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Foot-and-Mouth Disease in India: Progress, Persistent Challenges and the Road Ahead

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INTRODUCTION

Foot-and-mouth disease (FMD) is so well known to livestock owners that its seriousness is sometimes underestimated. It usually does not kill large numbers of adult cattle or buffaloes, yet it can sweep through a susceptible herd within days. Fever is followed by painful blisters and erosions in the mouth, between the claws and around the coronary band; lesions may also appear on the teats. Affected animals drool, stop eating, become lame and show a sudden fall in milk production. The visible sores may heal, but the production shock can last much longer. For a small dairy household, the economic effect is immediate. Milk sales fall just when veterinary expenses and labour demands increase. Breeding may be delayed, growing animals lose condition and draught animals cannot work normally. At a wider level, outbreaks interrupt livestock markets, restrict movement and limit access to high-value trade. FMD is therefore not simply a disease of the mouth and feet; it is a disease of productivity, livelihoods and market confidence (Knight-Jones & Rushton, 2013; World Organisation for Animal Health (WOAH, 2025). Young animals deserve particular attention. Calves, lambs and piglets may die suddenly from viral myocarditis even when typical blisters are limited or absent. In adults, mortality is generally low, but morbidity can be extremely high. That combination—many animals sick at the same time, few dying immediately—explains why the disease can quietly drain farm income without producing the dramatic mortality associated with some other transboundary infections. FMD is caused by foot-and-mouth disease virus (FMDV), a small, non-enveloped, positive-sense RNA virus in the genus Aphthovirus. Seven immunologically distinct serotypes are recognised: O, A, C, Asia1 and the three Southern African Territories serotypes, SAT1, SAT2 and SAT3. Immunity is largely serotype-specific, so protection against one serotype does not reliably protect against another.

India has historically detected serotypes O, A, C and Asia1, but serotype C has not been reported in the country since 1995; current vaccination and surveillance concentrate on O, A and Asia1 (Singh et al., 2019). The viral capsid contains exposed proteins, particularly VP1, VP2 and VP3, that are recognised by neutralising antibodies.

FMDV replicates with an error-prone RNA polymerase, continuously generating genetic variation. Most mutations do not create a major control problem, but changes within antigenic sites can reduce how well antibodies induced by an existing vaccine recognise a field virus. This is why "a vaccine against serotype O" is not the end of the scientific discussion: the antigenic relationship between the vaccine strain and the circulating lineage also matters. Recent Indian molecular studies describe continuing lineage turnover. Serotype O remains the principal driver, with O/ME-SA/Ind2001e and O/ME-SA/Cluster-2018 among the important recent lineages. Serotypes A and Asia1 occur less frequently but remain relevant because their lineages can reappear, spread across borders or replace earlier variants. Sequencing is therefore not an academic luxury. It helps trace outbreaks, recognise incursions and decide whether vaccine strains still provide an appropriate antigenic match.

How the virus travels through India's livestock networks

FMDV is shed in breath, saliva, milk, semen and other secretions. Direct contact is highly efficient, and infected cattle can release large quantities of virus in respiratory aerosols. The virus also moves on contaminated footwear, clothing, hands, buckets, vehicles, instruments and animal housing. Milk, feed and animal products may carry infection when they are untreated or handled unsafely. Because animals can shed virus before classical lesions become obvious, apparently normal transport can move infection ahead of clinical recognition (WOAH, 2025). Different hosts play different epidemiological roles. Cattle are highly susceptible to infection by the respiratory route and often act as sensitive indicators of viral circulation. Pigs can produce enormous quantities of airborne virus and function as amplifiers. Sheep and goats may show mild or easily overlooked lesions, allowing infection to circulate quietly. Water buffaloes, yaks, mithun and many wild cloven-hoofed species are also susceptible. Humans are not considered a public-health risk from FMD. India's livestock economy connects these hosts through village grazing, shared water points, seasonal migration, animal fairs, markets, milk routes and long-distance transport. A local immunity gap can therefore become a regional problem. Vaccination reduces susceptibility, but movement determines how rapidly the remaining infection opportunities are connected. Control programmes must address both.

