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Review Article

Resurgence of lumpy skin disease in India poses a looming threat to the livestock farmers: A comprehensive review

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Abstract

Lumpy skin disease (LSD) is an emerging viral infection that affects cattle and water buffalo, caused by the *Capripoxvirus* of the family *Poxviridae*. Originally limited to sub-Saharan Africa, the disease has rapidly expanded over the past two decades to the Middle East, Europe, and Asia, with India experiencing widespread outbreaks since its first detection in 2019. The 2022 epidemic in India was devastating due to high morbidity, mortality, and severe economic losses across the dairy and livestock sectors. Transmission occurs primarily through blood-sucking arthropods, but animal movement also played a major role. Clinically, LSD is characterized by fever, nodular skin eruptions, lymphadenopathy, decreased milk yield, infertility, and hide damage, with complications such as pneumonia, mastitis, and abortion contributing to prolonged recovery and production losses. The socio-economic impact in India is severe, particularly for smallholder farmers, with national-level losses during 2022 estimated in billions of USD. Diagnosis is based on clinical signs and supported by PCR, ELISA, virus isolation, and novel, rapid isothermal assays like SRCA. Although no specific antiviral therapy exists, supportive care, vector control, and strict biosecurity measures are critical. Vaccination continues to be the cornerstone of control, with homologous live attenuated vaccines showing effectiveness, though challenges such as adverse reactions and incomplete protection persist. Future directions emphasize the need for next-generation vaccines, field-deployable diagnostics, genomic surveillance, and integrated "One Health" approaches. Regional cooperation, strengthened veterinary infrastructure, and farmer engagement will be pivotal in mitigating LSD's impact and advancing toward sustainable control and eventual eradication.

Keywords: Cattle, Economic loss, Lumpy skin disease, Transboundary diseases, Vaccination

Highlights

- LSD is a re-emerging disease in India, causing widespread morbidity and mortality in cattle.
- The 2022 outbreak caused severe economic losses, crippling dairy output and rural livelihoods.
- Diverse LSDV lineages on molecular level, indicated repeated introductions and evolving virulence.
- SRCA-based isothermal assays enable rapid and sensitive detection alongside PCR and ELISA
- LSD control requires improved vaccination, genomic surveillance and integrated One Health approach.

INTRODUCTION

Lumpy Skin Disease (LSD) is a transboundary viral infection of cattle and water buffalo, caused by a *Capripoxvirus* belonging to the family *Poxviridae*. The disease is clinically manifested by pyrexia, nodular eruptions on the skin, enlargement of superficial lymph nodes, edema of the udder, reduced milk production, reproductive disturbances, and in severe cases, mortality (Gautam et al., 2022). Lumpy skin disease was first recognized in India in 2019, following its introduction in Odisha, and rapidly disseminated across several states, leading to considerable economic repercussions (Sudhakar et al., 2020). The situation escalated in 2022, when widespread outbreaks resulted in high morbidity and notable mortality among indigenous cattle, with profound consequences for rural livelihoods and the dairy sector. Emerging epidemiological evidence, particularly from Punjab and other affected regions, points to the critical role of vector-borne transmission and livestock movement in driving the spread of the virus. Overall, these findings highlight the pressing need for robust vaccination strategies and strengthened surveillance systems to mitigate the growing threat of LSD to India's cattle population (Kumar et al., 2025).

Transmission of LSDV primarily occurs through mechanical vectors, including biting flies, mosquitoes, and ticks; however, indirect routes such as infected

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semen, milk, secretions, and contaminated fomites also contribute to the infection (Akther et al., 2023). The disease inflicts significant economic losses arising from reduced milk yield, hide damage, infertility, and trade restrictions, with localized annual losses in some regions amounting to millions of U. S. dollars (Jyoti et al., 2022; Akther et al., 2023). Effective management relies on early detection, implementation of strict biosecurity protocols, regulation of animal movement, and extensive vaccination programs employing quality-assured vaccines consistent with WOAH recommendations (Jyoti et al., 2022). This communication presents the comprehensive information on the resurgence of lumpy skin disease in India that poses an emerging threat to livestock industry. In addition, epidemiological trends and control measures are also discussed.

