, South-East Asia, China, central Asian countries and most parts of Africa (but the serotype distribution differs in these regions)
- was controlled or eradicated with the use of mass vaccination programs in South America, and most South American countries are free of the disease
- incursions into previously free countries have had severe economic impacts, for example, in the United Kingdom, Japan and the South Korea.

For the latest information on the distribution of FMD, please refer to the WAHIS information database website of the World Organisation for Animal Health (OIE) [http://www.oie.int].

Occurrences in Australia

FMD has not occurred in Australia since the late 1800s when minor outbreaks are thought to have occurred in 1801, 1804, 1871 and 1872. The 1872 incident occurred in Victoria where the disease was introduced with an imported bull, and involved two farms before being eradicated.

Epidemiology

FMD is one of the most contagious viral animal diseases as virus is excreted in high quantities in expired air, in all secretions and excretions (including saliva, milk and semen), and from ruptured vesicles. Note that:

- pigs are regarded as important amplifying hosts for the disease, because of their capacity to excrete large quantities of virus in their exhaled breath
- cattle are regarded as indicator hosts because of their susceptibility to infection
- sheep and goats are considered silent or maintenance hosts, because the infection can spread through flocks with limited clinical disease.

Modes of transmission

Transmission occurs via:

- **direct contact between infected and susceptible animals**—the main route of infection is via the oronasal route; virus can also enter through breaks in the skin or mucosae. Stocking density is a determinant of the rate of spread of disease within an infected premises, with higher stocking densities seeing faster rate of spread. Movement of infected animals enables rapid dissemination of the virus over wide geographical areas
- **mechanical spread** by people, rodents, insects and birds
- **contact with the carcasses** of infected animals
- **contact with secretions**
- **semen and embryos** containing virus
- **ingestion of infected swill**—pigs have a higher relative susceptibility to infection through ingestion of contaminated feed, and swill feeding is illegal in Australia. Transmission occurs through the feeding of infected animal products including meat scraps and bones, or untreated raw milk and milk products from infected animals
- **fomites**—indirect contact by means of contaminated animal feed, straw, water, vehicles (including milk tankers) and other fomites (such as hypodermic needles) can spread the disease
- **airborne spread**—cattle and sheep are most susceptible to infection by inhalation of contaminated aerosols and extremely small doses of virus can initiate infection. Airborne spread can occur over long distances. The pattern of airborne spread has generally been from pigs as source to cattle downwind, and is likely to occur only when there are high concentrations of the appropriate livestock species at these locations. Long distance spread only occurs under very specific climatic conditions.

The transmission of FMD tends to be different in tropical and semitropical regions from that in temperate regions. In tropical areas, reasonably close contact is required between infected and susceptible animals for successful transmission, probably because of faster inactivation of the virus in hotter environments. The epidemiology of the disease in northern Australia could thus be expected to be different from that in southern Australia.

Healthy people can harbour FMDV subclinically in the nasal passages and throat for up to 28 hours, which means that during FMD outbreaks responders should avoid moving between premises for a directed amount of time (to avoid the possibility of transmitting FMDV to susceptible, uninfected animals).

Disease dynamics

FMDV is considered highly contagious, but mortality is low. In addition:

- the incubation period is variable depending on the virus strain, exposure dose, route of entry and species infected
- the incubation period for clinical signs is 1–14 days, but most commonly is 2–5 days
- excretion of FMDV can begin up to 4 days before clinical signs become apparent
- excretion of the virus decreases about 4–6 days after the appearance of vesicles, when circulating antibodies appear
- excretion of virus from foot lesions tends to last a day or two longer than from mouth lesions, so foot lesions may be a better source of virus for diagnostic purposes in older cases
- FMDV has been detected in the milk and semen of experimentally infected cattle for 23 and 56 days post-infection, respectively
- following infection with FMDV, it is possible for ruminants (but not pigs) to become persistently infected when virus persists in the pharynx in the presence of circulating antibody. Despite a number of anecdotal reports, as yet there is no evidence from the field that persistently infected animals (other than African buffalo) have been responsible for initiating new infections in susceptible animals
- vaccinated animals may become infected even when they are fully protected against clinical disease. Such animals are capable of excreting virus for about 1 week, though at lower levels. A proportion of vaccinated infected ruminants may also become persistently infected.

Persistence of the agent

FMDV:

- is most stable at pH 7.2–7.6 but will survive at pH 6.7–9.5 if the temperature is reduced to 4°C or lower
- has a half-life of approximately 12 hours at pH 6.5, 1 minute at pH 6, and 1 second at pH 5 (although inactivation times depend on many factors)
- can be inactivated with acidic solutions (e.g. acetic acid, straight vinegar or citric acid solutions), alkaline solutions (sodium hydroxide or sodium carbonate) or the disinfectant Virkon®
- survival time is reduced by higher temperatures and most strains of FMDV are inactivated when placed at 56 ˚C for 60 minutes. The effect of temperature on viral infectivity is influenced by the presence of organic material
- remains stable for prolonged periods at temperatures below freezing
- is largely unaffected by sunlight
- can remain infective in the environment for several weeks, and possibly longer in the presence of organic matter (such as soil, manure and dried animal secretions) or on chemically inert materials such as straw, hair and leather.