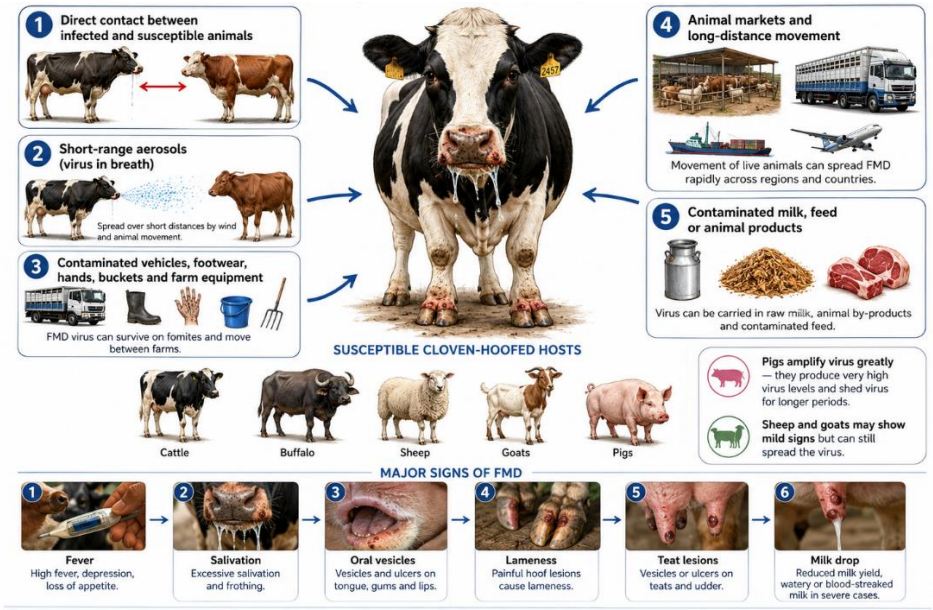

Figure 1. How FMD spreads among susceptible livestock and the major signs farmers may observe. Direct contact, aerosols, contaminated materials and animal movement can act together during an outbreak.

From first exposure to visible disease

After inhalation, FMDV usually begins replicating in the nasopharyngeal region of cattle. The virus then enters the bloodstream and reaches tissues with stratified epithelium, producing vesicles in the mouth, feet and teats. Fever and viraemia may occur before blisters become obvious, which creates a dangerous window when animals are already infectious but have not yet been recognised as cases. The clinical picture varies by species. Cattle commonly show fever, strings of saliva, tongue or dental-pad erosions, lameness and reduced milk yield. In pigs, severe foot lesions may dominate and make standing difficult. Sheep and goats may have only small oral or foot lesions, so careful examination is needed during mixed-species outbreaks. No clinical appearance should be treated as final proof: other vesicular conditions can look similar, and laboratory confirmation is essential. The preferred diagnostic samples are vesicular epithelium and fluid from fresh lesions. Real-time reverse-transcription PCR provides rapid detection, while antigen assays, virus isolation and sequencing support serotyping, strain characterisation and epidemiological investigation. A good sample collected early is often more valuable than a large number of poorly timed specimens.

India today: major progress, but not freedom

India launched the National Animal Disease Control Programme (NADCP) in September 2019, with the national ambition of controlling FMD and progressively moving toward disease-free status through repeated mass vaccination. FMD vaccination is now supported under the Livestock Health and Disease Control Programme with central assistance, quality testing, seromonitoring, cold-chain support and digital recording. The programme covers susceptible livestock and increasingly emphasises the difficult final-mile tasks of animal registration, microplanning and verification (Department of Animal Husbandry and Dairying (DAHD, 2019); Press Information Bureau (PIB, 2026). Official data indicate substantial improvement. Reported FMD outbreaks declined from 132 in 2019 to 49 in 2023 and 32 in 2025. Approximately 44.57 crore vaccine doses were administered during 2024, while cumulative coverage reached 110.49 crore doses by February 2025. Post-vaccination monitoring in 2024 reported protective titres of 82.3% for serotype O, 76.7% for A and 78.7% for Asia1 in the latest round. A later national update reported average seroconversion of 70% and a fall in non-structural-protein antibody prevalence from 16% during 2021–2023 to 7.8% (PIB, 2025a, 2025b, 2026).

