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EVOLVING EPIDEMIOLOGY, CLINICAL FEATURES AND CONTROL STRATEGIES OF LUMPY SKIN DISEASE IN KERALA, INDIA

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ABSTRACT

Lumpy skin disease (LSD), caused by lumpy skin disease virus (*Capripoxvirus*), has intensified across India in recent years, with Kerala reporting recurrent outbreaks since 2020 despite not being the epicentre of the 2022 national epidemic. The state's repeated, molecularly confirmed cases, including those affecting indigenous Vechur cattle, highlight the establishment of LSDV in tropical smallholder dairy systems where monsoon-associated vector abundance facilitates efficient transmission. This review consolidates recent advancements in the epidemiology, clinical features, diagnostics, therapeutic practices and prevention strategies of LSD, with a specific focus on Kerala. National and global evidence indicates that LSD spread is driven primarily by mechanical transmission by biting flies, mosquitoes and ticks, compounded by environmental stability of the virus and extensive cattle movement. Clinically, the disease manifests as fever, nodular dermatitis, lymphadenopathy and systemic complications, resulting in substantial economic losses due to reduced milk yield, mastitis, infertility, and hide damage. Diagnostic confirmation relies mainly on lesion-derived qPCR, supported by multiplex assays, histopathology and serological surveillance. Treatment remains supportive, centred on wound care, antibiotics, NSAIDs, hydration and vector control; although methylene blue has been included in recent advisories, its efficacy remains unvalidated. Control efforts depend on high vaccination coverage, preferably with homologous Neethling-strain vaccines along with vector suppression, farm-level biosecurity, movement restrictions and coordinated surveillance. Kerala's extensive vaccination campaign covering more than 1.9 million cattle has significantly reduced outbreak severity. Strengthened genomic surveillance, climate-linked vector studies, and validation of adjunct therapies are essential to achieve sustainable control under tropical endemic conditions.

Keywords: Lumpy skin disease, Capripoxvirus, Epidemiology, Clinical signs, Diagnostics, Vaccination, Vector control

Introduction

Lumpy skin disease (LSD), caused by lumpy skin disease virus (LSDV; *Capripoxvirus*), has emerged as one of the most consequential transboundary diseases of cattle in the last decade, producing major production losses through reduced milk yield, hide damage, abortions and occasional mortality. Large-scale incursions in South Asia since 2019 culminated in explosive epidemics across India in 2022–2023, affecting millions of bovines and exposing gaps in surveillance and control capacity (Kumar and Sharma ,2025). Kerala, though not the epicentre of the 2022 LSD epidemic, has reported recurrent, molecularly confirmed outbreaks affecting both crossbred and indigenous cattle, including the Vechur breed, underscoring the virus's adaptability across diverse agro-ecological systems and smallholder herds (Manoj *et al.,* 2025).

These episodes reveal diagnostic, clinical, and epidemiological challenges distinct from those observed in the intensive dairy regions of northern and western India (Sudhakar *et al.,* 2023). These Kerala episodes also highlight unique clinical and epidemiological features shaped by the region's humid tropical climate and high vector densities, raising questions about local transmission dynamics, viral evolution, and host susceptibility (Liang *et al.,* 2022, Kumar et al., 2021)). The growing body of evidence underscores an urgent need to consolidate current knowledge on LSD in Kerala and situate it within the broader national and global context to inform robust diagnostic, therapeutic, and control strategies suitable for endemic tropical settings.

Epidemiology of Lumpy Skin Disease — Global, Indian, and Kerala Perspectives

Lumpy skin disease (LSD) is a re-emerging, economically important poxviral infection of cattle caused by *Lumpy Skin Disease Virus* (LSDV), a member of the genus *Capripoxvirus*. The disease was historically confined to sub-Saharan Africa but has expanded over the past two decades to the Middle East, Europe, and Asia due to livestock movement and vector transmission (Tuppurainen and Oura, 2012). The global spread of LSD has been facilitated by mechanical transmission through biting arthropods such as *Stomoxys calcitrans*, mosquitoes, and ticks, leading to establishment in naïve populations and significant production losses (Tuppurainen et al., 2017). The virus's high environmental stability and wide vector range contribute to its persistence in endemic regions (Bianchini *et al.,* 2023).

