Sheep and Goat Pox Disease: Epidemiology, Diagnosis, Prevention and Control

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Sheep and goats play a crucial role in the economy of the rural population through their contributions of meat, wool, and hides. However, their productivity is threatened by various infectious diseases, with sheep and goat pox (SGP) being particularly significant. The economic impact of pox diseases extends beyond animal health, as they hinder the international trade of ovine and caprine livestock and their derivatives. While the symptoms of sheep and goat pox (SGP) can be suggestive, a conclusive diagnosis can only be reached through laboratory testing. The condition's etiology can be attributed to distinct yet closely related viral pathogens: the Sheep pox virus (SPV) affecting sheep and the goat poxvirus (GPV) infecting goats. These viral agents exhibit notable antigenic and genomic homology, not only with each other but also with the lumpy skin disease virus (LSDV) responsible for lumpy skin disease (LSD). Taxonomically, all three viruses are classified within the genus Capripoxvirus, a member of the Poxviridae family. In some regions, SPV and GPV can infect each other's hosts, complicating diagnosis and epidemiological studies. Recent research has shown that these viruses are phylogenetically distinct, and molecular tools can be used to differentiate them. The most effective control measure for SGP is vaccination with attenuated vaccines, which provide long-lasting immunity. Comprehensive information on the isolation, identification, pathology, epidemiology, diagnosis, and prevention of sheep pox is essential. Such knowledge is valuable for the

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scientific community and policymakers to develop effective strategies for controlling and eradicating the disease. This chapter presents an updated overview of sheep and goat pox and its management.

Introduction

In recent years, India's livestock industry has emerged as a vital component of the country's expanding and multifaceted agricultural economy (Tisdell & Gali, 2000). Following rice, milk represents the second most significant agricultural commodity contributing to the Indian economy. Numerous studies have demonstrated that livestock rearing promotes a more equitable distribution of wealth and creates employment opportunities in rural areas. By providing a stable source of income and cushioning seasonal variations in livelihoods, livestock farming plays a crucial role in supporting the rural poor (Singh et al., 2020). Sheep and goats play a vital role in sustaining the livelihoods of impoverished rural communities. These small ruminants provide a range of essential products-including meat, milk, fiber, skin and contribute significantly to the socio-economic stability and resilience of farming systems (Shivakumara et al., 2017). According to the latest Livestock Census (2019), India holds a substantial livestock population, ranking second globally in goat numbers (148.88 million) and fourth in sheep numbers (74.26 million), reflecting increases of 14.1% and 10.1%, respectively (Sumana et al., 2020). Despite this large population of small ruminants, their full economic potential remains largely untapped. This underperformance is primarily attributed to suboptimal rearing practices, limited farmer education, inadequate sanitation, and restricted access to veterinary services. These challenges collectively contribute to the high prevalence of infectious diseases. Among these, pox diseases in sheep and goats stand out as major constraints to the growth, productivity, and profitability of the small ruminant sector. Pox infections in sheep and goats are highly contagious and represent economically significant viral diseases on a global scale. Clinical manifestations vary depending on the host species and geographical region but typically include extensive pox lesions on the skin and mucous membranes, persistent high fever (pyrexia), swelling of superficial lymph nodes, and generalized nodular eruptions on hairless or non-wool-covered areas of the body. In some cases, affected animals may also develop pneumonia (Manjunatha Reddy et al., 2015). Within a susceptible flock, morbidity rates can reach up to 75%, while mortality may rise as high as 50%. Although the disease affects all age groups, it tends to be more severe in young animals, where the case fatality rate can approach 100% (Zewdie et al., 2021).

Economic Consequence of Sheep and Goat Pox Disease

Sheep and Goat Pox (SGP) poses substantial economic challenges, particularly for farmers engaged in subsistence agriculture in developing countries. The disease exerts both immediate and long-term impacts (Babiuk et al., 2009). Livestock losses due to mortality result in direct financial setbacks, while the expenses associated with treatment and care of infected animals further burden limited household resources. Even animals that survive the infection often suffer a decline in market value due to residual health effects or visible lesions. The presence of SGP can disrupt local economies, leading to reduced income, job losses, and, in some cases, forced migration as individuals seek alternative livelihoods. At the national and international levels, the disease hampers trade by limiting the movement of animals and animal products, restricting the importation of improved genetic stock, and hindering the transition to more intensive and productive livestock systems. Collectively, these consequences contribute to a significant economic burden on affected communities and national economies. Based on research sheep and goat pox has been identified as a significant economic threat to livestock production (Singh & Prasad, 2008; Singh & Prasad, 2009). Their findings suggest that this disease ranks as the third most impactful ailment in sheep farming, resulting in annual financial losses of approximately 17.38 lakh rupees. The disease's impact on goat production is even more severe, ranking second to Peste des Petits in Ruminants (PPR) regarding economic damage. Yearly losses attributed to goat pox are estimated at around 37.2 lakh rupees. These figures underscore the substantial economic burden of sheep and goat pox on small ruminant farming operations. A study conducted in Maharashtra revealed significant impacts of SGP outbreaks, leading to an average morbidity of 63.5% and a mortality rate of 49.5%. The study also opined that an affected flock can take up to 6 years to recover from the disease, resulting in average annual income losses of 30-43%. Approximately 5000 flocks in Maharashtra are annually affected by SGP, with a loss of up to INR 107.5 million (Garner et al., 2000, Naidu et al.2025). Measuring the economic losses caused by SGP and the potential benefits of interventions is crucial for decision-making on disease control programs and helping to determine whether the reduction in disease losses justifies the costs of control measures (Rawlin et al., 2022). The impact of Sheep Pox Virus (SGP) differs from country to country, both in quality and quantity. SGP is considered a potential animal bioterrorism agent due to its high morbidity and mortality rates, rapid spread, and severe socio-economic and public health implications. Amongst the 15 animal pathogens recognized by the World Health Organization (WHO) and 23 by the Animal and Plant Health Inspection Service (USDA), it is considered one of the potential biological warfare agents. Therefore, maintaining stringent biosecurity measures for this virus is crucial. The Centers for Disease Control and Prevention (CDC) in Atlanta classifies SPV as a Risk Group II viral agent (Bhanuprakash et al., 2006). In contrast, in India, the Department of Biotechnology classifies it as a Group III viral agent (Office Memorandum, 2021).

