DOI: 10.53992/njns.v10i1.248 NUST Journal of Natural Sciences, Vol. 10, Issue 1, 2025

**Review Article**

# Lumpy skin disease in Pakistan: unraveling the outbreak and charting future horizons

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## Abstract

Lumpy skin disease (LSD) emergence in Pakistan threatens agricultural economics centered on endemic bovine species. Originally restricted to Africa, LSD epidemics recently disseminated to Middle East and South Asia via infected cattle imports and biting vectors. The 2021 outbreak in Pakistan, which involved over 220,000 cases, was examined with respect to transmission among smallholder herds, diagnostic challenges, control measures, and research priorities concerning this *Capripoxvirus*. Clinical manifestations include hide lesions and debilitating lactation reductions. Initial cases likely originated from cross-border animal movement. Dominant transmission involves arthropod vectors while herd immunity remained nonexistent enabling spread to naive cattle populations across provinces. Ring vaccinations around detected cases therefore focused on *sheeppox* or *goatpox* inoculums - albeit suboptimal protection - complemented by quarantines and animal tracing. However, localized, inability to curb outbreak emphasizes poor vaccine access and movement control. As Pakistan's livestock sector constitutes 60% agricultural GDP across mostly smallholder production, LSD inflicts serious socioeconomic repercussions. Quantifying burden and livestock-specific transmission dynamics is thus imperative to prevent future LSD epidemics through integrated approaches blending vaccination, surveillance, farmer training, and advocacy of evidence-based control policies suited for Pakistan's unique circumstances. The research explores the 2021 LSD outbreak in Pakistan to examine its economic impact combined with disease transmission patterns alongside obstacles for disease management. The study combines epidemiological evidence with real-world control approaches to deliver critical guidelines for policymakers and veterinary practitioners who aim to enhance LSD preventative and response systems in Pakistan.

**Keywords:** Lumpy skin disease, Capripoxvirus, Livestock epidemics, Agricultural economics in Pakistan, Integrated disease control strategies.

**Article History**: **Received:** 15 Sep 2024, **Revised:** 19 Mar 2025, **Accepted**: 24 Mar 2025, **Published:** 30 Apr 2025.

## Introduction

Lumpy skin disease (LSD) is a contagious viral disease in which lumpy skin disease virus (LSDV) is the main culprit. LSDV belong to *Capripoxvirus* subfamily and member of Poxviridae family [1, 2]. LSD is cross-border, vector mediated, non-zoonotic infectious disease that is currently targeting ruminants specially cow and buffaloes. Although sheep and goats do not catch this infection naturally but when sheep, goats as well as giraffe and gazelles impalas were deliberately injected with infectious fluid, they developed some symptoms such as skin lesions and fever [3]. Although the animals exhibit severe symptoms, the mortality rate remains low [4]. Arthropod vectors, such as mosquitoes, ticks, and biting flies, facilitate the transmission of viruses between cattle that are separated by short geographical barriers.[5]. Typical symptoms of the disorder are decreased lactation, temperature, swelled lymph nodes, fluid filled lesions causing loss of appetite and emaciation and sterility [6]. It is a notifiable condition to alert other countries as it has a huge impact on international livestock trade. It was 1$^{st}$ reported in Zambia in the year 1929 but later on spread to other countries of Africa and South Asia including India and Pakistan as they are agricultural based countries [7]. The exact nature and reasons behind spreading of infection in India and Pakistan are not much clear but suspected causes are cross border trade and transfer of virus through vectors from neighboring countries because restriction of cattle trade across border is challenging when official data of cattle population number is unavailable, checking and identification of animals and proper scrutiny of moving animals is not well managed, resultantly transboundary trade of animals continues at limited scale despite the legal sanctions. Farmers play primary role in controlling the virus but they are reluctant to report the suspected LDS affected animal to veterinary authorities due to fear of potential ban on their trade, adding another challenge in virus management [8].

LSD is now threatening the sustainability of this vital economic sector by causing reduced milk yields, severe hide damage, inability to draft infected animals, and mortalities. Trade restrictions on import of cattle and bovine products from LSD endemic countries have also impacted the livestock economy. Annual economic losses from LSD in Pakistan are conservatively estimated at over US $27 million [9]. However, lack of surveillance, diagnosis, and reporting constraints the true quantification of its burden. Given the food security and livelihood implications involved, tackling the LSD epidemic is critical for Pakistan. This warrants an in-depth understanding of its epidemiology, diagnosis, prevention and control in the uniquely diverse livestock production systems found in the country. Significant knowledge gaps exist on the dynamics of LSDV transmission between smallholder dairy herds, breeds and production environments that are more susceptible, and molecular characterization of strains circulating in different regions [10]. Several studies exist on Lumpy Skin Disease's global epidemiology but research about transmission dynamics and economic impacts and control measures for Pakistan's livestock remains scarce. A review study serves to address this knowledge gap through an extensive evaluation of Pakistan's recent LSD outbreak while recommending systematic disease control methods in this sector. This review aims to provide a comprehensive overview of the current status of LSD in Pakistan and insights into priority areas for future research and policy to help curtail this economically important emerging disease.

