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## **Epidemiology and Transmission of Foot and Mouth Disease among Small Ruminants – A Review**

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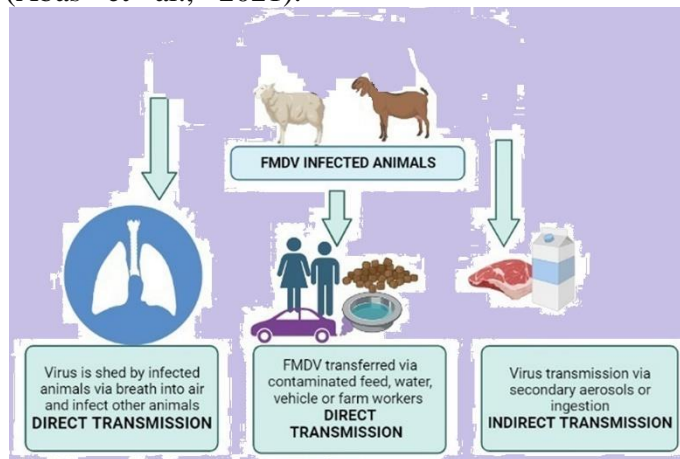
**ABSTRACT:** *Foot-and-mouth disease (FMD) is a highly contagious viral infection that affects cloven-hoofed animals, including small ruminants such as sheep and goats. FMD causes severe economic losses due to reduced productivity, trade restrictions, and control measures. The epidemiology and transmission of FMD among small ruminants are influenced by various factors, such as the virus strain, the host species, the environmental conditions, and the animal management practices. This paper reviews the current knowledge on the epidemiology and transmission of foot-and-mouth disease (FMD) among small ruminants. It also examines the global distribution and prevalence of FMD in small ruminants, the clinical signs and lesions of FMD in small ruminants, the role of small ruminants in the maintenance and spread of FMD, the transmission routes and risk factors of FMD in small ruminants, and the implications of FMD in small ruminants for disease control and eradication. The paper also identifies the knowledge gaps and research priorities for improving the understanding and management of FMD in small ruminants.*

**Keywords:** *Foot-and-mouth disease, Sheep, Goats, Epidemiology, Transmission*

## INTRODUCTION

Foot and mouth disease is the virus that causes FMD in animals. It has seven different types (O, A, C, Asia 1, SAT 1, SAT 2, and SAT 3) and many subtypes that can vary in spread and affecting the animals (Azeem et al., 2020). FMDV infects the skin cells of animals and makes blisters on their feet, mouth, and mammary glands (Arzt et al., 2011). The virus can also damage other organs like the heart, pancreas, and milk glands, causing problems like heart inflammation, pancreas inflammation, and mastitis (Arzt et al., 2011). The symptoms of FMD in sheep and goats are not the same for all animals. They depend on many things, such as the type of virus, the genes of the animal, the weather, and other infections (Abas et al., 2021).

Usually, sheep and goats have less severe symptoms than cows and pigs, so they are harder to notice and report (Law et al., 2011). But some types of viruses can cause very bad disease in sheep and goats, especially in young animals or those with weak immune systems. Also, sheep and goats can carry the virus without showing any symptoms for a long time, and they can pass the virus to other animals that can get sick (Clemmons et al., 2021). FMD can spread among sheep and goats in different ways. They can get the virus by close contact with sick animals or their saliva, milk, urine, or poop, or through indirect contact with contaminated fomites or aerosols (Fig. 1) (Paton et al., 2018).