Geographical Pattern of Sheep and Goat Pox

Sheep and goat pox disease is prevalent across North Africa. It extends to various East Africa, the Middle East, and Asia countries, including Tanzania, Turkey, Iran, Iraq, Afghanistan, Pakistan, Nepal, India, China, Bangladesh, Vietnam, and Chinese Taipei. The primary mode of SPV and GPV transmission is respiratory, but these viruses can also enter the body through other mucous linings or broken skin. The viral particles may be excreted through saliva, nasal and eye secretions, milk, urine, feces, and scabs. However, insects like flies can transmit them via contaminated objects or mechanically. Hansen first documented goat pox in Norway in 1879, while sheep pox in Central Asia spread to various Western nations. The first outbreak of goat pox (GP) was reported in India in 1936 by the Indian Veterinary Research Institute, Izatnagar whereas sheep pox (SP) in Bombay (1931-1932) and Karnataka (Manjunatha Reddy et al., 2024). Over time, goat pox cases have been reported in several states, including Haryana, Uttar Pradesh, Orissa, Madhya Pradesh, Tamil Nadu, and Maharashtra, and sheep pox has been recorded in nearly all states of India (Rao & Bandopadhyaya, 2000, Bayyappa M.R.G 2025 et al). Since these initial reports, frequent outbreaks have occurred across various states, making India endemic to small ruminant pox diseases (Sumana et al., 2020) and according to Bardhan et al. (2020), Karnataka, Rajasthan, West Bengal, Andhra Pradesh, and Odisha belonged to the high-risk sheep & goat pox category. A recent study by Bora et al. (2021) has documented the spread of GTPV infection from domestic animals to wild species in northeastern India, highlighting its impact on both wild gorals and domestic goats, with evidence suggesting possible cross-transmission. Factors such as climate change, habitat loss, rising international trade, and tourism can facilitate the establishment of new diseases in previously unaffected areas. National Institute Veterinary Epidemiology and Disease Informatics (NIVEDI)) reports that, from 2013 to 2023, Tripura's highest outbreaks occurred in Jammu and Kashmir, followed by the third place occupied by Karnataka.

Transmission

Sheep pox and goat pox viruses commonly spread via the respiratory route during close interactions and can also penetrate through other mucous membranes or broken skin (Hurisa et al., 2018). These viruses are present in various bodily fluids and excretions, including saliva, nasal and eye secretions, milk, urine, feces, skin lesions, and scabs. SPPV and GTPV are notably resilient and can remain viable in the environment for extended durations, potentially infecting susceptible animals. There is experimental evidence of mechanical transmission of sheep pox and goat pox virus by the insect vector *Stomoxys calcitrans* (the stable fly). However, other species such as *Mallophaga, Damalinia*, *Hydrotaeairritans,* and *Culicoidesnubeculosus* have not been effective in transmitting SPPV, even though *Hydrotaeairritans* has been found with the virus after feeding on infected sheep (Kitching and Mellor, 1986). These findings suggest that insect vectors may play a role in transmission, but their significance in natural outbreaks remains uncertain. SPP and GTP outbreaks can occur year-round, underscoring the importance of non-vector transmission (Tuppurainen et al., 2017, GBM Reddy et al.2023).

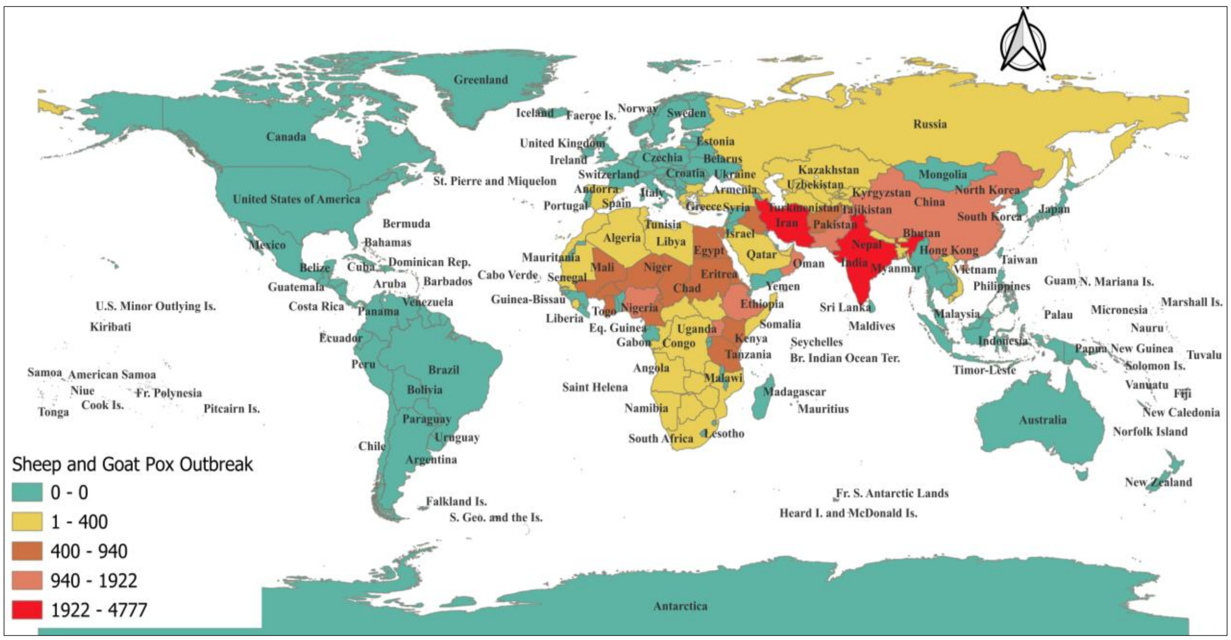

Figure 1. Global transmission routes and hotspots of sheep pox and goat pox virus (WOAH)