In India, LSD was first confirmed in 2019 in Odisha (Sudhakar *et al.,* 2020) and subsequently spread nationwide within three years, establishing endemicity across diverse agro-climatic zones (Fig 1, 2). The 2022 epidemic was particularly devastating, affecting over two million cattle and causing nearly 100,000 deaths (Mathivanan *et al.,* 2022). Molecular characterisation from outbreaks in Karnataka, Gujarat, and Rajasthan revealed LSDV strains clustering within the Kenyan KSGP-like lineage, indicating a single or limited introduction event followed by extensive intra-country dissemination (Bayyappa *et al.,* 2025). Further supporting this, Akash *et al.* (2022) reported the first major LSD outbreak in

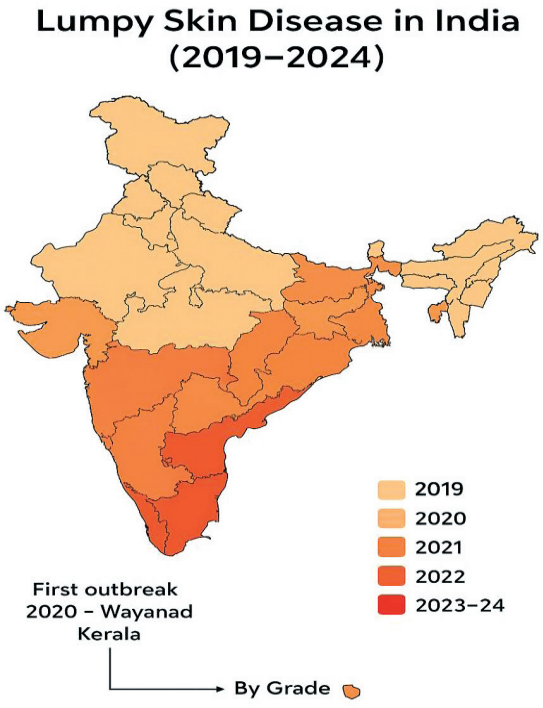

Fig 1. Year-wise outbreak of Lumpy skin disease in India

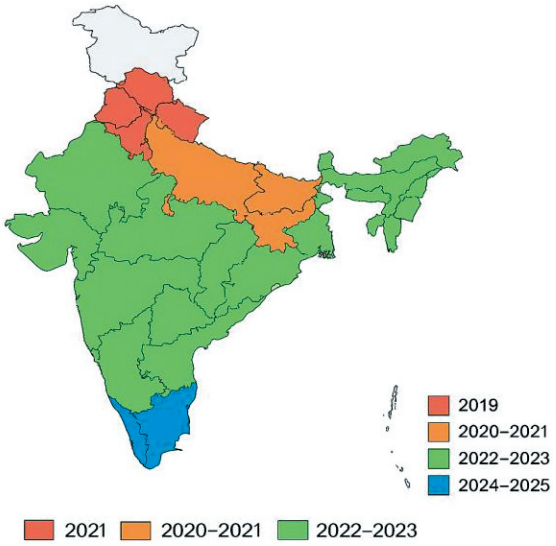

Figure 2. Temporal progression of Lumpy Skin Disease spread in India

Bidar district, Karnataka, where over 90% of villages were affected with an overall morbidity of 3.55 per cent (6% in cattle and 0.17% in buffaloes). The comparative Epidemiological Profile of Lumpy Skin Disease in Selected Indian States (2019–2025) is presented in Table 1.

The outbreak peaked between August and October, showing a strong positive correlation with temperature, humidity, and rainfall, implicating Haematobia (horn) flies as key mechanical vectors driving LSDV transmission in tropical zones. Seasonal analyses across India similarly demonstrate outbreak peaks during the monsoon and post-monsoon months, coinciding with heightened vector abundance and environmental conditions conducive to disease spread (Bhuiyan, 2025).