Diagnosis and pathology

The classical signs and lesions of FMD are described below. Note that a wide range of clinical syndromes can occur, ranging from inapparent disease with minimal lesions to severe clinical disease.

Clinical signs

Morbidity is close to 100 per cent in fully susceptible cloven-hoofed domestic animals but variable in wildlife species. Mortality due to FMD virus infection is very low in adult animals (<5 per cent) but is higher in young calves, lambs and piglets (20 per cent or higher).

The course of FMD in cattle may last for 2–3 weeks, or longer if there are serious secondary bacterial infections. Long-term sequelae may include hoof deformities and permanent damage to the udder. Clinical signs in cattle include:

- pyrexia accompanied by severe depression, inappetence and (in milking animals) a sudden drop or cessation of milk production
- followed (within 1–2 days) by the appearance of vesicles, the predilection sites for which are the tongue, lips, gums, dental pad, interdigital skin of the feet, coronary bands, bulbs of the heels and teats. Note that vesicles can burst readily, within 24 hours, so it is more common to see ulcers
- occasionally, vesicles and ulcers appear inside the nostrils or on the muzzle or vulva (see Table 3.10.1 for description of lesions)
- in the mouth, vesicles and ulcers are particularly prominent on the tongue, dental pad and cheeks. In severe cases, most of the dorsal surface of the tongue may slough. In uncomplicated cases, mouth lesions heal fairly rapidly over a 7–10 day period and eating may resume within a few days of rupture of vesicles
- painful stomatitis (associated with unruptured and freshly ruptured vesicles), which causes excess salivation, lip smacking and cessation of eating, leading to rapid loss of body condition
- foot lesions, which are accompanied by acute lameness and reluctance to move (secondary infections may lead to severe involvement of the deeper structures of the foot)
- teat lesions, which may lead to secondary mastitis
- abortion
- infection of very young calves may cause sudden death due to cardiac involvement, without vesicular lesions (mortality can be as high as 50 per cent).

Clinical signs in pigs include:

- initially, pyrexia (>40˚C), inappetence and lameness or reluctance to move
- vesicles and ulcers (within 1–2 days of disease onset)
- vesicles and ulcers are most pronounced on the feet and result in acute lameness, pain and recumbency, particularly if the pigs are housed on a hard floor (the disease may be difficult to detect when affected pigs are housed on soft bedding)
- vesicles and ulcers may occur on the coronets, interdigital skin, or bulbs of the heel, or other areas of friction
- vesicles and ulcers that encircle the coronet may lead to separation of the keratinised layers of the hoof from the corium—in severe cases there may be sloughing of the hoof, otherwise a line of separation between old and new horn moves steadily down the hoof at a rate of about 1 mm per week, starting a week after rupture of coronary band vesicles (the age of FMD lesions in pigs can often be estimated in this way)
- vesicles occur on the snout, but rupture quickly
- vesicles and ulcers on the tongue are relatively uncommon in pigs, and when they occur are small and heal rapidly

- sows often develop vesicles and ulcers on their teats
- pregnant sows may abort (in some herds this is the first overt sign of the disease)
- there may be high mortality in suckling pigs, with sudden deaths but no vesicular lesions (in some herds this is the first overt sign of the disease).

Clinical signs in sheep and goats include:

- lameness (often the only overt sign of disease in a flock)
- foot lesions are most pronounced on the coronary bands and interdigital skin
- foot lesions are particularly prone to secondary bacterial infections, including footrot
- mouth lesions are not prominent (vesicles and ulcers are most likely to occur on the dental pad and the posterior portion of the dorsal surface of the tongue, and they tend to be small and heal rapidly)
- pregnant animals may abort
- sudden deaths may occur in young lambs as a result of cardiac lesions (the mortality rate may be as high as 90 per cent, but is more usually about 50 per cent).

FMD is generally much milder in small ruminants than in other species, and may escape detection. Therefore, careful individual examination of all individuals in a flock may be required to detect the disease.

Lesions usually progress in this manner:

- a small, blanched, whitish area develops in the epithelium
- fluid fills the area and a vesicle is formed
- vesicle enlarges and may coalesce with adjacent ones
- vesicle ruptures
- vesicular covering sloughs leaving an eroded red area
- grey fibrinous coating forms over the eroded area
- coating becomes yellow, brown or green
- epithelium is restored, but the line of demarcation remains (this gradually fades with time).

The following table can be used as a guide for ageing FMD lesions in cattle and pigs. Lesions in sheep are too transient to be used for gauging the time of infection.

