Review

Clade Ib Mpox Virus: How Can We Respond?

Lin Ai[1,&]; Xinyi Cui[2,&]; Yanqiu Zhou[1,#]

ABSTRACT

In recent years, mpox virus Clade Ib has emerged as a significant global public health threat due to its rapid transmission and potential for severe disease outcomes. This strain was first identified in the Democratic Republic of the Congo (DRC) in September 2023 and began spreading to neighboring African countries by July 2024. It was subsequently imported through international travel to 12 non-African countries across Asia, Europe, and the Americas. Clade Ib exhibits increased transmissibility, and current data suggest that infections may lead to more severe symptoms, with higher risks of severe illness and mortality, particularly among vulnerable populations such as children, pregnant individuals, and immunocompromised groups (e.g., people living with HIV/AIDS). Epidemiologically, Clade Ib primarily spreads through sexual contact, close household contact, and healthcare-related exposure. This review aims to provide an overview of the current understanding of mpox virus Clade Ib, including its genetic characteristics, epidemiological patterns, and prevention and control strategies. Additionally, it discusses the strategies and interventions needed to address this emerging threat.

The mpox virus (MPXV) comprises two lineages: Clade I (Central African/Congo Basin strain) and Clade II (West African strain) (*1*), which have traditionally been associated with zoonotic transmission and limited human-to-human spread (*2*). The 2022–2023 global Clade II outbreak marked a significant shift, representing the first international emergence of MPXV, predominantly affecting male-to-male sexual networks in Europe and the Americas (*3*). Concurrently, the emergence of the Clade Ib variant in the Democratic Republic of Congo in 2023 triggered a substantial surge in Clade I infections across Africa (*4*–*5*). Following the World Health Organization (WHO)'s declaration of a public health emergency in August 2024 (*6*), intensified research on Clade Ib MPXV has become imperative to address critical knowledge gaps in viral evolution, outbreak prediction, and development of effective countermeasures. These research efforts are vital for enhancing global surveillance systems and optimizing containment strategies against MPXV dissemination.

The Harm of Mpox Virus Clade Ib to Human Health

Following the decline of Clade II, Central Africa's forest zones have experienced rising Clade I prevalence linked to zoonotic spillover and intrahousehold transmission (*7*). Clade Ib strains exhibit heightened virulence with a case fatality ratio (CFR) of 5.3% as of May 2024, characterized by distinctive clinical manifestations including disseminated eruptions, pharyngitis, persistent fever, and lymphadenopathy (*8*). Surveillance data indicate expanding geographic spread across 23 of 26 provinces in the Democratic Republic of Congo, disproportionately affecting pediatric populations (under 15 years) with severe outcomes (*6*). The 2023 epidemiological shift reveals novel transmission clusters in previously unaffected regions, underscoring intensified human-to-human spread alongside more than 700 suspected infections reported in 2024 (*9*).

The Genetic Characteristics of Mpox Virus Clade Ib

Genomic characterization has identified a distinct Clade Ib variant in South Kivu, originating from independent zoonotic transmission (*3*). While Clades I and II share high conservation (99.3% identity), accurate lineage differentiation requires insertion/deletion (INDEL) profiling (*10*). Although phylogenetically grouped within Clade I, these strains lack the CDC-endorsed diagnostic target due to a 1,114-nucleotide deletion (OPG032 loss), which compromises PCR reliability (*5*). Significant evolutionary divergence is evident between subclades, with Clade Ib exhibiting 16.7% APOBEC3-driven

SNPs compared to just 0.3% in Clade Ia, suggesting distinct evolutionary trajectories (*11*). The deletion of the C3L gene in Clade Ib, a key Clade I marker, presents critical diagnostic challenges that may result in false-negative results, particularly during periods of Clade II co-circulation (*5*,*10*,*12*).