Etiology

The etiological agent of lumpy skin disease, Lumpy skin disease virus (LSDV), belongs to the *Poxviridae* family, which is further divided into two subfamilies: *Chordopoxvirinae*, and *Entomopoxvirinae*, affecting both vertebrates and invertebrates, respectively (Quinn et al., 2015). The *Chordopoxvirinae* subfamily includes 10 genera, among which the *Capripoxvirus* genus consists of three species- sheep pox virus (SPPV), goat pox virus (GTPV), and lumpy skin disease virus (LSDV), which primarily infect sheep, goats, and cattle, respectively (King et al., 2012). Morphologically, LSDV is a brick-shaped, enveloped virus measuring about 320 × 260 nm, with a double-stranded DNA genome exhibiting complex symmetry and replicating within the host cell cytoplasm. The viral genome is about 151 kbp in length, consisting of a central coding region flanked by two identical 2.4 kbp inverted terminal repeats, and encoding around 156 predicted genes. Among these, about 30 structural and non-structural genes are highly conserved, sharing nearly 97% nucleotide homology with SPPV and GTPV (Tulman et al., 2001; Tulman et al., 2002). Fig. 1 illustrates the structure of Lumpy Skin Disease Virus (LSDV), showing the mature virus (MV) with an ER-derived membrane and the enveloped virus (EV) containing an additional host cell membrane–derived outer envelope (Liang et al., 2022).

LSDV exhibits remarkable stability under ambient conditions, allowing its persistence under diverse conditions. Although exposure to sunlight and lipid solvents rapidly inactivates the virus, it remains viable for months in dark and shaded environments such as cattle sheds and feed storage facilities. Thermal inactivation occurs at 55°C within 2 hours or at 65°C within 30 minutes. The virus is sensitive to extreme pH levels but can tolerate a pH range of 6.6-8.6 for 5 days at 37°C without a notable decline in titre. It is inactivated by several chemical agents, including ether (20%), chloroform, formalin (1%), phenol (2% for 15 min), sodium hypochlorite (2-3%), iodine solutions (1:33 dilution), and quaternary ammonium compounds (0.5%). The LSDV demonstrates exceptional resilience, as viable virus has been recovered after 10 years from nodular tissue stored at –80°C and after 6 months from infected culture fluid maintained at 4°C (Mulatu & Feyisa, 2018). The transboundary expansion has largely been facilitated by mechanical transmission via blood-feeding arthropods, including *Stomoxys calcitrans*, mosquitoes, and ticks, in addition to animal movement and trade activities (Sudhakar et al., 2020; Sudhakar et al., 2022). Reported morbidity rates range from 5- 45%, with mortality typically between 1-5%.

The first confirmed incursion of LSDV in India in 2019 was associated with the KSGP/"Kenyan-like" lineage, with isolates from Odisha and West Bengal clustering phylogenetically with the historical NI-2490/Kenya/KSGP-like field strains based on *GPCR*, *RPO30*, *P32* and *EEV* gene sequences (Sudhakar et al., 2022). In 2020, the complete genome of the Indian isolate LSDV/208/PVNRTVU/2020 was sequenced, serving as a national reference for subsequent genomic analyses (Putty et al., 2023). However, during the 2022 epidemic in Rajasthan, a genetically distinct Indian lineage was identified, with multiple mutations relative to both, the Neethling reference strain and earlier Indian isolates, with no molecular evidence

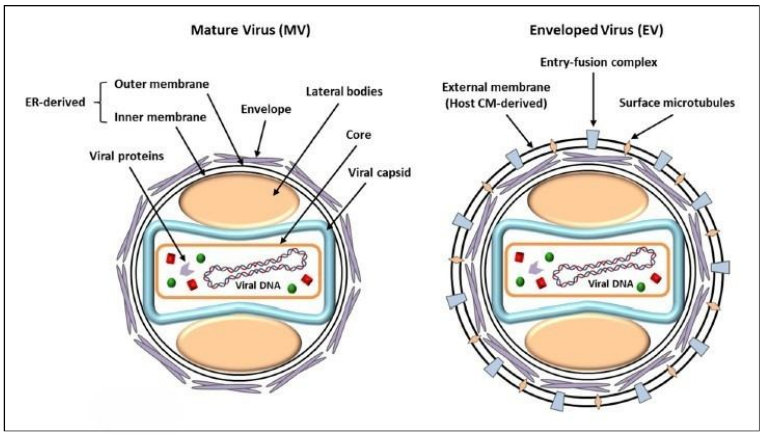


Fig. 1. Structural organization of Lumpy Skin Disease Virus (LSDV) (Moudgil et al., 2023)