TABLE 3.10.1 Guide for ageing lesions in cattle and pigs

Day of clinical disease	Appearance of lesion
Day 1	blanching of epithelium, followed by formation of fluid-filled vesicles
Day 2	freshly ruptured vesicles, characterised by raw epithelium, a clear edge to the lesion and no deposition of fibrin
Day 3	lesions start to lose their sharp demarcation and bright red colour; deposition of fibrin starts to occur
Day 4	considerable fibrin deposition has occurred, and regrowth of epithelium is evident at the periphery of the lesion
Day 7	extensive scar tissue formation and healing have occurred; some fibrin deposition is usually still present

Histological lesions are not specific. However, in addition to the external gross lesions already described, the following may be seen at post-mortem:

- vesicular lesions and ulcers on the ruminal pillars (ruminants)
- in young animals, focal necrosis of cardiac muscle. The lesions appear as small grey foci of irregular size and may give the myocardium a stripped appearance ('tiger heart') and similar lesions may also occur on skeletal muscles (all species).

Pathology

Gross lesions at post-mortem are generally restricted to vesicles described in the diagnosis and pathology section of Foot-and-mouth disease. Erosions may also be present on the ruminal pillars. There can also be 'tiger heart' striping of cardiac muscle in young animals.

Differential diagnosis

FMD is clinically undistinguishable from other exotic vesicular viral diseases of livestock, namely:

- Senecavirus A (Seneca Valley virus) infection
- swine vesicular disease
- vesicular exanthema of swine (not seen globally since 1956)
- vesicular stomatitis.

Regard any cattle, pigs, sheep or goats exhibiting vesicular lesions and ulcers on their feet or teats as being infected with FMD until proven otherwise by laboratory testing.

A number of other diseases cause similar clinical signs to the viral vesicular diseases, particularly during their more advanced clinical stages. Although mouth and muzzle lesions in these diseases are not vesicular, they could be confused with FMD lesions. These include:

- exotic diseases
  - bluetongue disease (infection present in Australia but without clinical disease)
  - peste des petits ruminants
  - rinderpest (now recognised by OIE as eradicated from all countries with susceptible populations)
- endemic diseases
  - bovine papular stomatitis
  - dermatophilus and other types of mycotic stomatitis
  - footrot
  - infectious bovine rhinotracheitis
  - mucosal disease (BVDV-1 only)
- non-infectious diseases that can also be confused with the viral vesicular diseases are:
  - phototoxic dermatitis with vesicle formations from contact with the leaves of plants of the family *Umbelliferae* (parsley, parsnips and celery)
  - chemical irritants and scalding
  - traumatic lesions of the mouth and feet.

Samples required

Sample collection

FMD virus is very sensitive to both acid and alkaline conditions. Inappropriate buffer conditions can inactivate the virus making virus isolation difficult or impossible. To maximise chances of virus isolation:

- use phosphate buffered saline or virus transport media with a pH of 7.6.
- if a sample is to be submitted after 24 hours or more, add glycerol to the phosphate buffered saline
- dilute oropharyngeal fluid collected with a probang in an equal volume of phosphate buffered saline pH 7.6, and mixed vigorously for 1 minute.

Note that collection of samples in these buffers is optimal (for the growth of FMD virus) but not essential for RNA or antigen detection assays.

Take samples from at least 10 live, clinically affected animals. Collect:

- **serum**, 7–10 ml/animal in plain tubes
- **vesicular fluid**, carefully use a syringe and needle to aspirate the vesicular fluid from unruptured vesicles, and place in a sterile container. Alternatively, collect fluid from small vesicles onto a swab and place the swab in 500 µl of buffer, such as phosphate buffered saline or virus transport medium
- **fresh tissue**, epithelium, epithelial tags, oral, nasal and tonsillar swabs and oropharyngeal fluid and submit in phosphate buffered saline or virus transport medium, if available.

Transport of samples

- chill blood samples and unpreserved tissue samples at 4°C, or with frozen gel packs
- DO NOT FREEZE SAMPLES at –20°C, it reduces the sensitivity when used for virus isolation and molecular diagnostic tests
- send samples with dry ice if the journey is expected to take several days.

Sample submission

The relevant state or territory laboratory should coordinate sample packaging and consignment for delivery to CSIRO-AAHL.

Diagnostic tests

Laboratory tests currently available for primary FMD testing include PCR, antigen ELISA, virus isolation, and serological assays for the detection of antibodies. Testing strategies are based on samples submitted and clinical and epidemiological information provided.

Reporting requirements

FMD is an OIE-listed disease and Australia has an international obligation to report cases. If you suspect FMD, report it immediately by phoning the **Emergency Animal Disease Watch Hotline on 1800 675 888**, wherever you are in Australia. Alternatively, contact a government veterinarian in your state or territory.

Biocontainment and personal protective equipment

There are no public health implications for FMD, but you should implement biocontainment protocols until advised by government veterinary authorities. This includes isolating suspected cases and using and appropriately disposing of personal protective equipment such as gloves, coveralls, rubber boots (or disposable boots) and a mask.

Thoroughly disinfect and decontaminate clothing, vehicle and equipment before leaving the property. Remember that people can harbour FMDV subclinically in the nasal passages and throat for up to 28 hours, which means that during FMD outbreaks responders should avoid moving between premises for a directed amount of time.