## Etiology of lumpy skin disease virus

Almost one dozen viruses belong to Poxviridae family including LSDV,

majorly targeting pet animals, only dogs are omitted. *Chordopoxvirinae* and *Entomopoxvirinae* are the two subfamilies targeting vertebrates and invertebrates respectively. LSDV causing lumpy skin disease belong to *Capripoxvirus*, genus of *Chordopoxvirinae* family which constitutes other viruses of domestic animal species such as sheep and goats called *sheeppox virus* and *goatpox virus* respectively [11] . LSDV has enveloped rectangular morphology with size of 320 × 260 nm, comprises dsDNA genetic material and resides in host cytoplasm for its replication. Genome length of virus is 151k bp, number of putative genes is 156 and has incredible nucleotide homology of 97% with relative viruses e.g sheep and goat poxviruses. Terminal region of LSDV encodes nine genes with potential virulence are absent in other poxviruses of *Capripoxviruses* genus due to accumulation of mutations which has direct implications of host range limitation and made them unable to cause disease in bovines. LSDV contains 146 conserved genes responsible for encoding group of proteins that control range of functions from transcription, genetic material replication, nucleotide synthesis to virulence and host range [12]. Other viruses particularly *suipox virus*, *yatapox virus* and *leporipoxvirus* have remarkable amino acid and collinearity homology of approximately 65% with LSDV. However, less similarity is found (43%) at terminal regions due to augmented mutations. Similar genes of LSDV with other members of poxviruses include interleukin-1 binding protein, IL-10, GPCR and EGF protein [13]. Figure 1 shows structural diagram of LSD virus [14].

**Host range**

European and Asian cow breeds (also termed as Bos Taurus and Bos Indicus respectively) and buffalo are the target hosts for the virus but statistics and studies elaborate that Bos Taurus are more vulnerable. Also, calves have more tendency to catch virus and produce symptoms in 1-2 days only [1]. It is seen that wild animals are more immune to this virus but deliberate administration of virus in wild animals such as giraffe, oryx and impala can cause clinical symptoms [3]. No significant observations have been made regarding the transmission and persistence of the virus by wild animals.

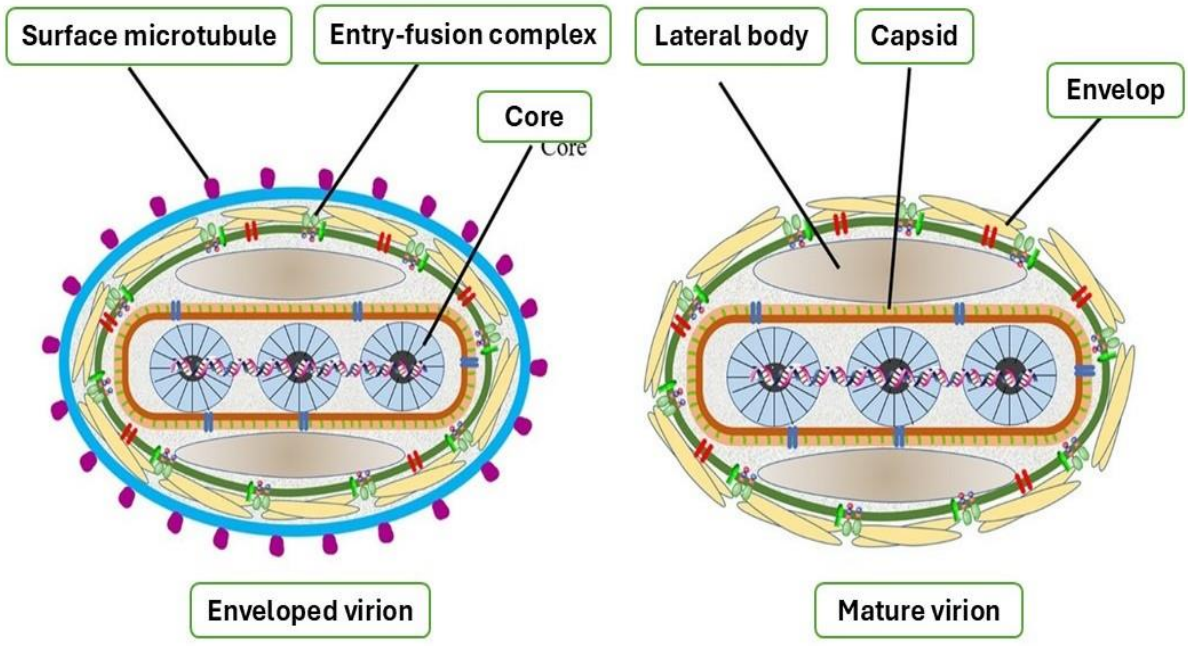


Figure 1: Structural diagram of Lumpy skin virus.

