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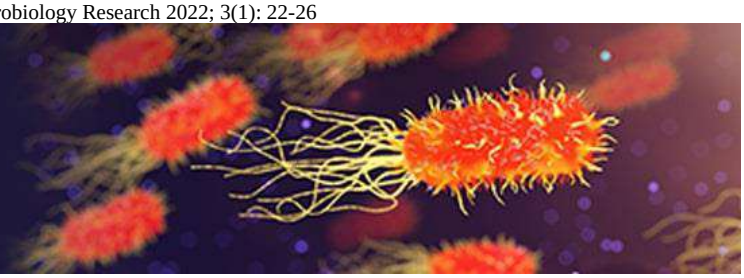

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Human cowpox: A viral zoonosis that poses emerging health threat

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Abstract
Human cowpox, an emerging zoonotic disease, is caused by the virus that belonged to the genus *Orthopoxvirus*. Human cases of cowpox have been reported in Europe on a sporadic basis, with the majority of cases being linked to the handling of diseased animals, most commonly the rats and cats. Cowpox virus, or at least cowpox, the disease, has long been connected with Edward Jenner and the smallpox 'vaccination,' however, the modern smallpox vaccine is vaccinia virus, which belongs to the same genus, *Orthopoxvirus*. Despite its name, the cowpox virus is endemic in wild rodents. The cats acquire the infection from small wild rodents, which are thought to be the main reservoir. Domestic cats play a significant role in disease transmission to humans. There is no indication of cowpox transmission from person to person. The infection is primarily transmitted to people through sores on exposed skin, and most often the lesion is localized on the hands or in the face, at the site of primary inoculation. Cowpox can be diagnosed via electron microscopy, virus isolation, or molecular testing. In immunocompetent people, the disease is self-limiting. Serious complications may occur in the immunocompromised patients. There is no specific treatment for this condition. Basic hygiene practices, such as avoiding direct contact with animals with skin lesions and using gloves during cat and rat examinations, as well as thorough hand washing with antiseptic soap or solution after handling the animals, are recommended prevention and control strategies.

Keywords: Cat, cowpox, cowpox virus, emerging zoonosis, public health, wild rodent

Introduction
Buffalo pox, camel pox, cow pox, goat pox, monkey pox, and pseudo-cowpox are zoonotic pox diseases that are important in terms of public health and economics (Pal, 1996; Ratnam and Pal, 2006; Pal, 2007, Pal *et al.*, 2022) [19-22]. Cowpox virus (CPXV) is a member of the *Poxviridae* family and *Orthopoxvirus* (OPV) genus (Pal, 2007) [20]. Cowpox is an uncommon zoonotic infection that spreads by contact with diseased cows and other animals, such as cats, and rats in the workplace (William and James, 2020) [30]. The genus *Orthopoxvirus* includes cowpox and monkey pox viruses, both of which have a rodent reservoir, as well as vaccinia and smallpox viruses, which are both human diseases (Damon and Esposito, 2003) [5]. Cowpox infections transmitted by rats have recently been observed in Europe, with most cases resulting in minor, self-limiting lesions (Vogel *et al.*, 2012) [26].
Cowpox is historically significant since Edward Jenner used cowpox inoculation instead of the more dangerous variolation technique due of the immunity to smallpox of persons who had cowpox (James and Paterson, 2021). Edward Jenner treated a young English child with cowpox material from a dairymaid and demonstrated that the boy grew resistant to smallpox more than 200 years ago, in one of the first demonstrations of vaccination (Esposito *et al.*, 2001) [7]. The disease has been documented in a number of countries. Humans acquire the virus through direct contact with infected animals (Pal, 2007) [20]. Cowpox is characterized by the emergence of erythematous papules that move via vesiculation and umbilication over the course of a 4- to 6-week period (Gough *et al.*, 1982) [10]. The face, scrotum, and palmar or plantar areas are the most commonly affected (Matz-Rensing *et al.*, 2006) [16].
Ultrastructural investigation was used to identify the causal agent. The viral etiology has been identified to be a poxvirus with close similarity to cowpox utilizing molecular methods (Matz-Rensing *et al.*, 2006) [16]. Cowpox is usually a self-limiting condition, thus treatment is mostly supportive (Smee *et al.*, 2003). The present communication describes the significance of human cowpox as an emerging viral disease that causes a public health concern.