Epidemiological Characteristics of Mpox Virus Clade Ib

Epidemic regions: Clade Ib emerged in South Kivu, Democratic Republic of Congo (September 2023) as a phylogenetically distinct lineage (*12*), rapidly expanding to 14 health zones within 11 months and crossing borders into four neighboring nations (Burundi, Rwanda, Uganda, Kenya) by August 2024 (*13*). The World Health Organization reissued its mpox Public Health Emergency of International Concern following this accelerated transnational spread, with travel-associated cases subsequently reported in Sweden (*14*) and Thailand (*15*) in August 2024. By autumn, autochthonous transmission was documented in India (September) (*16*), Germany (October) (*17*), England (October/November) (*18*–*19*), the United States (November) (*20*), and Brazil (November) (*21*), demonstrating Clade Ib's significant global dispersal capacity despite ongoing questions regarding its transmissibility.

Transmission route: Genomic epidemiology reveals Clade Ib's sustained human-to-human transmission through host-adaptive mutations (*12*), contrasting with Clade Ia's predominantly zoonotic and household transmission patterns (*22*). The absence of a defined core transmission group — combined with unsubstantiated associations between sexual orientation and transmission risk — creates potential for stigmatization and undermines surveillance effectiveness in non-endemic regions (*12*,*23*). Clade Ib demonstrates distinct transmission dynamics from Clade IIb, which primarily affects men who have sex with men (MSM) populations (*23*). In the Democratic Republic of Congo, Clade Ib infections show a demographically balanced sex distribution, with 72% [95% confidence interval (*CI*): 65%, 78%] linked to sexual networks, disproportionately affecting adolescents (15–19 years) and young adults (20–24 years), including sex workers (*23*). While sexual contact frequency significantly increases infection risk [odds ratio (*OR*)=3.4, $P<0.01$], no specific sexual practices or orientations show significant association (*12*), challenging assumptions that conflate particular intimate behaviors with Clade Ib transmission.

Susceptible population: Epidemiological data confirm two distinct Clade Ib outbreak patterns in the DRC: 1) clusters among adult female sex workers (*24*), and 2) pediatric populations exhibiting heightened susceptibility and mortality (*25*). Surveillance records from 2024 document over 7,000 suspected cases with a case fatality ratio of 5.3%, with children aged ≤15 years constituting 67% of cases and 84% of fatalities (*9*). Infants under 5 years demonstrate a fourfold higher mortality risk compared to older age groups (*26*), highlighting household and community transmission as the predominant infection pathway.

Detection on Clade Ib Mpox

The high genomic conservation between MPXV Clades I and II (>99% nucleotide identity in core regions) and broad *Orthopoxvirus* homology (>90%) presents significant challenges for lineage-specific assay development (*10*). Phylogenetic convergence necessitates structural variation analysis, with validated INDEL polymorphisms serving as critical Clade-discriminatory markers (*10*).

PCR remains the gold standard for MPXV confirmation. CDC-endorsed real-time PCR assays effectively distinguish Clades I/II from other *Orthopoxvirus* species (*27*–*28*), though some C3L-adjacent assays demonstrate uncertain reliability for Clade Ib differentiation (*29*). Recent advancements include a Clade Ib-specific TaqMan probe targeting C3L deletions, which enhances transmission network tracking in non-endemic regions (*30*).

Whole genome sequencing (WGS) analyses of Clade Ib strains have revealed seven hotspot mutations (C9L-B21R) and consistent OPG032 (D14L) deletions, establishing a novel subgroup (VI) within Clade I through phylogenetic clustering (*31*). These findings underscore the necessity for enhanced genomic surveillance in endemic regions.

Serological surveillance complements molecular diagnostics by detecting subclinical infections. African studies demonstrate 6.3% *Orthopoxvirus* IgG seropositivity in asymptomatic populations (*32*), while 2022 outbreak data revealed 10.2% asymptomatic transmission-capable cases (*33*). Recent investigations identified 8.1% (91/1,119) suspected undiagnosed infections through serology (*34*). Modern immunoblot techniques improve Clade-specific antibody detection, overcoming cross-reactivity challenges inherent to conventional enzyme-linked immunosorbent assay (ELISA) (*35*). Neutralization assays differentiate

vaccine-derived from natural infection antibodies, which is critical for epidemiological mapping (*36*–*37*). Integrated sero-genomic surveillance could refine pandemic models by quantifying gaps in symptom-based reporting systems.