No significant observations have been made regarding the transmission and persistence of the virus by wild animals. As this virus is non-zoonotic, humans are also excluded from its host range [15].

**Transfer of virus**

Research has demonstrated the transmission of LSDV by insect vectors, including mosquitoes and ticks, as illustrated in Figure 2. In South Africa, LSDV outbreak occurred in localized herd of animals by arthropod vectors, emerged due to moist and warm climate conditions. This highlights the challenge of virus management as only quarantine was not enough. Likewise, some experiments carried out to see the role of insect vector and observed that when Aedes mosquito was allowed to feed on infected cattle for 2 days to 1 week, it was able to transfer the virus to healthy cattle. Additionally, stable flies were also actively transporting the virus among sheep animals which was confirmed after live virus was found in the body of stable flies fed on diseased animal [16, 17]. However, the species *Stomoxys calcitrans*, a member of the Stomoxys genus, was unable to transmit the virus [18].

Recent studies are elaborating the potential role of ticks in spreading of LSDV [19]. Studies reveal that African blue ticks transfer virus through transstadial manners, while brown ear ticks follow interstadial transmission pattern. Similarly, study conducted on factors encouraging lumpy virus concluded that moist weather was contributing in vector population rearing. Also, migration of exotic animals in the native herd multiplied the risk percentage. An unexpected outcome was observed, as no correlation could be established between animal drift and disease incidence [20].

Another experiment was performed and observed that when healthy cattle were allowed to share water drinking trough with diseased animals, infection transmitted in healthy animals. These results become complex when latest studies explain only half of the naturally infected cattle experience clinical sign while major proportion of deliberately infected ruminants for experiment purposes, turned into viremic [19]. As latest diagnostic tools were not invented at the time when these experiments were conducted, so new tools will assist in complete understanding of complicated transmission pattern of lumpy disease virus. Although LSDV transmission through semen has not been elaborated but deliberate infected male animals had presence of virus in their semen even after three weeks of viral attack [17].

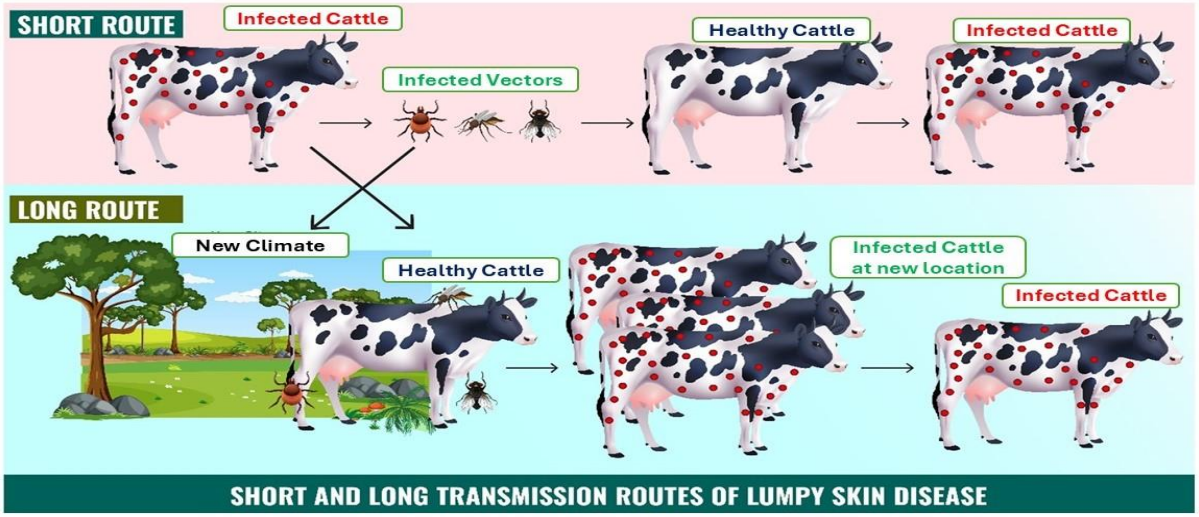


Figure 2: Transmission routes of LSD

Relatively new study concluded that even 6 weeks of post infection, virus was still there in the semen of bull, similarly another study observed presence of virus in semen after 258 days infection [21]. When bulls were vaccinated with live attenuated vaccine of Neethling variant then virus was not detected in their semen [22]. In both experiments, viruses were detected in the semen of bulls whose genitalia were infected and remained under viral attack. In a similar vein, a cohort of gynecologists conducted examinations on approximately 600 to 650 cows daily over a period of 30 consecutive days during a viral outbreak in Egypt in 2006. Their observations revealed that one-quarter of the female animals were infected with the virus, approximately 90% exhibited disruptions in their estrous cycles, and there was a noticeable reduction in ovarian size compared to normal conditions. Additionally, hormone levels, such as progesterone, were found to be below optimal levels [23].