Etiology

Cowpox virus is a DNA virus that belongs to the genus *Orthopoxvirus* and the family *Poxviridae* (Pal, 2007) [20]. It is antigenic ally and genetically related to variola virus, vaccinia virus, and monkey pox virus (Martina *et al.,* 2006, Campe *et al.,* 2009) [14], but can be distinguished using complement fixation, agar gel diffusion, and antibody absorption tests. This genus' virions are brick-shaped, measuring around 300 by 240 by 100 nm, with an irregular tubule arrangement on the outer membrane. Orthopoxvirus are the world's largest viruses (Acha and Szyfres, 2001) [1]. Though Edward Jenner's publications refer to 'cowpox virus' as the agent employed to prevent smallpox, it has been speculated that a now extinct (or extremely rare) Orthopoxvirus of horses resembling vaccinia virus may have been the virus utilized in his immunization studies (Mary *et al.,* 2017) [17].

Transmission

The cowpox virus is thought to have a low infectivity for humans, and infection requires direct contact with skin lesions or mucous membranes (Pal, 2007, Weese and Fulford, 2011) [20, 28]. The domestic cat is the most common source of infection in humans. Wild animal reservoirs (small wild rodents like mice and voles) are the source of infection for cats (Williams and James, 2020) [30]. The domestic cats play a key role in the transmission of infection to human beings. In this context, Zaba and co-investigators (2017) described cowpox in a child who acquired the infection after contact with a domestic cat.

Cowpox virus has recently attracted increased interest due to transmission from pet rats and cats to humans, as well as severe infection in felids and other animal species (Roth *et al.*, 2011) [23]. Willemse and Egberink (1985) are credited to record the first case of human-to-domestic-cat transmission. Because of their close contact with humans and thus the risk of transmission, the infection in domestic cats in the United Kingdom has gotten a lot of attention (Acha and Szyfres, 2001) [1]. In the United States, prairie dogs (*Cynomysludo vicianus*) have been thought to be a plausible reservoir for monkey pox virus, and they are susceptible to cowpox virus infection via wild rodents. After contact with infected brown rats, a cowpox virus outbreak in nonhuman primates was also documented (Martina *et al.,* 2006) [14]. In cats, the major lesion often begins with a bite, indicating that they may have contacted the infection from an infected rodent (Acha and Szyfres, 2001) [1].

Pathogenesis

Although the skin appears to be the most common route of entry, oronasal infection is certainly a possibility. The virus travels to local lymph nodes after local replication and the establishment of a primary cutaneous lesion, and a leukocyte-associated viremia occurs (Gibbs, 2021) [9]. Cowpox is an Orthopoxvirus that replicates in the cytoplasm of cells. The viral genome is reproduced and viral progeny are assembled in the cytoplasm after viral particles attach to plasma membrane receptors on host cells. The host cell lyses once new viral particles are produced, releasing infectious virus that can infect nearby cells. Poxviruses employ a variety of techniques to escape the immune system of their hosts. The production of mammalian tumor necrosis factor receptor, interleukin-1beta receptor, interleukin 18-binding protein, interferon-alpha/beta receptor, and interferon-gamma receptor homologues, as well as a complement-binding protein and a caspase inhibitor, are among them (Moss and Shisler, 2001) [18]. By attaching to cytokines and complement proteins and limiting their function, these proteins are hypothesized to counteract the host's antiviral response. Cowpox virus also inhibits intracellular transit of major histocompatibility class I molecules, allowing it to avoid cytotoxic T cells (Dasgupta *et al.,* 2007) [6].

Epidemiology

Cowpox is a viral anthropozoonosis that has been found in humans and animals, including cattle, cats, monkey, and rodents (Pal, 2007) [20]. The disease is widespread in European rodents, and while there have been multiple reported cases of rodent-to-human infection, only one has been verified (Acha and Szyfres, 2001) [1]. Bank voles (*Clethrionomys glareolus*) and wood mice (*Apodemus sylvaticus*) are the principal reservoirs in Europe, but cowpox virus has been found rarely in rats (*Rattus norvegicus*) (Martina *et al.,* 2006) [14]. Unintentional hosts include cattle, cats, zoo animals, and humans. In the last three decades, cowpox has not been isolated from cattle, and the majority of diseases are now discovered in cats and zoo animals (Weese and Fulford, 2011) [28]. In this context, Voru and co-workers (2008) mentioned that human cowpox virus infection is an emerging zoonosis that raises public health threat. The infection due to cowpox virus has been reported from several countries including France, Germany, Poland, Finland, England and others (Krankowska *et al*., 2021) [13].