suggesting vaccine spillover (Bhatt et al., 2023). Further genome-based surveillance revealed two co-circulating subclades1.2a and 1.2b, associated with variable morbidity and mortality patterns (Mishra et al., 2024). Moreover, the 2022 outbreak in Gre at Nicobar Island revealed an island-specific genotype, extending the known genetic diversity of Indian LSDV strains (Sudhakar et al., 2025). The detection of LSDV in free-ranging Indian gazelles further demonstrated its capacity to infect wild ruminants, representing a wild-type strain related to Middle Eastern lineages and suggesting multiple introductions of LSDV into India (Sudhakar et al., 2023).

Epidemiology

Lumpy skin disease was initially discovered in Zambia in 1929, restricted to sub-Saharan Africa which subsequently disseminated across southern and eastern Africa, Egypt and Israel in the following decades (Abera et al., 2015). Over the past twenty years, the virus has shown a marked expansion beyond its endemic zones, spreading to the Middle East, Europe and Asia (Moudgil et al., 2024). Around 2012, LSD emerged in Southeast Europe and the Balkans, and between 2019 and the mid-2020s, it rapidly advanced across South and Southeast Asia, leading to extensive outbreaks in India, Bangladesh, Nepal, China, and adjacent countries (Azeem et al., 2022). LSD had extended to Mongolia and Eastern Siberia by the end of 2022 (Liang et al., 2022). As of July 2025, Italy and France reported their first ever occurrences of the disease, marking a change in the distribution of the virus and highlighting the need for heightened global disease surveillance and coordination (World Organization of Animal Health [WOAH], 2025). Fig. 2 depicts the progressive transboundary spread of LSD from its origin in Africa to Europe and Asia, since 1929.

LSD has been widely distributed across India, with outbreaks documented in over 20 states and millions of cattle affected since 2019. The 2022 epidemic was particularly severe, with the most pronounced impact in Rajasthan, Gujarat, Punjab, Haryana, Maharashtra, and Uttar Pradesh. Rajasthan reported more than 75,000 cattle deaths, underscoring the extensive scale of the epidemic. This widespread distribution highlights both the transboundary threat posed by LSDV and the pivotal role of livestock movement and trade in facilitating its spread (Pal et al., 2024a; Alka et al., 2025).

The recent outbreaks in India have revealed markedly higher case fatality rates, reaching up to 20% (Kumar et al., 2021). Epidemiological investigations across India and neighbouring countries indicate that indigenous cattle breeds exhibit greater susceptibility to LSD compared to crossbred or exotic breeds, with outbreak intensity typically peaking in warm, humid seasons conducive to high vector activity (Sudhakar et al., 2020). Modelling studies conducted during the 2021- 22 epidemic in Punjab, revealed a basic reproduction number (Ro) of approximately 1.8, reflecting moderate transmission potential under natural conditions (Kumar et al., 2021). The disease dynamics are further influenced by its extended environmental persistence, possible involvement of wildlife reservoirs, and emerging genomic evidence of multiple co-circulating viral lineages within India (Sudhakar et al., 2020).

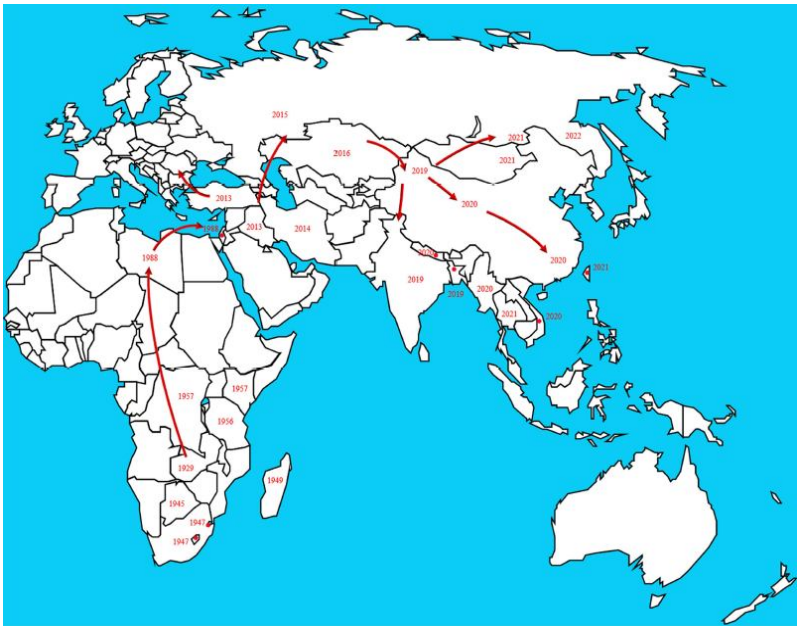


Fig. 2. Global prevalence and transmission of LSD (Liang et al., 2022)