**Fig. 1. Transmission routes of FMDV (Aslam and Alkheraije, 2023)**

The viruses spread depend on many things, such as the weather, the type of virus, and the type of

animals. For example, the viruses can spread more easily in the air when it is humid and windy, or

when the virus is very infectious or stable. Also, the virus can spread more easily by touching when there are many animals or different kinds of animals together, or when the animal is very sensitive or sheds a lot of viruses (Brown et al., 2022). There are many things that can make sheep and goats more likely to get or spread FMDV. These things include how old, what sex, and what breed they are, what kind of production they are used for, where they live, how they move or trade, what the climate and plants are like, and what their immune system and other infections are like. Many studies have tried to find out and measure using different methods, such as blood tests (Chepkwony et al., 2021), outbreak studies (Wood et al., 2020), virus tests (Yousif et al., 2017), math models (Chepkwony et al., 2021), and so on. To control FMD in sheep and goats, we need to use different ways that can stop the virus from coming in, stop the virus from going out, and get rid of the virus completely. These ways include watching and reporting sick animals, limiting and checking animal movement, keeping things clean and safe, giving vaccines and having vaccine plans, killing sick animals and paying farmers, and teaching and telling people about FMD. How well these ways work depends on how much money, how easy, how acceptable,

and how followed they are (Blacksell et al., 2019).

By addressing these gaps in our knowledge of FMD epidemiology and transmission among small ruminants, we can enhance our comprehension of FMD dynamics, refine control strategies, and ultimately contribute to minimizing the impact of this economically devastating disease. Closing these gaps will empower us to protect small ruminant populations and uphold the broader stability of agricultural and economic systems. This requires collaborative efforts from researchers, veterinary experts, and policymakers, who can share their expertise, resources, and experiences. By delving into these unexplored areas, we can advance the science and practice of FMD control and prevention.

### **1. Epidemiology**

Animals with split hooves, like cows, pigs, sheep, and goats, can get FMD, a viral infection. It leads to huge economic losses for people who farmed or trade these animals globally. Sheep and goats are very important for how FMD spreads among animals (Dabasa et al., 2021). FMD in these animals is hard to study and control, especially in places like Asia, where many people depend on livestock for their income. The prevalence of FMD in Asia and Pakistan is high due to the large number of livestock, and the

disease poses many challenges for these regions. FMD in Pakistan is affected by many factors, such as the weather, the way people trade animals, animal movement, and the type of the virus (Rashid et al., 2020). FMD is endemic and persistent in Pakistan. Researchers are investigating the epidemiology and pathogenesis of FMD and developing effective vaccines and biosecurity measures. FMD can spread among sheep and goats in different ways. They can get the virus from other sick animals, from the air, or from fomites that have the virus on them. Sheep and goats may not look very sick, but they can still have the virus and spread it to other animals (Jena et al., 2022). Sometimes, they may not show any signs of the disease, but they can still carry the virus for a long time. This makes it hard to find and stop the disease, and it makes these animals possible sources of the virus. Trade and Movement in Pakistan: Animals move around a lot for different reasons, such as food (e.g., seasonal grazing), money (livestock markets), and travel (cross-border migration), for religion, and for fun. This helps FMD spread among animals. Sometimes, animals move across countries, and they can bring new types of the virus with them. This means that countries need to work together and have the same rules to stop FMD from spreading (Apolloni et al., 2019). Animals

move around in Pakistan for many reasons, such as trade, grazing, migration, religious festivals, and social events. For example, every year, there is a big festival called Eid-ul-Adha, where people buy and slaughter millions of animals. This is a time when FMD can spread easily (Sherman et al., 2011). Also, Pakistan has borders with other countries, like Afghanistan, Iran, India, and China, where animals can move in and out. This can bring new types of the virus into Pakistan (Osmani et al., 2019).