Environment factors

Annual trends in sheep pox incidence can fluctuate due to various factors, including reporting efficiency, host susceptibility, and environmental conditions. The disease typically peaks between November and May, coinciding with adverse climatic conditions that may stress sheep and suppress their immune systems. Macro-ecosystems play a role, with higher incidence rates observed in areas of low rainfall, high temperatures, and vegetation dominated by thorny plants like Acacia species. Soil type also influences occurrence, with red and black soils associated with a higher incidence rate (Bhanuprakash et al., 2005).

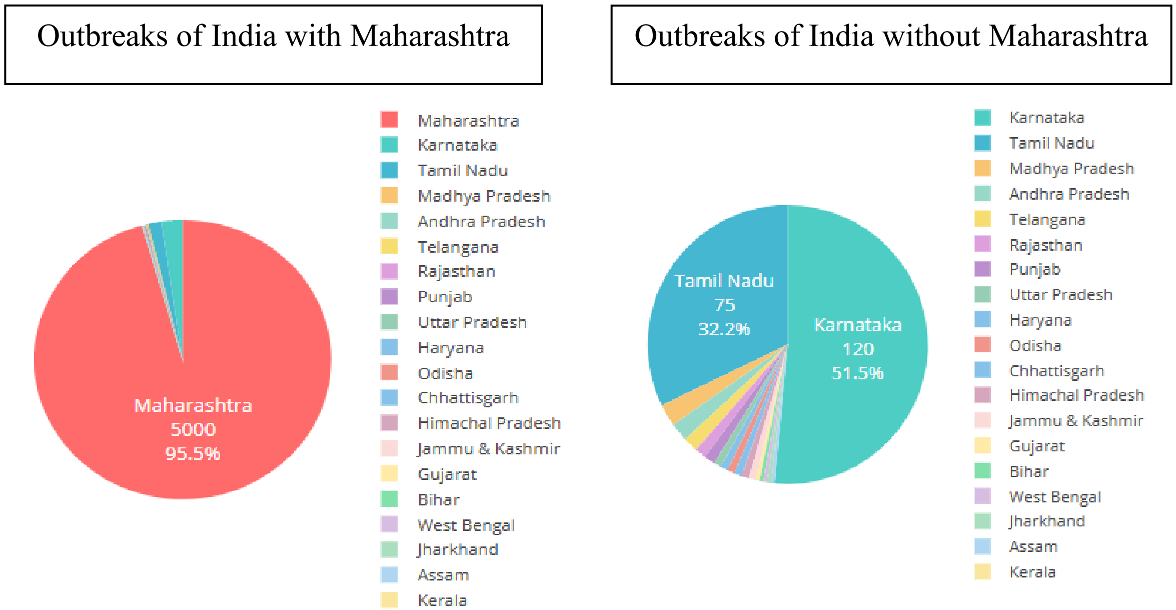

Figure 2. Spatial Distribution of Sheep and Goat Pox Outbreaks in India (DAHD, GoI)

