Review on Mpox on Animals and its Zoonotic Importance

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ABSTRACT: Fatal epidemics such as the Middle East respiratory syndrome coronavirus, Ebola, Novel swine-origin influenza, severe acute respiratory syndrome, Zika virus infection, and Nipa virus infection, including mpox and severe acute respiratory syndrome coronavirus 2, which were relatively recently prevalent worldwide, and the mentioned diseases were infected to humans due to contact with host animals. Also, HIV, one of the worst diseases in human history, was also zoonosis. Monkeypox virus (MPXV) is a complex cytoplasmic double-stranded DNA virus, belonging to the genus *Orthopoxvirus* (OPXV), family *Poxviridae*. Monkeypox virus is an emerging zoonotic disease and can infect a wide range of mammal species, including Human beings, monkeys, anteaters, hedgehogs, prairie dogs, squirrels, shrews and dogs. The virus can be transmitted from animal-to-human, human-to-human and from a contaminated environment-to-human. There has been a single report of sick people transmitting Monkeypox virus to animals (a dog). Mpox symptoms usually appear 6–13 days (up to 21 days) after infection. Methods for treating mpox include supportive care, medication such as anti-virals, tecovirimat, brincidofovir and cdofovir, and vaccinia immune globulin. Mpox vaccines are available for primary prevention (pre-exposure) and post-exposure vaccination for persons and communities at risk of mpox. This paper provides a brief historical overview of mpox morphology, transmission, clinical signs, diagnosis, Differential Diagnosis, treatment and prevention and control as well as its zoonosis.

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INTRODUCTION

Several infections have emerged in humans, domestic animals, wildlife, and plant populations, causing a severe problem for humanity (1). Fatal epidemics such as the Middle East respiratory syndrome coronavirus, Ebola, Novel swine-origin influenza, severe acute respiratory syndrome, Zika virus infection, and Nipa virus infection, including mpox and severe acute respiratory syndrome coronavirus 2, which were relatively recently prevalent worldwide, and the mentioned diseases were infected to humans due to contact with host animals. Also, HIV, one of the worst diseases in human history, was also zoonosis (2). As an emerging virus, the *Monkeypox virus* has spread from Africa to other regions of the World, including India, and hence is a growing concern. It can cause infection in humans, domestic and wild animals, ranging from moderate to life-threatening consequences (1).

Monkeypox virus (MPXV) is a complex cytoplasmic double-stranded DNA virus, belonging to the genus *Orthopoxvirus* (OPXV), family *Poxviridae* (3, 4). OPXVs are a diverse group that includes pathogenic viruses of significance to public health and veterinary medicine and low pathogenic viruses that circulate undetected in wild animals (5,6,).The genus Orthopoxvirus affects humans and animals, with 12 identified members. The most well-known member is, which causes smallpox; others are MPXV, vaccinia virus (smallpox vaccine virus) the variola virus, Abatino macacapox virus, Akhmeta virus, Camelpox virus, Cowpox virus, Ectromelia virus, Raccoonpox virus, Skunkpox virus, Taterapox virus, and Volepox virus (7,8,9).

The monkeypox virus (MPXV) was first identified in 1958 in monkeys imported from Singapore and kept for research in Denmark which gave it its name (10,11). However, given that the monkey was not the primary host of the disease, this nomenclature was subsequently called into question. In November 2022, the World Health Organization (WHO) announced its intention to adopt the term "Mpox" in its communications, urging other organizations to follow this recommendation (12).

Two clades of MPXV have been identified: clade I, formerly known as the Congo Basin or Central African clade, and clade II, formerly known as the West African clade, which is divided into subclades IIa and IIb. Clade I is found in both animals and humans and is linked to sporadic cases as well as large outbreaks. (13, 14).

Mpox (formerly monkeypox) is an emerging zoonotic disease caused by Mpox virus infection, which affects both humans and animals (15, 16).

Monkeypox virus can infect a wide range of mammal species, including monkeys, anteaters, hedgehogs, prairie dogs, squirrels, shrews and dogs. There has been a single report of sick people transmitting Monkeypox virus to animals (a dog).We are still learning which species of animals can get monkeypox. While we do not know if reptiles, amphibians, or birds can get monkeypox, it is unlikely since these animals have not been found to be infected with other orthopoxviruses. Not all animals may have a rash when they have monkeypox. Infected animals can spread Monkeypox virus to people, and it is possible that people who are infected can spread Monkeypox virus to animals through close contact, including petting, cuddling, hugging, kissing, licking, sharing sleeping areas, and sharing food. Monkeypox virus can be found in the rash caused by monkeypox (scabs, crusts, fluids) and infected bodily fluids,including respiratory secretions, and potentially in urine and feces (18,19).