Table 1. Comparative Epidemiological Profile of Lumpy Skin Disease in Selected Indian States (2019–2025)

State	Year of First Reported Outbreak	Major Outbreak Periods	Estimated Morbidity (%)	Estimated Mortality (%)	Cattle Population Affected (approx.)	Vaccination Coverage (as of mid-2025)
Odisha	2019	2019–2020	5–15	1–3	>25,000	80%
Rajasthan	2022	2022 (July–Sept)	30–40	4–6	~1.2 million	92%
Gujarat	2022	2022 (July–Oct)	20–35	2–5	~0.9 million	88%
Maharashtra	2022	2022–2023	15–25	1–3	~0.7 million	90%
Tamil Nadu	2022	2023 (March–June)	5-10	<1	~50,000	85%
Kerala	2020	2022, 2023, 2025	10–15	1–2	~0.15 million	95% (1.906 million cattle)
Punjab	2022	2022–2023	20–30	3–4	~0.8 million	91%
Karnataka	2022	2022–2023	10–20	1–2	~0.4 million	87%

Kerala's experience exemplifies LSD's dynamics in smallholder, tropical systems. Although not the epicentre of the 2022 epidemic, the state has reported repeated, localised outbreaks since 2020, predominantly in livestock-dense districts such as Wayanad, Palakkad, and Thrissur. (Press Information Bureau, 2025). Between July 2022 and July 2023, 829 cattle deaths were reported, and 917,086 bovines were vaccinated, increasing to 1.9 million by mid-2025 (DAHD, 2023). The first molecular confirmation of Lumpy Skin Disease in indigenous Vechur cattle in Kerala demonstrated the virus's establishment in native herds and the susceptibility of local breeds, underscoring its endemic circulation. Histopathology revealed pyogranulomatous myositis and fibrinous vasculitis, highlighting the need for strengthened surveillance, vaccination, and vector control in the state (Manoj *et al.,* 2025). Transmission in Kerala mirrors national patterns, with peak activity during the warm, humid monsoon months that favour vector proliferation (Tuppurainen *et al.,* 2017). Overall, India's and Kerala's epidemiological patterns underscore LSD's transition from an exotic incursion to an endemic threat.

Clinical Spectrum of Lumpy Skin Disease

Lumpy skin disease (LSD) in cattle manifests as an acute or sub-acute febrile illness followed by characteristic cutaneous and systemic lesions. The disease typically begins with a sudden rise in body temperature exceeding 40°C, accompanied by anorexia, depression, and enlargement of superficial lymph nodes. Within one to three days, multiple firms, circumscribed

cutaneous nodules (1–5 cm in diameter) appear, often distributed on the head, neck, limbs, udder, and genitalia (Haider *et al*., 2024; Mazloum *et al.,* 2023). These nodules may extend to the mucous membranes of the mouth, nostrils, and respiratory tract and often undergo necrosis and ulceration. As healing progresses, thick crusts form and sometimes adhere to the underlying dermis, producing the characteristic "sitfast" lesions that slough slowly and leave permanent scars (Das *et al.,* 2025).

Ocular and nasal discharges, conjunctivitis, excessive salivation, enlargement of lymph nodes (prescapular, supramammary, and prefemoral), and marked oedema of the limbs, brisket, or ventral abdomen are frequently observed (Gharban *et al.,* 2019). Lameness may occur due to oedema or nodules on the limbs, and lesions on the muzzle or mouth can cause difficulty in eating. In lactating cows, a sharp decline in milk yield is common and often associated with secondary mastitis (Hidayat *et al.,* 2025). Severe infections may lead to pneumonia, gastroenteritis, or orchitis. Pregnant cows are prone to abortion or fetal death, and surviving animals may exhibit temporary infertility or prolonged anoestrus, whereas heifers and young bulls generally show milder disease (Haider *et al.,* 2024; Das *et al.,* 2025).

Morbidity in naïve herds can approach 100 per cent, but mortality generally remains below 5 per cent. During recent Eurasian and Asian outbreaks, morbidity of about 10 per cent and fatality of 1–2 per cent were reported (Mazloum *et al.,* 2023; Das *et al.,* 2025). Most animals recover within two to three weeks, though healing of ulcerated lesions may take longer. Residual scars and hide damage are common, contributing to significant economic loss through decreased hide value and production decline (Haider *et al.,* 2024).

The differential diagnosis includes pseudo-LSD caused by *Bovine herpesvirus-2*, photosensitisation, allergic dermatoses, and other poxvirus infections such as buffalopox (Mazloum *et al.,* 2023). Subclinical and atypical cases have been increasingly recognised in partially immune or vaccinated populations, and recombinant vaccine-derived strains may show altered clinical expression (Yang *et al.,* 2025; Haider *et al.,* 2024). Field observations from India and Indonesia have demonstrated regional variation in lesion distribution and severity, possibly influenced by breed susceptibility, climate, and management factors (Das *et al.,* 2025; Hidayat *et al*., 2025).

