Archives of Advances
in Biosciences

Review Article:

Human Monkeypox Re-emerges While the World is Healing from the COVID-19 Pandemic: A Systematic Review

Rasoul Raesi[1,2], Mohmmad Hossein Gholami[3], Negin Esfandiari[4], Saied Bokaie[4], M. Reza Najafi[5], Rasta Haddadi[6], Kiavash Hushmandi[7*]

1. Department of Nursing, Torbat Jam Faculty of Medical Sciences, Torbat Jam, Iran.
2. Department of Health Services Management, Mashhad University of Medical Sciences, Mashhad, Iran.
3. Faculty of Veterinary Medicine, Kazerun Branch, Islamic Azad University, Kazerun, Iran.
4. Department of Food Hygiene and Quality Control, Division of Epidemiology, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran.
5. Department of Pathobiology, Faculty of Veterinary Medicine, Urmia University, Urmia, Iran.
6. School of Allied Medical Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
7. Nephrology and Urology Research Center, Baqiyatallah University of Medical Sciences, Tehran, Iran.

Cite this article as: Raesi R, Gholami MH, Esfandiari N, Bokaie S, Najafi MR, Hushmandi K. Human Monkeypox Re-emerges While the World is Healing from the COVID-19 Pandemic: A Systematic Review. Archives of Advances in Biosciences. 2023; 14E40479. https://doi.org/10.22037/aab.v14i. 40479

https://journals.sbmu.ac.ir/aab/article/view/40479

Article info:
Received: 01Jan 2023
Accepted: 17 May 2023
Published: 30 Oct 2023

*** Corresponding author:**

Kiavash Hushmandi, PhD.

Address: Department of Food Hygiene and Quality Control, Division of Epidemiology, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran.

E-mail:
kiavash.hushmandi@gmail.com

Abstract

Contex: While the world is still struggling with the COVID-19 pandemic, the newly emerging viral disease, monkeypox, first broke out in the United Kingdom on April 29th, 2022, amid the coronavirus crisis. Now that routine human smallpox vaccination has ended and herd immunity is waning, new assessments about monkeypox are needed.

Evidence Acquisition: In this systematic review, the epidemiological characteristics and clinical features of monkeypox disease were investigated. Persian articles were searched and retrieved using the keywords monkeypox, epidemic, COVID-19, an emerging infection in Magiran, Iran Medex, SID, and Irandoc databases, and so were the English articles using the same keywords in PubMed, Google Scholar, Science Direct, Scopus, Web of Science databases without time limit. In the end, 343 articles were selected and used in this study.

Results: From the review of the studies, it was concluded that although cases of this disease have been reported in many non-endemic countries of the world, and we should be prepared for its prevention and proper treatment, considering its slower transmission method it seems that this disease can be controlled and prevented much more easily than COVID-19.

Conclusion: although it is recommended that the proper and complete training of people and doctors regarding the symptoms and transmission of this disease by the relevant institutions should be initiated quickly, one should be careful that raising the awareness of the public about this disease is accompanied by fear and panic. There is a need for a cautious teaching method, by following health principles.

Keywords: COVID-19, Communicable Diseases, Epidemic, Humans, Monkeypox, Pandemics, Re-emerging.

Introduction

Monkeypox is a zoonotic viral disease. Zoonosis is a term used for common diseases between animals and humans. This disease manifests itself with symptoms similar to human smallpox. Skin lesions are the most common symptom of the monkeypox virus in all people [1]. These lesions generally start from the head and face and progress quickly and can involve the whole body. These skin lesions have special characteristics in a way that they quickly turn

into blisters. The number of these blisters increases with the progress of the disease and their color also changes to yellow. These blisters may leave a scar after healing [2, 3].

Historically, smallpox-like lesions were first found on the skin of the Egyptian king Ramesses V between 1100 and 1580 BC, who is believed to have died of a smallpox infection at the age of 35 [4, 5]. Most poxviruses infect multiple hosts, including mammals, birds, reptiles, insects, and marsupials. However, some studies have shown that the smallpox virus infects a limited number of animals, which may be related to genetic determinants responsible for different host phenotypes [6].

One of the important things in differentiating monkeypox disease from smallpox, chicken pox, measles, scabies, syphilis, other bacterial skin infections, and blisters is the use of standard scientific methods. Sampling skin blister (surface or liquid inside the blister) followed by performing PCR tests on these samples is one of the most accurate and definitive methods for diagnosing monkeypox disease [7, 8].

Prevention of monkeypox is considered as one of the most important things in controlling this contagious disease. Avoiding contact with sick animals or animal carcasses, avoiding direct contact, cleaning the place where sick and suspected animals are kept, quarantining people with symptoms and suspected ones, washing hands with soap and water, and disinfecting with alcohol-containing solutions after contact are some preventive measures. Moreover, vaccinating the people who have contact with livestock is among the crucial things in preventing monkeypox [9, 10].

Monkeypox virus is the most important orthopoxvirus affecting human populations. Clinical recognition, diagnosis, and prevention are still challenging in poor endemic areas where monkeypox is found. The epidemiology of monkeypox has been characterized by studies conducted at the end of smallpox eradication, but new assessments are needed now that routine smallpox vaccination has ended, and herd immunity is waning [11]. In addition, basic ecological studies are warranted to better understand the animal species involved in the transmission and maintenance of the virus and to further inform preventive measures.

The aim of this study was to perform a detailed review of different aspects of monkeypox in a world healing from the covid-19 pandemic.

Animals and humans can be reservoirs of the monkeypox virus and reports of the disease have been recorded in numerous studies of monkeypox in different regions of the world, including our neighboring countries and also recently one case with a definite diagnosis was reported in our country, Iran [12]. This being the scenario, conducting a detail review on the various epidemiological aspects of this zoonotic disease was deemed necessary by the authors. One of the concerns about this virus is that it is likely to become a new pandemic in the context of the ongoing COVID-19 pandemic. Now that routine human smallpox vaccination has ended and herd immunity is waning, new assessments about monkeypox are needed. Therefore, this research aims to know the epidemiological situation and clinical characteristics of monkeypox disease to answer whether monkeypox disease can become an epidemic disease like Covid-19 or not.

2. Materials and Methods

This systematic review was carried out in the summer of 2022 by searching Persian articles using the keywords monkeypox, epidemic, covid-19, and emerging infection in Magiran, Iran Medex, SID, and Irandoc databases, and also by retrieving English articles using the same keywords in PubMed, Google scholar, Science Direct, Scopus, Web of Science databases without time limit.

The inclusion criteria for the studies were writing articles in English or Farsi in line with the purpose of the study, whereas the exclusion criteria for studies was the lack of access to the full text of the studies. In the conducted search using the aforementioned keywords and suitable search strategy, 3896 article titles were obtained. Due to the overlap of some databases and the simultaneous indexing of an article in several databases, many duplicate titles were identified and deleted using the Endnote software. As a result, 1890 articles remained. Then, the screening of abstracts began. After applying the entry and exit criteria, 1427 abstracts were removed. The full text of the remaining 463 articles was reviewed. Studies that were not related to the purpose of the study were discarded. In the end, 343 articles were selected and used in this study (Chart 1); the full texts of all the articles were studied and relevant data were extracted considering the purpose of the research. No special evaluation was conducted on the quality of the reviewed manuscripts, and the credit of the journal was considered sufficient.

Agent specifications

Poxviruses are double-stranded DNA viruses of the Poxviridae family, which have a size between 200 and

400 nm [13]. Poxviruses are divided into two groups: the first is Chordopoxvirinae, which infects vertebrates, while the second is Entomopoxvarinae, infecting insects [14].