Mpox (formerly monkeypox) is a viral disease caused by the monkeypox virus (MPXV), which is present in the wildlife in several central- and west African countries (20). MPXV in humans appears to have originated in parts of Africa, where hunting forest animals and preparation of wild game (bush meat) are considered sources of exposure (13, 14). Approximately thirty years later, the first MPX case outside Africa—due to virus exposure via zoonotic transmission from an infected animal—was reported in the U.S. (26). In 2022, an outbreak occurred in Europe and globally where the disease was transmitted between humans through mainly sexual contact (20). The main factors in the disease outbreak were travel from African countries and animal importation. From this point on, MPX cases were reported occasionally worldwide. However, in 2022, the MPX outbreak became international and was thus declared a global health emergency independent of travel issues (21)**.**

On 13 August 2024, Africa CDC officially declared mpox a Public Health Emergency of Continental Security (PHECS), marking the first such declaration by the agency since its inception in 2017. The declaration will enable the mobilisation of resources across affected countries, unlocking essential funding, strengthening risk communication and community engagement, boosting surveillance and laboratory testing efforts, and enhancing human resource capacities to respond effectively to the outbreak (22). On 14 August 2024, the Director General of the World Health Organization declared the outbreak a public health emergency of international concern (PHEIC) (23).

Therefore, the objective of this paper is:

Review on Mpox on Animals and its Zoonotic importance.

MORPHOLOGY OF MPOX VIRUS

Morphologically, poxviruses are the largest viruses in animals that can be visualized by light microscopy (24). The human mpox virus is an oval-shaped virus with a length of 220 to 450 nm, larger than viruses such as HIV or SARS-CoV-2. It is brick-shaped, enveloped, and cytoplasmic, binding to glycosaminoglycans to enter host cells (25). It is an enveloped, double-stranded DNA virus (66) as an enveloped virus, it has been postulated to alternatively employ the classical apoptotic mimicry mechanism for entry into host cells (26).

The MPXV virion is composed of four main parts: the outer lipoprotein envelope, central core, outer membrane, and lateral bodies. The outer membrane, which features many tubules on the surface, encloses the palisade layer, lateral bodies, and the core. The central core includes double-stranded DNA (dsDNA) from viruses and core fibrils, encircled by the palisade layer's tightly packed rod-shaped structure **(**Fig. 1**) (27,28)**. When viruses are released spontaneously, they typically retain the outer lipoprotein envelope, whereas viruses released through cellular rupture do not. The extracellular enveloped virus and the intracellular mature virus are the two infectious viral particles that are produced during replication. The peripheral bodies and viral core, which include specific proteins, are encased within the lipoprotein envelope covering the intracellular mature virus's surface (29).In contrast to virions released by cellular rupture, spontaneously generated virions typically contain the outer lipoprotein membrane (30). A mature virion seems to have around 80 viral proteins (31).

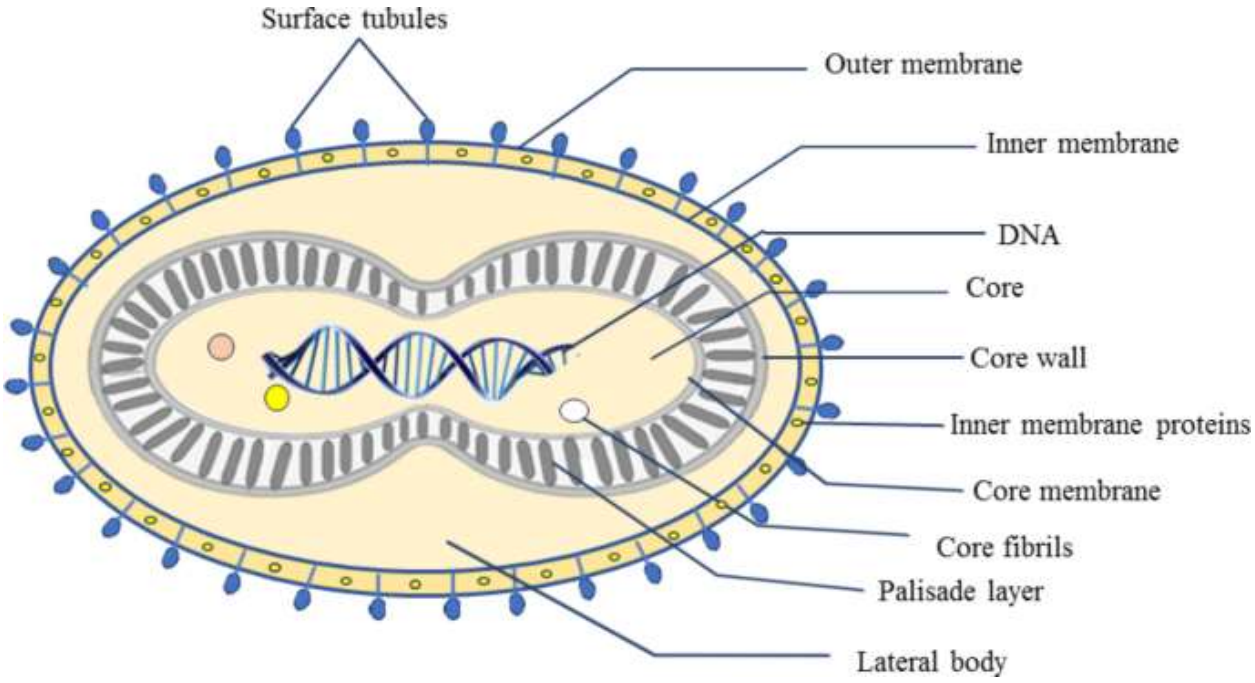

Fig:1 structure of mpox Source (27)