Prevention and Control Measures

Effective prevention and control of MPXV, particularly Clade Ib, requires a comprehensive strategy encompassing enhanced surveillance, public education, and isolation protocols (*38*). Robust surveillance systems are essential for early detection and rapid outbreak response (*39*). Healthcare settings should implement rapid diagnostic testing, complemented by targeted public health campaigns that educate high-risk populations — including healthcare workers and individuals in close contact with infected animals — about transmission mechanisms, symptom recognition, and preventive measures (*24*,*40*).

Vaccines

Vaccination remains the cornerstone of mpox prevention, particularly given the high pediatric mortality rates associated with Clade Ib infections (*41*). Three live-attenuated smallpox vaccines are currently available:

Routine vaccines: MVA-BN (JYNNEOS®/Imvamune®/Imvanex®). This non-replicating vaccine is globally approved and safe for immunocompromised individuals, pregnant women, and those with dermatologic conditions. It requires a two-dose regimen with a 4-week interval and demonstrated 62%–85% efficacy during the 2022 outbreaks, significantly reducing disease severity (*42*–*44*).

LC16m8. This low-replicating strain developed in Japan confers 100% protection in non-human primates (NHPs) against Clade I MPXV (*45*). It induces neutralizing antibodies with 70% seroconversion (*46*) and exhibits only mild side effects, including fever and lymphadenopathy (*47*). Over 90,000 individuals, including 50,000 children, have been vaccinated with LC16m8 without significant safety concerns (*48*).

ACAM2000. This replication-competent vaccine is authorized for emergency use but contraindicated in immunocompromised individuals due to risks of myopericarditis. It served as the primary mpox vaccine in the U.S. until 2019 (*49*–*50*).

Next-generation vaccines: Several innovative vaccine platforms are currently under development for mpox prevention. Quadrivalent mRNA vaccines (e.g., mRNA-A/B-LNP) targeting A29L, A35R, M1R, and B6R have demonstrated robust neutralizing antibody production and T-cell responses in murine models (*51*).

Multivalent mRNA vaccines such as Mpoxac-097 induce protective CD8+ T-cell responses against vaccinia virus (VACV) challenge, representing a promising advancement in orthopoxvirus immunization (*52*).

Additional candidates include encapsulated mRNA vaccines targeting A35R/M1R antigens and multicomponent formulations, which elicit Th1-biased immune responses with efficacy comparable to traditional vaccines in preclinical murine studies (*53*–*54*).

Drugs and Clinical Treatment

Drugs: Tecovirimat, a broad-spectrum antiviral, inhibits the p37 protein (encoded by the C17L gene in VARV), a conserved *Orthopoxvirus* target essential for viral envelope formation and pathogenicity (*55*). Approved by the U.S. FDA in 2018 for smallpox treatment, it effectively blocks the production of enveloped virions across the *Orthopoxvirus* genus.

Brincidofovir, an oral cidofovir analog approved in 2021 for smallpox, offers reduced nephrotoxicity compared to its injectable predecessor (*56*). Both agents inhibit viral replication through DNA polymerase inhibition (*57*).

Clinical treatment: Interim analyses from the National Institute of Allergy and Infectious Diseases (NIAID)-sponsored PALM007 (NCT05559099) and STOMP (NCT05534984) trials demonstrated tecovirimat's safety but found no efficacy in accelerating lesion resolution compared to placebo. PALM007, which enrolled hospitalized adults and children receiving high-quality supportive care, reported 1.7% mortality (historically ≥3.6%), attributing improved outcomes to enhanced supportive measures rather than tecovirimat. Similarly, STOMP's double-blinded cohort (mild-to-moderate cases, 2:1 allocation) showed no significant lesion or pain reduction with tecovirimat. Both trials confirmed the drug's tolerability (no serious adverse events) but demonstrated limited clinical benefit in immunocompetent patients with low-severity disease (*58*). Subgroup analyses are ongoing for immunocompromised individuals, patients with advanced HIV coinfection, and those receiving early treatment initiation.

Brincidofovir, FDA-approved for smallpox across all age groups, has demonstrated efficacy against *Orthopoxvirus* in both in vitro and animal studies, though human data specific to MPXV remain limited (*58*).