Overall, LSD presents a variable clinical spectrum ranging from mild

nodular eruptions to severe systemic disease. Although fatality is low, the infection imposes heavy economic burdens due to reduced productivity, infertility, and hide damage. Awareness of these variable clinical forms is crucial for early field recognition and differential diagnosis in endemic and newly affected regions.

Diagnostic approaches for LSD

Diagnosis of LSD requires a combination of clinical suspicion, epidemiological context and laboratory confirmation. Clinically, the sudden onset of fever, enlarged superficial lymph nodes and characteristic circumscribed cutaneous nodules may strongly suggest LSD in cattle; however, laboratory tests are essential for definitive confirmation, given overlap with other dermatologic or poxvirus-associated conditions. Among laboratory modalities, nucleic-acid detection assays—especially real-time (quantitative) polymerase chain reaction (qPCR) targeting conserved capripoxvirus genes (for eg. P32, GPCR, LSDV126 or other locus) — remain the gold standard. For example, a universal real-time PCR assay covering field, vaccine and recombinant strains achieved high sensitivity and specificity over five orders of magnitude (Alexander *et al.,* 2019). In large-scale investigations, qPCR on skin scabs or lesion material detected positivity in 98.6 per cent of scab samples versus only 4.2 per cent of whole blood samples in cattle from an outbreak in China, highlighting the superior yield of lesion-derived material (Li *et al.,* 2022). The international standards by World Organisation for Animal Health (WOAH) recommend real-time or conventional PCR specific for capripoxviruses as the most rapid laboratory confirmation.

In practice, tissue from skin nodules (biopsy or crust) or scab material is the optimal specimen: PCR sensitivities from such samples are significantly higher than from blood or swabs, given the transient nature of viremia and lower virus loads in peripheral blood (Aerts *et al.,* 2021). Multiplex or triplex qPCR assays capable of differentiating between wild-type, vaccine and recombinant strains of LSDV (and other capripoxviruses) have been recently developed (for example a triplex qPCR detecting LSDV, goatpox virus and sheeppox virus in a single reaction with limits of detection of ~5 copies/µL) and are recommended for surveillance and strain-differentiation workflows (Nan *et al.,* 2023).

Virus isolation remains a confirmatory tool and is especially valuable when coupled with sequencing of poxvirus genes or full genomes; although more time-consuming and requiring cell culture or embryonated egg systems, isolation enables phenotypic and genotypic

characterisation of emerged strains. Histopathology of skin nodules typically reveals granulomatous dermatitis with eosinophilic intracytoplasmic inclusions and, in some cases, necrotising vasculitis, thereby contributing to morphological confirmation, although not strictly diagnostic alone (Farag *et al.,* 2025).

Serological assays (e.g., capripoxvirus-specific ELISA, virus-neutralisation test) are less suited for acute diagnosis but play an important role in herd-level surveillance, seroprevalence estimation and post-vaccination monitoring. A field study in which asymptomatic cattle in India showed ~11–12 per cent seroprevalence demonstrates the utility of serology for detecting subclinical exposure. Recent reviews emphasise that subclinical infections (including animals without nodular lesions but with detectable virus DNA) are increasingly recognised, implicating them in virus transmission dynamics and surveillance gaps (Shumilova *et al.,* 2024).

Rapid field diagnostics are emerging: such as isothermal amplification (polymerase spiral reaction, PSR) assays targeting LSDV126 gene fragments have been described as pen-side tools with detection limits in the nanogram to femtogram range, offering potential for on-farm screening and rapid response in outbreak settings (Nandi *et al.,* 2023).

In sum, the optimal diagnostic algorithm in an LSD outbreak is: clinical and epidemiological assessment → sampling of skin nodules/crusts → real-time qPCR (with or without multiplex/triplex capacity) → virus isolation/sequencing if warranted → herd-level serology for surveillance. Given the critical influence of specimen type, targeted sampling of nodular lesions rather than blood is strongly recommended to maximise sensitivity. Recent advancements in strain differentiation assays and pen-side molecular methods further enhance diagnostic capacity for surveillance, outbreak control and epidemiological investigations.