Cowpox virus (CPXV), monkeypox virus (MPXV), vaccinia virus (VACV), variola virus (VARV), and the causative agent of smallpox are among the viruses of this family that can cause disease in humans. Poxviruses contain a concave viral core in which the DNA genome, DNA-dependent RNA polymerase, and enzymes necessary for particle coating are present [15, 16]. The nucleosome is surrounded by a nuclear

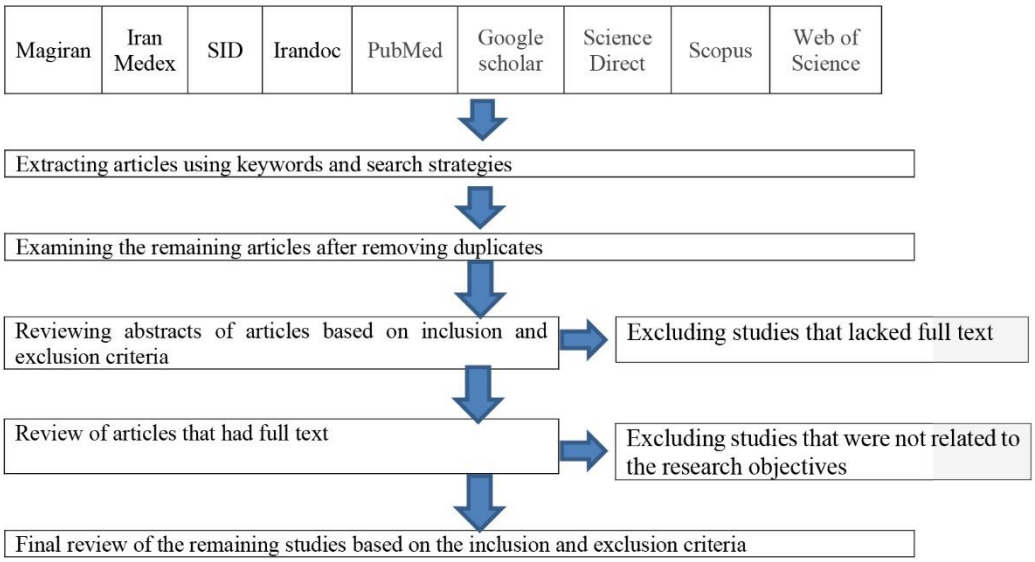

Chart 1: Algorithm of using related articles in the current research

membrane and two protein bodies. It also contains a monolipid membrane associated with the mature virion (MV) cell. The second lipid coat derived from the host covers the extracellular virion (EV) [17, 18]. Poxvirus genomes consist of a large, linear, double-stranded viral DNA genome that encodes 200 genes. The structural genes of the virus are highly conserved in a way that these genes are mostly found in the middle of the genome, while the pathogenic genes that act as disease agents and viral pathogenesis are found at the end of the genome [19].

Monkeypox is a zoonotic poxvirus infection, which can occur in both humans and some other animals. The Congo Basin Clade and the West African Clade are two well-known types of monkeypox, whereas the West African type is milder in terms of pathogenicity and disease symptoms [20, 21]. This rare disease occurs mostly in countries with rainforests in Central and West Africa. A number of studies suggest that evidence of orthopoxvirus infection has also been found in a number of African rodents [22, 23].

The main route of inertance for most smallpox viruses is through the skin; however, reports show that orthopoxviruses can also enter the body of animals and humans through the respiratory and mucosal routes [24]. In general, poxviruses cause localized lesions that progress through the macular, popular, vesicular, and pustular stages. Depending on the type of virus and the host, systemic infections may develop, where the spread of the virus from lymph nodes into the blood leads to primary viremia [25, 26].

Children, the elderly, people with underlying diseases, as well as people with immune system defects are susceptible to severe forms of monkeypox. Hence, there is a higher possibility of disease complications such as pneumonia (bronchopneumonia), severe blood infection (sepsis), brain infection (encephalitis), and corneal infection in these groups [2, 27].

Viruses spread with the help of their hosts. Host cells provide a platform for viruses to grow, allowing them to make thousands of new viruses. Eventually, when the viruses are done with the cells, they destroy them and shed them so that they can make more of their own population. Sometimes, they can also infect other species, and thus the growth rate of their family increases as well. Viruses, like other living organisms, can undergo mutations, which helps their transmission to other hosts. Monkeypox has also opened its way to infect humans and has infected many people in recent

decades and is still spreading today [28, 29].

Major reservoirs

Various animal species have been identified as susceptible reservoirs of the monkeypox virus. Some of these animals include chipmunks, tree squirrels, rats, anteaters, hedgehogs, rabbits, dogs, monkeys, and other species. Uncertainty about the natural history of the monkeypox virus remains, and further studies are needed to identify its reservoir(s) and circulation modes of the virus in nature [30].

People can become infected with the virus through direct contact with infected animals, often during hunting, trapping, and slaughtering infected animals or through contaminated animal body parts and fluids. Small mammals can carry the virus. In 2003, an outbreak of monkeypox occurred in domestic prairie dogs after they shared bedding and cages with a shipment of infected small mammals from West Africa. This resulted in 47 human cases in 6 states in the United States. Reports of cases of virus transmission from animal to animal as well as from animal to human, like the outbreak of monkeypox in 2003, show the importance of reducing the risk of secondary infections from animals; this vital measure can be taken by isolating infected people as well as animals at risk [31, 32].

Not all animals may develop a skin rash when infected with monkeypox. It is possible to transmit the monkeypox virus from infected and asymptomatic animals to humans and other animals. Also, the monkeypox virus can be transmitted from infected people through close contact, including petting, hugging, kissing, and feeding animals [33].

Monkeypox virus can be found in the monkeypox rash (skin and fluid) and body fluids, including respiratory secretions, and potentially in urine and feces. In order to prevent the virus from spreading, people with monkeypox should avoid contact with animals including pets, domesticated animals, and related wildlife species. Pets that have had close contact with a symptomatic person with monkeypox should be kept away from other animals and other people for 21 days after the last contact with the infected person [34].

If a person is infected with monkeypox and has to take care of their pets, they should wash their hands or use alcohol-containing solutions before and after treating the animal. It is also important to cover any rashes as much as possible (e.g., long-sleeve shirts and long pants) and to use appropriate gloves and masks when handling animals [35].

Findings indicate that monkeypox spreads in pets and other animals, so it should be considered that any mammal can be infected with the monkeypox virus [36].

The main routes of transmission and spread of the monkeypox virus between humans and animals

Monkeypox virus is transmitted through large respiratory particles (droplets) and in some cases through respiratory particles (bioaerosols) and direct contact with skin lesions. The transmission of the monkeypox virus is often through respiratory particles, so unlike the infection of COVID-19, the infection of the monkeypox disease often requires close and prolonged contact [37, 38].

Most human cases of monkeypox have originated from an infected animal. The monkeypox virus can enter the body through unhealthy skin, the respiratory tract, or mucous membranes of the eyes, nose, or mouth. When a human becomes infected, transmission to other humans and animals is common, so the patient's family members and hospital staff are at high risk of infection [39].

Monkeypox can be more accurately described as "sexually transmitted". In other words, sexual intercourse is one of the ways through which monkeypox is transmitted. Outbreaks of monkeypox have already been linked to direct exposure to infected animals and animal products with limited person-to-person spread. In the current outbreak of monkeypox, however, the virus is spreading primarily through close personal contact. This may include contact with infectious lesions or respiratory secretions through close, continuous skin-to-skin contact occurring during intercourse. Nevertheless, any close and continuous skin-to-skin contact with a person who has monkeypox can spread the virus [40, 41].

Monkeypox can spread from person to person through direct contact with an infected rash, scab, or body fluids. It can also be transmitted through respiratory secretions during prolonged, face-to-face contact, or during intimate physical contact, such as kissing, caressing, or sex. Monkeypox can spread from the time symptoms start until the rash has completely healed and a new layer of skin has formed. Anyone in close personal contact with a person with monkeypox can contract it and should take steps to protect themselves [42, 43].

Orviz et al. investigated the clinical and virological aspects of this disease in their study on the outbreak of monkeypox in Madrid (Spain) [44]. The results of their study showed that the clinical manifestations of monkeypox patients highlight the frequent presence of

sexually transmitted infections. According to the investigations, no reports of simultaneous infection with the monkeypox virus and covid-19 and other communicable diseases have been published. The findings of Santi Nolasco et al. showed the first case of co-infection with the monkeypox virus, SARS-CoV-2, and HIV. The results of their study indicated that monkeypox virus and SARS-CoV-2 infection can occur simultaneously, and flu-like symptoms and SARS-CoV-2 positivity should not rule out the possibility of monkeypox infection in people. Also, the results of their study showed that monkeypox is often diagnosed in people with sexually transmitted infections [45].