Challenges and Future Prospects

The emergence of MPXV Clade Ib in China presents significant public health challenges alongside strategic opportunities. Key challenges include its potential to escape existing vaccines, which could compromise immunization strategies and outbreak containment efforts, and its elevated mutation rate, necessitating continuous real-time genomic surveillance and adaptive public health responses. Conversely, this emergence creates opportunities to accelerate development of Clade Ib-specific vaccines and therapeutics while strengthening cross-border collaborations for coordinated resource mobilization. The escalating transmission risks underscore the urgent need for targeted health communication strategies to enhance community-level outbreak preparedness.

CONCLUSION

In summary, MPXV Clade Ib has emerged as a significant strain with substantial impact on disease epidemiology. It poses a considerable public health threat due to its enhanced transmission potential and the severity of illness it causes. The strain's rapid geographic spread, coupled with its distinct clinical presentation and higher case fatality ratio, underscores the urgent need for coordinated global surveillance, targeted prevention strategies, and continued development of effective vaccines and therapeutics. As international cases continue to emerge, strengthening cross-border collaboration and implementing evidence-based public health measures remain essential to mitigate the impact of this evolving pathogen.

Conflicts of interest: No conflicts of interest.

Funding: Supported by Research on Genetic Evolution Characteristics and Key Techniques for Tracing of Highly Pathogenic Viruses (2023YFC2605602) , the key research project of Three-Year Initiative Plan for Strengthening Public Health System Construction in Shanghai (2023-2025) (GWVI-3), Three-Year Initiative Plan for Strengthening Public Health System Construction in Shanghai (2023-2025) Key Discipline Project (GWVI-11.1-12), Key Discipline- Infectious Diseases of Three-year Action Program of Shanghai Municipality for Strengthening the Construction of Public Health System (2023–2025) (GWVI-11.1-01), the Key Discipline Program on Public Health System Construction of Shanghai (GWVI-11.1-15), Shanghai Municipal Science and Technology Major Project (ZD2021CY001).

doi: 10.46234/ccdcw2025.165

[#] Corresponding author: Yanqiu Zhou, zhouyanqiu@scdc.sh.cn.

[1] Institute of Microbiology Laboratory, Shanghai Municipal Center for Disease Control and Prevention, Shanghai, China; [2] Shanghai Academy of Preventive Medicine, Shanghai, China.
[&] Joint first authors.

Submitted: December 27, 2024
Accepted: April 18, 2025
Issued: July 18, 2025

REFERENCES

1. Gessain A, Nakoune E, Yazdanpanah Y. Monkeypox. N Engl J Med 2022;387(19):1783 – 93. https://doi.org/10.1056/NEJMra2208860.
2. Ježek Z, Grab B, Szczeniowski MV, Paluku KM, Mutombo M. Human monkeypox: secondary attack rates. Bull World Health Organ 1988;66 (4):465 – 70.
3. Gao L, Shi Q, Dong X, Wang M, Liu Z, Li Z. Mpox, Caused by the MPXV of the Clade IIb Lineage, Goes Global. Trop Med Infect Dis 2023;8(2):76 https://doi.org/10.3390/tropicalmed8020076.
4. Centers for Disease Control and Prevention (CDC). 2022-2023 Mpox outbreak global map. https://www.cdc.gov/poxvirus/mpox/response/2022/world-map.html. [2024-7-20].
5. Masirika LM, Udahemuka JC, Schuele L, Ndishimye P, Otani S, Mbiribindi JB, et al. Ongoing mpox outbreak in Kamituga, South Kivu Province, associated with monkeypox virus of a novel clade I sub-lineage, Democratic Republic of the Congo, 2024. Euro Surveill 2024;29(11):2400106. https://doi.org/10.2807/1560-7917.ES.2024.29.11.2400106.
6. World Health Organization (WHO). WHO Re-Declares Monkeypox as a Public Health Emergency of International Concern. https://www.who.int/news/item/14-08-2024-who-director-general-declares-mpox-outbreak-a-public-health-emergency-of-international-concern. [2024-8-14].
7. Djuicy DD, Sadeuh-Mba SA, Bilounga CN, Yonga MG, Tchatchueng-Mbougua JB, Essima GD, et al. Concurrent clade I and clade II monkeypox virus circulation, cameroon, 1979-2022. Emerg Infect Dis 2024;30(3):432 – 43. https://doi.org/10.3201/eid3003.230861.
8. Charniga K, McCollum AM, Hughes CM, Monroe B, Kabamba J, Lushima RS, et al. Updating reproduction number estimates for mpox in the Democratic Republic of Congo using surveillance data. Am J Trop Med Hyg 2024;110(3):561 – 8. https://doi.org/10.4269/ajtmh.23-0215.
9. Titanji BK, Hazra A, Zucker J. Mpox clinical presentation, diagnostic approaches, and treatment strategies: a review. JAMA 2024;332(19): 1652 – 62. https://doi.org/10.1001/jama.2024.21091.
10. Li Y, Zhao H, Wilkins K, Hughes C, Damon IK. Real-time PCR assays for the specific detection of monkeypox virus west African and Congo Basin strain DNA. J Virol Methods 2010;169(1):223 – 7. https://doi.org/10.1016/j.jviromet.2010.07.012.