TRANSMISSION

The available information suggests mpox is a disease of mammals (including humans), but exactly which mammals is still being discovered. We know that nonhuman primates and African rodents are susceptible. In the United States and other non-endemic regions, a significant concern is the potential for spillover of mpox to wildlife from infected people or domestic mammals, emphasizing the importance of infection control measures to contain the disease. (32)

In nature, many animal species were found to be infected with MPXV, including rope and tree species of squirrels, Gambian pouched rats (*Cricetomys gambianus*), striped mice, dormice, and primates (33). It can infect a wide range of mammal species, including monkeys, anteaters, hedgehogs, prairie dogs,squirrels, shrews and dogs (34).

The virus can survive for a long period on objects that can become a vector for transmission (10).The incubation period for mpox averages between 7 and 14 days. During this period, infected animals or people typically have no signs of illness and are not contagious. Afterward, initial signs of infection in animals differ slightly from those in people, and likely even differ by animal species. What all infected individuals seem to have in common is **fever** and **swollen lymph nodes**. This helps to distinguish mpox from smallpox and chickenpox, which do not cause lymph nodes to swell. Nonhuman primates and prairie dogs also have been reported to have the following: Cough, Conjunctivitis (reddened eyes), Runny nose and Lack of appetite (32).

The virus can be transmitted from animal-to-human, human-to-human and from a contaminated environment-to-human Index cases are infected by direct contact with the blood, bodily fluids, or cutaneous or mucosal lesions of infected animals, including through their bite or scratch. Human infections through the handling of infected monkeys, Gambian giant rats and squirrels have been documented in Africa, while eating inadequately cooked meat of infected animals has also been identified as a possible risk factor for transmission (35).

Traditionally, mpox was considered a zoonotic disease. Nevertheless, many of the reported cases in recent outbreaks have been linked to intimate and sexual contact, particularly among men who have sex with

men (MSM). This pattern has raised concerns about mpox's association with sexual health (36).

Small mammals can carry the virus, sometimes without apparent symptoms, while non-human primates can get sick with monkeypox and have signs of disease like humans. In 2003, an outbreak of monkeypox in domesticated prairie dogs occurred after they shared bedding and caging with a shipment of infected small mammals from West Africa. This led to 47 human cases in 6 states in the United States. Instances of animal-to-animal and animal-to-person spread, such as the 2003 outbreak, demonstrate the need to reduce the risk of secondary infections to and from animals by isolating infected people as well as exposed and infected animals. (18).
Animal-to-human transmission can occur through bites from animals, in aerosols during close contact, or by direct contact with lesions, blood or body fluids. In Africa, human outbreaks have often been linked to the handling, preparation of and consumption of wild animal meat. The prevalence of monkeypox infection in wild primates is unknown but some studies have shown that 8% of non-human primates in West Africa were seropositive **(37).** Typically, outbreaks of mpox occur in the population that hunts, handles, and eats infected wild animals (38).

Besides sexual contact, non-sexual contact, household and healthcare facility contacts have been reported by cases in DRC (39).

The rodents or squirrels living in the Sub-Saharan Africa rain forests act as potential reservoirs, amplifying Mpox. Humans and monkeys are accidental Mpox hosts (41).

During pregnancy or birth, the virus may be passed to the baby. Contracting mpox during pregnancy can be dangerous for the fetus or newborn infant and can lead to loss of the pregnancy, stillbirth, death of the newborn, or complications for the parent (42).

Though animal-to-human and human-to-human transmission has been scientifically established, there are recent reports suggesting human-to-animal transmission (43).

The virus is transmitted between animals via fecal-oral transmission or through wounds, the nose, and ingestion of infected meat. The available data on the disease in animals is insufficient, and further studies are currently being conducted (44, 55).

Further evidence suggests that the virus is evolving to become more transmissible between humans and to infect a wider range of host species, and that human-to-animal transmission may also occur. It is therefore possible that an epidemic state of the disease may occur in the future (46).