The proliferation of LSDV vectors depends heavily on environmental condition primarily influenced by temperature, humidity and rainfall. Warm temperatures combined with high humidity drive mosquito (Aedes spp.) and tick (Rhipicephalus spp.) and stable fly (Stomoxys spp.) breeding that leads to higher LSDV transmission rates [24]. Regions characterized by higher annual precipitation, which result in stagnant water conditions, facilitate the development of breeding sites for vectors, thereby enhancing the transmission of diseases. Vector control operations need a solid science foundation to execute targeted control programs effectively [25].

**Signs and symptoms**

Lumpy skin disease is a contagious viral infection that can affect cattle of every breed and age. Yet, virulence of virus and severity of infection are majorly described by the type of viral strain and immunity of infected animal as cattle may experience no clinical signs to life threatening symptoms. Clinical signs [24]are multiple but frequent and prominent are fever, skin lesion filled with fluid, swelling of lymph nodes, edema of internal organs, lachrymation and reduced lactation [4]. Earliest symptoms are viremia and temperature that followed by inflammation of lymph nodes. That inflammation cause lachrymation and after this, skin lesions become visible and entire animal goes under the severe virulent attack. Figure 3 shows the progression pattern of lumpy skin disease in an animal.

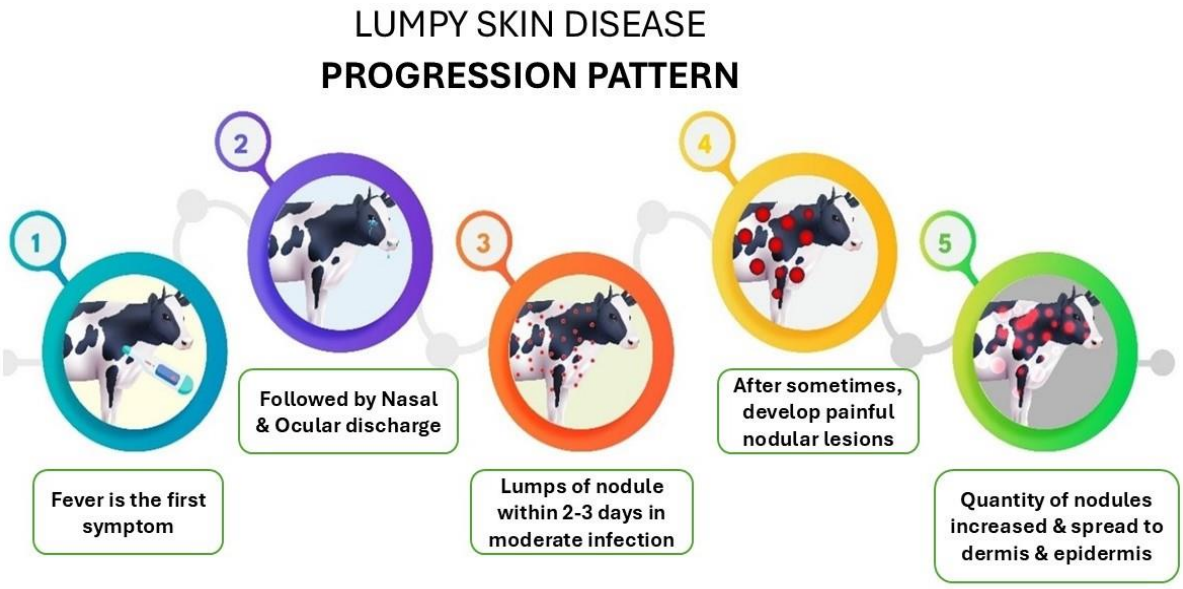


Figure 3: Progression pattern of LSD

Critically ill animal may also witness the development of ulcerative blisters or lesions in mucosal boundaries of eye and in mouth tissues that lead to mastication discharge from nose and lachrymation. Also, pox lesions fill all the respiratory track from larynx to lungs [26]. Virus takes almost 3-12 days as incubation time before violent attack. And time duration between incubation and infection detection is one to two weeks [1]. Body temperature of animal increases from 40 to 42◦C for 1-3 days and in rarely for 10 days. Other symptoms include dizziness, discharge from pharynx, loss of appetite and depression etc. [4]. Multiple solid nodules appear in the epidermal layer of animal skin, number of nodules are not specific, they are few to numerous. Severity and number of nodule lesions have no impact of age and gender of animal but they tend to target head, throat, fore and hind limbs, reproductive organs and udders [1]. Diameter of lesions is between 2 to 5cm. Moreover, infected animals may exhibit excessive salivation, weakness, and, in severe cases, mortality. In summary, clinical sign & symptoms of viral infection are contagious disease with extensive fluid filled lesions on the epidermis and dermis of the skin [8]; high morbidity with low mortality; [27] lesions on head, throat, chest, sex organs, respiratory and gastrointestinal track [28]; edema and fever [29]; inflamed synovitis and tenosynovitis [30]; can have bacterial infection such as pneumonia; skipping of estrous cycle due to high fever and instable pregnancy (OIE). Severity of illness may vary but highly affected animals take longer time to recover from viral infection. Although mortality rate is only up to 5% but economic losses are huge [31].