As these pathogens continue to spread, people can become infected with the monkeypox virus, SARS-CoV-2, and sexually transmitted infections at the same time. Considering that not all patients with monkeypox have skin lesions and that COVID-19 may rarely be associated with rash and vesicles, it becomes difficult for doctors to correctly diagnose the disease as it requires comprehensive clinical examinations and records of the patient's sexual behaviors [46-48]

The results of the studies show that if a person is suspected of having monkeypox, even in the absence of skin manifestations, a PCR test should be performed for this patient. One reason is that while the symptoms of the disease may not have developed on the skin, the virus may be present in the mucous membrane of the mouth or rectum [49, 50]. What is extracted from the results of the studies is that sex can be the dominant way of transmission of monkeypox disease. Therefore, a thorough investigation of sexual history and high-risk sexual behaviors of individuals is recommended to diagnose monkeypox [51].

There are several routes of transmission for the monkeypox virus. Transmission happens through damaged skin, mucous secretions (eyes, mouth, and nose), semen, vaginal fluids, urine, and feces, bites by infected animals, contact with the meat of an infected animal during preparation, or contact with the place where the animal is kept, oral sex, anal and vaginal sex with a person with monkeypox. It can also happen through touching cloths and objects that have been used by a person with monkeypox and were not disinfected, transmission from mother to baby during childbirth and direct contact between humans and animals, humans and objects [52-54]. Monkeypox virus is no longer contagious after all the blisters and skin rashes of infected people dry up and heal [55, 56].

Interspecies transmission of monkeypox (Figure 1) mainly occurs through direct or indirect contact from an infected animal to a human and then transmission from human to human to the animal [57].

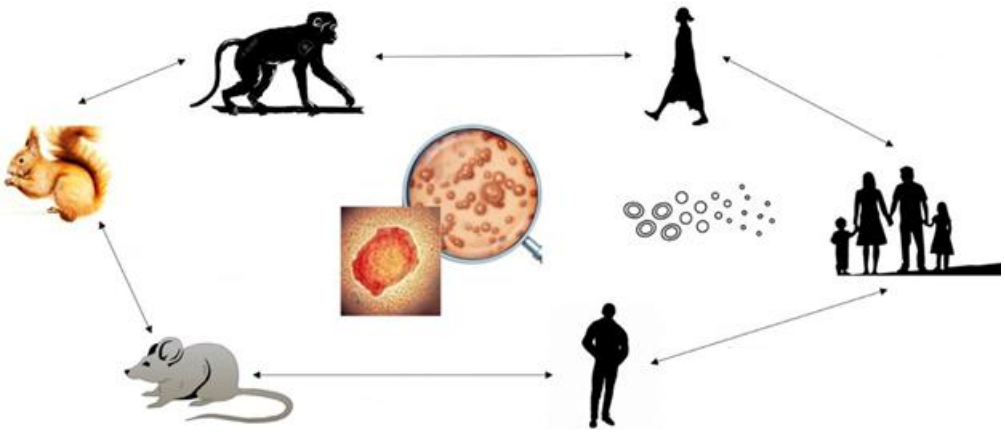

Figure 1: Interspecies transmission of monkeypox [58].

The facts of the disease in the world

Several reasons have been proposed for the recent increase and spread of epidemics in the world. Based on current evidence, exploitation of the environment caused by land use changes, deforestation, expansion of agriculture, trade and intrusion into wildlife, high-risk sexual behaviors, urbanization development, breeding of wild animals, and feeding on animal products are some of the prominent causes for the outbreak of emerging diseases and the creation of epidemics [59, 60].

Monkeypox disease has spread worldwide, but its incidence varies in different countries of the world, considering the epidemiological conditions and the existence of the reservoir of the agent. The monkeypox virus was first reported in 1958 in a research center studying monkeys. The first human case was also reported in 1970 in the Republic of Congo [61].

In 2003, more than 70 cases of monkeypox were observed in America due to transmission from infected dogs from Africa. After several cases were reported in Africa, cases of monkeypox were also reported in other countries such as the United States, England, Singapore, and Israel due to the travel of people and the transportation of animals between different countries [62, 63].

In 2017, monkeypox became an epidemic in Nigeria. The country's health minister said that "the virus has spread to 11 states and 74 people are suspected of being infected". The epidemic is thought to have been caused by river flooding, which brought infected wild animals into closer contact with humans as it is a zoonotic disease that is transmitted and spread from animals to humans [64, 65].

In September 2018, three British nationals who had traveled to Nigeria were reported to have contracted monkeypox. Since 2017, the disease has been present in Nigeria with 89 reported cases and six deaths. Probably, these three English patients were exposed to the virus while traveling to Nigeria [66].

On May 27th, 2021, a 53-year-old Chinese veterinarian died of this disease. According to reports, this veterinarian had autopsied two dead monkeys a few months earlier. After that, the US government recorded the first case of monkeypox. This patient came to Texas from Nigeria [67, 68].

Monkeypox as an emerging infection was first reported in the United Kingdom on April 29th, 2022 [69]. The person with monkeypox was a British citizen who had a history of traveling to Lagos and Delta State in Nigeria [70]. In these areas, monkeypox is known as an endemic disease. This person was in Nigeria on April 29th, and at the same time, he had symptoms of monkeypox, including skin rashes. On May 4th, this person returned to his home country, the United Kingdom, and went to the hospital on the same day due to clinical symptoms and skin lesions (blisters). This person was admitted to the hospital with the possibility of having contracted monkeypox [71, 72]. Paraclinical tests, as well as PCR tests, were performed for the patient; due to the positive PCR test, the patient was treated in the respiratory isolation department [73].

In May 2022, the Nigerian government reported official statistics and information about the disease and the death rate caused by monkeypox in this country. Cases of monkeypox were reported in other countries and regions from May 18th onwards. New cases were reported mainly in Europe, and in the countries of England, Scotland, Wales, and Ireland, as well as from North and South America, the Middle East, and Australia [74, 75]. According to the spokesperson of Iran's Ministry of Health, and Medical Education, on Tuesday, August 16th, 2022, the first case of monkeypox was recorded in Iran [12].

Due to the increasing numbers and new cases of monkeypox, the World Health Organization declared this disease a global emergency on June 23, 2022 [75, 76].

The US Centers for Disease Control and Prevention (CDC) has reported 6 deaths from monkeypox in 6 different states between 2017 and 2022. This center also reported the mortality rate of this disease as 3.3% [77, 78] On May 20th, 2022, the World Health Organization convened an emergency meeting to discuss the spread and assess the threat level of monkeypox. Hans Kluge, the head of the World Health Organization in Europe, expressed concern that as people gather for parties and festivals in the summer, infections may spread further in Europe and the world [79, 80].

The spread of monkeypox in a number of countries in the world is one of the reasons that makes the importance of understanding monkeypox more obvious to everyone. Therefore, knowing different aspects of this disease, its prevention, and treatment methods should be given more attention.

Clinical aspects of monkeypox

In Animals

In general, most animals infected with monkeypox may not show any symptoms of the disease, yet they can carry the virus and spread the virus between humans and animals. Symptoms of the disease in the animal itself can include general weakness, skin, and respiratory symptoms [23]. The results of studies show that in countries where monkeypox is endemic, only wild animals (rodents and primates) can be carriers of the monkeypox virus [81]. However, the results of limited studies have reported transmission of the monkeypox virus in prairie dogs in the United States [82] and in zoo mammals in Europe [83] that were in contact with imported infected animals. Until the first official report of transmission of monkeypox from humans to domestic dogs in Brazil was announced for the first time in the world, it had never been reported among domestic animals such as dogs and cats [84]. In this report, the Minister of Health announced the positive result of monkeypox in a sample taken from a dog in the state of Minas Gerais. The virus was detected in a dog in the city of Juiz de Fora in June 2022, whose owner had contracted the disease earlier that month. The symptoms of monkeypox disease in

this animal included skin itching, skin peeling, and purulent pimples. After conducting a PCR test from oral and anal secretions, it was determined that this dog was infected with monkeypox [82, 84].