Further information

Weaver, G.V., Domenech, J., Thiermann, A.R., Karesh, W.B. (2013) Foot and mouth disease: a look from the wild side. Journal of Wildlife Diseases, 49:759-78.

Jamal SM, Belsham GJ. (2013) Foot-and-mouth disease: past, present and future. Veterinary Research, 44:116.

Paton DJ, Gubbins S, King DP. (2018) Understanding the transmission of foot-and-mouth disease virus at different scales. Current Opinions in Virology 28:85-91.

FIGURE 3.10.1 Cow with hypersalivation

Image credit: EuFMD

FIGURE 3.10.2 Vesicles on the lower lip of a cow, suggestive of one-day old lesions

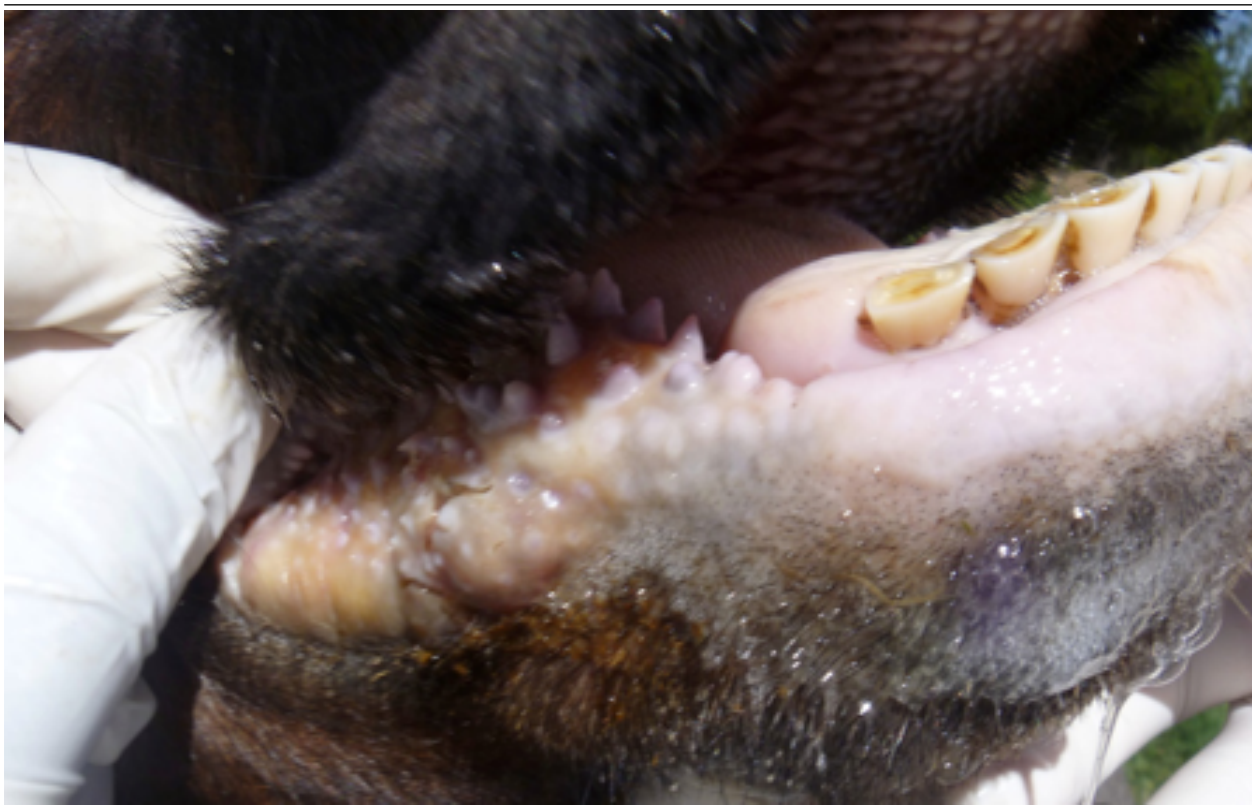

Image credit: EuFMD

FIGURE 3.10.3 Fresh lesions (2–3 days old) with epithelial tags on the upper gum of a cow