Domestic cats are now the most regularly recognized animals clinically afflicted by cowpox virus in Europe (Gibbs, 2021) [9], and they may be the most important source of human infection due to their frequent contact with humans. In some areas, up to 5% of domestic cats carry antibodies to cowpox. While most pet rat cowpox infections are rare, higher numbers, including outbreaks, can develop if rat breeding or distribution facilities become infected, resulting in the sale of large numbers of infected rats. Cowpox virus shedding is short-lived (2–3 weeks), and there are no long-term effects. The absence of smallpox immunization, which would have offered cross-protection, is likely to have raised the likelihood of human cowpox infections (Weese and Fulford, 2011) [28].

Human cowpox virus infections are infrequent, with most cases occurring in Europe, the former Soviet Union's western regions, and areas of Northern and Central Asia (Weese and Fulford, 2011) [28]. Cowpox is a rare human disease in the United Kingdom, with about one or two cases each year. During the 13-year period 1969–1981, just 20 cases were documented, and only 23 cases were reported in the next 12 years (1982–1993). Although the decline and discontinuation of smallpox vaccinations, as well as the rise in the number of people taking immunosuppressive drugs or living with HIV, may also be factors, the apparent increase in cases could be the result of increased interest in the disease rather than a real increase in its incidence (Acha and Szyfres, 2001) [1].

Clinical Signs and Symptoms

In Humans

In most cases, infections are self-limiting. The immunocompromised are at a higher risk of developing a serious illness (Baxby *et al.,* 1994) [2]. The complications

have been recorded in the persons whose immunity is decreased ((Baxby *et al.*, 1994) [2]. The incubation period of disease lasts 3–7 days on average, but can last up to 14 days. Cowpox infection in humans mainly causes sores on the hands and fingers and rarely on the other parts of the body (Pal, 2007) [20]. The lesions resemble "pox" lesions. Before creating a hard black crust, a macular lesion proceeds through popular, vesicular, and pustular stages. Edema and erythema are typical surrounding the lesion's location, and lesions are painful. In most cases, only one lesion is observed, however several lesions might result from multiple inoculations or autoinoculation. Although vascular or lymphatic spread is possible, it is uncommon (Acha and Szyfres, 2001) [1]. Influenza-like symptoms like fever and tiredness, as well as lymphadenopathy, are frequently observed (Pal, 2007) [20]. Conjunctivitis is also a possibility. In immunocompromised individuals and people with severe eczema, serious, even lethal infection can ensue. Pneumonia caused by a virus is possible, but it is uncommon. Milkers may contract it, which causes a pustular eruption on the hands, forearms, or face, as well as a minor fever and lymphadenitis (James and Paterson, 2021). Skin lesions due to cowpox in a patient who acquired infection from pet rat is shown in Figure 1. In persons who have already been vaccinated against smallpox, the incubation time may be longer and the disease is milder (Weese and Fulford, 2011) [28].

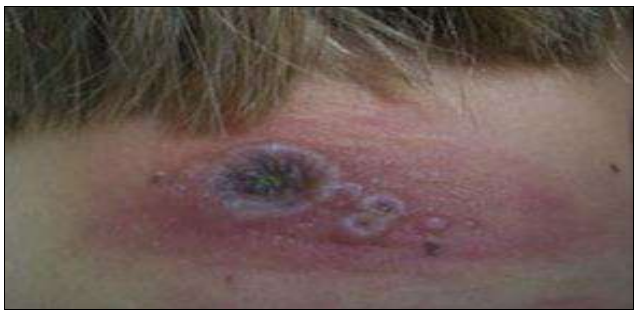

Fig 1: Cowpox lesions in a patient who acquired infection from pet rat. Source: (Campe *et al.*, 2009).