CLINICAL SIGNS AND SYMPTOMS

Mpox symptoms usually appear 6–13 days (up to 21 days) after infection. The clinical manifestation of the disease includes general febrile symptoms, a distinct rash (papules) on the skin and sores on the mucosa, back pain and muscle aches. The rash may spread quickly throughout the body within three days of experiencing the initial symptoms. Most people experience mild to moderate symptoms that usually last two to four weeks, followed by a full recovery. (20).

The disease in people is generally mild and self-limiting, and recovery is typically within two to four weeks. However, more severe disease and death have been reported, particularly in Africa and in children, young adults, and immunocompromised individuals (32). MPXV infection can be fatal, with mortality rates as high as 10–17% for more virulent strains (47, 48).

Clinical signs and outcomes for animals with mpox have not been fully described (47, 48). It is not clear what symptoms infected animals may have; watch them for potential signs of illness including lethargy, lack of appetite, cough, nasal secretions or crust, bloating, fever, and pimple or blister-like skin rash (49).

DIAGNOSIS

Monkeypox can have serious health consequences; a rapid, sensitive, specific, and cost-effective diagnosis is required for appropriate management (1).

The gold standard for differentiating MPXV from other orthopoxviruses is whole genome sequencing, so the MPXV associated with the current global outbreak has been sequenced. According to this sequencing, the current MPXV outbreak is associated with Clade II and is more closely linked to the MPXV isolate from the 2018– 2019 outbreak in the UK, Singapore, and Israel (50).

A few diagnostic techniques are applicable, including real-time PCR, immunohistochemistry, electron microscopy visualization, viral culture, and anti-orthopoxvirus IgG and IgM. PCR can be used alone,

but the result is enhanced when combined with epidemiological data (17, 51).

Laboratory testing of people and animals with suspected mpox is critical to confirm the infection and prevent or contain outbreaks. Veterinarians can play an important role by collecting and submitting appropriate patient specimens to a reference laboratory in the Laboratory Response Network (32).

The Polymerase Chain Reaction (PCR) is a normally preferred method for the diagnosis of mpox due to its high accuracy and sensitivity (52).

DIFFERENTIAL DIAGNOSIS

It is important to distinguish mpox from chickenpox, Smallpox, measles, bacterial skin infections, Rickettsialpox, scabies, herpes, syphilis, Generalized vaccinia, Disseminated zoster, Yaws, Eczema herpeticum, other sexually transmitted infections, and medication-associated allergies. Someone with mpox may also have another sexually transmitted infection at the same time, such as syphilis or herpes (42, 53, 54).

TREATMENT

Currently, researchers are devoted to developing anti-Mpox drugs by interfering with the DNA or RNA synthesis of the viral genome (55).

Human and animal surveillance should be done continuously to predict possible Mpox outbreaks. Except for the smallpox vaccination, which provides some protection, there is no particular therapy for Mpox infection. Medicinal plants are a rich source of secondary metabolites that may help offer natural and safe treatments without specific vaccines or antiviral medications for Mpox. (1).

There is no recommended treatment for Mpox (monkeypox) infection, but supportive veterinary options (such as analgesics) are available to reduce suffering in severe cases (43).

Methods for treating mpox include supportive care, medication such as anti-virals, tecovirimat, brincidofovir and cdofovir, and vaccinia immune globulin (56). Since most patients with mpox are treated individually without special medication, appropriate supportive care is required depending on the symptoms. For example, patients with gastrointestinal symptoms, such as vomiting and diarrhea, need desperate hydration to minimize water loss. Likewise, appropriate supplementation can alleviate symptoms, manage complications, and prevent long term after effects. Some antiviral supplementation may be effective in treating mpox, but these drugs have been approved for smallpox management based on animal models. Although dose studies have been performed on these drugs according to the human body, the efficacy of the drug cannot be completely trusted (57).

PREVENTION AND CONTROL

OPXVs are a diverse group that includes pathogenic viruses of significance to public health and veterinary medicine and low pathogenic viruses that circulate undetected in wild animals (58, 59, 60).

Because the MPXV is highly contagious, people must understand how to protect themselves and what precautions to take. Simple suggestions for prophylaxis include wearing masks when interacting with any suspected or confirmed case, particularly in medical settings; frequently cleaning surfaces and hands; being extra cautious when handling animals, pets, and raw meat; avoiding multiple partners or engaging in safe sex, etc. (61).

Preventing Mpox (monkeypox) virus from establishing in new animal reservoirs from currently non-endemic countries and territories is critical to preventing the global expansion of countries with endemic Mpox (monkeypox) (43).

It is therefore imperative that healthcare professionals in all countries are fully informed about the virus and the disease it causes, as well as the means of preventing infection, with vaccination being a particularly important method of protection (40).