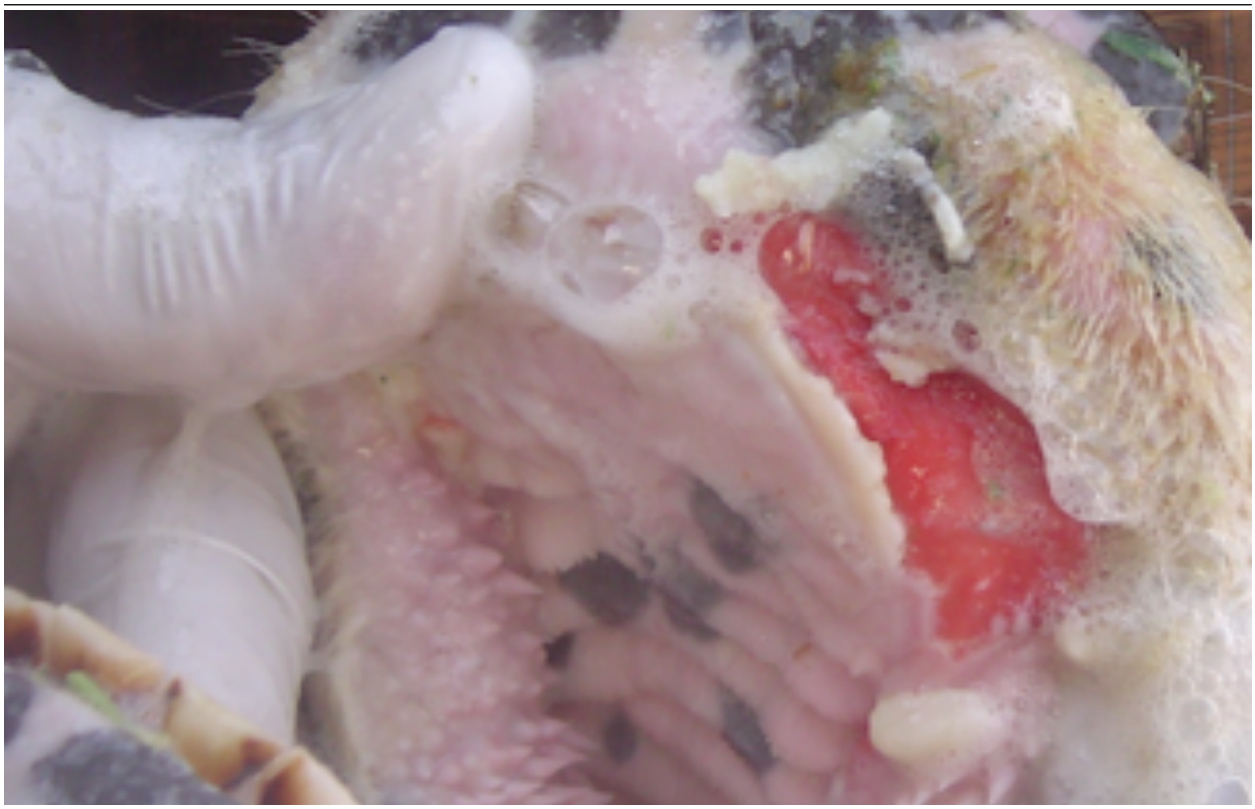

Image credit: EuFMD

FIGURE 3.10.4 Lesions with fibrin deposition on the upper gums of a cow. This is suggestive of 4-5 day old lesions