Risk Factors Associated with Sheep and Goat Pox Disease

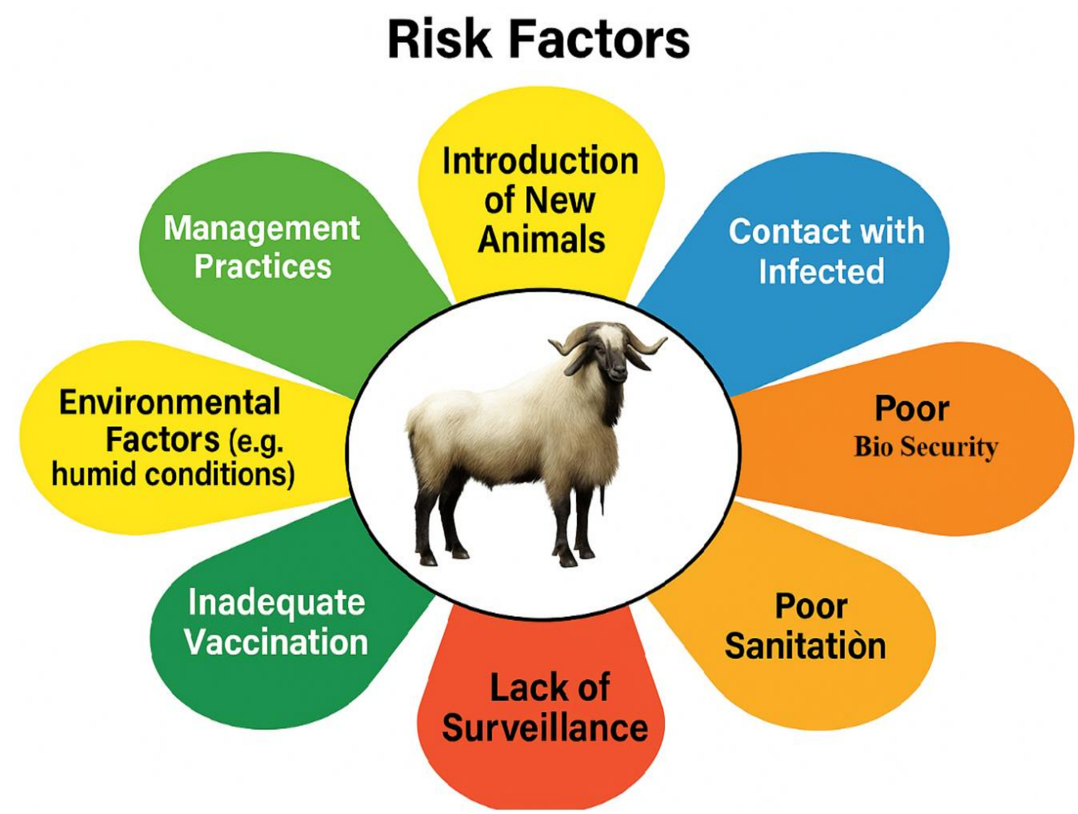

Figure 3. Interaction of epidemiological drivers

Risk factors for disease can be categorized into three interconnected groups: agent factors, host factors, and environmental factors. These categories are not isolated but rather influence each other in complex ways, collectively shaping the course and spread of diseases. The interplay between these factors is crucial in understanding and predicting disease patterns and outcomes (Figure 2).

Agent factors

Sheep pox and goat pox viruses are the members of the Capripox genus within the Chordopaxvirinae subfamily of the Poxviridae family. Their large size and complex structure characterize these viruses. Their genetic material consists of double-stranded DNA enclosed within a protective envelope. The structure of these viruses is distinctive, featuring an outer layer composed of tubular structures arranged in an irregular pattern (Figure 3). This outer layer encapsulates a core shaped like a dumbbell, along with two lateral bodies whose function remains unclear.

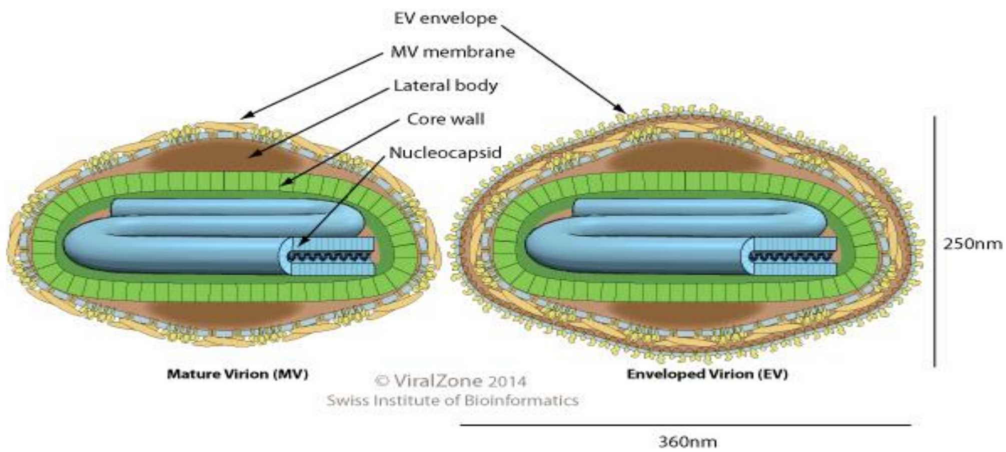

Figure 4. Morphology of pox virus Source: Guyassa, C. (2022).

The core of the viral particles houses the viral DNA and various proteins essential for viral replication. When these viruses are released from host cells through budding rather than cell lysis, they acquire an additional envelope containing lipids from the host cell membrane and virus-specific proteins. The presence of lipids in the viral structure makes Capripox viruses susceptible to various disinfectants, lipid solvents, and acidic substances, which can disrupt their structural integrity. These characteristics of SGP viruses are crucial for understanding their behavior, transmission, and potential vulnerabilities to various control measures.

Capripoxviruses, which include the poxviruses affecting sheep and goats, share significant antigenic and physicochemical similarities. However, they remain distinct entities. Interestingly, these viruses can occasionally undergo recombination, leading to strains capable of infecting both host species. A key distinguishing feature among sheep and goat poxviruses lies in the P32 protein (Kiran Kumar et al., 2020). Specifically, the sheep poxvirus uniquely possesses an Aspartic acid residue at position 55th of this protein, a characteristic absent in other viruses within the same genus. This molecular difference is an important marker for differentiating these closely related pathogens. Evidence shows that Kenya's sheep pox, goat pox virus, and Yeman and Oman infect sheep and goats. African pathogen variants typically exhibit comparable virulence in both ovine and caprine hosts, whereas Indian strains generally display a pronounced species-specific tropism, primarily infecting their corresponding host animals (Suman et al., 2020). The Capripoxvirus demonstrates remarkable resilience in typical environmental conditions, maintaining its viability for extended periods regardless of the presence of potential host animals. While sunlight and elevated temperatures can neutralize the virus, it thrives in cool, dark settings for up to half a year. The virus can endure multiple cycles of freezing and thawing, though this process may diminish its ability to infect hosts. These characteristics contribute to the virus's persistence and potential for transmission over time (WOAH, Manual)

Host factors

Host factors such as Stress and concurrent infections, like PPR and Orf, can increase the likelihood of SGP infection. Age is another crucial factor, with younger animals being more vulnerable and experiencing more severe symptoms and higher mortality rates compared to adult ones (Manjunatha Reddy et al., 2017). Additionally, genetic predisposition appears to influence disease occurrence, as studies have indicated that European breeds may be more susceptible to SGP than African and Asian breeds. It suggests that breed-specific factors contribute to the prevalence and severity of SGP in different populations (Mirzaie et al., 2015).