In Human beings

Headache, muscle pain, fever, and fatigue are among the first symptoms of this disease. Symptoms may initially resemble the flu [56]. This disease can be similar to chicken pox, measles, and smallpox, but its characteristic is the presence of swollen lymph nodes. This swelling typically appears behind the ear, under the jaw, in the neck or groin, before the skin rash develops. Then, within a few days after the fever, the lesions appear characteristically on the face and then elsewhere, such as the palms and soles, in a centrifugal distribution [85, 86]. Three-quarters of affected people have lesions on the palms and feet, more than two-thirds in the mouth, one-third in the genital area, and one out of five people have lesions in the eyes. The lesions appear as small, flat spots before turning into small bumps. These bumps then fill with a clear, then yellow, fluid, which subsequently ruptures and becomes scaly [87, 88].

There may be a few lesions or several thousand lesions that sometimes merge to form large lesions. In each affected part of the body, lesions develop at the same stage [28]. The rash usually lasts about 10 days [89]. A sick person may be weak and lethargic for two to four weeks. After healing, the lesions may leave faint marks before turning into a dark scar [90].

Other symptoms of the monkeypox virus include weakness and lethargy, sore throat, cough, skin itching, and lymph node involvement. The involvement of lymph nodes in monkeypox is one of the most important symptoms that can distinguish it from chicken pox and other vesicular diseases [91].

This disease can cause complications in sufferers. Complications of monkeypox include secondary infections, pneumonia, sepsis, and encephalitis, and in case of severe eye infection, it can lead to vision loss. If the infection occurs during pregnancy, the baby may be stillborn or malformed. The disease may be milder in people who were vaccinated against smallpox in childhood [92, 93].

The incubation period of monkey pox disease is 7 to 14 days; some studies have reported the incubation period of this disease to be up to 21 days. Therefore, if a person has suspected contact with an infected patient or animal, he or she should be quarantined for 3 weeks and monitored for clinical symptoms. The suspected person should be quarantined until the symptoms of the disease disappear, and during the quarantine period, the sick person and everyone around him or her should use masks [8, 26]. Table 1 shows the clinical characteristics of monkeypox.

Table 1: Clinical characteristics of monkeypox disease (39)

Clinical characteristics of monkeypox	**Fever**	**More than 38 degrees**
	Rash	1-3 days after contract
	Rash shape	Macule, papule, vesicle, pustule Can be seen all over body
	Rash progress	Slow, 3-4 weeks
	Skinrash distribution	They start over; denser in the face and limbs; And then they appear on the palms of the hands and feet
	Classic characteristic	Lymphadenopathy
	Mortality rate	11%

Prevention and treatment

Vaccination against smallpox protects against human monkeypox infection because they are closely related viruses; studies have shown that the smallpox vaccine reduced the risk of developing monkeypox among previously vaccinated individuals [94]. People who research monkeypox outbreaks and are involved in the care of infected people or animals should receive the smallpox vaccine. People who have had close contact with people or animals with confirmed monkeypox should also be vaccinated [95, 96].

The Centers for Disease Control and Prevention (CDC) recommends that healthcare providers use a full set of personal protective equipment before caring for an infected person. This equipment includes overalls, masks, gloves, and eye shields. People should also prioritize personal hygiene and hand washing [97, 98].

Imvamune or Imvanex vaccine is a live attenuated virus vaccine that is used to prevent monkeypox. This vaccine has been approved by the US Food and Drug Administration (FDA). This vaccine is used in many countries, including the United States, as prophylaxis against monkeypox for people with high-risk jobs and those with a high probability of contact with infected animals or laboratory workers. It should be known that

there is no effective medicine for monkeypox and only supportive treatments, symptomatic treatments, prevention, and treatment of secondary infections in monkeypox disease are available [10, 99].

Monkeypox disease is self-limiting and resolves spontaneously within 2–3 weeks after initial infection [100]. The treatment management of the disease depends on the severity of the symptoms and complications of the disease, which may require supportive care. In addition, antiviral drugs can be used according to the clinical conditions of the affected people. Antiviral drugs (tecovirimat, cidofovir) and immunoglobulins are used in acute and worsening conditions of the patient [8, 99].

Recommendations and suggestions for the future

Unlike COVID-19, monkeypox is known to be endemic in Central and West Africa. It is significantly less contagious than the coronavirus. The increased resurgence of outbreaks suggests that other communicable diseases have been neglected since the COVID-19 pandemic. Globalization and increasing communication between different nations of the world can augment the spread of epidemics [101, 102].

Focusing on vaccination and disease surveillance operations and closely monitoring the impact of such programs are critical to achieving the eventual eradication of monkeypox in Africa [103, 104]. To protect people who are more vulnerable to the virus, campaigns such as information programs in schools, communities, and virtual spaces, especially at the city level should be implemented. Meanwhile, countries that do not have enough access to health facilities should be prioritized. Local risk assessments should be conducted and consistently incorporated into immunization programs. Vaccination programs and other public health initiatives should be independent of politics [105, 106].

The government should consider measures to finance research on monkeypox and shared viruses between animals and humans, by providing research grants, encouraging experts and researchers to produce drugs and vaccines which can lead to the complete eradication of the disease [107-109].

5. Conclusion

The re-emergence and increase in cases of monkeypox shows lack of adequate surveillance systems regarding this disease. This is why assessing the severity of the global health situation is so important for effective prevention and preparedness for a potential pandemic. Unlike COVID-19, monkeypox is not a new disease to the scientific community since its first recorded case goes back to 1970. It shares many similarities with its close relative, smallpox.

One of the most effective factors in reducing the risk in Africa has been smallpox vaccination. However, immunity is waning in people vaccinated with the smallpox vaccine before 1980, and the risk is increasing for the unvaccinated population. Challenges observed in African countries include lack of an efficient surveillance system for early detection of the disease. Lack of awareness of monkeypox disease among the general population, health and treatment facilities and trained and professional healthcare workers can be the factors behind the unfolding of newly emerging diseases and the re-emergence of communicable diseases. Therefore, establishing cross-border collaborations with international sectors, FAO, OIE, and WHO, and different national sectors in a true One Health spirit, is critical to prevent the emergence and spread of monkeypox.

The monkeypox virus has posed a potential and actual threat worldwide since smallpox vaccination was discontinued. Significant improvements in the quality and quantity of diagnoses of cases and outbreaks of the disease have led to an increase in the world's awareness of this zoonotic disease. It seems necessary to conduct research related to this disease in order to know and possibly manage it.

Available findings provide an incomplete picture of monkeypox outbreak patterns over time. It is plausible and reasonable that the rise in reported cases of monkeypox is the result of increased population density, human encroachment on animal habitats and unknown animal reservoirs, and an increase in the population of susceptible individuals since the cessation of the smallpox vaccination program. Almost everyone under the age of 40 has not been vaccinated against smallpox. The apparent rise in the mean age of monkeypox cases over time probably reflects the increase in the mean age of susceptible individuals born after smallpox vaccination was discontinued in 1980. It seems that the tendency of this age group towards high-risk sexual behaviors, playing with animals, and keeping and hunting them can be among the issues raised in the spread of this disease.

According to the explanations given, it can be concluded that monkeypox is a widespread disease in most countries of the world, but the exact extent of its prevalence in human and animal populations has not been known yet. The wide spread of this disease in the world is due to its long-term survival in various animal populations and in the environment caused by humans

and infected animals. Considering that the monkeypox virus is the cause of acute infections in humans and animals, it can have many effects on the overall population structure and economic issues of a country and threaten the health of human and animal populations.

Lack of attention to health issues, risky sexual behaviors, low level of personal hygiene, close contact between animals and humans, use of contaminated raw and semi-raw milk and animal products, especially in rural and less developed areas, and the risk of zoonotic diseases can lead to the emergence of epidemics. Therefore, it is necessary to raise the level of public awareness regarding this disease and to implement active surveillance in animal and human populations in order to determine its exact extent, especially its acute type in the human population in the early stages. Then, if a new epidemic occurs after the corona virus, it could be prevented.

After the corona pandemic and the death of many people together with the restrictions created for combating it, the fear of a new pandemic has caused a lot of anxiety for many people. Yet, do we really need to worry about a new pandemic? Although cases of this disease have been reported in many non-endemic countries of the world, and the necessary measures should be taken for its prevention and proper treatment, it seems that the probability of a new pandemic due to monkeypox, is much less than the risk for corona like microorganisms.