There is no safe vaccine that is currently approved for pets or other animals. Vaccination of high-risk humans at the human-animal interface should be prioritized based on their clinical susceptibility, exposure, and availability of the vaccine, and should adhere to the WHO guidelines (43).

mpox vaccines are available for primary prevention (pre-exposure) and post-exposure vaccination for persons and communities at risk of mpox. Vaccines deployed for the global public health response to mpox are primarily MVA-BN, a non-replicating live vaccinia virus vaccine consisting of a modified Ankara strain of vaccinia which requires two doses and is approved for use in adults, and LC16-KMB, a single-dose minimally-replicating live vaccinia virus vaccine

derived from the Lister strain of vaccinia and approved for use in adults and children. Both these live attenuated vaccines were developed with the purpose of improving the vaccine safety profile through attenuation of strains used to eradicate smallpox globally. Due to the cross-protection which is a feature of orthopoxviruses, these newer minimally-replicating or non-replicating vaccinia virus vaccines which were developed for smallpox preparedness were also approved for prevention of mpox prior to (MVA-BN) or during (LC16) the global outbreak. Other platforms for mpox vaccines such as mRNA and protein subunit vaccines are in development (13).

Pre-exposure prophylaxis:-Highly recommended for healthcare workers as a means of individual protection and epidemiologically to help prevent the spread of the virus; **Post-exposure Prophylaxis:**-This type of prophylaxis is recommended in the case of unprotected contact with skin mucous membrane or any other bodily fluids of a confirmed infected patient; Also recommended for people who closely share space with the infected person, as infection is possible through aerosol secretions (51).

Animals immunized with two doses of the JYNNEOS vaccine and a single dose of the ACAM2000 vaccine were fully protected against the severe and lethal effects of the disease. In contrast, immunization with a single dose of JYNNEOS did not abolish disease severity and fatal impact (62).

Anyone presenting with symptoms compatible with mpox should be advised to seek medical care and abstain from sex and close contact with others until a diagnosis is made or until symptoms resolve if infected (20).

Disinfect animal bedding, enclosures, food dishes, and any other items in direct contact with infected animals following the Disinfecting Home and Other Non-Healthcare Settings (19).

Nonetheless, to prevent further viral spread and potential evolution and establishment of new endemic areas, during public health emergencies caused by emerging zoonotic diseases, responders should apply a One Health approach to investigate potential spillback of human infections to animals, including pets (63).

The One Health initiative recognizes the intrinsic links between human, animal, and environmental health and aims to prevent and mitigate health risks at their interface. The environment is a fundamental component of public health, and greater attention to environmental factors is essential for promoting health and well-being within societies (13, 64, 65).

One Health: an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes that the health of humans, domestic and wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilizes multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development (13).

CONCLUSION

There is an urgent need for increased research to understand susceptible animal species and reservoir hosts in both endemic and non-endemic countries. Preventing Mpox (monkeypox) virus from establishing in new animal reservoirs from currently non-endemic countries and territories is critical to preventing the global expansion of countries with endemic Mpox (monkeypox).

Taking a One Health approach to combat mpox requires a comprehensive framework that incorporates an understanding of the socio ecological processes driving the epidemic pattern and synergistic strategies to promote population, animal, and environmental health.

REFERENCES

1. Boora, S., Yadav, S., Soniya, K. *2023. Monkeypox virus* is nature's wake-up call: a bird's-eye view. *VirusDis.*34, 191–203. https://doi.org/10.1007/s13337-023-00826-x

2. Lieberman, N.A.P., Mathias, P.C, Bradley, B.T., Greninger, A.L. 2022. Clinical performance and trends during the first two months of Monkeypox Virus PCR testing at two united states reference labs. J Clin Microbiol. e0137122.

3. *Hendrickson, R.C., Wang, C., Hatcher, E.L., Lefkowitz, E.J. 2010. Orthopoxvirus genome evolution: The role of gene loss. Viruses.;2:1933–1967. doi: 10.3390/v2091933.* [DOI] [PMC free article] [PubMed] [Google Scholar]

4.*Gubser, C., Hue, S., Kellam, P., Smith, G.L. 2004. Poxvirus genomes: A phylogenetic analysis. J. Gen. Virol.;85:105–117. doi: 10.1099/vir.0.19565-0.* [DOI] [PubMed] [Google Scholar]

5.*Pauli, G., Blumel, J., Burger, R., Drosten, C., Groner, A., Gurtler, L., Heiden, M., Hildebrandt, M., Jansen, B., Montag-Lessing ,T. 2010. Orthopox Viruses: Infections in Humans. Transfus. Med. Hemotherapy. 2010;37:351–364. doi: 10.1159/000322101.* [DOI] [PMC free article] [PubMed] [Google Scholar]

6. *Emerson, G.L., Li, Y., Frace, M.A., Olsen-Rasmussen, M.A., Khristova ,M.L., Govil, D., Sammons, S.A., Regnery, R.L., Karem, K.L., Damon, I.K. 2009. The phylogenetics and ecology of the orthopoxviruses endemic to North America. PLoS ONE.;4:e7666. doi: 10.1371/journal.pone.0007666.* [DOI] [PMC free article] [PubMed] [Google Scholar]