Therapeutic interventions and supportive management

As no licensed antiviral therapy exists for Lumpy Skin Disease Virus (LSDV), clinical management is entirely supportive and targets pain control, prevention of complications, and restoration of physiological function. Current guidelines (WOAH, 2024) emphasise early wound management through cleansing and debridement of necrotic nodules ("sit-fasts") and the application of antiseptic or antibiotic topical agents to limit fly-strike and secondary bacterial invasion. Broad-spectrum systemic antibiotics, most commonly oxytetracycline or penicillin–streptomycin combinations, are

recommended to prevent or treat secondary bacterial dermatitis, pneumonia and mastitis arising from epithelial and mucosal damage (Haider *et al.,* 2024). Anti-inflammatory medication, particularly NSAIDs such as flunixin or meloxicam, is routinely administered to reduce pyrexia, oedema and pain, thereby improving feed intake, while corticosteroids are reserved for severe oedematous presentations because of their immunosuppressive potential. Fluid therapy (intravenous or oral electrolytes) and enhanced nutritional support, including vitamins A and B-complex, are critical for animals with anorexia or dehydration. Additional supportive measures include gentle milking or temporary cessation in cows with udder lesions, strict hygiene, stress minimisation, and robust vector control using repellents, insecticide sprays and fly-netting. Isolation of affected cattle and stringent biosecurity further reduces transmission risk. Recent Indian field advisories have proposed oral methylene blue (0.1%) as an adjunct therapy based on its putative broad-spectrum antiviral properties (Shrirame *et al.,* 2023; MAFSU Advisory, 2023), although robust, controlled clinical evidence supporting its efficacy or safety in cattle remains lacking, and its use should therefore be considered experimental and strictly supervised (Table 2). Overall, treatment mitigates clinical severity but does not influence viral clearance, reinforcing that vaccination and vector control remain the cornerstone of LSD prevention and herd-level disease management (Haegeman *et al.,* 2021; WOAH, 2024).

Prevention and Control Strategies

The control of Lumpy Skin Disease (LSD) depends on an integrated strategy combining vaccination, movement regulation, vector management, enhanced biosecurity, and strong institutional coordination. Mass vaccination remains the most effective and central intervention, with homologous live attenuated Neethling-strain vaccines demonstrating superior protection and field performance (Haegeman *et al.,* 2021; Tuppurainen & Oura, 2012). In India, where homologous vaccines have historically been limited, heterologous goatpox vaccines have served as emergency alternatives under national schemes such as ASCAD within the Livestock Health and Disease Control (LH&DC) programme. Kerala has achieved extensive coverage, vaccinating over 1.9 million cattle between 2022 and 2025, with boosters administered in accordance with WOAH guidelines to maintain population immunity. Movement restrictions—including zoning of outbreak areas, temporary transit bans, and mandatory isolation of affected animals—have been instrumental in reducing inter-district and inter-state dissemination. Complementing

Table 2. Therapeutic and Supportive Management Options for Lumpy Skin Disease (LSD) in Cattle

Treatment / Agent	Dose & Duration	Purpose / Mechanism	Evidence & Comments	Withdrawal Period
Methylene Blue (0.1 % oral solution)	Adults ≈ 300 mL PO q8h × 4 days; calves ≈ ½ dose. Topical 0.1 % spray for lesions.	Redox compound with potential antiviral and tissue-healing effect; may inactivate viral particles and reduce oxidative stress.	Included in the Government of India advisory (2023); field reports suggest improved appetite and healing but no controlled trial evidence.	Milk 96 h; Meat 14 days (Govt. advisory 2023).
Broad-spectrum antibiotics	e.g. Oxytetracycline 10 mg/kg IM × 5–7 days or Penicillin + Streptomycin as per label.	Prevent or treat secondary bacterial infections of skin lesions, respiratory tract, or udder.	Widely recommended in field manuals; not virus-specific but reduces mortality due to secondary sepsis.	As per drug label.
NSAIDs / Antipyretics	Meloxicam 0.5 mg/kg IM SID × 3 days or Flunixin 2 mg/kg IV SID × 3 days.	Alleviate fever, pain and inflammation; improve feed intake and comfort.	Standard supportive measure endorsed by FAO and Indian veterinary guidelines (2023).	As per drug label.
Antihistamines	Chlorpheniramine maleate 0.5 mg/kg IM SID × 3 days.	Reduce allergic and inflammatory responses; assist comfort.	Anecdotal support in field practice.	As per drug label.
Fluid & Nutritional Support	Oral electrolytes, molasses, vitamin and mineral supplements.	Correct dehydration and nutritional deficits; support recovery.	Universally recommended supportive therapy.	N/A
Wound & Fly Control	Topical antiseptics (e.g. povidone-iodine) and fly repellents (permethrin).	Prevent myiasis and secondary infection.	Field standard; essential to reduce spread via vectors.	N/A
Vaccination (prevention)	Live-attenuated LSD vaccine (India developed 2023) or heterologous goatpox/sheep pox vaccine during outbreaks.	Induces protective immunity; limits outbreak spread.	Proven effective in the Indian field	