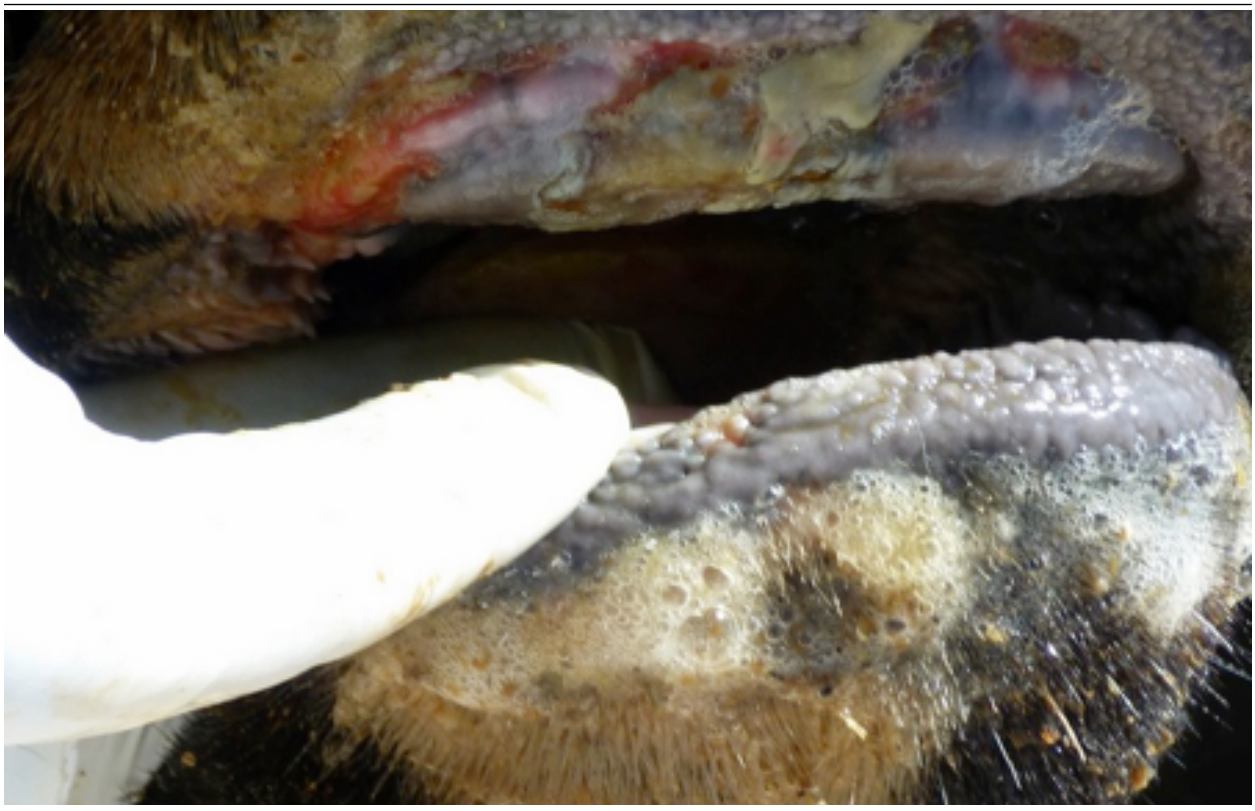

Image credit: EuFMD

FIGURE 3.10.5 Lesions on the upper gum of a cow. The re-epithelisation is suggestive of an 8-10 day old lesion

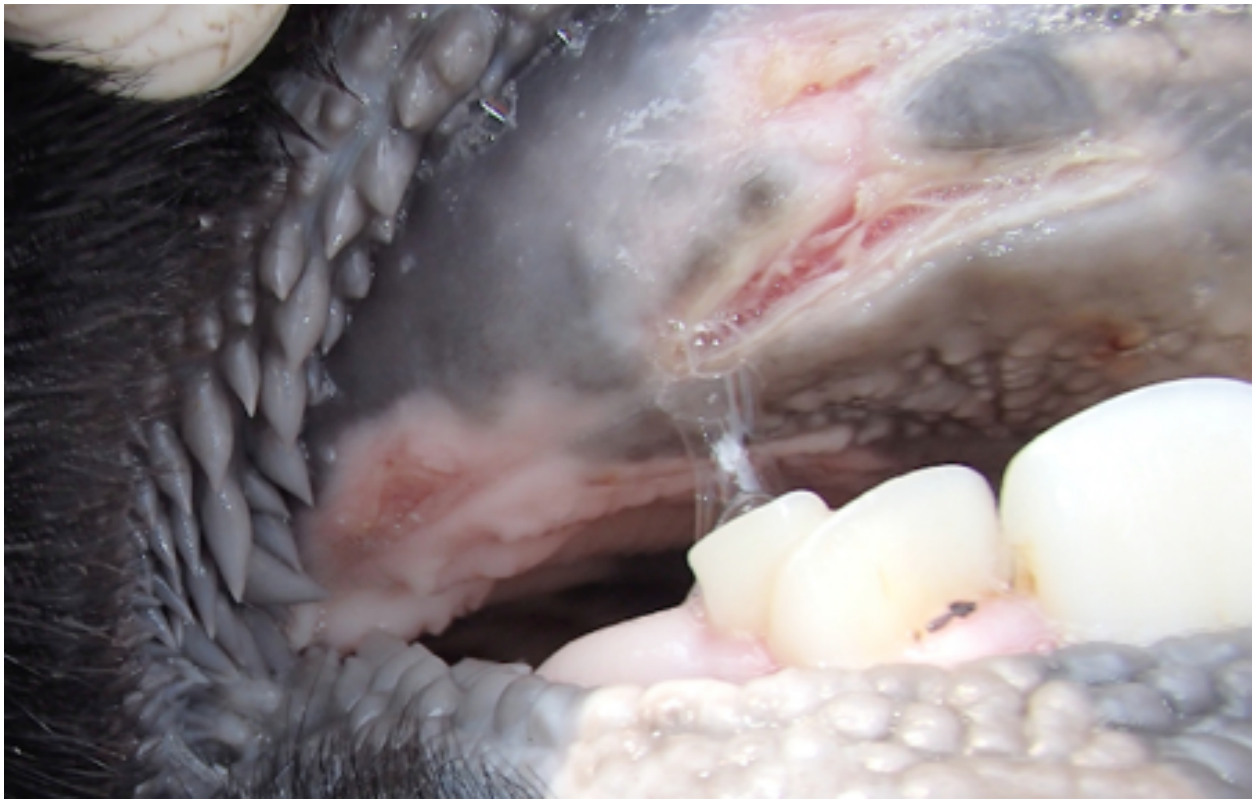

Image credit: EuFMD

FIGURE 3.10.6 Fresh lesions (~2–3 days old) on the teat of a cow

Image credit: EuFMD

FIGURE 3.10.7 Fresh vesicles on the snout of a pig (note the blanched epithelium at the base of the snout