11. Kinganda-Lusamaki E, Amuri-Aziza A, Fernandez-Nuñez N, Makangara-Cigolo JC, Pratt C, Vakaniaki EH, et al. Clade I mpox virus genomic diversity in the Democratic Republic of the Congo, 2018-2024: predominance of zoonotic transmission. Cell 2025;188(1):4 – 14.e6. https://doi.org/10.1016/j.cell.2024.10.017.
12. Vakaniaki EH, Kacita C, Kinganda-Lusamaki E, O'Toole Á, Wawina-Bokalanga T, Mukadi-Bamuleka D, et al. Sustained human outbreak of a new MPXV clade I lineage in eastern Democratic Republic of the Congo. Nat Med 2024;30(10):2791 – 5. https://doi.org/10.1038/s41591-024-03130-3.
13. Marty AM, Beÿ CK, Koenig KL. 2024 Mpox outbreak: A rapidly evolving public health emergency of international concern: Introduction of an Updated Mpox Identify-Isolate-Inform (3I) Tool. One Health 2024;19:100927 https://doi.org/10.1016/j.onehlt.2024.100927.
14. Treutiger CJ, Filén F, Rehn M, Aarum J, Jacks A, Gisslén M, et al. First case of mpox with monkeypox virus clade Ib outside Africa in a returning traveller, Sweden, August 2024: public health measures. Euro Surveill 2024;29(48):2400740. https://doi.org/10.2807/1560-7917.ES.2024.29.48.2400740.
15. Wappes J. More global mpox spread as clade 1b confirmed in Thailand, the 2nd case outside Africa. CIDRAP. 2024. https://www.cidrap.umn.edu/mpox/more-global-mpox-spread-clade-1b-confirmed-thailand-2nd-case-outside-africa. [2024-9-3].
16. Sah S, Dhandh YK, Mehta R, Singh MP, Bushi G, Shabil M, et al. First imported clade 1b mpox case in India: implications for travel medicine and public health surveillance. Travel Med Infect Dis 2024;62:102766. https://doi.org/10.1016/j.tmaid.2024.102766.
17. Nzoyikorera N, Nduwimana C, Schuele L, Nieuwenhuijse DF, Koopmans M, Otani S, et al. monkeypox clade Ib virus introduction into Burundi: first findings, July to mid-August 2024. Euro Surveill 2024;29(42):2400666. https://doi.org/10.2807/1560-7917.ES.2024.29.42.2400666.
18. Kmietowicz Z. UK confirms first case of clade Ib mpox. BMJ 2024;387:q2406. https://doi.org/10.1136/bmj.q2406.
19. Iacobucci G. UK reports two further cases of clade Ib mpox. BMJ 2024;387:q2442. https://doi.org/10.1136/bmj.q2442.
20. Mahase E. Mpox: US reports first clade Ib case as campaigners call for cheaper tests. BMJ 2024;387:q2576. https://doi.org/10.1136/bmj.q2576.
21. Martins-Filho PR, Carvalho TA, Rodrigues SSA, de Sousa DS, Araújo FWC, Tenório MDL, et al. Confronting mpox in Brazil amid global spread of clade Ib. Lancet Reg Health Am 2024;40:100917. https://doi.org/10.1016/j.lana.2024.100917.
