The Pharma Innovation Journal 2021; SP-10(12): 776-778

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(12): 776-778

www.thepharmajournal.com
Received: 07-10-2021
Accepted: 09-11-2021

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Foot and mouth disease: Epidemiology, economic significance, prevention and control strategy in India: A review

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Abstract
Foot and mouth disease (FMD) has been acknowledged as a significantly important disease of epidemic proportions affecting a variety of cloven-footed domesticated and wildlife animal species. It is caused by RNA virus belonging to the family of Picornaviridae. In India, the prevalent serotypes are serotype O, A and Asia 1. It is a highly transmissible virus that has a complex epidemiological cycle differing in various Indian endemic regions involving close contact between wildlife and domesticated species. The economic significance of FMD outbreaks in India is massive because of its chronic, production hampering nature of virulence. Different approaches for prevention and control strategies for FMD include continuous monitoring and disease surveillance, vaccination of all animals, ideal zoo-sanitary measures, the study of virus transmission dynamics and biosecurity measures.

Keywords: foot and mouth disease, epidemiological cycle, wildlife, economic, India

Introduction
In India, the livestock sector has a population asset of 53.578 crores, of which bovines account for 30.234 crores, porcine amount to 0.906 crores and caprine and ovine account for 22.306 crores. The livestock sector contributes milk, meat, fibre, skin and so forth to the developing populace. Globally, Foot-and-Mouth disease poses an important threat to trade and commodity markets because it is a highly contagious disease of livestock. Among the most important diseases of cloven-hoofed animals, FMD affects cattle, buffaloes, pigs, sheep, goats, camels and approximately 70 wildlife species, like the Indian Gaur (Rahman *et al*.) [7]. Almost every state where livestock is kept has been affected by the FMD. There are more than 100 countries affected by FMD worldwide, and distribution is closely linked to economic development. It is still common for developing nations like India to struggle with sudden large scale outbreaks which is creating a need for deeper epidemiological data analyses and interpretations to reach a conclusion that might curb the economic losses caused by FMD outbreaks.

Etiology
The disease is caused by the RNA virus, Foot-and-Mouth Disease Virus (FMDV), belonging to the genus *Aphthovirus* genus in the *Picornaviridae* family. The FMDV is spherical in shape and approximately 25–30 nm wide. It consists of RNA genome (8400 nucleotides in length) surrounded by a protein shell or capsid. The capsid is made up of 60 copies of capsomers. Each capsomer consists of four structural polypeptides, VP1, VP2, VP3 and VP4 (Tomar *et al*., 2020) [10]. Because of the rapid spread of FMD and the serious economic consequences that can result from an outbreak, rapid, critical and accurate laboratory diagnosis and the identification of a serotype of pathogens involved in the outbreak are important. Symptoms of the disease may appear after incubation for 1 to 8 days but usually develop within 3 days. The FMD virus (FMDV) lives in the bone marrow as well as the lymph nodes but is destroyed in muscle when the pH is below 6. Based on the temperature and pH of the feed and its surroundings, the virus can survive for up to 30 days.

Epidemiology
a. Occurrence
FMD virus has been categorized into seven geographical pockets worldwide, classified based on the genetic and antigenic constitution. The outbreaks occurring in the Indian sub-continent involve 3 serotypes, namely – serotype O, A and Asia-1.

There were 80% confirmed outbreaks/cases of serotype O, while serotype Asia-1 and serotype A caused 12% and 8%, respectively. These three serotypes are known to have a group of sub serotypes that are unique with respect to their antigenicity and epidemiological trends. Cross-protection between such variants isn't always ensured which is creating a demand for categorization of such strains or sub serotypes and development of strain-specific vaccines (Jamal and Belsham, 2013) [4].