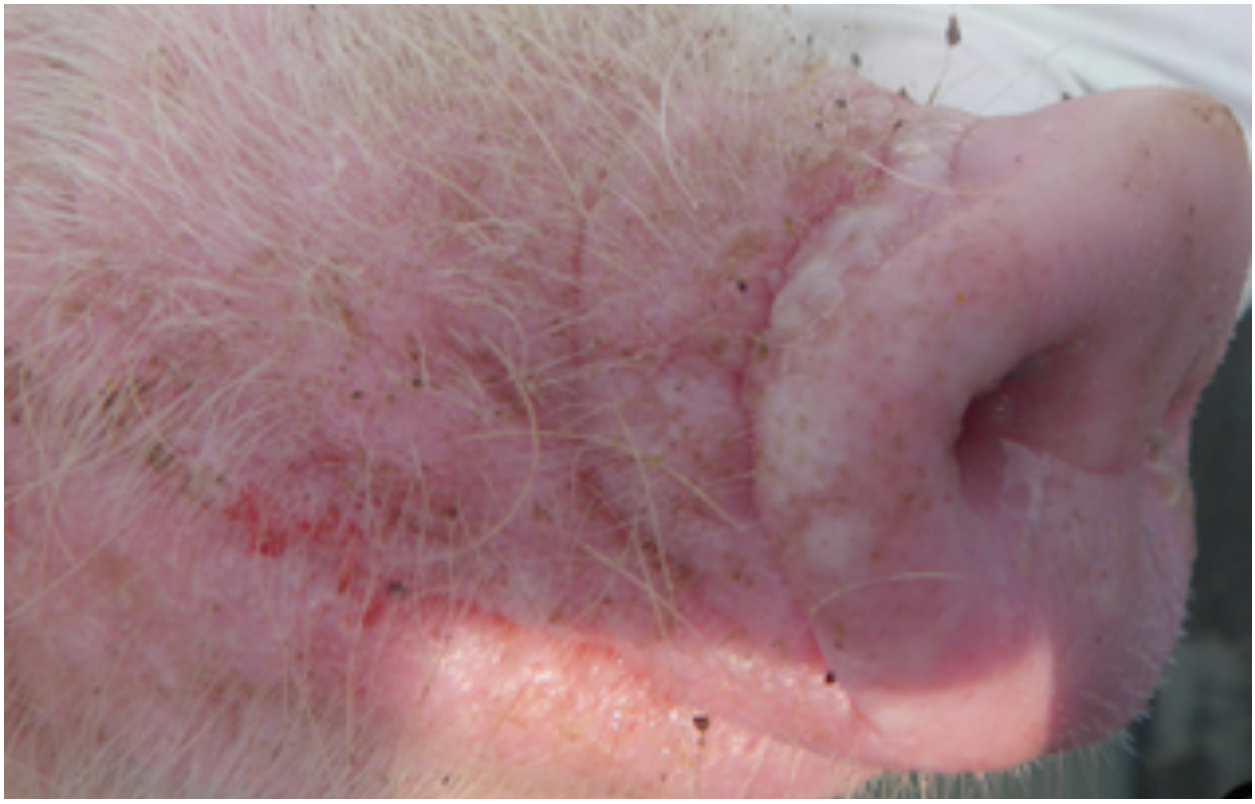

Image credit: EuFMD

FIGURE 3.10.8 Coronary band lesions on the feet of a pig

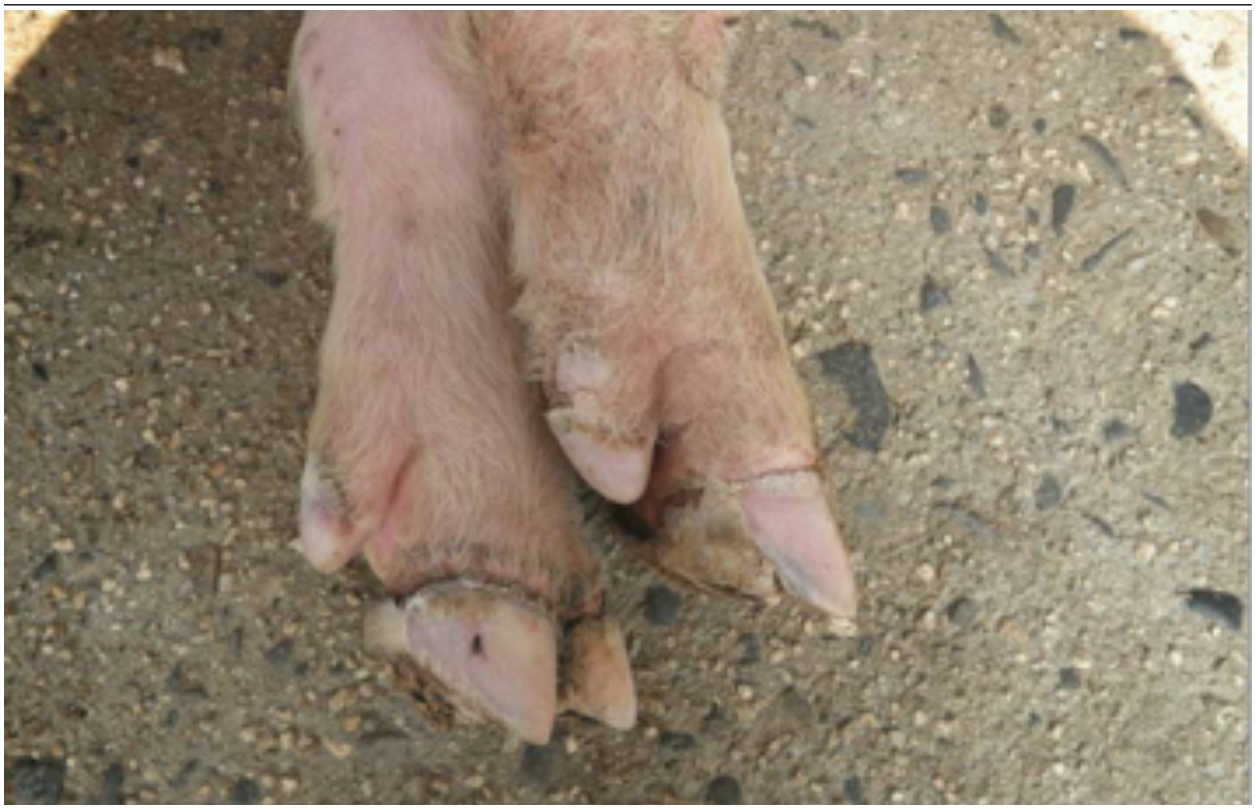