Research and Challenges to fight FMD well, we need to know how the disease works in sheep and goats. We need to use good tools and methods to study how the virus moves and changes. We need to look at the genes of the virus to see how they are different in different places (Clemmons et al., 2021). The weather also affects how the virus lives and spreads. The virus can live longer in cold and wet weather than in hot and dry weather. So, FMD is more likely to happen in winter and spring than in summer (Björnham, 2020). Also, the virus can travel far in the air when the wind is strong and in the right direction. Wild animals can also have the virus and give it to farm animals. Some wild animals that can get FMD are wild pigs, deer, antelopes, gazelles, yaks, camels, and buffaloes (Gortázar et al., 2022; Admassu et al., 2015). Farm

and wild animals can meet and share the virus when they used the same land, water, fences, or hunting (Knight-Jones et al., 2016). FMD affects the health of humans, animals, and the environment. There is need to work together with animal doctors, disease experts, government people, and communities to stop FMD by making good plans (Calistri et al., 2013). In Pakistan, people keep their sheep and goats in different ways. Some people keep them in small places and do not let them meet other animals. Some people move them around a lot to find food and water. This is more common in dry areas of Pakistan, where sheep and goats are very important for people's lives and food (Chepkwony et al., 2022).

## **2. Virus Excretion in Small Ruminants and Its Implications in FMD Transmission**

FMD is an infection that impacts animals with split hooves, like sheep and goats. They can transmit the virus, even when they are less ill than cows. We need to understand how these animals release the virus to prevent FMD. Research shows that these animals can give out the virus in different ways, such as through their breath, spit, nose, and poop (De Rueda et al., 2014). They can give out a lot of viruses in the air, which can make other animals sick (Alexandersen et al., 2003). Some

of these animals may not look sick, but they can still have the virus and pass it on. This can make FMD stay longer and come back again (Casey et al., 2014). It is hard to control FMD when the virus is hidden in these animals (Sutmoller et al., 2003). There is need to know how long the viruses stays in these animals. Studies showed that these animals give out the most viruses right after they get sick. Sellers et al. (1977) found two main times when this happens: from half an hour to a day after they get sick (virus stuck in their wool) and from two to seven days after they get sick (virus growing in their throat). This matches with high virus levels in their throat fluids (Nishi, 2021), which are important for FMD to spread. There is a lot of debate and research about how the virus stays in these animals. Some research says that the virus levels in their throat fluids are too low to make other animals sick (Sutmoller, 2003), but sometimes the viruses can be found there. This means that the virus may still grow a little in these animals. So, we need to know how likely these animals are to infect other animals.

## **3. Species Adaptation and Virulence of FMD Viruses in Small Ruminants**

The way Foot-and-Mouth Disease Virus (FMDV) spreads among small animals like sheep and goats

is very important to understand. It helps us to know how different types of FMDV can affect different animals and change over time (Arzt et al., 2011). Sheep and goats can pass FMDV to other animals, so we need to study how easily they get infected and how much they can spread the disease (Knowles et al., 2003). Some FMDV types are more suited to sheep and goats than others, and they may cause different levels of sickness in other animals, such as cows and pigs. The genes and history of FMDV types from small animals affect how they can grow and cause disease in other animals (Klein et al., 2009).

Some experiments have shown that FMDV types from small animals may have different features and effects when they infect other animals (Bauer et al., 1977). Some real-life situations have also shown interesting things, such as sheep and goats having FMDV antibodies without getting sick recently, even living with cows that do not have antibodies (Mackay, 1994; Mackay and Rendle, 1996). This shows the complicated relationships among animals as possible sources or carriers of FMDV. Khukhorov et al. (1973) pointed out the role of sheep and goats in FMDV spread, showing their ability to keep and maintain the virus within their groups. The genetic variety of FMDV types

affects how they interact with different animals. Anahory (2016) stressed that genetic changes influence FMD patterns and show the possibility of FMDV types to change and adapt to new animal environments. The genetic features of FMDV types that infect small animals in places like Asia, especially Pakistan, tell us about their potential to cross animal boundaries and adjust to different animal reactions (Knight-Jones et al., 2016).