these measures, active surveillance through the NADRES platform and ICAR-NIVEDI's national forecasting system has strengthened early warning capacity and guided targeted interventions at the farm and panchayat levels.

Vector control constitutes a critical pillar of LSD containment given the role of haematophagous insects in mechanical transmission. Strategic use of pyrethroid or organophosphate sprays, insecticide-impregnated ear tags, elimination of breeding habitats, and housing animals during peak vector activity substantially reduce attack rates (Tuppurainen *et al*., 2017). Enhanced biosecurity, disinfection, segregation and farmer education further support outbreak containment (WOAH, 2024).

Despite significant progress, important research gaps remain. Critical gaps persist in understanding virus–vector–environment interactions, highlighting the need for climate-linked and GIS-based transmission modelling to improve outbreak prediction in tropical systems. Strengthening genomic surveillance is crucial for monitoring viral evolution and assessing the risk of vaccine-escape variants, particularly under high vaccination pressure. Development and large-scale evaluation of homologous live-attenuated vaccines specifically tailored to Indian field conditions remain key long-term priorities.

Overall, Kerala's combination of high vaccination coverage, stringent movement control, aggressive vector management, and intensive farmer engagement has contributed to effective suppression of LSD, with active outbreaks largely limited to other Indian states by mid-2025. Sustained vigilance, continued investment in research, and a comprehensive One Health framework that integrates livestock, vector ecology, and environmental monitoring are crucial for durable, long-term control of LSD in India.

CONCLUSION

Lumpy skin disease has now established itself as an endemic transboundary threat in Kerala and across India, sustained by favourable climatic conditions, abundant vector populations, and continuous movement of cattle. Kerala's experience clearly demonstrates that high vaccination coverage, strengthened vector control, improved farm-level biosecurity and coordinated surveillance can significantly reduce disease burden even in smallholder tropical dairy systems. Despite these gains, critical knowledge gaps persist, including limited genomic surveillance to track emerging or recombinant strains, incomplete understanding of virus–vector–climate interactions, and the absence of validated antiviral therapies. The increasing field use of adjunct agents such as methylene blue underscores the urgency for controlled clinical trials to evaluate therapeutic efficacy and safety. Advances in molecular diagnostics and the emerging use of GIS-based risk prediction offer promising tools for earlier detection and more targeted response. Sustained control of LSD in Kerala and India will require long-term investment in homologous vaccine programmes, continuous farmer engagement and the adoption of a comprehensive One Health framework that integrates livestock health, vector ecology and environmental monitoring to safeguard the productivity and resilience of the dairy sector.

REFERENCES

Aerts, L., Haegeman, A., De Leeuw, I., Philips, W., Van Campe, W., Behaeghel, I., Mostin, L., & De Clercq, K. (2021). Detection of clinical and subclinical lumpy skin disease using ear notch testing and skin biopsies. *Microorganisms, 9*(10), 2171. https://doi.org/10.3390/microorganisms9102171

Akash, Shilpa, Ravindra, B. G., Halmandge, S., Kumar, T. R., Kasaralikar, V. R., & Kumar, D. (2022). Epidemiological studies on lumpy skin disease in cattle and buffaloes. *The Pharma Innovation Journal, 11*(10), 1057–1062.