22. Whitehouse ER, Bonwitt J, Hughes CM, Lushima RS, Likafi T, Nguete B, et al. Clinical and epidemiological findings from enhanced monkeypox surveillance in Tshuapa Province, Democratic Republic of the Congo during 2011-2015. J Infect Dis 2021;223(11):1870 – 8. https://doi.org/10.1093/infdis/jiab133.
23. Allan-Blitz LT, Gandhi M, Adamson P, Park I, Bolan G, Klausner JD. A position statement on mpox as a sexually transmitted disease. Clin Infect Dis 2023;76(8):1508 – 12. https://doi.org/10.1093/cid/ciac960.
24. Decousser JW, Keita-Perse O, Aho Glele LS, Baron R, Carre Y, Cassier P, et al. Transmission pathways and personal protective equipment requirement for mpox clade Ib lineage: nothing new on this front. J Hosp Infect 2025;156:125 – 7. https://doi.org/10.1016/j.jhin.2024.10.018.
25. Brosius I, Vakaniaki EH, Mukari G, Munganga P, Tshomba JC, De Vos E, et al. Epidemiological and clinical features of mpox during the clade Ib outbreak in South Kivu, Democratic Republic of the Congo: a prospective cohort study. Lancet. 2025;405(10478):547 – 559 https://doi.org/10.1016/S0140-6736(25)00047-9.
26. Yinka-Ogunleye A, Dalhat M, Akinpelu A, Aruna O, Garba F, Ahmad A, et al. Mpox (monkeypox) risk and mortality associated with HIV infection: a national case-control study in Nigeria. BMJ Glob Health 2023;8(11):e013126 https://doi.org/10.1136/bmjgh-2023-013126.
27. de Vries HJ, Götz HM, Bruisten S, van der Eijk AA, Prins M, Oude Munnink BB, et al. Mpox outbreak among men who have sex with men in Amsterdam and Rotterdam, the Netherlands: no evidence for undetected transmission prior to May 2022, a retrospective study. Euro Surveill 2023;28(17):2200869. https://doi.org/10.2807/1560-7917.ES.2023.28.17.2200869.
28. Liesenborghs L, Coppens J, Van Dijck C, Brosius I, De Baetselier I, Vercauteren K, et al. No evidence for clade I monkeypox virus circulation, Belgium. Emerg Infect Dis 2024;30(2):402. https://doi.org/10.3201/eid3002.231746.
29. Huo ST, Chen YD, Lu RJ, Zhang ZX, Zhang GQ, Zhao L, et al. Development of two multiplex real-time PCR assays for simultaneous detection and differentiation of monkeypox virus IIa, IIb, and I clades and the B. 1 lineage. Biosaf Health 2022;4(6):392 – 8. https://doi.org/10.1016/j.bsheal.2022.10.005.
30. Schuele L, Masirika LM, Udahemuka JC, Siangoli FB, Mbiribindi JB, Ndishimye P, et al. Real-time PCR assay to detect the novel clade Ib monkeypox virus, September 2023 to May 2024. Euro Surveill 2024;29(32):2400486. https://doi.org/10.2807/1560-7917.ES.2024.29.32.2400486.
31. Masirika LM, Kumar A, Dutt M, Ostadgavahi AT, Hewins B, Nadine MB, et al. Complete genome sequencing, annotation, and mutational profiling of the novel clade I human mpox virus, Kamituga strain. J Infect Dev Ctries 2024;18(4):600 – 8. https://doi.org/10.3855/jidc.20136.