**LSDV Management**

Lumpy skin disease has no ultimate cure. However the implementation of preventive measures and administration of antiviral and antibacterial drugs can help to alleviate the symptoms of illness. As bacterial attack is common in LSD infected animals, certain antibiotics are used on a routine basis that include penicillin, tetracycline and cephalosporin for 5 days to one week according to severity of disease. Treatment studies carried out in 2011 concluded that conjugate drugs strategies are more effective [32]. Also Abdelbari, Elshafeey [33] suggested the administration of steroid free inflammatory drugs and antihistaminic medicines. To regulate elevated body temperature, the administration of antipyretic medications, such as paracetamol, is recommended. Multivitamins help to alleviate anorexia attacks. While the treatment of LSD is costly and complete recovery is rarely attained, it is often recommended to limit movement as a feasible measure to enhance health and prevent economic hardship [4].

**Restricted movement of animals**

Cattle movement to and from infected area should be strictly prohibited. The medical surveillance team must actively monitor regions with an elevated risk of viral transmission [34]. Quarantine with medical facilities, culling of severely infected animals, proper burying of carcass, disinfecting the area under the use of animals and pest population control are the inevitable measures to take. While quarantine, effective vaccination, and the culling of diseased animals are commonly recommended measures, but ethical concerns associated with animal culling render this option less practical [35].

**Pest control**

Pest control is a precautionary measure not a clinical solution as it is unable to restrain virus virulence or its outbreak. Regular application of pesticide or insect repellents along with disinfectants are recommended to be effective means to manage arthropod vectors [36]. However, complete elimination of virus is unlikely because of presence of insect vectors anyways and

lapses in management of infected animals due to any reason. Hence, risk factor is always there [26].

**Awareness**

Awareness is unescapable because significant control of virus is not possible without contribution of people associated with animal value chain and agriculturist. It is imperative to educate cattle handlers, veterinary professionals, agriculturists, cattle transporters, and artificial inseminators, as well as the general public, on the necessary precautionary measures. Education can help veterinary handlers and workers in early detection of virus [8].

**Vaccination**

The most effective strategy for controlling LSDV infection to date is the vaccination of cattle, particularly prior to viral exposure. Live attenuated vaccines are more preferable as they have the ability to activate effective and constant immune response [37]. However, certain challenges are also associated with vaccines such as inflammatory reactions in vaccine administered animals [38].

**Homologous vaccine**

Live attenuated vaccine is homologous vaccine which has high efficacy against LSDV. Commonly used strains of lumpy skin disease virus are Neethling, KSGP-O 180 and 240 strains. During virus outbreak in South Africa, Neethling strain was recovered and made attenuated by multiple passages through kidney cells of lamb followed by chicken eggs for 60 times and 21 times respectively [39]. Similarly, Madagascan strain attenuated by passing through rabbit and calf kidney cells for almost hundred times. High passage numbers indicate the virulency of LSDV. Despite attenuation, still these vaccines impart certain health issues in animals on maiden administration that may comprise appearance of tiny lesions, inflammation and reduced lactation [40]. Successful elimination of infection through bulk administration of Neethling strain attenuated vaccine was seen in southeast Europe in year 2017 [41]. KSGP-O 180 and 240 strains are abbreviated as Kenyan sheep & goat virus while actually these are LSDV strains and vaccines based on these strains have been used in multiple countries such as Egypt, Israel and Ethiopia [13]. A potential safety concern is the virulency of attenuated vaccines which varies in different hosts, in some hosts they act as less virulent while present health issue in another host [42]. Reduced attenuation passages are typically required for the KSGP strain, which is suitable for sheep and goats. However, cattle and buffalo may exhibit clinical symptoms even following vaccine administration [39]. Suggested administration route is subcutaneous because UV rays of sun can damage the activity of vaccine in field.