Finally, although it is recommended that the proper and complete training of people and doctors regarding the symptoms and transmission of this disease by the relevant institutions should be initiated quickly, one should be careful that raising the awareness of the public in relation to this disease is accompanied by fear and panic. There is a need for cautious teaching method, by following health principles; this disease can be controlled and prevented much more easily than COVID-19. Regarding the limitations of the present study, lack of studies related to the purpose of the present study can be highlighted. The strengths of this research can be the novelty of the research, conducting a systematic review on a new disease and predicting whether this disease can become an epidemic or not.

Ethical Considerations

Compliance with ethical guidelines

This article is the result of a research project approved by Mashhad University of Medical Sciences with ethics code IR.MUMS.REC.1401.290.

Funding

This research was done with the financial support of Mashhad University of Medical Sciences Research Vice.

Author's contributions

Conceptualization: Rasoul Raesi, Mohammad Hossein Gholami

Data curation: Rasoul Raesi, Negin Esfandiari, M. Reza Najafi

Methodology: Saeid Bokaei, Negin Esfandiari

Project administration: Kiavash Hushmandi.

Conflict of interest

According to the authors of this article, there is no conflict of interest.

Acknowledgments

This article is the result of a research project approved by the Ethics and Research Committee of Mashhad University of Medical Sciences. We would like to express our sincere thanks to the Vice President of Research and Technology of Mashhad University of Medical Sciences and all the people who helped us in carrying out this research project.

References

[1] Chakraborty C, Bhattacharya M, Nandi SS, Mohapatra RK, Dhama K, Agoramoorthy G. Appearance and re-appearance of zoonotic disease during the pandemic period: long-term monitoring and analysis of zoonosis is crucial to confirm the animal origin of SARS-CoV-2 and monkeypox virus. Vet Q. 2022; 42(1):119-24. DOI: 10.1080/01652176.2022.2086718 [PMID] [PMCID]

[2] Di Giulio DB, Eckburg PB. Human monkeypox: an emerging zoonosis. Lancet Infect Dis. 2004; 4(1):15-25. [DOI: 10.1016/s1473-3099(03)00856-9] [PMID] [PMCID]

[3] Magnus Pv, Andersen EK, Petersen KB, Birch-Andersen A. A pox-like disease in cynomolgus monkeys. APMIS. 1959; 46(2):156-76. [DOI:10.1111/j.1699-0463.1959.tb00328.x]

[4] Fenner F, Henderson DA, Arita I, Jezek Z, Ladnyi ID. Smallpox and its eradication: World Health Organization Geneva; 1988. [PMCID]

[5] Hopkins DR. The greatest killer: smallpox in history: University of Chicago press; 2002. https://press.uchicago.edu/ucp/books/book/chi

cago/G/bo3647267.html

[6] Werden SJ, Rahman MM, McFadden G. Poxvirus host range genes. Adv Virus Res. 2008; 71:135-71. [DOI: 10.1016/S0065-3527(08)00003-1] [PMID]

[7] Kulesh DA, Loveless BM, Norwood D, Garrison J, Whitehouse CA. Monkeypox virus detection in rodents using real-time 3'-minor groove binder TaqMan assays on the Roche LightCycler. Lab Invest. 2004; 84(9):1200-8. [DOI: 10.1038/labinvest.3700143] [PMID] [PMCID]

[8] McCollum AM, Damon IK. Human monkeypox. Clin Infect Dis. 2014; 58(2):260-7. [DOI: 10.1093/cid/cit703] [PMID]

[9] Kenner J, Cameron F, Empig C, Jobes DV, Gurwith M. LC16m8: an attenuated smallpox vaccine. Vaccine. 2006; 24(47-48):7009-22. [DOI: 10.1016/j.vaccine.2006.03.087] [PMID] [PMCID]

[10] Saijo M, Ami Y, Suzaki Y, Nagata N, Iwata N, Hasegawa H, et al. LC16m8, a highly attenuated vaccinia virus vaccine lacking expression of the membrane protein B5R, protects monkeys from monkeypox. J virol. 2006; 80(11):5179-88. [DOI: 10.1128/JVI.02642-05] [PMID] [PMCID]

[11] Mahmoud A, Nchasi G. Monkeypox virus: A zoonosis of concern. J Med Virol. 2023; 95(1):e27968. [DOI: 10.1002/jmv.27968] [PMID]

[12] https://behdasht.gov.ir/.

[13] Petersen B, Damon I. Smallpox, monkeypox, and other poxvirus infections. Goldman-Cecil Medicine. Philadelphia, PA: Elsevier; 2020. https://www.clinicalkey.com/#!/content/book/3-s2.0-B9780323532662003489?indexOverride=GLOBAL

[14] Sah R, Mohanty A, Singh P, Abdelaal A, Padhi BK. Monkeypox and occupational exposure: Potential risk toward healthcare workers and recommended actions. Front Public Health. 2022; 10:1023789. [DOI: 10.3389/fpubh.2022.1023789] [PMID] [PMCID]

[15] Minhaj FS, Ogale YP, Whitehill F, Schultz J, Foote M, Davidson W, et al. Monkeypox outbreak—Nine states. Wiley Online Library; 2022. [DOI: 10.15585/mmwr.mm7123e1]

[16] Minhaj FS, Ogale YP, Whitehill F, Schultz J, Foote M, Davidson W, et al. Monkeypox outbreak—nine states, May 2022. Morbidity and Mortality Weekly Report. 2022;71(23):764.

[17] Shchelkunov S, Totmenin A, Safronov P, Mikheev M, Gutorov V, Ryazankina O, et al. Analysis of the monkeypox virus genome. Virology. 2002; 297(2):172-94. [DOI: 10.1006/viro.2002.1446] [PMID] [PMCID]

[18] Okoh M, Nwachukwu KC. A virulent disease called monkeypox: a case report of countries in africa where the disease is endemic. Indo Glob res j pharm sci. 2022; 12:237-44. [DOI: 10.35652/IGJPS.2022.12030]

[19] Luna N, Ramírez AL, Muñoz M, Ballesteros N, Patiño LH, Castañeda SA, et al. Phylogenomic analysis of the monkeypox virus (MPXV) 2022 outbreak: Emergence of a novel viral lineage? Travel Med Infect Dis. 2022; 49:102402. [DOI: 10.1016/j.tmaid.2022.102402] [PMID] [PMCID]

[20] Taseen S, Nasir F, Abbas M, Altaf M, Asghar MS, Tahir MJ. Post-pandemic world at the mercy of monkeypox virus outbreak: Time to worry or not. J Med Virol. 2023; 95(1):e27948. [DOI: 10.1002/jmv.27948] [PMID]

[21] Kugelman JR, Johnston SC, Mulembakani PM, Kisalu N, Lee MS, Koroleva G, et al. Genomic variability of monkeypox virus among humans, Democratic Republic of the Congo. Emerg Infect Dis. 2014; 20(2):232. [DOI: 10.3201/eid2002.130118] [PMID] [PMCID]

[22] Jiang Z, Sun J, Zhang L, Lai A. Laboratory diagnostics for monkeypox: an overview of sensitivities from various published tests. Travel Med Infect Dis. 2022; 49:102425. [DOI: 10.1016/j.tmaid.2022.102425] [PMID] [PMCID]

[23] Hutson CL, Olson VA, Carroll DS, Abel JA, Hughes CM, Braden ZH, et al. A prairie dog animal model of systemic orthopoxvirus disease using West African and Congo Basin strains of monkeypox virus. J Gen Virol. 2009; 90(2):323-33. [DOI: 10.1099/vir.0.005108-0] [PMID]

[24] Hutson CL, Gallardo-Romero N, Carroll DS, Clemmons C, Salzer JS, Nagy T, et al. Transmissibility of the monkeypox virus clades via respiratory transmission: investigation using the prairie dog-monkeypox virus challenge system. PLoS One. 2013; 8(2):e55488. [DOI: 10.1371/journal.pone.0055488] [PMID] [PMCID]

[25] Palumbo GJ, Buller RM, Glasgow WC. Multigenic evasion of inflammation by poxviruses. J virol. 1994; 68(3):1737-49.