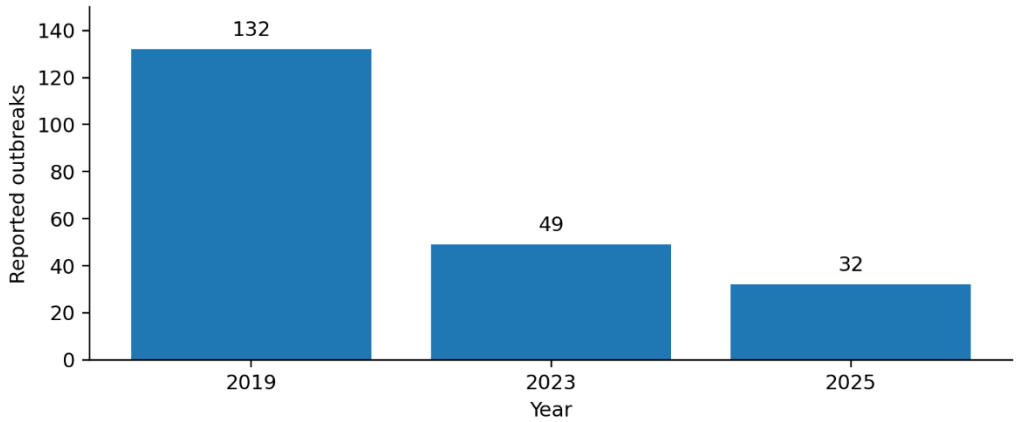

Figure 2. Officially reported FMD outbreaks in India declined from 132 in 2019 to 32 in 2025. The trend is encouraging, although reported numbers are also influenced by surveillance and reporting intensity.

These indicators show that vaccination is changing the national disease landscape, but they are not equivalent to freedom from infection. An outbreak count is influenced by how intensively disease is sought and reported. Seroconversion measures vaccine-induced antibodies, while antibodies to non-structural proteins indicate evidence of infection or viral exposure at population level. Each measure answers a different question. Together they support a conclusion of strong progress with continuing circulation, rather than elimination.

Vaccination: the cornerstone, not the whole building

India uses an inactivated, oil-adjuvanted trivalent vaccine containing antigens from serotypes O, A and Asia1. Inactivated vaccines cannot cause infection when properly manufactured and quality controlled, but they do require a dependable cold chain and repeat administration. Protection is not lifelong, which is why six-monthly mass campaigns are central to the programme. High coverage must be achieved quickly across connected populations; scattered vaccination leaves pockets through which the virus can continue to move. When disease occurs after vaccination, it is tempting to blame the vial. A systematic investigation is more useful. Was the animal actually vaccinated and correctly recorded? Was the dose administered by the correct route? Was the vaccine exposed to heat or freezing? Was the booster delayed? Was the animal incubating infection before vaccination? Did maternal antibody interfere in a young calf? Was herd coverage high enough? Finally, was the circulating virus antigenically matched to the vaccine strain? Most apparent failures are a mixture of coverage, timing, handling and exposure problems rather than proof that vaccination itself is ineffective. Vaccine matching must remain linked to molecular surveillance. Genetic difference does not automatically mean antigenic mismatch, so sequence analysis and serological matching tests should complement one another. Regular review is especially important for serotype A, which is antigenically variable, and for newly emerging or re-emerging lineages. Potency testing, post-vaccination monitoring and investigation of every breakthrough outbreak are part of vaccine policy—not optional laboratory extras.

What successful vaccination should look like

A successful vaccination campaign is more than a large number of doses delivered. It should produce high, relatively even immunity across villages, species and age groups before the next high-risk period. Coverage must be measured against the actual eligible population, not only against the number of doses dispatched. The animals most likely to be missed—newborn calves, migratory flocks, pigs in small units, animals at temporary markets and livestock in remote terrain—are often the same animals that can reconnect transmission chains. Post-vaccination Sero monitoring asks whether vaccinated animals developed antibodies to the structural proteins of the vaccine serotypes. Serosurveillance for antibodies against non-structural proteins asks a different question: whether animals show evidence of infection or exposure to replicating virus. Neither result should be interpreted alone. Low protective titres may reveal weak delivery or poor response, while clusters of NSP-positive animals can direct field teams toward areas of hidden circulation. Used together, these tools turn a campaign into a measurable disease-control programme. Timing is equally important. Immunity takes time to develop, so vaccinating after animals have already been exposed cannot prevent that outbreak. Campaigns should be completed rapidly and before predictable risk periods. Newly purchased animals should be quarantined, checked and brought into the vaccination schedule. Calves should enter the programme at the recommended age and receive repeat doses according to official guidance. The objective is not simply to vaccinate individual animals, but to maintain

population immunity without a seasonal window through which FMDV can return.