#### **4. Vaccination of Small Ruminants against Foot-and-Mouth Disease**

Foot-and-mouth disease (FMD) is a very contagious disease that affects animals with split hooves, like goats and sheep. FMD can cause a lot of problems for farmers and rural people, as it can make animals produce less, die more, face trade restrictions, and cost more to control. FMD is common in many parts of the world, especially in Africa, the Middle East and Asia, where it is a big challenge for the livestock sector and rural development (Choudhury et al., 2021) Giving vaccines to small animals is a keyway to prevent and control FMD. However, there are many difficulties and limitations in vaccinating small animals against FMD. These include not enough vaccines and not good distribution of vaccines, especially in poor countries where FMD is always

present. The need for FMD vaccines is often more than the supply, and the delivery of vaccines is difficult because of bad roads, lack of cold storage, and not enough money (Lombard et al., 2007). Bad quality and effectiveness of vaccines are also big difficulties. The quality and effectiveness of FMD vaccines depend on many things, such as how well the vaccine matches the virus, how strong and clean the vaccine is, how stable and stored the vaccine is, how and how much the vaccine is given, and how healthy the animal is (Chepkwony et al., 2021). Many FMD vaccines are killed or weakened, which need more than one dose and booster to make enough immunity. Also, some FMD vaccines may not stop the carrier state of FMD virus (FMDV) in small animals. This state can last for several months after infection and recovery, and carrier animals may infect other animals that can get sick under good conditions (Mansoo et al., 2018). Low awareness and compliance among farmers are important difficulties in FMD vaccination for small animals. Many farmers in areas where FMD is always present do not know the benefits and importance of FMD vaccination, and some may have wrong ideas or distrust about the safety and effectiveness of FMD vaccines. Also, some farmers may not follow the recommended

vaccination times or ways because of various reasons, such as no access, no money, or no convenience (Win et al., 2021). The high cost of vaccination is also a big concern. The cost of FMD vaccination for small animals includes the cost of the vaccine itself, as well as transportation, storage, delivery, labour, and equipment costs. These costs may be too high for small farmers with little resources and income. Also, the cost-effectiveness of FMD vaccination may depend on many things, such as how common and frequent FMD is, how the animals are raised and sold, and how available and reachable other control measures are (Choudhury et al., 2021). New generation vaccines have many benefits over old vaccines. They make wider and longer-lasting immunity, stop the carrier state, reduce the need for more than one dose and booster, improve the stability and storage of vaccines, make it easier to tell the difference between infected and vaccinated animals (DIVA), and simplify the production and quality control of vaccines (Olsen et al., 2011)

A good way to stop FMD from spreading is to give vaccines to the small animals that are most likely to get sick or are most important for farmers. This way is called risk-based vaccination strategies. It helps to use less vaccines but more effectively,

lower the chance and spread of FMD, protect important farming areas or markets, and control or get rid of FMD. To use this way, you need to know well how FMD spreads in different places and situations. You also need a good system to watch and find high-risk areas or groups (Wada et al., 2022). Teaching people is important. By having campaigns, farmers can learn about FMD in their animals, like what causes it, what happens, how to prevent it, and how to control it. Education programs can teach farmers how to store, use, give, and throw away FMD vaccines properly. Not only farmers, but also animal doctors, workers, policymakers, and buyers, can help and support FMD vaccination for small animals (Sieng et al., 2022). It's also important to work together across borders. By working together, information, resources, and experiences can be shared among different groups, like national authorities, international organizations, research institutions, vaccine makers, and civil society groups. Working together can also help stop FMDV from crossing borders and support the regional or global control or eradication of FMD (Gongal et al., 2022).

### **CONCLUSIONS**

Research is needed to understand the role of sheep and goats in spreading foot-and-mouth disease (FMD) and

their potential to transmit the virus. Regular vaccination programs should be implemented in endemic and high-risk areas, and sufficient vaccine supplies maintained in FMD-free regions. These measures will help reduce the risk and impact of FMD outbreaks.

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Not applicable

### **Conflict of Interest**

Authors declare there is no conflict of interest.

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