[DOI: 10.1128/JVI.68.3.1737-1749.1994] [PMID] [PMCID]

[26] Breman JG, Henderson DA. Diagnosis and management of smallpox. N Engl J Med. 2002; 346(17):1300-8. [DOI: 10.1056/NEJMra020025] [PMID]

[27] Weinstein RA, Nalca A, Rimoin AW, Bavari S, Whitehouse CA. Reemergence of monkeypox: prevalence, diagnostics, and countermeasures. Clin Infect Dis. 2005; 41(12):1765-71. [DOI: 10.1086/498155]

[28] Rizk JG, Lippi G, Henry BM, Forthal DN, Rizk Y. Prevention and treatment of monkeypox. Drugs. 2022; 82(9):957-63. [DOI: 10.1007/s40265-022-01742-y] [PMID] [PMCID]

[29] Weiner ZP, Salzer JS, LeMasters E, Ellison JA, Kondas AV, Morgan CN, et al. Characterization of Monkeypox virus dissemination in the black-tailed prairie dog (Cynomys ludovicianus) through in vivo bioluminescent imaging. PLoS One. 2019; 14(9):e0222612. [DOI: 10.1371/journal.pone.0222612] [PMID] [PMCID]

[30] Mpox (Monkeypox). April 18, 2023. https://www.who.int/news-room/fact-sheets/detail/monkeypox.

[31] Walker M. Monkeypox virus hosts and transmission routes: a systematic review of a Zoonotic pathogen. 2022. https://scholarworks.uark.edu/biscuht/69/

[32] Nolen LD, Osadebe L, Katomba J, Likofata J, Mukadi D, Monroe B, et al. Introduction of monkeypox into a community and household: risk factors and zoonotic reservoirs in the Democratic Republic of the Congo. Am J Trop Med Hyg. 2015; 93(2):410. [DOI: 10.4269/ajtmh.15-0168] [PMID] [PMCID]

[33] MacNeill AL. Comparative pathology of zoonotic orthopoxviruses. Pathogens. 2022; 11(8):892. [DOI: 10.3390/pathogens11080892] [PMID] [PMCID]

[34] Simpson K, Heymann D, Brown CS, Edmunds WJ, Elsgaard J, Fine P, et al. Human monkeypox–After 40 years, an unintended consequence of smallpox eradication. Vaccine. 2020; 38(33):5077-81. [DOI: 10.1016/j.vaccine.2020.04.062] [PMID] [PMCID]

[35] Petersen E, Zumla A, Hui D, Blumberg L, Valdoleiros S, Amao L, et al. Vaccination for monkeypox prevention in persons with high-risk sexual behaviours to control on-going outbreak of monkeypox virus clade 3. Int J Infect Dis. 2022; 122:569-71. [DOI: 10.1016/j.ijid.2022.06.047] [PMID] [PMCID]

[36] Costello V, Sowash M, Gaur A, Cardis M, Pasieka H, Wortmann G, et al. Imported monkeypox from international traveler, Maryland, USA, 2021. Emerg Infect Dis. 2022; 28(5):1002. [DOI: 10.3201/eid2805.220292] [PMID] [PMCID]

[37] Farahat RA, Abdelaal A, Shah J, Ghozy S, Sah R, Bonilla-Aldana DK, et al. Monkeypox outbreaks during COVID-19 pandemic: are we looking at an independent phenomenon or an overlapping pandemic? Ann Clin Microbiol Antimicrob. 2022; 21(1):26. [DOI: 10.1186/s12941-022-00518-2] [PMID] [PMCID]

[38] Verreault D, Killeen SZ, Redmann RK, Roy CJ. Susceptibility of monkeypox virus aerosol suspensions in a rotating chamber. J Virol Methods. 2013; 187(2):333-7. [DOI: 10.1016/j.jviromet.2012.10.009] [PMID] [PMCID]

[39] Petersen E, Kantele A, Koopmans M, Asogun D, Yinka-Ogunleye A, Ihekweazu C, et al. Human monkeypox: epidemiologic and clinical characteristics, diagnosis, and prevention. Infect Dis Clin North Am. 2019; 33(4):1027-43. [DOI: 10.1016/j.idc.2019.03.001] [PMID] [PMCID]

[40] Sah R, Abdelaal A, Reda A, Katamesh BE, Manirambona E, Abdelmonem H, et al. Monkeypox and its possible sexual transmission: where are we now with its evidence? Pathogens. 2022; 11(8):924. [DOI: 10.3390/pathogens11080924] [PMID] [PMCID]

[41] Girometti N, Byrne R, Bracchi M, Heskin J, McOwan A, Tittle V, et al. Demographic and clinical characteristics of confirmed human monkeypox virus cases in individuals attending a sexual health centre in London, UK: an observational analysis. Lancet Infect Dis. 2022; 22(9):1321-8. [DOI: 10.1016/S1473-3099(22)00411-X] [PMID] [PMCID]

[42] Guarner J, Del Rio C, Malani PN. Monkeypox in 2022—what clinicians need to know. JAMA. 2022; 328(2):139-40. [DOI: 10.1001/jama.2022.10802] [PMID]

[43] Rodriguez-Morales AJ, Lopardo G. Monkeypox: another sexually transmitted infection? Pathogens. 2022; 11(7):713. [DOI: 10.3390/pathogens11070713] [PMID] [PMCID]

[44] Orviz E, Negredo A, Ayerdi O, Vázquez A, Muñoz-Gomez A, Monzón S, et al. Monkeypox outbreak in Madrid (Spain): clinical and virological aspects. J Infect. 2022; 85(4):412-7. [DOI: 10.1016/j.jinf.2022.07.005] [PMID] [PMCID]

[45] Nolasco S, Vitale F, Geremia A, Tramuto F, Maida CM, Sciuto A, et al. First case of monkeypox virus, SARS-CoV-2 and HIV co-infection. J Infect. 2023; 86(1):21-3. [DOI: 10.1016/j.jinf.2022.08.014] [PMID] [PMCID]

[46] Raccagni AR, Mileto D, Canetti D, Tamburini AM, Rizzo A, Bruzzesi E, et al. Monkeypox and pan-resistant Campylobacter spp infection in Entamoeba histolytica and Chlamydia trachomatis re-infection in a man who have sex with men. J Infect. 2022; 85(4):436-80. [DOI: 10.1016/j.jinf.2022.06.028] [PMID]

[47] Marzano AV, Genovese G, Fabbrocini G, Pigatto P, Monfrecola G, Piraccini BM, et al. Varicella-like exanthem as a specific COVID-19–associated skin manifestation: Multicenter case series of 22 patients. J Am Acad Dermatol. 2020; 83(1):280-5. [DOI: 10.1016/j.jaad.2020.04.044] [PMID] [PMCID]

[48] 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. [DOI: 10.1016/j.jviromet.2010.07.012] [PMID] [PMCID]

[49] Peiró-Mestres A, Fuertes I, Camprubí-Ferrer D, Marcos MÁ, Vilella A, Navarro M, et al. Frequent detection of monkeypox virus DNA in saliva, semen, and other clinical samples from 12 patients, Barcelona, Spain, May to June 2022. Euro Surveill. 2022; 27(28):2200503. [DOI: 10.2807/1560-7917.ES.2022.27.28.2200503] [PMID] [PMCID]

[50] Thornhill JP, Barkati S, Walmsley S, Rockstroh J, Antinori A, Harrison LB, et al. Monkeypox virus infection in humans across 16 countries—April–June 2022. N Engl J Med. 2022; 387(8):679-91. [DOI: 10.1056/NEJMc2213969] [PMID]

[51] Bhagavathula AS, Khubchandani J. Monkeypox outbreaks and global health emergency declaration: Can such declarations influence public interest in the disease? Brain Behav Immun. 2022; 106:113-4. [DOI: 10.1016/j.bbi.2022.08.009] [PMID] [PMCID]

[52] Guarner J, Johnson BJ, Paddock CD, Shieh W-J, Goldsmith CS, Reynolds MG, et al. Monkeypox transmission and pathogenesis in prairie dogs. Emerg Infect Dis. 2004; 10(3):426. [DOI: 10.3201/eid1003.030878] [PMID] [PMCID]