7. International Committee on Taxonomy of Viruses, https://ictv.global/taxonomy;[accessed 8 August 2022]. Google Scholar

8. Alakunle, E., Moens, U., Nchinda, G., Okeke, M. I. 2020. Monkeypox virus in Nigeria: infection biology, epidemiology, and evolution. *Viruses* 12, 1–29. doi: 10.3390/v12111257

9. Meyer, H., Damon, I.K., Esposito, J,J. 2004. Orthopoxvirus diagnostics. Methods Mol Biol. 269:119–34. https://doi.org/10.1385/1-59259-789-0:119. Article CAS PubMed Google Scholar

10. Antinori, A., Mazzotta, V., Vita, S., Carletti, F., Tacconi, D., Lapini, L.E. 2022. Epidemiological, clinical and virological characteristics of four cases of Monkeypox support transmission through sexual contact, Italy, May 2022. Euro Surveill. 2022 Jun;27(22):2200421. DOI: 10.2807/1560-7917.ES.2022.27.22.2200421

11. Srivastava, Ga., Srivastava Go.2022. Human monkeypox disease. Clinics in Dermatology, Volume 40, Issue 5, Page 604.; ISSN 0738- 081X. DOI: 10.1016/j.clindermatol.2022.08.00

12. Mitjà, O., Ogoina, D., Titanji, B.K., Galvan, C., Muyembe, J.J., Marks, M. 2023. Monkeypox. The Lancet. 401(10370):60-74.

13. World Health Organization (WHO, 2024). Strategic framework for enhancing prevention and control of mpox 2024-2027 ISBN 978-92-4-009291-4 (print version)

14. Happi, C., Adetifa, I., Mbala, P., Njouom, R., Nakoune, E., Happi, A. 2022. Urgent need for a non-discriminatory and non-stigmatizing nomenclature for monkeypox virus. *PLoS Biol.* 20, 1–6. doi: 10.1371/journal.pbio.3001769

15, McCollum, A. M., Damon, I. K. 2014. Human monkeypox. *Clin. Infect. Dis.* **58**, 260–267. Article PubMed Google Scholar

16. Otu, A. 2022. Global human monkeypox outbreak: atypical presentation demanding urgent public health action. *Lancet Microbe* **3**, e554–e555. Article PubMed PubMed Central Google Scholar

17. Likos, A.M., Sammons, S.A., Olson, V.A. 2005. A tale of two clades: *Monkeypox* viruses. J Gen Virol. 86(10):2661–72. https://doi.org/10.1099/vir.0.81215-0. Article CAS PubMed Google Scholar

18. Centre for Disease Prevention and Control (CDC, 2022). Monkeypox in Animals. Updated August 17, 2022

19. Centre for Disease Prevention and Control (CDC, 2023). Mpox in Animals and Pets. Updated August 18, 2023

20. European Centre for Disease Prevention and Control (. ECDC, 2024). Risk assessment for the EU/EEA of the mpox epidemic caused by monkeypox virus clade I in affected African countries. Stockholm. TQ-09-24-695-EN-N, ISBN: 978-92-9498-742-6, DOI: 10.2900/087147

21. Abdullah F. 2022. Monkeypox virus: future role in Human population J Infect Public Health, 15:1270–5 Google Scholar

22. Africa Centre for Disease Control and Prevention (AfricaCDC, 2024). Africa CDC Declares Mpox A Public Health Emergency of Continental Security, Mobilizing Resources Across the Continent. Addis Ababa: Available at: https://africacdc.org/news-item/africa-cdc-declares-mpox-a-public-health-emergency-of-continental-security mobilizing-resources-across-the-continent/

23. World Health Organization (WHO, 2024). WHO Director-General declares mpox outbreak a public health emergency of international concern. Geneva: Available at: https://www.who.int/news/item/14-08-

2024-who director-general-declares-mpox-outbreak-a-public-health-emergency-of-international-concern

24. Pauli, G., Blümel, J., Burger, R., Drosten, C., Gröner, A., Gürtler L. 2010. Orthopox Viruses: Infections in Humans. Transfus Med Hemother. 37(6):351-64. DOI: 10.1159/000322101

25. Lim, CK., Roberts, J., Moso, M., Liew, K.C., Taouk, M.L., Williams, E. 2023. Mpox diagnostics: Review of current and emerging technologies; 95(1):e28429.

26. Okwor, T., Mbala, P.K., Evans, D.H., Kindrachuk, J. 2023. A contemporary review of clade specific virological differences in monkeypox viruses. Clinical Microbiology and Infection. 29(12):1502-7.