Image credit: EuFMD

FIGURE 3.10.9 Coronary band lesion on the foot of a sheep

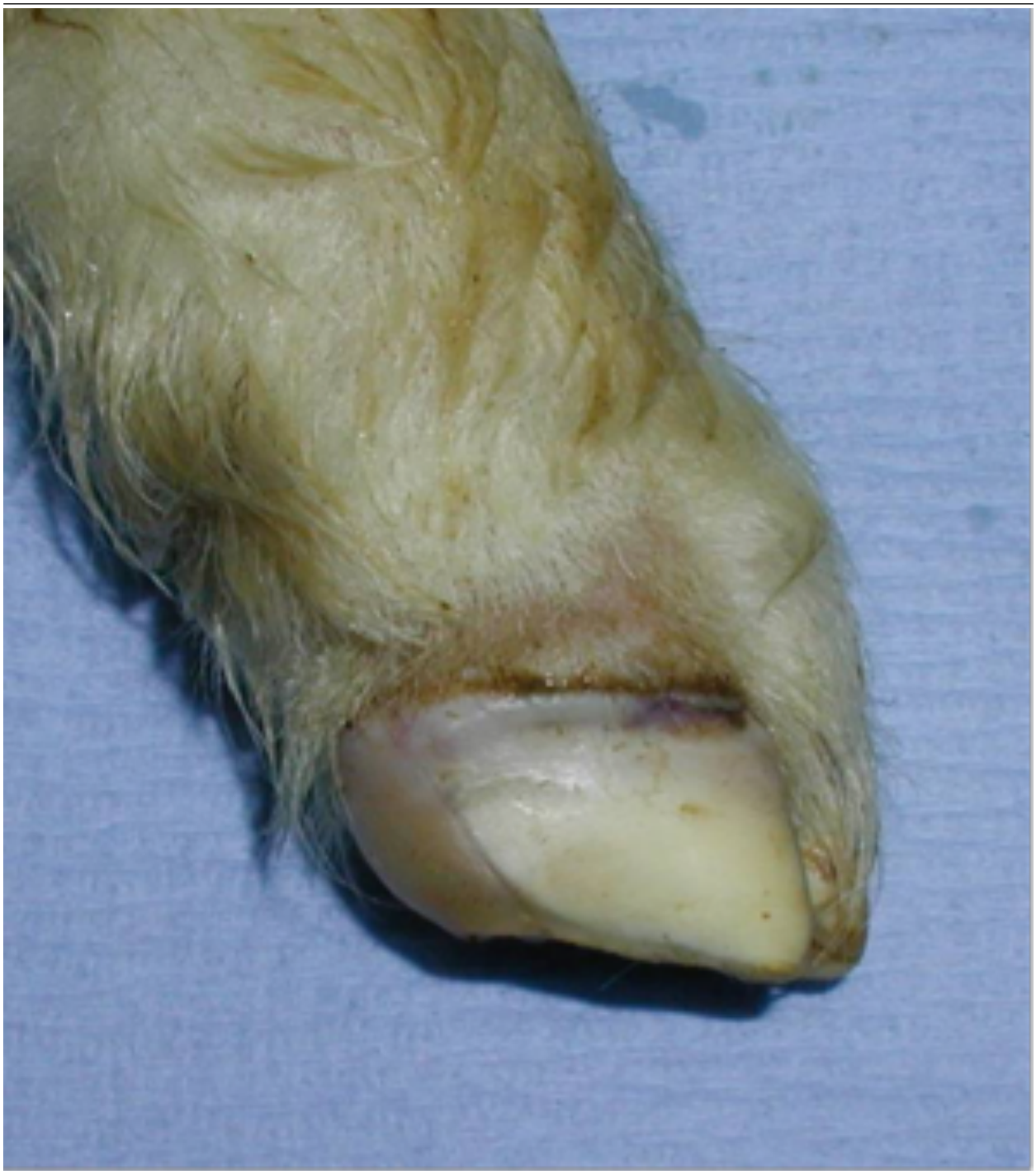

Image credit: EuFMD