Alexander, S., Olga, B., Svetlana, K., Valeriy, Z., Yana, P., Pavel, P., & Aleksandr, K. (2019). A real-time PCR screening assay for the universal detection of lumpy skin disease virus DNA. *BMC Research Notes, 12*(1), 371. https://doi.org/10.1186/s13104-019-4412-z

Bayyappa, M. R. G., Uma, C. R., Bijalwan, S., Tadakod, S., Nagaraj, S., Naragund, M., Pabbineedi, S. M., Basavarajappa, C. K. H., & Gulati, B. R. (2025). Molecular epidemiological and spatiotemporal analysis of lumpy skin disease outbreaks in cattle from Karnataka, India. *Frontiers in Cellular and Infection Microbiology, 15*, 1596973. https://doi.org/10.3389/fcimb.2025.1596973

Bhuiyan, M. R. (2025). Seasonal epidemiology and vector ecology of lumpy skin disease in South and Southeast Asia: A comprehensive review of knowledge gaps and future perspectives. *Bulgarian Journal of Veterinary Medicine*. https://doi.org/10.15547/bjvm.2025-0096

Bianchini, J., Simons, X., Humblet, M. F., & Saegerman, C. (2023). Lumpy skin disease: A systematic review of mode of transmission, risk of emergence and risk entry pathway. *Viruses, 15*(8), 1622. https://doi.org/10.3390/v15081622

Das, S., Srinivas, K., Milton, A. A. P., et al. (2025). Epidemiology of Lumpy Skin Disease in Northeast India and a New Method for Rapid Field Diagnosis. *AMB Express, 15*, 85. https://doi.org/10.1186/s13568-025-01891-9

Farag, T. K., Abou-Zeina, H. A. A., Abdel-Shafy, S., Allam, A. M., & Ghazy, A. A. (2025). Progress in diagnostic methods and vaccines for lumpy skin disease virus: A path towards understanding the disease. *Veterinary Research Communications, 49*(3),

134. https://doi.org/10.1007/s11259-025-10667-2

Gharban, H. A. J., Al-Shaeli, S. J. J., Al-Fattli, H. H. H., & Altaee, M. N. K. (2019). Molecular and histopathological confirmation of clinically diagnosed lumpy skin disease in cattle, Baghdad Province of Iraq. *Veterinary World, 12*(11), 1826–1832. https://doi.org/10.14202/vetworld.2019.1826-1832

Haegeman, A., De Leeuw, I., Mostin, L., Van Campe, W., Aerts, L., Venter, E., Tuppurainen, E. S. M., Saegerman, C., & De Clercq, K. (2021). Comparative evaluation of lumpy skin disease virus-based live attenuated vaccines. *Vaccines, 9*(5), 473. https://doi.org/10.3390/vaccines9050473

Haider, A., Abbas, Z., Taqveem, A., Ali, A., Khurshid, M., Naggar, R. F. E., Rohaim, M. A., & Munir, M. (2024). Lumpy skin disease: Insights into molecular pathogenesis and control strategies. *Veterinary Sciences, 11*(11), 561. https://doi.org/10.3390/vetsci11110561

Hidayat, Y. T., Primatika, R. A., & Drastini, Y. (2025). Prevalence of lumpy skin disease and associated risk factors in beef cattle in Rembang Regency, Central Java, Indonesia. *Veterinary World, 18*(1), 76–84.

Kumar, N., Chander, Y., Kumar, R., Khandelwal, N., Riyesh, T., Chaudhary, K., et al. (2021). Isolation and characterization of lumpy skin disease virus from cattle in India. *PLoS ONE, 16*(1), e0241022. https://doi.org/10.1371/journal.pone.0241022

Kumar, N., Sharma, S., & Tripathi, B. N. (2025). Pathogenicity and virulence of lumpy skin disease virus: A comprehensive update. *Virulence, 16*(1), 2495108. https://doi.org/10.1080/21505594.2025.2495108

Li, L., Qi, C., Li, J., Nan, W., Wang, Y., Chang, X., Chi, T., Gong, M., Ha, D., De, J., Ma, L., & Wu, X. (2022). Quantitative real-time PCR detection and analysis of a lumpy skin disease outbreak in Inner Mongolia Autonomous Region, China. *Frontiers in Veterinary Science, 9*, 936581. https://doi.org/10.3389/fvets.2022.936581

Liang, Z., Yao, K., Wang, S., Yin, J., Ma, X., Yin, X., Wang, X., & Sun, Y. (2022). Understanding the research advances on lumpy skin disease: A comprehensive literature review of experimental evidence. *Frontiers in Microbiology, 13*, 1065894. https://doi.org/10.3389/

fmicb.2022.1065894

Maharashtra Animal & Fishery Sciences University. (2023). *Revised treatment protocol for management of lumpy skin disease in cattle* (Advisory No. MAFSU/Advisory-11/2023).