In Animals

The majority of infected cats have a single initial skin lesion on the head, neck, or forelimb. Cowpox lesion in a domestic cat is presented in Figure 2. A minor, scabbed wound to a big abscess can be the main lesion. Widespread secondary lesions begin to form 7–10 days after the original lesion appears. These grow into distinct, round, ulcerated papules with a diameter of 0.5–1 cm over the course of 2–4 days. Scabs cover the ulcers quickly, and recovery is usually complete within 6 weeks. Although most cats show no symptoms other than skin lesions, about 20% of them may develop minor coryza or conjunctivitis. During the viremic phase, shortly before and during the early development of secondary lesions, some cats may become pyrexic, depressed, and inappetent. In domestic cats, more severe pulmonary disease is unusual, but it is prevalent in cheetahs, and it is typically fatal in both species. Immunosuppression is frequently connected with more severe disease in domestic cats, either as a result of corticosteroid medication or as a result of infection with feline leukemia or immunodeficiency viruses (Gibbs, 2021) [9].

Fig 2: Cowpox lesions in a domestic cat Source: (Foster, 2004).

The disease in cattle starts with a slight fever after a 3-6 day incubation period. On the teats of the cows, papules that proceed to vesicles and then pustules can be seen. When pustules burst out, they develop red scabs, which can lead to ulcers that can take up to a month to cure. Despite the fact that the cowpox virus infects cattle, it is rarely implicated as a source of infection for cats, because cows are not the virus's natural reservoir (Acha and Szyfres, 2001) [1]. Rats can get characteristic pox-like skin lesions, which can lead to death in some situations; nevertheless, transmission can happen even if there are no visible skin lesions. Symptoms of respiratory disease have also been reported (Weese and Fulford, 2011) [28]. Cats afflicted with the cowpox virus are frequently voracious hunters who come into touch with infected prey, such as the bank vole (*Clethrionomys glareolus*), field vole (*Microtus agrestis*), and wood mouse (*Apodemus sylvaticus*), among others. Infected rodents normally don't display any signs (Martin Glatz *et al.*, 2010) [15].

Diagnosis

Cowpox infection can be diagnosed via electron microscopy, virus isolation, or molecular testing (Pal, 2007) [20]. The most quick and useful technique for assisting in diagnosis is electron microscopy of vesicle fluid or scab extracts. Cowpox and other orthopoxviruses have distinct "mulberry" and "capsule" forms that distinguish them from parapoxviruses and herpes viruses. Because electron microscopy cannot tell the difference between cowpox, smallpox, vaccinia, and molluscum viruses, clinical data is essential (Dagny *et al.*, 2021) [4]. Very recently, polymerase chain reaction (PCR) has been recognized as the key technique to diagnosis cowpox virus infection (Krankowska *et al.*, 2021) [13].

Virus can be grown in cell culture from the skin lesions and then examined using electron microscopy. On the chorioallantoic membrane of chicks, growth results in hemorrhagic pocks. To amplify the cowpox A36R, thymidine kinase, or hemagglutinin gene and identify it by sequencing or restriction fragment length polymorphism analysis, polymerase chain reaction can be done on biopsy material or cell culture extracts (Schlupp *et al.*, 2001). Serologic tests for antibodies to the cowpox virus are not typically available in hospital laboratories, but they can be done in research labs. False-positive findings from previous

vaccinia vaccination are possible; although they can be avoided with the use of particular immunoglobulin M assays (Gilchul *et al.*, 2016). It is pertinent to mention that cowpox should be differentiated from cat scratch fever, cutaneous anthrax, and tularemia by employing standard laboratory techniques (Krankowska *et al*., 2021) [13].

Treatment

Cowpox infection in humans is usually self-limiting (Pal, 2007). Presently, there are no specific medications are available for the treatment of cowpox infection. The infections as severe as viral pneumonia can occur, although they are uncommon. In moderate to severe cases, supportive therapy may be required (Weese and Fulford, 2011) [28]. Although cidofovir has been demonstrated to have antiviral efficacy *in vitro* against Orthopox viruses in some investigations, there is currently no particular antiviral medication for cowpox virus infection, and treatment is primarily supportive (Graef *et al.*, 2013) [11]. Antibiotics are typically prescribed to treat secondary bacterial infections or avoid bacterial super infections (Dagny *et al.*, 2021) [4].

Prevention and Control

Currently, no specific antiviral therapy is available for cowpox virus infection. Cowpox has the potential to emerge as a problem in areas where the virus is endemic in wild rodents and/or rodent-breeding facilities, as smallpox diminishes and population protection in pet rats and cats rises. Because of the cross-protection that occurs between orthopoxviruses, smallpox vaccination after exposure to cowpox could be considered, but it is probably unnecessary due to the disease's typically mild and self-limiting nature, as opposed to monkey pox, another *Orthopoxvirus* that can cause serious disease (Weese and Fulford, 2011) [28].