b. Transmission and communicability

A single factor contributing to the changing dynamics of FMD outbreaks is the unrestricted animal movement across state boundaries. The role of carrier animals is largely unknown. The evolution and emergence of new virus strains cause successive rounds of infection, which sometimes extend to FMD-free zones. Transmittal from ruptured vesicles, as well as from bodily excretions and secretions, including milk, saliva, and semen, is facilitated during acute infection. By breathing in very low doses of inhaled virus, susceptible ruminants may be infected, either directly or indirectly, by direct contact with the body secretions of other acutely ill animals, or indirectly by suspended aerosols present on exposed contaminated materials. It is relatively difficult for pigs to get infected with the FMD virus by inhalation. Other routes of infection, such as those that involve ingestion or abrasions, require a greater amount of virus titre. FMDV can survive in the environment for days to months, and in various animal products, such as meat. Some ruminant hosts continue to carry the virus, developing low and diminishing FMDV levels in specific nasopharyngeal epithelial locations and related lymphoid organs (Paton *et al*., 2018) [6].

c. Geographical and seasonal variance

Geographically, the prevalence rate varied by region, with 43.5% being found in the Eastern region, 31.5% in the Southern region, 11.6% in the North-Eastern region, 5% in the Central region, 4.4% in the Western region, and 4% in Northern region. In India, it is worth mentioning that the number of outbreaks/cases of FMD was highest in September (63.4) and lowest in June (23.6). The increase in incidences of FMD began in August and peaked in September and was maintained until January. It is believed that high relative humidity and heavy rainfall reduce aerosol transmission during rainy seasons. Relatively dry weather and moderate relative humidity, which make virus transmission very conducive, contributed to FMD outbreaks during the monsoon and post-monsoon seasons. There were fewer outbreaks during the summer due to very high ambient temperatures. An association between serotype prevalence and season could not be established (Subramaniam *et al*., 2013) [9].

a. Prevalence in wildlife

The role of wildlife species has not been understood in-depth and is often neglected. FMD has been observed in wild animals and such animals can contribute in complex epidemiological cycles which might incorporate domestic livestock thus resulting in consequent production losses. Wildlife species like Mithun, Black Buck, Nilgai, Wild Boar, Indian gaur, deer, spotted deer, Four-horned antelope (*Chousingha*), sambar deer, Indian Gazelle (Chinkara), camel and elephant have all been found to be affected by the disease owing to serotype O. Cross-species transmission among domestic and wild ungulates living in close quarters can jeopardize endangered species conservation efforts. In Indian wild animals, there is a chronic as well as carrier form of infection, as well as its shedding even after the infection has been treated. Because cloven footed wildlife species act as a reservoir for FMDV, it appears to provide a challenge to the FMD-Progressive Control Pathway, which was jointly developed by the OIE and the FAO to aid disease eradication in different endemic states and districts of India.

Economic significance of FMD

Currently, the livestock industry contributes a total of 25.6% to the agricultural GDP and 4.11 percent to the national economy. It also provides nutrition for the world's most vulnerable and helps empower the landless. According to National Accounts Statistics 2020, buffalo contributed more than half (53.4%) of the total milk production in India during 2010-2011. Pigs contribute 9% to the total meat production. The incidence risk because of FMD in the cloven-footed livestock in the Indian states went from 0.5%–23.1% with huge contrast across species, sex and classes. Although FMD is a relatively low mortality disease, the frequency of outbreaks and a large number of animals and species involved in each outbreak lead to FMD having a profound and long-lasting impact in an endemic geographical area (Knight-Jones and Rushton, 2013) [5].

FMD impacts can be broken down into two categories: 1) Direct losses and 2) Indirect losses

Direct losses can be further categorized into those which are visible and those which are invisible. Visible losses include losses in milk production, losses in draught power, losses due to lesser weight gain potential in affected animals, losses due to abortion which causes the farmer to rear a dam for another breeding season without gaining anything and Losses due to mortality. Losses in production are most apparent in intensive production systems for pigs, dairy cattle and buffalo which are the decisive production resources of India. These visible losses account for a total of 33% of losses in endemic countries like India (Ellis and Putt 1981) [2]. Invisible losses include losses due to reduced overall fertility in affected animals, losses due to changes in herd composition, losses due to the delayed sale of animals of their products. In addition to fertility problems due to abortion and reduced conception rates, it is necessary to maintain a greater number of breeding animals for a given livestock business, which means that for every kilo of meat or milk produced, there is an extra cost of rearing more breeding animals (Knight-Jones and Rushton, 2013) [5].