32. Guagliardo SAJ, Monroe B, Moundjoa C, Athanase A, Okpu G, Burgado J, et al. Asymptomatic orthopoxvirus circulation in humans in the wake of a monkeypox outbreak among chimpanzees in Cameroon. Am J Trop Med Hyg 2020;102(1):206 – 12. https://doi.org/10.4269/ajtmh.19-0467.
33. Satapathy P, Mohanty P, Manna S, Shamim MA, Rao PP, Aggarwal AK, et al. Potentially asymptomatic infection of monkeypox virus: a systematic review and meta-analysis. Vaccines (Basel) 2022;10(12):2083. https://doi.org/10.3390/vaccines10122083.
34. Marcus U, Michel J, Lunchenkov N, Beslic D, Treindl F, Surtees R, et al. A seroprevalence study indicates a high proportion of clinically undiagnosed MPXV infections in men who have sex with men in Berlin, Germany. BMC Infect Dis 2024;24(1):1153. https://doi.org/10.1186/s12879-024-10066-z.
35. Minhaj FS, Singh V, Cohen SE, Townsend MB, Scott H, Szumowski J, et al. Prevalence of undiagnosed monkeypox virus infections during global mpox outbreak, United States, June-September 2022. Emerg Infect Dis 2023;29(11):2307 – 14. https://doi.org/10.3201/eid2911.230940.
36. Hubert M, Guivel-Benhassine F, Bruel T, Porrot F, Planas D, Vanhomwegen J, et al. Complement-dependent mpox-virus-neutralizing antibodies in infected and vaccinated individuals. Cell Host Microbe 2023;31(6):937 – 48.e4. https://doi.org/10.1016/j.chom.2023.05.001.
37. Marchi S, Piccini G, Cantaloni P, Guerrini N, Zannella R, Coluccio R, et al. Evaluation of monkeypox- and vaccinia-virus neutralizing antibodies before and after smallpox vaccination: a sero-epidemiological study. J Med Virol 2024;96(6):e29728. https://doi.org/10.1002/jmv.29728.
38. Ndembi N, Abdool Karim SS. Africa aims to avert an mpox pandemic. Science 2024;386(6717):7. https://doi.org/10.1126/science.adt4793.
39. Mukadi-Bamuleka D, Kinganda-Lusamaki E, Mulopo-Mukanya N, Amuri-Aziza A, O'Toole Á, Modadra-Madakpa B, et al. First imported cases of MPXV clade Ib in Goma, Democratic Republic of the Congo: implications for global surveillance and transmission dynamics. medRxiv 2024;24313188. http://dx.doi.org/10.1101/2024.09.12.24313188.
40. Adebisi YA, Ezema SM, Bolarinwa O, Bassey AE, Ogunkola IO. Sex workers and the mpox response in Africa. J Infect Dis 2024;230(4):786 – 8. https://doi.org/10.1093/infdis/jiae435.
41. Prompetchara E, Ketloy C, Khawsang C, Ruxrungtham K, Palaga T. Mpox global health emergency: insights into the virus, immune responses, and advancements in vaccines PART I: insights into the virus and immune responses. Asian Pac J Allergy Immunol 2024;42(3):181 – 90. https://doi.org/10.12932/AP-111024-1945.
42. Navarro C, Lau C, Buchan SA, Burchell AN, Nasreen S, Friedman L, et