Although cattle are the principal hosts of LSD, recent findings have confirmed natural infections in water buffaloes in India. A sero-molecular survey conducted between 2020 and 2023 reported approximately 10% PCR positivity and around 38% seroprevalence in buffalo populations, indicating that these animals may serve as secondary hosts and potentially contribute to the maintenance of the disease (Sudhakar et al., 2025). Fig. 3 depicts the transmission dynamics of LSDV. In India, LSD outbreaks show a

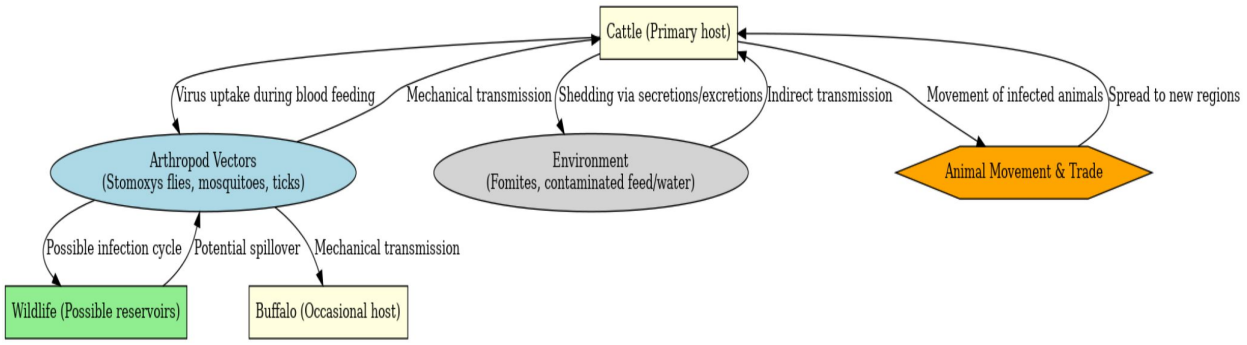


Fig. 3. Transmission dynamics of LSDV (Kumar et al., 2021)

clear seasonal pattern, with incidence peaking during the monsoon and post-monsoon periods when vector populations are at their highest. The transmission dynamics of LSD is shown in Fig-3. Elevated humidity and rainfall provide optimal breeding conditions for biting flies, thereby increasing the efficiency of LSDV transmission (Kumar et al., 2021).

Clinical presentation

The incubation period of lumpy skin disease (LSD) under natural conditions typically ranges from 2 to 5 weeks, whereas experimentally induced infections manifest clinical signs within 7 to 14 days. Clinically, the disease may occur in acute, sub-acute or chronic forms. The disease manifests with a biphasic fever initially, followed by the appearance of one or two nodular swellings within 2- 3 days in mild cases, accompanied by signs such as emaciation, ocular discharge, and agalactia. As the disease progresses, painful and hyperaemic nodules develop on various parts of the body, particularly the muzzle, nares, back, limbs, scrotum, perineum, eyelids, ears, nasal and oral mucosa and tail (Salib & Osman, 2011). In severe infections, cattle may develop over a hundred nodules across the body within 7 - 12 days as depicted in Fig. 4. These firm, raised nodules, often encircled by a haemorrhagic ring, extend into the dermis, epidermis, subcutis, and sometimes musculature. Lesions advance through stages of papules, vesicles, pustules with exudation, and eventually form scabs, with very slow healing. Over time, necrotic lesions can develop on the mucous membranes of the nostrils, respiratory tract, mouth, and vulva. Within 2 - 3 weeks, the cutaneous nodules harden and become necrotic, causing pain and reluctance to move. Sloughing of necrotic tissue may lead to the characteristic "sit-fast" lesions, which predispose animals to screwworm infestation, bacterial invasion and subsequent septicaemia (Abutarbush et al., 2015; Constable et al., 2016). Generalized lymphadenopathy is a common clinical finding. Histopathological lesions show ballooning degeneration of epithelial cells with eosinophilic intracytoplasmic inclusion bodies (Tuppurainen et al., 2018). Complications of LSD include pneumonia, often resulting from inhalation of necrotic material, as well as abortion during the acute phase. Infertility, with prolonged anoestrus in females and reduced fertility in bulls due to genital lesions is another predominant sequela. Recovery tends to be slow and is often hindered by secondary bacterial infections, mastitis, pneumonia, and myiasis in necrotic lesions, which may leave deep scars on the body (Al-Salihi et al., 2014).