**Heterologous vaccine**

**GTPV**

Goatpox virus GTPV is heterologous vaccine and its maiden administration (commercially as Gorgan goatpox virus vaccine) on cattle was done in the year 2015, Ethiopia. Immune response was closely monitored then to evaluate its efficacy [20]. Volume of vaccine was kept 1ml and viral titer of 3.6-4.4 TCID50 per ml (50% tissue culture infection dose) was used which generated satisfactory immune response and very minute clinical signs were appeared. Another comparative study of sheeppox virus (SPPV) and GTPV vaccines carried out and concluded that GTPV vaccine is more immunogenic that induce long term adaptive immunity. GTPV vaccines need less attenuation passages than homologous vaccine for safer application in cattle. Additionally, GTPV vaccines are cost-effective due to their production from

native sources, which facilitates their accessibility to a large population [20]. However, extensive safety evaluation of native vaccine is recommended to avoid any post vaccine complications.

**SSPV**

Sheeppox virus vaccine has been used in many regions especially in Middle East and Europe. The SSPV RM65 strain is predominantly employed in its attenuated form. It is noted that even strong dose of vaccine is unable to provide complete protection which was observed in LSD outbreak in Israel in the year 2006 [43]. Homologous vaccines are considered more successful due to high efficacy and immunogenicity [41]. Incomplete protection of SSPV vaccine is thought to be linked with poor control of vector, inability to restrict mobility of cattle and large population of animals. Deteriorating effects are very rarely caused by SSPV vaccine, however, high dose may attribute to produce certain clinical symptoms which include inflammation and appearance of small lesions [44].

**Inactivated vaccine**

These vaccines present benefits as well as drawbacks as compared to attenuated vaccines. The most prominent feature of inactivated vaccine is its safety due to inability to replicate. Their virulency is reversed along with conjugation of virulent variant [45]. Inactivated vaccines are particularly beneficial for vulnerable countries with sophisticated health system of animal identification and previous health record. As there are no separate terrestrial codes for inactivated and live attenuated vaccine in World Organization for Animal Heath (WOAH), any vulnerable country if use inactivated vaccine, will be deprived of the lumpy skin disease virus-free status [46]. Practically, if we talk about vaccine efficacy, it is seen that further dose administration is needed after two doses along with suitable adjuvant attachment for effective immune response generation. However, it will add sufficient cost and make it economically unfavorable [47, 48]. Inactivated vaccines have been used to trigger weak immune response to generate short term immunity [49]. There is an underway process to produce short term or transient immune response generating inactivated vaccine against sheeppox virus and goatpox virus and if it goes smooth, hopes are bright for the development of short-lived inactivated vaccine against LSDV. Since the initial attempt in 1982, numerous efforts have been undertaken, and recent experiments have successfully elicited a complete immune response against the sheeppox virus [45]. In a study conducted in 2020, animals vaccinated with both inactivated and attenuated Neethling strain of LSDV, in conjunction with adjuvants such as oily emulsion, elicited a sufficient immune response. When the live viral LSDV strain entered the animal's body, no clinical signs were observed; however, viral genetic material was detected in the animal's DNA [50].

**Post vaccination reactions**

The safety of vaccines against lumpy skin disease virus, especially of live attenuated vaccine is crucial factor for virus free yet vulnerable countries. As activation of vaccine mediated immunity requires nearly 14-21 days, in meantime animal suffers clinical symptoms. That might range from appearance of small lesions to adverse reactions of inflammation called “Neethling reaction” which are reported after 7-14 days of vaccination [51]. Other vaccine associated symptom include reduced lactation, temperature and lesions that are clearly different from virulent virus borne fluid filled lesions. Generally, viruses of sheep and goats have no impacts on cattle, however, when high potency SPPV and GTPV vaccines were Injected to cows and buffaloes, considerable immune response was generated. Practically,

maiden dose of live attenuated vaccine generates clinical signs while booster dose is harmless [52]. A recent study conducted in Israel demonstrated that animals previously vaccinated with SSPV exhibited no clinical symptoms when subsequently vaccinated with a live attenuated LSDV vaccine. The same study further examined the effects of vaccination on lactation over a one-month period and concluded that the vaccine does not significantly reduce milk production in cattle [41]. Whole genome sequencing study carried out by Croatian scientists suggest no change in genome occurs after full attenuation mimicking parent virus [53]. Although, very few research studies carried out on the outcome of injecting recombinant vaccine i.e. vaccines exposed to multiple *capripoxviruses* however, Russian scientists developed hypothesis on Gershon 1989 study stating that recombinant virus vaccines encourage various LSDV strains emergence in vaccinated animals. Same study further elaborates that administration of homologous vaccine can sufficiently decrease the lumpy skin disease virus incidence [54]. One of most impactful approaches is using genomic data to separate vaccine variant from field variant of virus. Exploitation of latest molecular tools will assist in elaborating commercial vaccine efficacy against newly identified strains of lumpy skin disease virus and hence better clinical strategies can be formed to combat virus.