al. Effectiveness of modified vaccinia Ankara-Bavarian Nordic vaccine against mpox infection: emulation of a target trial. BMJ 2024;386: e078243 https://doi.org/10.1136/bmj-2023-078243.
43. Grabenstein JD, Hacker A. Vaccines against mpox: MVA-BN and LC16m8. Expert Rev Vaccines 2024;23(1):796 – 811. https://doi.org/10.1080/14760584.2024.2397006.
44. Mason LMK, Betancur E, Riera-Montes M, Lienert F, Scheele S. MVA-BN vaccine effectiveness: a systematic review of real-world evidence in outbreak settings. Vaccine 2024;42(26):126409. https://doi.org/10.1016/j.vaccine.2024.126409.
45. Zuiani A, Dulberger CL, De Silva NS, Marquette M, Lu YJ, Palowitch GM, et al. A multivalent mRNA monkeypox virus vaccine (BNT166) protects mice and macaques from orthopoxvirus disease. Cell 2024;187 (6):1363 – 73.e12. https://doi.org/10.1016/j.cell.2024.01.017.
46. Morino E, Mine S, Tomita N, Uemura Y, Shimizu Y, Saito S, et al. Mpox neutralizing antibody response to LC16m8 vaccine in healthy adults. NEJM Evid 2024;3(3):EVIDoa2300290. https://doi.org/10.1056/EVIDoa2300290.
47. Tomita N, Terada-Hirashima J, Uemura Y, Shimizu Y, Iwasaki H, Yano R, et al. An open-label, non-randomized study investigating the safety and efficacy of smallpox vaccine, LC16, as post-exposure prophylaxis for mpox. Hum Vaccin Immunother 2023;19(2):2242219 https://doi.org/10.1080/21645515.2023.2242219.
48. Okumura N, Ishikane M, Ujiie M, Ohmagari N. "Take" after LC16m8 for mpox. Int J Infect Dis 2023;134:290 – 1. https://doi.org/10.1016/j.ijid.2023.07.005.
49. Kandeel M, Morsy MA, Abd El-Lateef HM, Marzok M, El-Beltagi HS, Al Khodair KM, et al. Efficacy of the modified vaccinia Ankara virus vaccine and the replication-competent vaccine ACAM2000 in monkeypox prevention. Int Immunopharmacol 2023;119:110206. https://doi.org/10.1016/j.intimp.2023.110206.
50. Katamesh BE, Madany M, Labieb F, Abdelaal A. Monkeypox pandemic containment: does the ACAM2000 vaccine play a role in the current outbreaks? Expert Rev Vaccines 2023;22(1):366-8. http://dx.doi.org/10.1080/14760584.2023.2198600.
51. Sang Y, Zhang Z, Liu F, Lu HT, Yu CX, Sun HS, et al. Monkeypox virus quadrivalent mRNA vaccine induces immune response and protects against vaccinia virus. Signal Transduct Target Ther 2023;8(1): 172. https://doi.org/10.1038/s41392-023-01432-5.
52. Fang ZH, Monteiro VS, Renauer PA, Shang XB, Suzuki K, Ling XY, et al. Polyvalent mRNA vaccination elicited potent immune response to monkeypox virus surface antigens. Cell Res 2023;33(5):407 – 10. https://doi.org/10.1038/s41422-023-00792-5.
53. Ye TX, Zhou JG, Guo C, Zhang KY, Wang YP, Liu YH, et al. Polyvalent mpox mRNA vaccines elicit robust immune responses and confer potent protection against vaccinia virus. Cell Rep 2024;43(6): 114269. https://doi.org/10.1016/j.celrep.2024.114269.
54. Zhang RR, Wang ZJ, Zhu YL, Tang W, Zhou C, Zhao SQ, et al. Rational development of multicomponent mRNA vaccine candidates against mpox. Emerg Microbes Infect 2023;12(1):2192815. https://doi.org/10.1080/22221751.2023.2192815.
55. Yang G, Pevear DC, Davies MH, Collett MS, Bailey T, Rippen S, et al. An orally bioavailable antipoxvirus compound (ST-246) inhibits extracellular virus formation and protects mice from lethal orthopoxvirus challenge. J Virol 2005;79(20):13139 – 49. https://doi.org/10.1128/JVI.79.20.13139-13149.2005.
56. Chittick G, Morrison M, Brundage T, Nichols WG. Short-term clinical safety profile of brincidofovir: a favorable benefit-risk proposition in the treatment of smallpox. Antiviral Res 2017;143:269 – 77. https://doi.org/10.1016/j.antiviral.2017.01.009.
57. Lanier R, Trost L, Tippin T, Lampert B, Robertson A, Foster S, et al. Development of CMX001 for the treatment of poxvirus infections. Viruses 2010;2(12):2740 – 62. https:// https://doi.org/10.3390/v2122740.
58. National Institutes of Health (NIH). NIH Study Finds Tecovirimat Was Safe but Did Not Improve Mpox Resolution or Pai. https://www.nih.gov/news-events/news-releases/nih-study-finds-tecovirimat-was-safe-did-not-improve-mpox-resolution-or-pain. [2024-12-10]