Fig. 4. LSD affected cattle with nodules developed across the body (Whittle et al., 2023)

Socio-economic impact

The World Organisation for Animal Health [WOAH] (formerly the OIE) classified LSD as a

notifiable disease due to its profound economic implications. Owing to its capacity to spread rapidly beyond its original African range and establish itself in new geographical regions, LSD has also been identified as a potential agro-terrorism threat (Abutarbush et al., 2017). The principal economic burden of LSD arises from its high morbidity rather than mortality, as death rates generally remain low. Substantial production losses are associated with severe emaciation, deterioration of hide quality, infertility in both sexes, mastitis, reduced milk yield, and abortion in affected animals (Tuppurainen et al., 2018). These impacts lower the overall quality of life of the affected animals, disrupting trade in live cattle and animal-derived products, thereby inflicting heavy financial damage on the meat, dairy, leather and related industries. Beyond commercial sectors, smallholder farmers dependent on livestock also face severe hardships due to the disease. The estimated economic losses from LSD across Indian states, analyzed through descriptive and stochastic modelling revealed the median milk loss per animal was 74, 90, 60, 45, 15, 15, and 8 L in Rajasthan, Gujarat, Tamil Nadu, Karnataka, Madhya Pradesh, Assam, and Odisha, respectively. Higher milk losses (237.8 USD), and mortality losses ranged from 12.2 - 1,084 USD per animal especially in crossbreeds. National losses were mainly from reduced milk yield, followed by draught power, treatment and vector control costs. The total estimated loss during 2022 - 2023 was 2440.29 million USD, with Rajasthan accounting for 314.18 million USD (Naidu et al., 2025).

A recent field-based assessment from 100 dairy farms in Punjab during the LSD epidemic, revealed morbidity rates in cattle (45.25%), buffaloes (0.19%) whereas in the pooled bovine population (27.04%), with mortality reaching 12.40% in cattle. Substantial economic losses including direct mortality losses in Punjab as well as in India, are as depicted in Fig. 5. These estimates highlight the significant socio-economic impact of LSD outbreaks, affecting both smallholder farmers and the livestock sector (Singh et al., 2023).

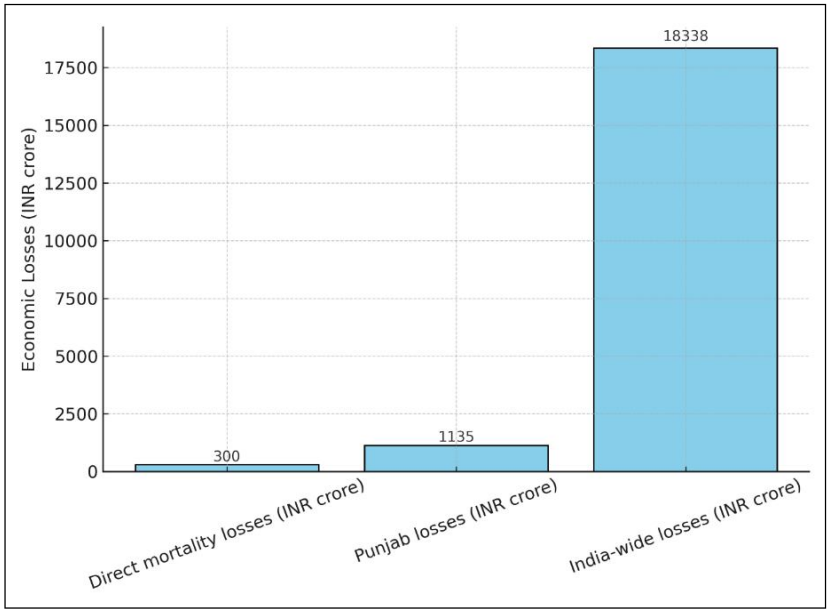


Fig. 5. Economic losses due to LSD in India (2022 epidemic) (Singh et al., 2023)