## Outbreak of LSD and economic losses in Pakistan

In November 2021, the index case of lumpy skin disease (LSD) was reported in the Jamshoro district of Sindh province, Pakistan. Over 36,000 cases of this viral infection were subsequently detected in livestock animals in this region alone. By April 2022, the Provincial Livestock Department declared an epidemic due to the disease's rapid spread and substantial impact on animal health and agricultural economics. LSD is caused by the lumpy skin disease virus (LSDV), a pathogen in the Capripoxvirus genus with no commercially available vaccine. Uncontrolled animal movement and an immunologically naïve population enabled dissemination to other provinces. While mortality was under 10%, morbidity approached 100% in some herds. Clinical signs included pyrogenicity, nodules on the skin, and lesions in mucosal membranes. Mitigation efforts focused on quarantines, movement restrictions, disinfection, supportive care (e.g. fluids, anti-

Table 01: Summary statistics of LSD cases in Pakistan

| Province/ Administrative Unit | Cattle population | Cases | | | | Rate (%) | |
|---|---|---|---|---|---|---|---|
| | | Total | Recovered | Died | Vaccinated | Mortality | Morbidity |
| **Punjab** | 14,635,446 | 35,046 | 26,509 | 1,242 | 2,261,178 | 0.0085 | 0.239 |
| **Sindh** | 11,392,469 | 53,668 | 53,097 | 571 | 3,711,538 | 0.005 | 0.471 |
| **KP** | 8,837,227 | 92,357 | 52,002 | 34,818 | 1,262,797 | 0.0532 | 0.844 |
| **Baluchistan** | 6,140,540 | 22,225 | 12,520 | 469 | 89,586 | 0.0076 | 0.362 |
| **Gilgit Baltistan** | - | - | - | - | - | - | - |
| **AJK** | 545 ,239 | 18,103 | 15,874 | 992 | 127,501 | 0.0653 | 1.165 |
| **Total** | 41,550,921 | 221,399 | 160,002 | 38,092 | 7,452,600 | 0.0917 | 0.533 |

inflammatory), and identification of possibly infected breeding bulls through intensive sampling. Further epidemiological investigations into transmission dynamics and genomic sequencing of viral isolates is imperative for developing evidence-based control policies against this emerging Capri poxvirus threat in Pakistan [55]. According to Pakistan Economic Survey 2022-2023, Table 1 shows the summary statistics of LSD cases in Pakistan [56].

The emergence of lumpy skin disease virus (LSDV) in Pakistan threatens agricultural economics and food security. With an estimated 49.6 million heads of cattle and 41.2 million buffaloes, Pakistan has the 2nd largest bovine population globally. These livestock contribute approximately 60% of the agricultural gross domestic product and 35-40% of income for ~8 million rural households. The high density of immunologically naïve hosts enabled the rapid spread of LSDV following its presumed introduction in 2021, resulting in morbidity approaching 100% in affected herds. Over 190,000 animals have been impacted as of 2022. As the 3rd largest milk producer globally, a widespread reduction in dairy yields could have devastating socioeconomic consequences. Previous outbreaks have documented a median loss of $375 USD per bovine fatality and $141 USD worth of milk loss per affected cow. The scarcity and higher prices of dairy could disproportionately impact the nutritional status of impoverished communities. Movement restrictions and compulsory stamping out may also disrupt the livestock value chain [57]. Mitigating this emerging viral threat necessitates research into LSDV genomic epidemiology and transmission dynamics in Pakistan. Cost-benefit analyses should guide vaccination policies and biosecurity protocols to contain future LSDV outbreaks. Monitoring milk yields and conducting farmer surveys can also quantify productivity losses to model the impact on national gross domestic product over time [10].

## Diagnostic and treatment approach used for LSD in Pakistan

### Diagnostic Approaches

As a previously exotic pathogen, rapidly and reliably detecting LSDV was crucial for Pakistan's mitigation response. Clinical signs like firm, circumscribed nodules on hairless areas and fever can indicate LSD, but laboratory-based diagnostics are required for confirmation [58]. Polymerase chain reaction (PCR) assays detect viral DNA in tissue biopsies, blood, or swabs. PCR-based diagnosis has over 90% accuracy, with results available within hours [59]. For this reason, Pakistan established PCR testing centers upon initial LSD detection. Serological techniques like virus neutralization tests also confirm LSDV exposure but require a wider surveillance net [60].

Pakistan further employed enzyme-linked immunosorbent assays (ELISAs) and lateral flow devices for mass antibody screening. While antigen-detecting ELISAs cannot differentiate between antibodies stimulated by infection or vaccination, their high-throughput capacity aids surveillance. Similarly, lateral flow devices provide on-site diagnosis in minutes via immunochromatographic detection of LSDV antibodies. Despite slightly lower sensitivity than PCR, serological assessments remain critical tracing tools [61].

### Treatment approaches

As viruses lack susceptibility to antibiotics, LSD therapies aim to alleviate clinical manifestations. Supportive treatment is essential, including fluid therapy and anti-inflammatories to reduce fever and lesions. Secondary bacterial infections common in LSD also warrant antibiotic administration.