The economic burden is unevenly shared

National estimates help communicate the scale of FMD, but the same outbreak does not cost every farmer equally. A high-yielding dairy cow may lose far more marketable milk than a low-producing animal, while a marginal household may suffer more severely because it has no second income source. Teat lesions can make milking painful and increase the risk of secondary mastitis. Lameness reduces grazing and feed intake. Even after visible recovery, animals may require weeks to regain body condition and previous productivity. The indirect burden can exceed the immediate veterinary bill. Traders avoid affected areas, markets are closed or restricted, animals cannot be moved for breeding, and transport vehicles require cleaning and downtime. For organised value chains, FMD status influences access to domestic and international markets. For smallholders, the same disease is experienced as lost daily cash flow. This uneven distribution of loss is why control programmes must protect both national trade ambitions and household resilience.

Carrier animals and silent circulation

Ruminants may retain FMDV in the oropharyngeal region for more than 28 days after infection and are then described as carriers. Vaccination protects strongly against clinical disease but does not always prevent initial infection or persistence. The epidemiological importance of the carrier state under field conditions remains debated, and carrier animals should not be presented as the explanation for every new outbreak. Nevertheless, persistence matters for surveillance, trade rules and research, particularly where the goal is verified freedom rather than simple reduction of clinical disease. Silent circulation is a broader concern than the classic carrier state. Mild infection in sheep and goats, missed lesions, delayed reporting and movement during incubation can maintain transmission without an obvious explosive outbreak. Surveillance must therefore include outbreak investigation, post-vaccination seromonitoring, non-structural-protein serosurveillance and targeted sampling in higher-risk populations such as markets, migratory flocks and border areas.

Biosecurity between vaccination rounds

Vaccination days receive public attention, but many of the decisive actions occur between campaigns. New animals should not enter the resident herd immediately; a short quarantine period allows observation, verification of vaccination history and veterinary assessment. Shared ropes, nose leads, milking utensils, footwear and treatment equipment should be cleaned before moving between groups. Needles must not be reused between animals. During a suspected outbreak, people, vehicles and feed movement should be reduced to the minimum necessary. Effective disinfection begins with cleaning. Organic material protects FMDV and can make some disinfectants ineffective, so manure, mud, bedding and milk residues must be removed before an approved disinfectant is applied at the correct concentration and contact time. Entry points for vehicles and visitors should be controlled, and livestock transporters should be included in awareness programmes because they link many farms in a single day. Biosecurity does not replace vaccination, but it reduces the number of opportunities that vaccination must block. Markets require special attention. Animals from several sources mix closely, often under stress, and may be resold before an incubation period has ended. Practical safeguards include checking identification and vaccination records, separating animals showing salivation or lameness, providing facilities for cleaning vehicles and temporarily suspending high-risk movement when an outbreak is confirmed. These measures are most effective when farmers understand that restrictions are short-term tools to prevent much larger losses.

The first 72 hours and the long road ahead

FMD control is a race against movement. When fever, drooling, mouth sores, teat lesions or sudden lameness appear, the affected group should be separated immediately and animal movement stopped. The nearest veterinary authority should be notified without delay. Vesicular epithelium or fluid should be collected under standard protocols, and laboratory confirmation should identify the serotype and, where possible, the lineage. Contact farms, recent purchases, markets, vehicles and milk routes should be traced. Emergency or ring vaccination should be applied only under official risk-based guidance. Long-term control requires less dramatic but equally important work. Ear tagging and reliable digital records allow teams to identify missed animals and verify repeat vaccination. Cold-chain monitoring must extend to the point of injection. Markets and transport vehicles need cleaning, disinfection and movement documentation. Border and interstate coordination are essential because a virus does not recognise administrative boundaries. Farmer communication must explain why animals need repeated vaccination even when no outbreak is visible. FAO and WOAH promote the Progressive Control Pathway for FMD, a risk- and evidence-based framework that helps endemic countries reduce viral circulation and advance toward officially recognised freedom. The lesson is that national progress is built step by step: first understanding risk, then reducing disease, strengthening veterinary systems and finally proving that control is sustainable (FAO and EuFMD, 2019).