Diagnosis

The diagnosis of exotic transboundary diseases often poses challenges due to limited familiarity and logistical constraints. The clinical signs of LSD may resemble those of other conditions, such as foot-and-mouth disease (FMD), insect bites, demodicosis, or hypersensitivity reactions, making clinical diagnosis alone unreliable (Palai et al., 2025). A presumptive diagnosis can be drawn based on the observation of characteristic cutaneous nodules typically distributed on the face, eyelids, muzzle, nostrils, udder, limbs and neck. The skin biopsy specimens should be collected aseptically and preserved in transport medium containing 20–50% glycerol in phosphate-buffered saline to maintain viral integrity for laboratory confirmation. Preliminary identification can be achieved through electron microscopy of skin samples, whereas virus isolation remains the diagnostic gold standard, particularly in newly affected or re-emerging regions. Primary and secondary cultures of bovine testicular or pre-pubertal lamb tissues have demonstrated high sensitivity for LSDV isolation (Davies et al., 1971). A range of laboratory techniques can further enhance diagnostic accuracy, including virus isolation and culture, Agar-Gel Immunodiffusion (AGID), Indirect Enzyme-Linked Immunosorbent Assay (ELISA), Direct Fluorescent Antibody Test, Polymerase Chain Reaction (PCR), Dot Blot Hybridization (DBH), Western blotting and histopathology (Awad et al., 2010). Differential diagnosis is essential to distinguish LSD from other dermatological and

poxviral infections such as demodicosis, pseudo-cowpox, dermatophytosis (ringworm), dermatophilosis, cutaneous tuberculosis, and cowpox (Chouhan et al., 2022; Pal et al., 2024a; Pal et al., 2024b). In addition to conventional assays, recent advances include the development of a Saltatory Rolling Circle Amplification (SRCA) based isothermal diagnostic test, which has demonstrated superior analytical sensitivity compared to conventional PCR and high concordance with real-time PCR. This method offers a rapid, cost-effective, and highly reliable diagnostic alternative, rendering it particularly advantageous for use in laboratories with limited resources or in field-based surveillance programs (Das et al., 2025).

Treatment, prevention and control

Lumpy skin disease virus has no specific antiviral treatment; therefore, management relies entirely on supportive care (Gautam et al., 2022). Therapeutic interventions typically include treatment of skin lesions, prescribing antibiotics to treat secondary bacterial infections and pneumonia, and the use of anti-inflammatory drugs to alleviate discomfort (Tuppurainen et al., 2018; Vinothraj et al., 2020). Broad-spectrum antibiotics have been shown to be effective in controlling secondary bacterial complications, while topical antiseptic ointments with fly-repellent properties can protect lesions from further damage (Vinothraj et al., 2020). Treatments to soothen the skin, and field use of glacial acetic acid and ascorbic acid has been associated with the regression of nodules and reduction of viral load have also been reported (Akther et al., 2023). Effective disease control requires a broader focus on preventive measures, including vector management, animal movement restrictions, strict quarantine enforcement, enhanced vaccination programs, timely veterinary care, and improved farm biosecurity (Das et al., 2021). Vaccination remains the cornerstone of prophylaxis, utilizing either homologous live attenuated vaccines (Neethling strain) or heterologous vaccines derived from sheep or goat pox viruses, with cross-protection being a characteristic feature of the *Capripoxvirus* genus (Abera et al., 2015; Pal & Gutama, 2023). Vaccine efficacy is determined by its ability to prevent clinical manifestations, suppress viremia, and reduce viral shedding, thereby promoting sterile immunity (Haegeman et al., 2021). Approximately 81% of vaccinated animals (homologous strain) showed positive for VNT after immunization, but 16% still got LSD clinical signs after viral exposure (Maneekesorn et al., 2025). The extensive use of the Bakırköy Specific Sheep Pox Virus (SPPV) vaccine in Turkey has probably contributed to some control of LSDV (Mazloum et al., 2023). The Gorgan goatpox strain (a goatpox virus-based vaccine), Romanian SPPV strain, and the Yugoslavian SPPV RM65 strain (Ramyar) are used as heterologous vaccines against LSDV. These vaccines were demonstrated to afford lower protection in cattle against LSDV and some effects such as fever, reduced milk production, the development of nodules in vaccinated cattle, and sometimes re-emergence were also reported in the vaccinated herds (Akther et al., 2023).