27. Shchelkunov, S.N., Totmenin, A.V., Safronov, P.F., Mikheev, M.V., Gutorov, V.V., Ryazankina, O.I. 2002. Analysis of the monkeypox virus genome. Virology. 297:172–94. Article CAS PubMed Google Scholar

28. Buller, R.M.; Palumbo, G.J. 1991. Poxvirus pathogenesis. *Microbiol. Rev. 55*, 80–122. [**Google Scholar**] [**CrossRef**

29. Naga, N.G., Nawar, E.A., Mobarak, A.A. *2025.* Monkeypox: a re-emergent virus with global health implications – a comprehensive review. *Trop Dis Travel Med Vaccines* **11**. https://doi.org/10.1186/s40794-024 00237-w

30. Appleyard, G., Hapel, A.J., Boulter, E.A. 1971. An antigenic difference between intracellular and extracellular rabbitpox virus. *J. Gen. Virol. 13*, 9–17. [**Google Scholar**] [**CrossRef**]

31. Resch, W., Hixson, K.K., Moore, R.J., Lipton, M.S., Moss, B. 2007 Protein composition of the vaccinia virus mature virion. *Virology 358*, 233–247. [**Google Scholar**] [**CrossRef**]

32. American Veterinary Medical Association (AVMA, 2025.).

33. Durski, KN., McCollum, AM., Nakazawa, Y., Petersen, B.W., Reynolds, M.G., Briand, S. 2018. Emergence of monkeypox—west and central Africa, 1970–2017. Morbidity and Mortality Weekly Report. 67(10):306. Available at: https://www.cdc.gov/mmwr/volumes/67/wr/mm6710a5.htm

34. Center for Diseases Control and Prevention (CDC, 2023). Mpox in Animals and Pets. Updated August 18, 2023

35. WHO. Monkeypox [Internet]. WHO. 2016 [cited 2019 Oct 19]. Available from: *https://www.who.int/news-room/fact-sheets/detail/monkeypox*

36. Velavan, TP., Meyer, C.G. 2022. Monkeypox 2022 outbreak: An update. Trop Med Int Health; 27(7):604-605. [PubMed]

37. Breman, J.G., Bernadou, J., Nakano, J.H. 1977. Poxvirus in West African nonhuman primates: Serological survey results. Bull. World Health Org. 55:605 612.18.19.

38. León-Figueroa, D.A., Barboza, J.J., Saldaña-Cumpa, H.M., Moreno- Ramos, E., Bonilla-Aldana, D.K., Valladares-Garrido, M.J. 2022. Detection of Monkeypox Virus according to The Collection Site of Samples from Confirmed Cases: A Systematic Review. Trop Med Infect Dis. ;8(1):4. DOI: 10.3390/tropicalmed8010004

39. World Health Organization (WHO, 2024). Mpox - Democratic Republic of the Congo. Geneva: Available at: https://www.who.int/emergencies/disease-outbreak-news/item/2024-DON522

40. **Soleimani, S., Motamed, N. 2024. An Overview of Monkey Pox Disease as a Current Important Disease in the World. Archives of Razi Institute. 79(6):1121-1133.** DOI: 10.32592/ARI.2024.79.6.1121

41. Khodakevich, L., Ježek, Z., Messinger, D. 1988. *Monkeypox virus*: ecology and public health significance. Bull World Health Organ. 66(6):747. CAS PubMed PubMed Central Google Scholar

42. World Health Organization (WHO, 2024). Mpox 26 August 2024.

43. World Organisation for Animal Healthn (WOAH, 2022). Risk Guidance on Reducing Spillback of Mpox (Monkeypox) Virus from Humans to Wildlife, Pet Animals, and Other Animals Paris: page2-4

44. Dumonteil, E., Herrera, C., Sabino-Santos, G. 2023. Monkeypox Virus Evolution before 2022 Outbreak. Emerg Infect Dis. 29(2):451-3.

45. Faherty EAJMM, Report MW. Notes from the field: emergence of an mpox cluster primarily affecting persons previously vaccinated against mpox—Chicago, Illinois, March 18–June 12, 2023. 2023;72.

46. Nguyen, P.Y., Ajisegiri, W.S., Costantino, V., Chughtai, A.A., MacIntyre, CRJEID. 2021. Reemergence of human monkeypox and declining population immunity in the context of urbanization, Nigeria ;27(4):1007.

47. *Cann, J.A., Jahrling, P.B., Hensley, L.E., Wahl-Jensen, V. 2013Comparative pathology of smallpox and monkeypox in man and macaques. J. Comp. Pathol.; 148:6–21. doi: 10.1016/j.jcpa.2012.06.007.* [DOI] [PMC free article] [PubMed] [Google Scholar]

48. *Huhn, G.D., Bauer, A.M., Yorita, K., Graham, M.B., Sejvar, J., Likos, A., Damon, I.K., Reynolds, M.G., Kuehnert, M.J.2005. Clinical characteristics of human monkeypox, and risk factors for severe disease. Clin. Infect. Dis. Off. Publ. Infect. Dis. Soc. Am. 41:1742–1751. doi: 10.1086/498115.* [DOI] [PubMed] [Google Scholar]