Following good hygiene procedures, particularly hand washing and avoiding bites, can help to decrease cowpox transmission from animals. It's best to stay away from diseased animals. Because cats are a major source of human infection, cowpox should be evaluated in any cat with skin lesions in an endemic area. Rats with skin lesions should be treated similarly. When handling cats and rats with skin lesions, gloves should be worn, and hands should be cleansed as soon as the gloves are removed. A rat's skin lesions, especially those on the feet, ears, or tail, should be examined by a veterinarian as soon as possible. Rats having lesions on their skin should not be bought. It is suggested that cats and pet rats should not approach wild rodents. It is not recommended that wild rats be trapped and maintained as pets. Rat keepers should be aware of proper handling techniques in order to decrease the danger of bites and to ensure that any bites are cleansed promptly and properly. Because of the potential for cowpox to spread widely through pet stores or rat breeding facilities, the discovery of cowpox in pet rats should prompt a public health investigation into the source. Although there is no evidence of cowpox transmission from person to person, basic hygiene procedures, especially avoiding contact with skin lesions, are advised (Acha and Szyfres, 2001; Weese and Fulford, 2011) [1, 28]. It is recommended that persons who come into contact with sick animals should wear protective gloves, and also follow the rules of hand hygiene in order to prevent the spread of infection (Krankowska *et al*., 2021) [13].

Conclusion

Cowpox poses an emerging zoonotic risk to people as a result of an increase in human cowpox infections in Europe, an enlarged animal host range, decreased immunity, and limited antiviral drug potential. This creates worries about public health as well as production issues. Cowpox is a disease that is difficult to diagnose. It is, therefore, necessary to introduce effective vaccinations and antiviral drugs. The vaccinia virus is a simple model for investigating the connection between endemic infectious pathogens and their natural hosts. It may provide a model for other zoonotic illnesses with wildlife reservoirs, such as monkeypox, that are connected with the orthopoxvirus. Overall, the risk of human infection is negligible, especially if standard infection control practices are sincerely followed. It seems imperative to undertake further studies on the reservoir, pathogenesis, and epidemiology of disease. It is emphasized that attempts should be directed to develop safe, potent, and low cost therapeutic agents for the treatment of cowpox that pose an emerging threat to human health.

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Contribution of authors

During the writing of the manuscript, all of the authors contributed equally. They read the final manuscript and gave it their approval for publishing.

Conflict of interest

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References

1 Acha PN, Szyfres B. Zoonoses and communicable diseases common to man and animals. 3rd edition, Pan American Health Organization, Washington, DC, USA, 2001.
2 Baxby D, Bennett M. Cowpox: A re-evaluation of the risks of human cowpox based on new epidemiological information. Viral Zoonoses and Food of Animal Origin. 1997;1:12.
3 Campe H, Zimmermann P, Glos K, Bayer M, Bergemann H, Dreweck C, *et al.* Cowpox virus transmission from pet rats to humans, Germany. Emerging infectious diseases. 2009;15:777-780.
4 Dagny C, Krankowska G, Piotr A, Woźniak D, Aneta C, Justyna I, *et al.* Cowpox: How dangerous could it be for humans? Case report. International Journal of Infectious Diseases. 2021;104:239-241.
5 Damon IK, Esposito JJ. Poxviruses that infect humans. In: Murray PR, Baron EJ, Jorgensen JH, *et al.*, editors. Manual of Clinical Microbiology. Washington, American Society for Microbiology, 2003, 1583-1591pp.