Clinical signs and pathology

Upon entry, the virus begins to multiply in the host's tissues. The time between infection and symptom onset varies between 4 to 8 days for Sheep pox and 4 to 15 days for goat pox and LSD. Initial symptoms include elevated body temperature, accelerated breathing, swollen eyelids, and nasal discharge. The virus first spreads through the bloodstream, concentrating in lymph nodes before disseminating to organs like the liver, lungs, and spleen. Infected sheep may experience loss of appetite and adopt a hunched posture. Within 48 hours, small round lesions of approximately 1 cm appear across the body. These are most visible in the head, neck, ears, armpits, and tail region. As the disease progresses, animals may develop eye and nasal inflammation and swelling of the lymph nodes, particularly those near the shoulder blades(Fig 4). Excessive drooling is another potential infection symptom (Hamdi et al*.,* 2021,GBM Reddy et.al 2024).

Figure 5. Popular lesions on the face, ear, and under the tail

Postmortem Findings and Histopathological Observations

Postmortem examination of affected animals revealed several consistent gross lesions, including congestion of the tracheal mucosa and the presence of nodules resembling lentils or bullets. The lungs and spleen exhibited characteristic white patches, and lymph nodes showed grayish necrotic lesions. An increased volume of blood-tinged fluid was observed in the pleural cavity. In certain cases, the lungs displayed multiple areas of consolidation, indicative of secondary bacterial infections or viral pneumonia. Histopathological examination of the skin demonstrated notable alterations in both the epidermis and dermis. These included hyperkeratosis (thickening of the outer keratin layer), acanthosis (increased number of epidermal cell layers), hyperkeratinization (excessive keratin production), intercellular and intracellular edema, and degenerative changes in the sebaceous glands and hair follicles. These microscopic changes are consistent with those reported by Zewdie et al. (2021) and Manjunatha Reddy et al. (2024).

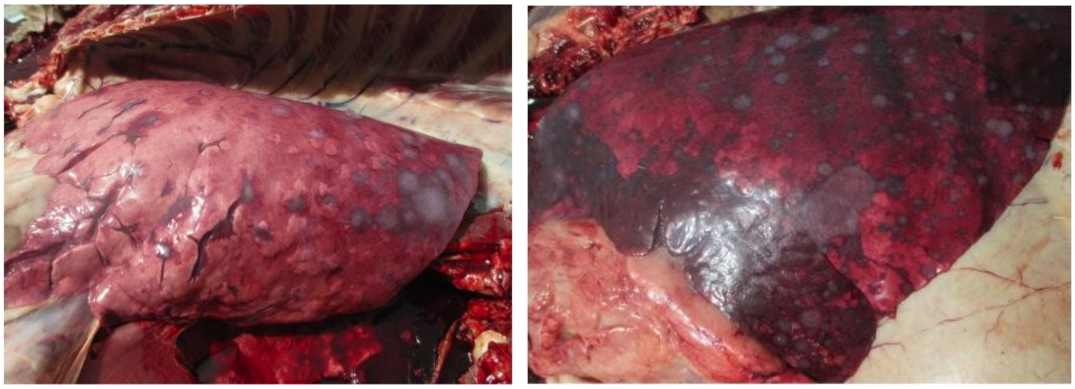

Figure 6. Lung of sheep pox case with concurrent apical pneumonia photograph Colin Scrivener

Microscopic examination of the affected lung tissue reveals congestion, red hepatization, exudation, and coagulative necrosis with a pronounced inflammatory response(Figure 5). There is also a thickening of the interlobular septae. Additionally, there is a notable reduction in lymphocyte numbers in the para-cortical regions, and both spleen and lymph nodes lack germinal centers (Rao & Bandyopadhyay, 2000; Manjunatha Reddy et al., 2015).

Diagnosis

Diagnosis of sheep and goat pox (SGP) begins with clinical observation, with affected animals typically presenting with small, round, nodular skin lesions localized to the head, neck, ears, axillary regions, and tail base. Postmortem examination may reveal distinctive white necrotic foci often described as "gunshot-like" lesions on the lungs, liver, and occasionally the rumen. However, since sheep pox and goat pox infections produce similar clinical and pathological manifestations, differentiating the two diseases based solely on symptoms and gross lesions remains challenging (Bowden et al., 2008). Historically, the agar gel precipitation test was widely employed for the identification of Capripoxviruses. Advances in diagnostics, particularly the use of soluble antigen fractions, have led to the development and refinement of various serological and molecular assays (Mirzaie et al., 2015). As such, a reliable diagnosis of SGP requires a combined approach, integrating clinical evaluation with laboratory-based confirmation to ensure accurate detection and differentiation.

Laboratory diagnosis

The diagnosis of sheep and goat pox is based on the detection of either specific viral antigens or the host antibody response. For antigen detection, virus isolation in tissue culture remains a traditional gold standard due to its specificity; however, it is labor-intensive and time-consuming, limiting its routine use (Mirzaie et al., 2015). As a presumptive diagnostic method, electron microscopy (EM) can be utilized to visualize the characteristic inclusion bodies in infected skin biopsy samples, which are indicative of poxvirus infections.