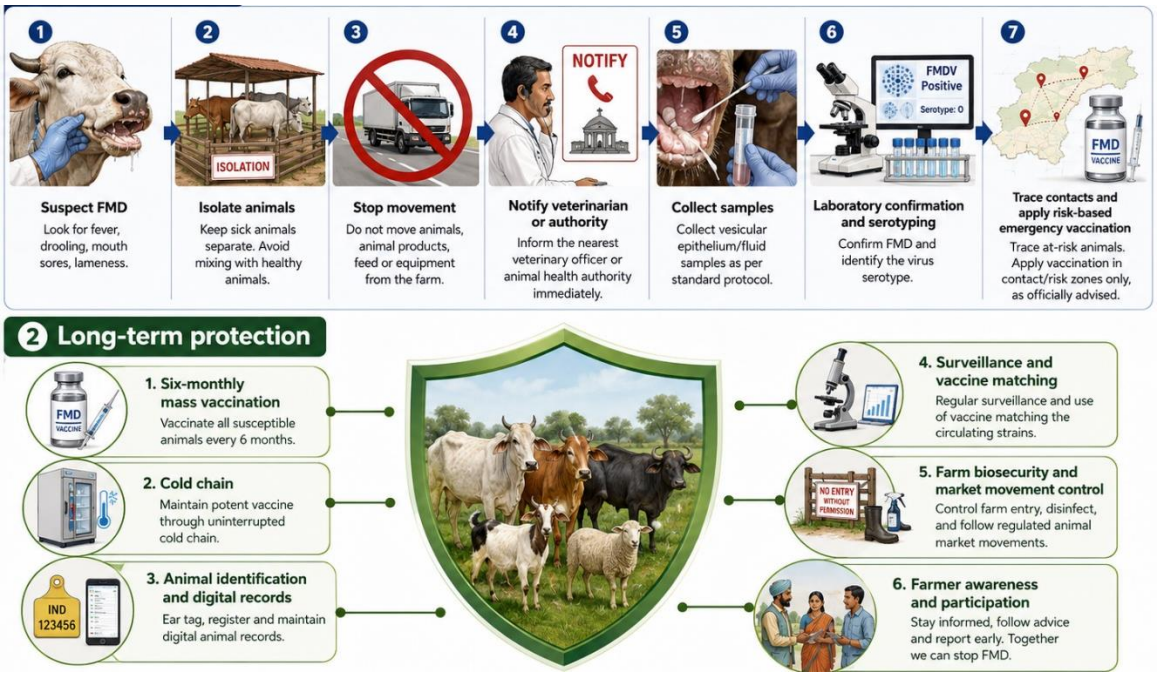

Figure 3. The two-time scales of FMD control: urgent action during the first 72 hours and sustained protection through vaccination, traceability, surveillance, biosecurity and farmer participation.

CONCLUSION: From Campaigns to a Culture of Prevention

India is no longer where it was in 2019. The fall in reported outbreaks, enormous vaccination effort and improving serological indicators demonstrate that coordinated national action works. The remaining challenge is more demanding because infection now survives in the gaps: an untagged animal, a missed village, a delayed booster, a warm vaccine carrier, an unreported market case or a new viral variant. The central message is therefore simple. Vaccination is indispensable, but vaccination alone cannot

deliver durable control. India needs vaccination that is complete, correctly timed, quality assured and connected to laboratory evidence. It also needs rapid reporting, disciplined movement control, digital traceability and farmer trust. Progressing toward FMD freedom would mean more than fewer blisters—it would mean steadier milk production, healthier young stock, stronger rural livelihoods and new opportunities for Indian livestock products.

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