In addition, strict biosecurity measures such as limiting livestock movement, culling infected or exposed animals, implementing quarantine before herd introduction, and preventing herd mixing during grazing or watering are vital in curtailing spread (Namazi & Khodakaram, 2021). Rapid and accurate clinical diagnosis is equally essential to enable the timely application of eradication measures, including isolation or slaughter of infected animals, safe carcass disposal, thorough disinfection of affected premises, and insect control (Tuppurainen et al., 2005; Constable et al., 2016). Public health precautions are also important; in outbreak-prone regions, residents are advised to avoid consumption of cattle meat and to exercise caution with aquatic food sources, as carcasses of diseased animals may be discarded into water bodies (Kamal, 2019).

Conclusion and future perspectives

LSD has transitioned from a historically neglected poxviral disease of African cattle to a rapidly expanding transboundary threat with profound implications for livestock health, rural livelihoods, and global trade. Its emergence in India in 2019 and subsequent spread across the subcontinent exemplify the capacity of capripox viruses to exploit ecological, climatic, and anthropogenic drivers such as vector abundance, livestock mobility, and inadequate vaccination coverage. The multifactorial impact of the disease ranged from production losses and infertility to hide damage and mortality, has culminated in heavy economic burdens, as demonstrated by the substantial losses during the 2022 epidemic in India. Despite advances in molecular epidemiology and diagnostic innovations, LSDV continues to challenge veterinary services due to its environmental resilience, vector-mediated transmission, and evolving viral diversity. Control strategies have highlighted the pivotal role of homologous vaccination,

complemented by strong surveillance systems, strict biosecurity measures, movement restrictions, and rapid outbreak response. Evidence from Southeast Europe and South Asia indicates that achieving and sustaining high vaccination coverage (≥80-90%) over successive years is critical to interrupting transmission and progressing toward regional elimination.

The sustainable control of LSD in India and other endemic countries will require integrated "One Health" approaches that combine large-scale vaccination, strengthened veterinary infrastructure, effective vector management, genomic surveillance, and farmer awareness. Investment in indigenous vaccine development, rapid diagnostics suited to field conditions, and transboundary cooperation will be critical in mitigating future incursions. Ultimately, the global trajectory of LSD highlights both the vulnerabilities of livestock systems to emerging viral pathogens and the opportunities to build more resilient disease control frameworks through coordinated scientific and policy action.

Although significant progress has been made in the control of LSD, several challenges persist that necessitate continued scientific, technological, and policy attention. Vaccination remains the cornerstone of prevention, yet current homologous live-attenuated vaccines are limited by adverse reactions such as the "Neethling response" and incomplete protection in some herds, highlighting the need for next-generation approaches including DIVA-compatible formulations, recombinant vector-based and thermostable vaccines to overcome cold chain barriers. Parallel investment in indigenous vaccine manufacturing is vital to ensure reliable supply in endemic regions. Diagnostics also require advancement, with isothermal amplification assays (e.g., SRCA, LAMP) and portable rapid tests offering promise for timely field detection, while portable sequencing technologies could enable real-time tracking of outbreak dynamics and viral evolution. Moreover, the role of vectors such as *Stomoxys*, mosquitoes, and ticks in transmission remains incompletely understood, and with climate change likely to expand vector habitats, targeted eco-epidemiological studies are essential. Alongside scientific advances, comprehensive economic modelling is necessary to inform vaccination policies, compensation schemes, and international trade decisions, while regional coordination in South and Southeast Asia will be critical for harmonized reporting and control. Finally, sustainable control will depend on strong veterinary infrastructure, farmer compliance with vaccination and biosecurity protocols, and improved risk communication, with participatory epidemiology and digital extension tools offering new opportunities for rapid reporting and farmer engagement. Collectively, these future directions demand a multidisciplinary integration of virology, vaccinology, epidemiology, entomology, and socio-economics, supported by regional and global collaboration, to strengthen preparedness and resilience against LSD and other emerging transboundary animal diseases.

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Author's contribution: MP: Conceptualized the topic and contributed to the manuscript writing; RP: Ensured comprehensive coverage of the topic; RJZ: Conducted a detailed review of literature and drafted the initial manuscript draft; ASN: Contributed to the edition of the language, and clarity of the manuscript. All authors have approved the final submitted version. All authors approved to submit the article.

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