[53] Del Rio C, Malani PN. Update on the monkeypox outbreak. JAMA. 2022; 328(10):921-2. [DOI: 10.1001/jama.2022.14857] [PMID]

[54] Kaler J, Hussain A, Flores G, Kheiri S, Desrosiers D. Monkeypox: a comprehensive review of transmission, pathogenesis, and manifestation. Cureus. 2022; 14(7):e26531. [DOI: 10.7759/cureus.26531] [PMID] [PMCID]

[55] Mahase E. Monkeypox: Healthcare workers will be offered smallpox vaccine as UK buys 20 000 doses. BMJ. 2022; 377:1379. [DOI: 10.1136/bmj.o1379] [PMID]

[56] Riedel-Baima B, Zielinski R, Polok K, Wnminz U. Pityriasis lichenoides et varioliformis acuta as a possible differential diagnosis for monkeypox during the 2022 outbreak in non-endemic countries. A critical review of the literature. https://www.researchgate.net/profile/Bozena-Riedel-Baima/publication/361670003

[57] Parvin R, Ali A, Nagy A, Zhu Z, Zhao S, Paul A, et al. Monkeypox virus: A comprehensive review of taxonomy, evolution, epidemiology, diagnosis, prevention, and control regiments so far. Ger J Microbiol. 2022; 2:1-15. [DOI: 10.51585/gjm.2022.2.0014]

[58] Murphy H, Ly H. The potential risks posed by inter-and intraspecies transmissions of monkeypox virus. Virulence. 2022; 13(1):1681-3. [DOI: 10.1080/21505594.2022.2127199] [PMID] [PMCID]

[59] Poorolajal J. Monkeypox virus infection: A global warning for the possible next pandemic. J Res Health Sci. 2022; 22(2):00545. [DOI: 10.34172/jrhs.2022.80] [PMID] [PMCID]

[60] Saied AA, Metwally AA, Choudhary OP. Monkeypox: an extra burden on global health. Int J Surg. 2022; 104:106745. [DOI: 10.1016/j.ijsu.2022.106745] [PMID] [PMCID]

[61] Ladnyj I, Ziegler P, Kima E. A human infection caused by monkeypox virus in Basankusu Territory, Democratic Republic of the Congo. Bull World Health Organ. 1972; 46(5):593. [PMID] [PMCID]

[62] Khattak S, Rauf MA, Ali Y, Yousaf MT, Liu Z, Wu D-D, et al. The monkeypox diagnosis, treatments and prevention: A review. Front Cell Infect Microbiol. 2023; 12:2005. [DOI: 10.3389/fcimb.2022.1088471] [PMID] [PMCID]

[63] Learned LA, Reynolds MG, Wassa DW, Li Y, Olson VA, Karem K, et al. Extended interhuman transmission of monkeypox in a hospital community in the Republic of the Congo, 2003. Am J Trop Med Hyg. 2005; 73(2):428-34. [PMID]

[64] Yinka-Ogunleye A, Aruna O, Ogoina D, Aworabhi N, Eteng W, Badaru S, et al. Reemergence of human monkeypox in Nigeria, 2017. Emerg Infect Dis. 2018; 24(6):1149. [DOI: 10.3201/eid2406.180017] [PMID] [PMCID]

[65] Yinka-Ogunleye A, Aruna O, Dalhat M, Ogoina D, McCollum A, Disu Y, et al. Outbreak of human monkeypox in Nigeria in 2017–18: a clinical and epidemiological report. Lancet Infect Dis. 2019; 19(8):872-9. [DOI: 10.1016/S1473-3099(19)30294-4] [PMID] [PMCID]

[66] Sadeuh-Mba SA, Yonga MG, Els M, Batejat C, Eyangoh S, Caro V, et al. Monkeypox virus phylogenetic similarities between a human case detected in Cameroon in 2018 and the 2017-2018 outbreak in Nigeria. Infect Genet Evol. 2019; 69:8-11. [DOI: 10.1016/j.meegid.2019.01.006] [PMID] [PMCID]

[67] Wang W, Qi W, Liu J, Du H, Zhao L, Zheng Y, et al. First human infection case of monkey B virus identified in China, 2021. China CDC Wkly. 2021; 3(29):632-3. [DOI: 10.46234/ccdcw2021.154] [PMID] [PMCID]

[68] Bhattacharya M, Dhama K, Chakraborty C. Recently spreading human monkeypox virus infection and its transmission during COVID-19 pandemic period: A travelers' prospective. Travel Med Infect Dis. 2022; 49:102398. [DOI: 10.1016/j.tmaid.2022.102398] [PMID] [PMCID]

[69] Zumla A, Valdoleiros SR, Haider N, Asogun D, Ntoumi F, Petersen E, et al. Monkeypox outbreaks outside endemic regions: scientific and social priorities. Lancet Infect Dis. 2022; 22(7):929-31. [DOI: 10.1016/S1473-3099(22)00354-1] [PMID] [PMCID]

[70] Jain N, Lansiaux E, Simanis R. The new face of monkeypox virus: an emerging global emergency. New Microbes New Infect. 2022; 47:100989. [DOI: 10.1016/j.nmni.2022.100989] [PMID] [PMCID]

[71] Mauldin MR, McCollum AM, Nakazawa YJ, Mandra A, Whitehouse ER, Davidson W, et al. Exportation of monkeypox virus from the African continent. J Infect Dis. 2022; 225(8):1367-76. [DOI: 10.1093/infdis/jiaa559] [PMID] [PMCID]

[72] Patel A, Bilinska J, Tam JC, Fontoura DDS, Mason CY, Daunt A, et al. Clinical features and novel presentations of human monkeypox in a central London centre during the 2022 outbreak: descriptive case series. BMJ. 2022; 378:072410. [DOI: 10.1136/bmj-2022-072410] [PMID] [PMCID]

[73] Hammerschlag Y, MacLeod G, Papadakis G, Sanchez AA, Druce J, Taiaroa G, et al. Monkeypox infection presenting as genital rash, Australia, May 2022. Euro Surveill. 2022; 27(22):2200411. [DOI: 10.2807/1560-7917.ES.2022.27.22.2200411] [PMID] [PMCID]

[74] Mahase E. Monkeypox: What do we know about the outbreaks in Europe and North America? BMJ. 2022; 377:1274. [DOI: 10.1136/bmj.o1274] [PMID]

[75] Abbas S, Karam S, Schmidt-Sane M, Palmer J. Social considerations for monkeypox response. 2022. [DOI: 10.19088/SSHAP.2022.021]

[76] Shanmugaraj B, Khorattanakulchai N, Phoolcharoen W. Emergence of monkeypox: Another concern amidst COVID-19 crisis. Asian Pac J Trop Med. 2022; 15(5):193. https://oaji.net/articles/2022/3555-1654075667.pdf

[77] Bunge EM, Hoet B, Chen L, Lienert F, Weidenthaler H, Baer LR, et al. The changing epidemiology of human monkeypox—A potential threat? A systematic review. PLoS Negl Trop Dis. 2022; 16(2):0010141. [DOI: 10.1371/journal.pntd.0010141] [PMID] [PMCID]

[78] Assessment RR. Monkeypox multi-country outbreak. European Centre for Dis-ease Prevention and Control. 2022. https://www.ecdc.europa.eu/en/publications-data/risk-assessment-monkeypox-multi-country-outbreak

[79] Vaughan AM, Cenciarelli O, Colombe S, de Sousa LA, Fischer N, Gossner CM, et al. A large multi-country outbreak of monkeypox across 41 countries in the WHO European Region, 7 March to 23 August 2022. Euro Surveill. 2022; 27(36):2200620. [DOI: 10.2807/1560-7917.ES.2022.27.36.2200620] [PMID] [PMCID]

[80] Jamil H, Tariq W, Tahir MJ, Mahfooz RS, Asghar MS, Ahmed A. Human monkeypox expansion from the endemic to non-endemic regions: Control measures. Ann Med Surg. 2022; 79:104048. [DOI: 10.1016/j.amsu.2022.104048] [PMID] [PMCID]

[81] Khodakevich L, Jezek Z, Kinzanzka K. Isolation of monkeypox virus from wild squirrel infected in nature. Lancet. 1986; 327(8472):98. [DOI: 10.1016/s0140-6736(86)90748-8] [PMID] [PMCID]