Indirect losses result from the cost of vaccines and their delivery, diagnostic tests involved in surveillance, losses due to failed investment on culled animals, costs incurred to restrict reservoirs in wildlife from getting in contact with production animals, cost of surveillance after an outbreak, suicides amongst farmers who get directly or indirectly affected, losses due to hindrances in access to remunerative markets, restricted use of improved production technologies and losses due to consumer's reluctance to consume animal products from endemic regions. The costs of sustaining an effective control programme for FMD are huge and additional funds need to be invested by the private sector which can be huge to incur and can't be neglected because of the risk of new FMD outbreaks. A short duration of immunity is induced as a result of FMD vaccines, which limits resources available to combat other diseases; cattle are vaccinated 1-4 times per year and sheep and goats once per year in ongoing control

programmes. In addition to livestock producers, other participants in the chain such as markets, abattoirs, and dairies to name just a few experience a domino effect (Knight-Jones and Rushton, 2013) [5]. The losses projected because of FMD in various Indian states and union territories state that they might be highest in Kerala in a high incidence scenario (Govindaraj *et al*., 2021) [3].

Prevention and control strategy

For Prevention of economic losses due to FMD and increased herd immunity in domesticated animals, the Government of India is implementing the Foot and Mouth Disease Control Programme in 54 districts of states of the country with 100% central subsidy on vaccination costs, cold chain supply and other transportation support. The Indian government has introduced a continuous control system for FMD in accordance with the guidelines provided by the Office Internationale-des-Epizooties (OIE) and Food and Agriculture Organization (FAO) to minimize economic losses of farmers. In order to control disease outbreaks, disease surveillance, monitoring and fast detection of outbreaks in susceptible hosts, especially at the livestock-wildlife interface is crucial. Due to the lack of data regarding its epidemiology and the contribution of infected wildlife to disease transmission, it is important to chart trends in spatial and temporal disease transmission in wildlife. A continuous disease surveillance programme in and around wildlife habitats could be taken as a top priority for strengthening disease control strategies while also preserving important animals and genetic diversity.

The current FMD control programme encompasses strategies such as vaccination at six-monthly intervals of all cloven-footed producing animals, publicizing the importance of the effects of FMD on Indian lives, identifying target victim animals, random monitoring and serosurveillance, obtaining a greater number of cold storage units and vaccines and procuring more number of rapid diagnostic testing kits (Audarya, 2020) [1]. Biosecurity measures concerning animals, transport vehicles, farmworkers, farm equipment and animal products is a necessity. Restriction of entry to feral animals and visitors to the production farms is a must. FMDV is highly contagious and the virus can be carried to any animal farm through fomites such as human shoes or foreign equipment or transport vehicle tires, hence appropriate disinfecting measures should be taken to disinfect any such sources of infection. In spite of all the efforts undertaken, there is scope for improvement in the current control programme. Herds of small and large migratory ruminants need to be identified, given a free pass and tracked to trace their journey and to identify the risk involved for the involved regions. Gayals and yaks play an important role as carrier hosts in the prevalence of FMD in the northern and north eastern regions of India, such animals need to be included in the FMD control programme. Cold chain maintenance from production to actual vaccination needs to be maintained. Encouragement should be there for more collaboration between veterinary and other allied and non-allied fields. One health approach can play an important role in FMD prevention and control. To prevent the recurrence of FMD threats calls for a multidisciplinary, multi-sectoral approach or a One Health approach. Vaccination of all domestic and wild cloven-footed animals with emphasis on seroprevalence and strain-specific vaccination in endemic geographical areas can improve the present-day situation. It is possible for India to suffer fewer economic losses if these strategies are implemented.

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