49. Washington State Depertment of Health. 2023.Guidance on Mpox and Animals.DOH 420-421

50. Thakur, V., Thakur, P., Srivastava, S., Kumar, P. 2022. Monkeypox virus (MPX) in humans a concern: Trespassing the global boundaries - Correspondence. Int J Surg. 104:106703. DOI: 10.1016/j.ijsu.2022.106703

51. Aneta-Rada, Goia., Delia, Muntean., Virgil, Musta., Alexandra, Herlo., Silvana, Vulpie., Oana, Izmendi. 2024. Romanita Jumanca6, Monica Licker2,3. Understanding the pathogenesis, clinical, laboratory diagnosis and treatment of the recent monkeypox virus outbreak. Revista Română de Medicină de Laborator 2024;32(1):97-106. DOI:10.2478/rrlm-2024-0005

52. Huang, B., Zhao, H., Song, J., Zhao, L., Deng, Y., Wang, W. 2022. Isolation and characterization of Monkeypox virus from the first case of Monkeypox – Chongqing municipality, China, China CDC Wkly. 4(46):1019-24.

53. Monkeypox. Wkly Epidemiol Rec. 2011 Oct 07;86(41):448-51. [PubMed]

54. McCollum, AM., Damon, IK.2014. Human monkeypox. Clin Infect Dis. 58(2):260 7. [PubMed]

55. Dsouza, L. 2023. Antiviral activities of two nucleos(t)ide analogs against vaccinia, Mpox, and cowpox viruses in primary human fibroblasts. *Antiviral Res.* **216**, 105651.

56. Cline, A., Marmon, S.2022. Demographics and disease associations of patients with Monkeypox and recipients of Monkeypox vaccine from safety net hospitals in New York City: A Cross-Sectional Study. J Am Acad Dermatol.

57. Rizk, J.G., Lippi, G., Henry, B.M., Forthal, D.N., Rizk, Y. 2022. Prevention and treatment of Monkeypox. Drugs. 82(9):957-63.

58. *Pauli, G., Blumel, J., Burger, R., Drosten, C., Groner, A., Gurtle,r L., Heiden, M., Hildebrandt, M., Jansen, B., Montag-Lessing, T. 2010. Orthopox Viruses: Infections in Humans. Transfus. Med. Hemotherapy. 37:351–364. doi: 10.1159/000322101.* [DOI] [PMC free article] [PubMed] [Google Scholar]

59. *Emerson, G.L., Li, Y., Frace, M.A., Olsen-Rasmussen, M.A., Khristova, M.L., Govil, D., Sammons, S.A., Regnery, R.L., Karem, K.L., Damon, I.K. 2009. The phylogenetics and ecology of the orthopoxviruses endemic to North America. PLoS ONE. 4:e7666. doi: 10.1371/journal.pone.0007666.* [DOI] [PMC free article] [PubMed] [Google Scholar]

60. *Shchelkunov, S.N. 2013. An increasing danger of zoonotic orthopoxvirus infections. PLoS Pathog.9:e1003756. doi: 10.1371/journal.ppat.1003756.* [DOI] [PMC free article] [PubMed] [Google Scholar]

61. Chauhan, R.P., Fogel, R., Limson, J. 2023. Overview of Diagnostic Methods, Disease Prevalence and Transmission of Mpox (Formerly Monkeypox) in Humans and Animal Reservoirs. Microorganisms. 11(5):1186. DOI: 10.3390/microorganisms11051186

62. G.J. Hatch., V.A. Graham., K.R. Bewley., J.A. Tree., M. Dennis., I. Taylor.,*2013.*Assessment of the protective effect of imvamune and Acam2000 vaccines against aerosolized monkeypox virus in cynomolgus macaques J Virol, 87 (14) pp. 7805-7815, 10.1128/JVI.03481 12 . View at publisherView in ScopusGoogle Scholar

63. Morgan, C.N., Wendling, N.M., Baird, N., Kling, C., Lopez, L., Navarra, T. 2024. One Health Investigation into Mpox and Pets, United States.

Emerg Infect Dis. 30(10):2025-2032. https://doi.org/10.3201/eid3010.240632

64. Food and Agriculture Organizatio of United Nations (FAO, 2024). Mpox situation, with a focus on FAO's actions and the One Health approach| 09 Sept. 2024

65. Aderaw Desta Mokonen., Marie Teshager Tsehay (2025). Review on Novel Coronavirus or Sars-Cov2

11/2/2025

Covid-19 on Animals. Journal of Life Sciences Research and Reviews. SRC/JLSRR 151. DOI: doi.org/10.47363/JLSRR/(3)134

66. Mpox (Monkeypox): Fact Sheet. [internet]. Geneva: World Health Organization; 2023. (https://www.who.int/news-room/fact-sheets/ detail/monkeypox, cited 1 April 2024).