[82] Parker S, Buller RM. A review of experimental and natural infections of animals with monkeypox virus between 1958 and 2012. Future Virol. 2013; 8(2):129-57. [DOI: 10.2217/fvl.12.130] [PMID] [PMCID]

[83] Arita I, Henderson D. Smallpox and monkeypox in non-human primates. Bull World Health Organ. 1968; 39(2):277. [PMID] [PMCID]

[84] Seang S, Burrel S, Todesco E, Leducq V, Monsel G, Le Pluart D, et al. Evidence of human-to-dog transmission of monkeypox virus. Lancet. 2022; 400(10353):658-9. [DOI: 10.1016/S0140-6736(22)01487-8] [PMID] [PMCID]

[85] Kantele A, Chickering K, Vapalahti O, Rimoin A. Emerging diseases—the monkeypox epidemic in the Democratic Republic of the Congo. Clin Microbiol Infect. 2016; 22(8):658-9. [DOI: 10.1016/j.cmi.2016.07.004] [PMID] [PMCID]

[86] Huhn GD, Bauer AM, Yorita K, Graham MB, Sejvar J, Likos A, et al. Clinical characteristics of human monkeypox, and risk factors for severe disease. Clin Infect Dis. 2005; 41(12):1742-51. [DOI: 10.1086/498115] [PMID]

[87] Miura F, van Ewijk CE, Backer JA, Xiridou M, Franz E, de Coul EO, et al. Estimated incubation period for monkeypox cases confirmed in the Netherlands, May 2022. Euro Surveill. 2022; 27(24):2200448. [DOI: 10.2807/1560-7917.ES.2022.27.24.2200448] [PMID] [PMCID]

[88] Ježek Z, Szczeniowski M, Paluku K, Mutombo M. Human monkeypox: clinical features of 282 patients. J Infect Dis. 1987; 156(2):293-8. [DOI: 10.1093/infdis/156.2.293] [PMID]

[89] Bragazzi NL, Kong JD, Mahroum N, Tsigalou C, Khamisy-Farah R, Converti M, et al. Epidemiological trends and clinical features of the ongoing monkeypox epidemic: A preliminary pooled data analysis and literature review. J Med Virol. 2023; 95(1): 27931. [DOI: 10.1002/jmv.27931] [PMID]

[90] Wise J. Monkeypox: New clinical symptoms are identified in confirmed cases. BMJ. 2022; 378:1845. [DOI: 10.1136/bmj.o1845] [PMID]

[91] Pan D, Sze S, Nazareth J, Martin CA, Al-Oraibi A, Baggaley RF, et al. Monkeypox in the UK: arguments for a broader case definition. Lancet. 2022; 399(10344):2345-6. [DOI: 10.1016/S0140-6736(22)01101-1] [PMID] [PMCID]

[92] UK G. Research and analysis qualitative assessment of the risk to the UK human population of monkeypox infection in a canine, feline, mustelid, lagomorph or rodent UK pet. https://www.gov.uk/government/publications/hairs-risk-assessment-monkeypox

[93] Ogoina D, Iroezindu M, James HI, Oladokun R, Yinka-Ogunleye A, Wakama P, et al. Clinical course and outcome of human monkeypox in Nigeria. Clin Infect Dis. 2020; 71(8):210-4. [DOI: 10.1093/cid/ciaa143] [PMID]

[94] Knipe D, Howley P, Cohen J, Griffin D, Lamb R, Martin M, et al. Fields virology, Wolters Kluwer. Lippincott Williams & Wilkins Health, Philadelphia, PA2013. https://search.worldcat.org/title/Fields-virology/oclc/71812790

[95] Buller R, Palumbo GJ. Poxvirus pathogenesis. Microbiol Rev. 1991; 55(1):80-122. [DOI: 10.1128/mr.55.1.80-122.1991] [PMID] [PMCID]

[96] Roess AA, Monroe BP, Kinzoni EA, Gallagher S, Ibata SR, Badinga N, et al. Assessing the effectiveness of a community intervention for monkeypox prevention in the Congo basin. PLoS Negl Trop Dis. 2011; 5(10):1356. [DOI: 10.1371/journal.pntd.0001356] [PMID] [PMCID]

[97] Harrison SC, Alberts B, Ehrenfeld E, Enquist L, Fineberg H, McKnight SL, et al. Discovery of antivirals against smallpox. Proc Natl Acad Sci U S A. 2004; 101(31):11178-92. [DOI: 10.1073/pnas.0403600101] [PMID] [PMCID]

[98] Eichner M, Dietz K. Transmission potential of smallpox: estimates based on detailed data from an outbreak. Am J Epidemiol. 2003; 158(2):110-7. [DOI: 10.1093/aje/kwg103] [PMID]

[99] Earl PL, Americo JL, Wyatt LS, Espenshade O, Bassler J, Gong K, et al. Rapid protection in a monkeypox model by a single injection of a replication-deficient vaccinia virus. Proc Natl Acad Sci U S A. 2008; 105(31):10889-94. [DOI: 10.1073/pnas.0804985105] [PMID] [PMCID]

[100] Robertson J, Susong J, Wong EB. Smallpox vaccine complications: the dermatologist's role in diagnosis and management. Cutis. 2018; 101(2):87-

90. [PMID]

[101] Uwishema O, Chalhoub E, Torbati T, David SC, Khoury C, Ribeiro LLPA, et al. Rift Valley fever during the COVID-19 pandemic in Africa: A double burden for Africa's healthcare system. Health Sci Rep. 2022; 5(1):e468. [DOI: 10.1002/hsr2.468] [PMID] [PMCID]

[102] Uwishema O, Okereke M, Onyeaka H, Hasan MM, Donatus D, Martin Z, et al. Threats and outbreaks of cholera in Africa amidst COVID-19 pandemic: a double burden on Africa's health systems. Trop Med Health. 2021; 49(1):93. [DOI: 10.1186/s41182-021-00376-2] [PMID] [PMCID]

[103] Sun J, Uwishema O, Kassem H, Abbass M, Uweis L, Rai A, et al. Ebola virus outbreak returns to the Democratic Republic of Congo: an urgent rising concern. Ann Med Surg. 2022; 79:103958. [DOI: 10.1016/j.amsu.2022.103958] [PMID] [PMCID]

[104] Uwishema O, Ayoub G, Badri R, Onyeaka H, Berjaoui C, Karabulut E, et al. Neurological disorders in HIV: hope despite challenges. Immun Inflamm Dis. 2022; 10(3):591. [DOI: 10.1002/iid3.591] [PMID] [PMCID]

[105] Uwishema O, Badri R, Onyeaka H, Okereke M, Akhtar S, Mhanna M, et al. Fighting tuberculosis in Africa: the current situation amidst the COVID-19 pandemic. Disaster Med Public Health Prep. 2022:1-3. [DOI: 10.1017/dmp.2022.142] [PMID] [PMCID: PMC9300973]

[106] Uwishema O, Adriano LF, Chalhoub E, Onyeaka H, Mhanna M, David SC, et al. Bird flu outbreak amidst COVID-19 pandemic in South Africa: efforts and challenges at hand. J Med Virol. 2021; 93(10):5676-9. [DOI: 10.1002/jmv.27124] [PMID] [PMCID]

[107] Uwishema O, Onyeaka H, Alshareif B, Omer M, Sablay A, Tariq R, et al. Current context of pneumonia amidst the COVID-19 pandemic in Africa. J Contemp Stud Epidemiol Public Health. 2021; 2(2):21007. [DOI: 10.30935/jconseph/11281]

[108] Uwishema O, Onyeaka H, Badri R, Yücel AN, Korkusuz AK, Ajagbe AO, et al. The understanding of Parkinson's disease through genetics and new therapies. Brain Behav. 2022; 12(5):2577. [DOI: 10.1002/brb3.2577] [PMID] [PMCID]

[109] Uwishema O, Berjaoui C, Correia IFS, Anis H, Karabulut E, Essayli D, et al. Current management of acute ischemic stroke in Africa: a review of the literature. Eur J Neurol. 2022; 29(11):3460-5. [DOI: 10.1111/ene.15495] [PMID]