Culling seriously affected animals that fail to respond to treatment prevents unnecessary suffering [62].

The vaccination control of LSDV outbreaks in Pakistan depends on heterologous vaccine strategies that use sheeppox and goatpox vaccines. These vaccines supply limited protection against the disease because their effectiveness ranges between 60% and 80%. Insufficient protection is a major issue because Pakistan needs a homologous vaccine against LSDV. Distribution problems with vaccines along with cold chain logistics and economic pressures that cause farmers to reject vaccination programs create further obstacles to vaccination programs. The immediate requirement exists for homologous vaccines specifically developed for local regions and better vaccine access needs immediate resolution. Pakistan implemented ring vaccination around detected cases using sheeppox or goatpox vaccines, which provide cross-protection against LSDV. However, vaccine efficacy remains variable and availability limited. Restricting livestock movement and disinfecting affected premises were also enforced. While still evolving, these integrated approaches demonstrate Pakistan's intent to control this agricultural threat. Field studies conducted in the region reveal that the protective effect ranges from 60 to 80% yet variable. The lack of a specific homologous LSDV vaccine poses a significant problem for the solution. Local vaccine production development alongside mass vaccination strategy research is vital to strengthen disease control in this region [42]

Early detection and containment efforts likely prevented more severe LSD consequences in Pakistan. Continuing to optimize diagnostic capacity, treatments, and vaccines while educating farmers on biosecurity will strengthen resilience against LSDV. With the virus now considered endemic regionally, it poses an enduring challenge requiring evidence-based mitigation policies that consider local dynamics in this heavily livestock-reliant nation [14]. Sustained political will and public-private coordination are paramount to safeguarding Pakistan's economy, food supply, and rural livelihoods against capripox threats.

**Recommendations**

Pakistan must prioritize robust surveillance and epidemiological investigations in order to fully characterize lumpy skin disease virus (LSDV) transmission patterns across the country's diverse livestock production systems. Implementing animal identification programs and tracing movement of animals would enable precise quarantines and ring vaccination strategies around detected cases, which requires strong coordination between provinces. Locally assessing the efficacy and safety profile of existing sheeppox and goatpox vaccine candidates in different Pakistani cattle breeds could uncover more cost-effective immunization options suitable for the massive at-risk bovine population. Additionally, innovative outreach initiatives are imperative to educate smallholder farmers on identifying LSD clinical manifestations in animals, promptly reporting suspected cases, and adopting biosecurity best practices to their circumstances. Biosecurity procedures must be effective to stop LSDV from spreading. The main biosecurity strategies involve these components: (1) Cattle movements need restrictions from infected areas and (2) Enforcement of strict isolation rules for new herd additions, and (3) Using pesticides combined with disinfectants for cleaning livestock operations, and (4) Immediate communication of potential instances to authorities by farm owners and operators. The spread of LSDV can be reduced by conducting awareness programs targeted at farmers who receive education about biosecurity standards to promote better compliance. Pakistan should pursue

integrated disease management guided by mathematical modeling to balance interventions like sheeppox vaccination, welfare culling in severe cases, quarantines, and strategic livestock movement restrictions against safeguarding the livestock value chain that underpins the economy. Characterizing circulating viral strains via genomic sequencing can uncover local virulence shifts, trace the geographic origins of outbreaks, and select vaccine candidates with cross-protection against emerging LSDV variants in Pakistan. Pursuing these evidence-based recommendations at the interface of monitoring, mitigation, and farmer behavior change provides the best opportunity for Pakistan to get ahead of this infectious livestock disease threatening crops, incomes, food availability and agricultural GDP for the millions dependent on endemic bovine species.

## Conclusion

Pakistan, as a lower-middle-income country, faces significant challenges in controlling infectious livestock diseases, primarily due to limited resources and a largely smallholder-based farming system. Lumpy skin disease (LSD) poses a severe threat to the economy, household incomes, food security, and agricultural GDP, which are largely dependent on endemic bovine species. With morbidity rates exceeding 90% in affected herds, it is clear that effective, integrative strategies are crucial to mitigate the spread of LSD and prevent productivity losses. Key priorities must include movement restrictions, farmer education on disease identification and biosecurity practices, as well as targeted vaccination and robust surveillance systems. By implementing proactive policies, fostering regional coordination, and promoting evidence-based outbreak prevention and contingency planning, Pakistan can significantly reduce the impact of LSD. Ultimately, these measures will help safeguard the livelihoods of millions of smallholder farmers who rely on livestock farming for their sustenance and economic stability.

## Declaration of interest statement

**Acknowledgement:** Not Applicable

**Funding:** Not Applicable

**Conflict of Interest Statement:** The authors declare that they have no direct or indirect conflict of interest

**Ethical Approval:** Not Applicable

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