Direct fluorescent antibody (DFA) testing enables the rapid detection of viral antigens in infected body fluids by employing labeled antibodies. In addition, antigen-capture enzyme-linked immunosorbent assays (ELISA) using specific immune sera have proven effective in detecting poxvirus antigens in lymph node biopsies. Among modern approaches, molecular diagnostic tools, especially polymerase chain reaction (PCR), have emerged as the most rapid and reliable techniques. PCR assays targeting highly conserved genes such as P32 and RPO30 offer excellent specificity and sensitivity, allowing for the detection of capripoxviral DNA directly from clinical specimens (Babu et al., 2018; Manjunatha Reddy et al., 2023). These molecular assays are increasingly favored in both field and laboratory settings due to their speed and diagnostic accuracy. For these various laboratory techniques, including electron microscopy, virus detection, and antigen-based assays, it is crucial to collect appropriate samples at appropriate times. Obtaining samples from skin papules, lung lesions, or lymph nodes is recommended through biopsy or postmortem examination. Virus isolation from a buffy coat of blood samples collected in the anticoagulant tubes can be done. For antigen detection through ELISA, it is ideal to collect the samples within the week of clinical symptom onset and before the emergence of neutralizing antibodies. On the other hand, PCR detects viral genomes; the samples can be collected before or after the development of the antibodies. However, it is essential to ensure that the tissue samples collected are sufficiently large to prevent the glycerol from reaching the center of the tissue, as this could potentially inactivate the virus. As per the OIE Terrestrial manual, 2018, the blood samples can be stored at 4°C before further processing but should not be frozen or kept at room temperature. Scabs and tissue samples should be kept at 4°C or at –20°C for prolonged storage. Transportation of these collected samples to the laboratory should be done by maintaining a cold chain and packed with gel packs to preserve the integrity of the virus. Serological tests detect disease-specific antibodies, and detecting antibodies specific to Capri pox viruses by virus neutralization test (VNT) is considered the gold standard method by the World Organization for Animal Health (OIE) due to its high specificity. Another serological method, western blotting of test sera against capripoxvirus-infected cell lysate, is highly sensitive and specific for detecting antibodies to the virus's structural proteins. However, this technique is relatively complex and expensive to perform. Recently, a new double antigen ELISA has shown promise as a tool for mass screening of capripoxvirus antibodies (Milovanović et al., 2019; Manjunatha Reddy et al., 2024). Since these serological tests can diagnose genus-level infections and due to cross-reactions with the results within the Capri pox genus, molecular diagnosis is required for specific detection of either sheep pox, goat pox, or LSD virus. PCR is the best molecular diagnostic method for viral diseases, including sheep and goat pox. Conventional and real-time PCR or qPCR-based assays have been reported for rapid diagnosis, and some advantages of qPCR include speed, sensitivity, and detection of real-time results (Hurisa et al., 2018).

Prevention and Control

Effectively controlling and eradicating capripoxvirus infections hinges on the combined efforts of veterinary services, raising awareness among farm owners, and the swift identification of the disease in affected regions. Essential control measures include culling infected animals, regulating animal movement, and implementing quarantine systems. Vaccination is the most efficient method to curb the spread of CaPVs, with live attenuated vaccines being the only available option against SPPV and GTPV. These vaccines are cost-effective and can offer substantial protection if herd immunity exceeds 80% through annual vaccinations. However, the lack of mandatory and consistent vaccination policies and poor control of animal movements often lead to the rampant spread of CaPV (Tuppurainen et al., 2017, Bayyappa GBM et al.2025).

Conclusion

Globally, sheep and goat pox (SGP) remain major transboundary diseases affecting small ruminant health and productivity, particularly in Africa, the Middle East, and Asia. These diseases lead to significant economic losses through high mortality, reduced production, and trade restrictions. Vaccination is the cornerstone of control, but inconsistent coverage, weak veterinary infrastructure, and limited disease awareness hinder effective management. Strengthening regional cooperation, expanding targeted vaccination campaigns, and improving disease surveillance are crucial. Integrated strategies combining prevention, rapid response, and farmer engagement are essential for sustainable global SGP control.

References

Babu, T. S., Rathnamma, D., Isloor, S. I., Chandranaik, B. M., Veeregowda, B. M., & Reddy, G. M. (2018). Diagnosis of orf virus infection in sheep and goats by virus isolation, polymerase chain reaction and sequencing. *Indian Journal of Animal Research, 52*(1), 176–187. https://doi.org/10.18006/2018.6(1).176.187

Babiuk, S., Bowden, T. R., Parkyn, G., Dalman, B., Hoa, D. M., Long, N. T., & Boyle, D. B. (2009). Yemen and Vietnam capripoxviruses demonstrate a distinct host preference for goats compared with sheep. *Journal of General Virology, 90*(1), 105–114. https://doi.org/10.1099/vir.0.004507-0

Bardhan, D., Kumar, S., Kumar, S., Singh, R. P., & Hosamani, M. (2020). Cost-benefit analysis of vaccination against goat pox. *The Indian Journal of Animal Sciences, 90*(4), 515–520. https://epubs.icar.org.in/index.php/IJAnS/article/download/104180/40780/343602

Bayyappa, M. R. G., Pyatla, M. K. G., Pabbineedi, S. M., Gunturu, N. T., Peela, S. M., Nagaraj, S., ... & Gulati, B. R. (2025). Exploring the evolutionary journey of the lumpy skin disease virus through the phylogenetic and phylo-geo network analysis. *Frontiers in Cellular and Infection Microbiology, 15*, 1575538. https://doi.org/10.3389/fcimb.2025.1575538

Bayyappa, M. R. G., Pabbineedi, S. M., Nagaraj, S., Bijalwan, S., Tadakod, S., Uma, C. R., ... & Gulati, B. R. (2025). Spatiotemporal epidemiology of lumpy skin disease and evaluation of the heterologous goatpox vaccine: Insights into immunogenicity and impact. *Vaccines, 13*(6), 641. https://doi.org/10.3390/vaccines13060641

Bhanuprakash, V., Indrani, B. K., Hosamani, M., & Singh, R. K. (2006). The current status of sheep pox disease. *Comparative Immunology, Microbiology and Infectious Diseases, 29*(1), 27–60. https://doi.org/10.1016/j.cimid.2005.12.001

Bhanuprakash, V., Moorthy, A. R. S., Krishnappa, G., Gowda, R. S., & Indrani, B. K. (2005). An epidemiological study of sheep pox infection in Karnataka State, India. *Revue Scientifique et Technique (International Office of Epizootics), 24*(3), 909–917. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=3739879163d331e82fcd75b761c4c81d855d5c20

Bora, D. P., Venkatesan, G., Arya, S., Pariat, A. O., Kumar, A., Ingtipi, S., ... & Balamurugan, V. (2021). Molecular evidence and sequence analysis of goatpox virus isolates from Assam, India: An emerging viral disease of goats. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 91*(3), 607–614. https://link.springer.com/article/10.1007/s40011-021-01256-9