6 Dasgupta A, Hammarlund E, Slifka MK, Fruh K. Cowpox virus evades CTL recognition and inhibits the intracellular transport of MHC class I molecules. Journal of Immunology. 2007;178:1654-61.
7 Esposito JJ, Fenner F. Poxviruses. In: Knipe D, Howley PM, Griffin DE, Lamb RA, Martin MA, Roizman B, Straus SE, (eds). Fields Virology. 4th ed. Philadelphia, Pa: Lippincott Williams & Wilkins, 2001.
8 Foster AP. Feline Medicine and Therapeutics 3rd ed In: Chandler FA, Gaskill CJ, Gaskill RM (eds.). The skin. Blackwell Publishing, Oxford, 2004, 73-123pp.
9 Gibbs P. Cowpox Virus Infections in Cats and Other Species. MSD Manual. 2021.
10 Gough AW, Barsoum NJ, Gracon SI, Mitchell L, Sturgess JM. Poxvirus infection in a colony of common marmosets (*Callithrix jacchus*). Laboratory Animals. 1982;32:87e90.
11 Graef S, Kurth A, Auw-Haedrich C, Plange N, Kern WV, Nitsche A, *et al.* Clinicopathological findings in persistent corneal cowpox infection. JAMA Ophthalmology. 2013;131:1089-91.
12 James W, Patterson MD. IN: Weedon's Skin Pathology. Elsevier ltd. 2021;27:757-786.e15.
13 Krankowska DC, Wozniak PA, Cybula A, Izdebska J, Suchacz M, Samelska K, *et al.* Cowpox: How dangerous could it be for humans? Case report. International Journal of Infectious Diseases. 2021;104:239-241.
14 Martina BE, van Doornum G, Dorrestein GM, Niesters HG, Stittelaar KJ, Wolters MA, *et al.* Cowpox virus transmission from rats to monkeys, the Netherlands. Emerging infectious diseases. 2006;12:1005-1007.
15 Martin Glatz MD, Susanne R, Gabriele GH, Werner A. Human cowpox in veterinary student. Lancet Infectious Disease. 2010;10:228.
16 Matz-Rensing K, Ellerbrok H, Ehlers B, Pauli G, Floto A, Alex M, *et al.* Fatal poxvirus outbreak in a colony of New World monkeys. Veterinary Pathology. 2006;43:212e218.
17 Mary G, Reynolds I, Damon K. Smallpox, Editor(s): Stella R. Quah, International Encyclopedia of Public Health (Second Edition), Academic Press, 2017, 524-533pp.
18 Moss B, Shisler JL. Immunology 101 at poxvirus U: immune evasion genes. Seminar in Immunology. 2001;13:59-66.
19 Pal M. Buffalo pox: An emerging zoonosis. The Veterinarian, 25, 4.
20 Pal Zoonoses M. 2nd Edition. Satyam Publishers, Jaipur, India, 2007.
21 Pal M, Singh R, Gutama KP, Savalia CV, Thakur R. Human monkeypox: An emerging and re-emerging infectious viral disease. Acta Scientific Microbiology. 2022;5:146-150.
22 Ratnam S, Pal M. Pseudocowpox and human infection. The Veterinary World. 2006;4:293-294.
23 Roth SJ, Höper D, Beer M, Feineis S, Tischer BK, Osterrieder N. Recovery of infectious virus from full-length cowpox virus (CPXV) DNA cloned as a bacterial artificial chromosome (BAC). Veterinary Research. 2011;42:3.
24 Schupp P, Pfeffer M, Meyer H, Burck G, Kolmel K, Neumann C. Cowpox virus in a 12-year-old boy: rapid identification by an orthopoxvirus-specific polymerase chain reaction. British Journal of Dermatolology. 2001;145:14.
25 Smee DF, Bailey KW, Sidwell RW. Comparative effects of cidofovir and cyclic HPMPC on lethal cowpox and vaccinia virus respiratory infections in mice. Chemotherapy. 2003;49:126-31.
26 Vogel S, Sardy M, Glos K, Korting HC, Ruzicka T. The Munich outbreak of cutaneous cowpox infection: transmission by infected pet rats. Acta Dermatology and Venereology. 2012;92:126-131.
27 Vorou RM, Papavassiliou VG, Pierroutsakos IN. Cowpox virus infection: an emerging health threat. Current Opinion in Infect Diseases. 2008;21(2):153-156.
28 Weese JS, Fulford MB. Viral Diseases. Viral Diseases: Companion Animal Zoonoses. Blackwell Publishing Ltd. 2011.
29 Willemse H, Egberink G. Transmission of cowpox virus infection from domestic cat to man. Lancet. 1985;1:1515.
30 William D, James MD, Dirk M, Elston MD, James R, Treat MD, *et al.* In: Andrews' Diseases of the Skin, Elsevier Inc. 2020;19:362-420.e8.
31 Zaba R, Jałowska M, Kowalczyk MJ, Bowszyc-Dmochowska M. Cowpox virus infection in a child after contact with a domestic cat: A case report. New Microbiologica. 2017;40:148-150.