Manoj, R. V., Tresamol, P. V., Preena, P., Manoj, M., Anoopraj, R., Justin Davis, K., Shyma, V. H., & Vijayakumar, K. (2025). Occurrence and molecular confirmation of lumpy skin disease among Vechur cattle in Kerala. *Journal of Veterinary and Animal Sciences, 56*(2), 387–392.

Mathivanan, E., Raju, K., & Murugan, R. (2023). Outbreak of lumpy skin disease in India 2022—An emerging threat to livestock and livelihoods. *Global Biosecurity, 5*. https://doi.org/10.31646/gbio.187

Mazloum, A., Schalkwyk, A. V., Babiuk, S., Venter, E., Wallace, D. B., & Sprygin, A. (2023). Lumpy skin disease: History, current understanding and research gaps in the context of recent geographic expansion. *Frontiers in Microbiology, 14*, 1266759. https://doi.org/10.3389/fmicb.2023.1266759

Nan, W., Gong, M., Lu, Y., Li, J., Li, L., Qu, H., Liu, C., Wang, Y., Wu, F., Wu, X., Wang, Z., Chen, Y., & Peng, D. (2023). A novel triplex real-time PCR assay for the differentiation of lumpy skin disease virus, goatpox virus, and sheeppox virus. *Frontiers in Veterinary Science, 10*, 1175391. https://doi.org/10.3389/fvets.2023.1175391

Nandi, S., Mahajan, S., Mishra, R., Nautiyal, S., Agrawal, R. K., Singh, M., Biswas, S. K., Chander, V., Singh, K. P., & Sharma, G. K. (2023). LSDV126 gene-based molecular assays for specific detection and characterization of emerging lumpy skin disease virus. *Journal of Virological Methods, 312*, 114665. https://doi.org/10.1016/j.jviromet.2022.114665

Press Information Bureau of India. (n.d.). *https://pib.gov.in*

Shrirame, D. S., Sawale, A. V., Muneshwar, S. D., Thipe, S. S., & Honale, V. S. (2023). Review on lumpy skin disease. *International Journal of Research and Technology Innovation, 8*, 408–417.

Shumilova, I., Prutnikov, P., Mazloum, A., Krotova, A., Tenitilov, N., Byadovskaya, O., Chvala, I., Prokhvatilova, L., & Sprygin, A. (2024). Subclinical infection caused by a recombinant vaccine-like

strain poses high risks of lumpy skin disease virus transmission. *Frontiers in Veterinary Science, 11*, 1330657. https://doi.org/10.3389/fvets.2024.1330657

Sudhakar, S. B., Mishra, N., Kalaiyarasu, S., Jhade, S. K., Hemadri, D., Sood, R., Bal, G. C., Nayak, M. K., Pradhan, S. K., & Singh, V. P. (2020). Lumpy skin disease outbreaks in cattle in Odisha State, India in August 2019: Epidemiological features and molecular studies. *Transboundary and Emerging Diseases, 67*, 2408–2422.

Tuppurainen, E. S. M., & Oura, C. A. L. (2012). Lumpy skin disease: An emerging threat to Europe, the Middle East and Asia. *Transboundary and Emerging Diseases, 59*, 40–48.

Tuppurainen, E. S. M., Venter, E. H., Shisler, J. L., Gari, G., Mekonnen, G. A., Juleff, N., Lyons, N. A., De Clercq, K., Upton, C., Bowden, T. R., Babiuk, S., & Babiuk, L. A. (2017). Capripoxvirus diseases: Current status and opportunities for control. *Transboundary and Emerging Diseases, 64*(3), 729–745. https://doi.org/10.1111/tbed.12444

World Organisation for Animal Health. (2024). *Lumpy skin disease* (Chapter 3.4.12). In *WOAH Terrestrial Manual 2024*.

Yang, Y., Jia, H., Sun, M., Guo, A., Xia, T., Shu, H., & Cao, L. (2025). Lumpy skin disease virus LSDV001 protein positively regulates inflammatory response by promoting assembly of the TAK1–TAB2/3 complex. *mBio, 16*, e01677-25. https://doi.org/10.1128/mbio.01677-25