Bowden, T. R., Babiuk, S. L., Parkyn, G. R., Copps, J. S., & Boyle, D. B. (2008). Capripoxvirus tissue tropism and shedding: A quantitative study in experimentally infected sheep and goats. *Virology, 371*(2), 380–393. https://doi.org/10.1016/j.virol.2007.10.002

Garner, M. G., Sawarkar, S. D., Brett, E. K., Edwards, J. R., Kulkarni, V. B., Boyle, D. B., & Singh, S. N. (2000). The extent and impact of sheep pox and goat pox in the state of Maharashtra, India. *Tropical Animal Health and Production, 32*(3), 205–223. https://link.springer.com/article/10.1023/A:1005263601964

Guyassa, C. (2022). Epidemiology and diagnostic methods of lumpy skin disease: A short review. *International Journal of Veterinary Science and Research, 8*(2), 064–070. https://dx.doi.org/10.17352/ijvsr.

Hamdi, J., Bamouh, Z., Jazouli, M., Alhyane, M., Safini, N., Omari Tadlaoui, K., ... & El Harrak, M. (2021). Experimental infection of indigenous North African goats with goatpox virus. *Acta Veterinaria Scandinavica, 63*(1), 1–9. https://doi.org/10.1186/s13028-021-00574-2

Hurisa, T. T., Jing, Z., Jia, H., Chen, G., & He, X. B. (2018). A review on sheeppox and goatpox: Insight of epidemiology, diagnosis, treatment, and control measures in Ethiopia. *Journal of Infectious Diseases and Epidemiology, 4*(3), 2474–3658. https://doi.org/10.23937/2474-3658/1510057

Kiran Kumar, B., Kumar, K. M., Manjunatha Reddy, G. B., Abraham, S., Yogisharadhya, R., & Prashantha, C. N. (2020). Molecular modelling and insilico engineering of PapMV-CP towards display and development of capripox viral like particles based on immunogenic P32 envelop protein is the homologous of the Vaccinia-Viral H3L gene: An insilico approach. *International Journal of Peptide Research and Therapeutics, 26*, 2155–2167. https://doi.org/10.1007/s10989-019-10007-4

Kitching, R. P., & Mellor, P. S. (1986). Insect transmission of capripoxvirus. *Research in Veterinary Science, 40*(2), 255–258. https://doi.org/10.1016/S0034-5288(18)30523-X

Manjunatha Reddy, G. B., Krishnappa, V. K., Siddalingaiah, C. D., Rao, S., Nayakvadi, S., Harlipura Basavarajappa, C. K., & Gulati, B. R. (2024). Epidemiological, pathological, and molecular studies on sheeppox disease outbreaks in Karnataka, India. *Microorganisms, 12*(7), 1373. https://doi.org/10.3390/microorganisms12071373

Manjunatha Reddy, G. B., Sumana, K., Apsana, R., Yogisharadhya, R., Prajapati, A., Patil, S. S., & Balamurugan, V. (2017). Investigation of malignant form of sheep pox outbreak in fattening lambs in Mandya, Karnataka. *Indian Journal of Veterinary Pathology, 41*(3), 184–188. https://doi.org/10.5958/0973-970X.2017.00045.1

Manjunatha Reddy, G. B., Sumana, K., Srinivasbabu, Janaradan Yadav, Balamurugan, V., Hemadri, Patil, S. S., Suresh, K. P., Gajendragad, M. R., & Rahman, H. (2015). Pathological and molecular characterization of Capripox virus outbreak in sheep and goats in Karnataka. *Indian Journal of Veterinary Pathology*, *39*(1), 11–14.

Manjunatha Reddy, G. B., Sumana, K., Yogisharadhya, R., Mohan, H. V., Lavanya, V. K., Chethankumar, B. H., Shivasharanappa, N., Saminathan, M., Basavaraj, S., Dhama, K., & Bhadravati Sathish, S. (2023).

Structural and sequence analysis of the RPO30 gene of sheeppox and goatpox viruses from India. *Veterinary Quarterly*, *44*(1), 1–12. https://doi.org/10.1080/01652176.2024.2331524

Manjunatha Reddy, G. B., Bijalwan, S., Jacob, S. S., Tadakod, S., Maharana, S. M., Nagaraj, S., Pabbineedi, S. M., Bhutia, Z., Kumar, A., Yadav, D., Sharma, D. K., & Gulati, B. R. (2025). Investigation of comorbidity and risk factors analysis during lumpy skin disease outbreaks in India. *Microorganisms*, *13*(3), 472. https://doi.org/10.3390/microorganisms13030472

Manjunatha Reddy, G. B., Pabbineedi, S. M., Nagaraj, S., Bijalwan, S., Tadakod, S., Bhutia, Z., Yadav, D., Kumar, A., Sharma, D. K., Singh, S. K., & Gulati, B. R. (2023). Lumpy skin disease (LSD) in yak (Bos grunniens): An evidence of species spillover from cattle in India. *Microorganisms*, *11*(12), 2823. https://doi.org/10.3390/microorganisms11122823

Manjunathareddy, G. B., Saminathan, M., Sanjeevakumar, L., Rao, S., Dinesh, M., Dhama, K., Chethankumar, B. H., Shivasharanappa, N., Basavaraj, S., Palanisamy, M., & Tripathi, B. N. (2024). Pathological, immunological and molecular epidemiological analysis of lumpy skin disease virus in Indian cattle during a high-mortality epidemic. *Veterinary Quarterly*, *44*(1), 1–22. [suspicious link removed]

Manjunathareddy, G. B., Sumana, K., Apsana, R., Yogisharadhya, R., Prajapati, A., Patil, S. S., & Balamuragan, V. (2017). Investigation of malignant form of sheep pox outbreak in fattening lambs in Mandya, Karnataka. *Indian Journal of Veterinary Pathology*, *41*(2), 173–175. https://doi.org/10.5958/0973-970X.2017.00045.1

Milovanović, M., Milićević, V., Valčić, M., Stević, N., Nišavić, J., & Radojičić, S. (2019). Detection and phylogenetic analysis of B2L gene of ORF virus from clinical cases of sheep in Serbia. *Pakistan Veterinary Journal*, *39*(3), 433–437. https://doi.org/10.29261/pakvetj/2019.034

Mirzaie, K., Barani, S. M., & Bokaie, S. (2015). A review of sheep pox and goat pox: Perspective of their control and eradication in Iran. *Journal of Advanced Veterinary and Animal Research*, *2*(4), 373–381. https://doi.org/10.5455/javar.2015.b117

Naidu, G. G., Shivappa, R. R., Rajanna, P. R., Gondali, H., Devaraju, M. H., Nagesh, P. K. S., Saravanakumar, A., Boro, P., Kumar, A., Pandey, S., Gupta, N., Singh, V. P., Gulati, B. R., & Saminathan, M. (2025). Assessment of economic burden of lumpy skin disease in India using stochastic modeling. *Scientific Reports*, *15*(1), 10160. https://doi.org/10.1038/s41598-025-94383-6

OMdated31March2021onSOPsforImportofLiveAnimalsintoIndia.pdf. (2021). https://dahd.gov.in/sites/default/files/2023/07/OMdated31March2021onSOPsforImportofLiveAnimalsintoIndia.pdf

OIE Terrestrial manual. (2018). *Chapter 3.8.12. Sheep pox and goat pox*. World Organisation for Animal Health. https://www.woah.org/fileadmin/Home/eng/Health_standards/tahc/2018/en_chapitre_sheep_pox_goat_pox.htm

Rao, T. V. S., & Bandyopadhyay, S. K. (2000). A comprehensive review of goat pox and sheep pox and their diagnosis. *Animal Health Research Reviews*, *1*(2), 127–136. https://doi.org/10.1017/s1466252300000116

Rawlins, M. E., Limon, G., Adedeji, A. J., Ijoma, S. I., Atai, R. B., Adole, J. A., Okwori, A. I., Shamaki, B. U., Kolo, A. J., Duku, S. I., & Alarcon, P. (2022). Financial impact of sheeppox and goatpox and estimated profitability of vaccination for subsistence farmers in selected northern states of Nigeria. *Preventive Veterinary Medicine*, *198*, 105503. https://doi.org/10.1016/j.prevetmed.2021.105503

Reddy, G. B. M., Mounica, P. S., Sudeep, N., Vikram, R., Garam, G. B., Lalzampuia, H., Lallianpuii, C., Kumar, A., Yadav, D., Gulati, B. R., & Sharma, D. K. (2024). First evidence of lumpy skin disease in mithun (Bos frontalis) in India. *Archives of Virology*, *169*(3), 65. https://doi.org/10.1007/s00705-024-05996-7

Shivakumara, C., Reddy, B. S., & Patil, S. S. (2017). Small ruminant production in Karnataka State of India—An overview. *European Journal of Zoological Research*, *5*(1), 28–35. https://www.researchgate.net/publication/324585750_Small_Ruminant_Production_in_Karnataka_State_of_India-an_Overview

Singh, B., & Prasad, S. (2008). Modelling of economic losses due to some important diseases in goats in India. *Agricultural Economics Research Review*, *21*(2), 297–302.

Singh, B., & Prasad, S. (2009). A model-based assessment of economic losses due to some important diseases in sheep in India. *Indian Journal of Animal Sciences*, *79*(12), 1265. https://epubs.icar.org.in/index.php/IJAnS/article/view/3052

Singh, R. K., Singh, A., Kumar, S., Sheoran, P., Sharma, D. K., Stringer, L. C., & Singh, D. (2020). Perceived climate variability and compounding stressors: Implications for risks to livelihoods of smallholder Indian farmers. *Environmental Management*, *66*, 826–844. https://doi.org/10.1007/s00267-020-01345-x

Sumana, K., Revanaiah, Y., Apsana, R., Roy, P., & Reddy, G. M. (2020). Molecular characterization of sheeppox virus from outbreaks in Karnataka, India. *Veterinary World*, *13*(2), 386–391. https://doi.org/10.14202/vetworld.2020.386-391

Sumana, K., Yogisharadhya, R., Sathish, B. S., Dipti, M., Apsana, R., Saminathan, M., Basavaraj, S., & Manjunatha Reddy, G. B. (2020). Molecular phylogeny of Capripoxviruses based on major immunodominant protein (P32) reveals circulation of host specific sheeppox and goatpox viruses in small ruminants of India. *Infection, Genetics and Evolution*, *85*, 104472. https://doi.org/10.1016/j.meegid.2020.104472

Tisdell, C. A., & Gali, J. (2000). *Trends and Developments in India's Livestock Industry*. University of Queensland. https://rsmg.group.uq.edu.au/files/1879/WP31.pdf

Tuppurainen, E. S. M., Venter, E. H., Shisler, J. L., Gari, G., Mekonnen, G. A., Juleff, N., Lyons, N. A., De Clercq, K., Van Der Stede, Y., & 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. (n.d.). *3.8.12 Sheep pox and goat pox*. Retrieved July 14, 2025, from https://www.woah.org/fileadmin/Home/fr/Health_standards/tahm/3.08.12_S_POX_G_POX.pdf

Zewdie, G., Derese, G., Getachew, B., Belay, H., & Akalu, M. (2021). Review of sheep and goat pox disease: Current updates on epidemiology, diagnosis, prevention, and control measures in Ethiopia. *Animal Diseases*, *1*(1), 28. https://doi.org/10.1186/s44149-021-00028-2