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Nipah Virus Disease: An Updated Review

Karnati Vandana [a], Panga Swarna [a], Battala Sreevidya [a], Akkiraju Sudheer [a], Bhupalam Pradeepkumar [a], Bandaru Revanth [a] and Kanala Somasekhar Reddy [a*]

[a] Department of Pharmacology, Raghavendra Institute of Pharmaceutical Education and Research (RIPER) – Autonomous, KR Palli Cross, Chiyyedu (Post), Anantapur, Andhra Pradesh, 515721, India.

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Review Article

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ABSTRACT

The Nipah virus (NiV) is a member of the Paramyxoviridae family of zoonotic viruses that is extremely contagious and potentially fatal. The Nipah virus was first discovered in 1999 during an outbreak in Malaysia. Since then, it has periodically caused outbreaks throughout South and Southeast Asia, especially in Bangladesh and India, and it continues to be a serious public health concern. The virus is primarily transmitted to humans through direct contact with infected fruit bats, which serve as natural reservoir hosts for the Nipah virus. Human-to-human transmission can also happen when infected people's body fluids come into close contact with one another. The Nipah virus has a high death rate that varies depending on the outbreak and can cause a variety of clinical presentations, including encephalitis, severe respiratory illnesses, and asymptomatic infections. Fever, headache, dizziness, drowsiness, and confusion are common signs of Nipah virus infections, which may lead to the rapid onset of coma in the patient. The Nipah virus does not

**Corresponding author: Email: somu.reddyvaru@gmail.com;*

presently have a specific antiviral treatment; instead, infection control methods and supportive care are the foundation of management to stop the virus from spreading. Nipah virus outbreaks must be stopped with an approach that includes community involvement, public health education, and surveillance of both human and animal populations. Additionally, efforts are directed toward developing vaccines as a more potent form of prevention. The Nipah virus is a clear reminder of the continuous threat that newly emerging infectious diseases pose, as well as the necessity of having strong surveillance systems and quick response times in place to lessen the effects that these outbreaks have on public health.

Keywords: Nipah virus; Nipah virus's structure and genome; transmission; vaccine development; prevention; control.

1. INTRODUCTION

A virus that belongs to the Henipavirus genus in the Paramyxoviridae family causes the Nipah virus (NiV) infection [1]. Its name came from Sungai Nipah, a pig farmer's village on the Malaysian Peninsula where encephalitis occurred [2]. The Nipah virus shares many similarities with the Mojang, Cedar, and Hendra viruses [3]. Pleomorphic, spherical, thread-like, and enveloped, NiV is negative-sense, non-segmented, and has an average length of about 18 kb for its single-stranded RNA, which has helical symmetry. Its dimensions range from 40 to 1900 nm [4]. Flying foxes, or fruit bats in the genus Pteropus, are the reservoir hosts of NiV. Based on sequencing data, it appears that NiV evolved from bat species and is most closely related to the Hendra virus [5]. Since its initial appearance in Malaysia in 1998, it has spread throughout South and Southeast Asia, causing multiple outbreaks [6]. Between 1998 and 1999, there was the first notable outbreak of the virus in Malaysia and Singapore, where 276 additional cases were reported. In 2001 and 2003, the disease reappeared in Bangladesh, causing ten outbreaks and the identification of 122 cases [7]. In Kozhikode district, Kerala, there were six laboratory-confirmed cases of the Nipah virus, including two fatalities, as a result of the recent outbreak in India [8]. Following a 21-days of observation and quarantine, 1288 contacts for the confirmed cases were tracked down in September 2023.

High-risk individuals and healthcare staff were involved in these interactions.387 samples have been analyzed as of 12th September 2001; six cases tested positive for Nipah virus infection, while the other samples were all negative. Since 15th September 2001, there have been no newly identified cases, and six Nipah virus outbreaks have occurred in India. Globally, these viral outbreaks are responsible for significant rates of mortality, morbidity, and economic loss. The World Health Organization (WHO) has classified NiV encephalitis as a serious public health concern. It is an infectious disease that is both emerging and re-emerging [9]. The Indian National Centre for Disease Control (NCDC) established guidelines for the definition of suspected, probable, and confirmed cases of NiV infection in response to recent human cases [10]. This was done to help control outbreaks early on and to regulate several public health initiatives aimed at containing the infection's spread i.e., a lot of researchers are working hard to find a cure for this serious zoonotic infection. However, the Nipah virus is one of the most deadly viruses that are currently recognized [11]. This means that even rare cases can have a significant effect on communities, healthcare providers, families, and healthcare systems. Humans can contract NiV directly from infected files, contaminated food, infected animals (such as pigs or bats), or other humans [12]. Pigs with NiV infections experience more severe respiratory symptoms than humans do.

2. NIPAH VIRUS VIROLOGY

2.1 Paramyxoviridae Family

A wide variety of enveloped, negative-sense, single-stranded RNA viruses belong to the family Paramyxoviridae [13]. Humans and other vertebrates are among the primary hosts of these viruses. Numerous illnesses, including measles, mumps, and respiratory infections in humans and animals, are caused by paramyxoviruses.

2.2 Henipavirus Genus

The Paramyxoviridae family contains the genus Henipavirus as a subgenus. The Hendra virus (HeV) and the Nipah virus (NiV), two viruses that are closely related, were the reasons behind their creation [14]. Because they can infect a wide

variety of hosts, including bats and some domestic animals that can act as intermediate hosts, henipaviruses differ from other paramyxoviruses [15].

2.3 The Nipah Virus's Structure and Genome

The Nipah virus is a paramyxovirus that is single-stranded, non-segmented, enveloped and has helical symmetry [16]. Six genes are sequentially arranged in the RNA genome from positions 3-5: nucleocapsid (N), phosphoprotein (P), matrix (M), fusion glycoprotein (F), attachment glycoprotein (G), and long polymerase (L) [17]. Forming the virus ribonucleoprotein (vRNP), the N, P, and L joined the viral RNA [18]. The virion attaches to cells and then enters the host cell to the roles of proteins F and G. The freshly produced precursor F protein (F0) is broken down into F1 and F2 subunits by host protease. The viral M protein controls budding and morphogenesis. Antibodies directed against the G protein are required to suppress NiV infectious potential.

It is interesting to note that after binding by the enveloped hepativiruses, including NiV, the target cell (i.e., host cell) is invaded by the coordinated actions of the fusion (F) (class I) and attachment (G) glycoproteins. The NiV G protein, in particular, participates in the adsorption phase but does not exhibit H functions [19]. By using alternate open reading frames (ORFs) and mRNA editing techniques, the P gene additionally produces the three non-structural proteins V, W, and C. At the plasma membrane, M molecules assemble to form virus-like particles, or VLPs. Viral particles driven by F, M, and M/F form more readily, which increases G protein recruitment into VLPs [20].

Because non-structural proteins obstruct immune interferon activity indirectly, they are important for virulence. The virus's high pathogenicity and the lack of reliable therapies or vaccinations have led to its classification as a BSL-4 (biosafety level 4) pathogen [21].

The NiV genomic sequence's precise length is reported in several isolations. Like the HeV genome, the entire viral genome is roughly 18 kilobases (kb) long, much longer than the average genomes of other Paramyxoviridae members (155 kb) [22]. The measles virus's mRNA editing site is identical to that found in the P gene of the HeV and NiV viruses. The V protein can be expressed with just one G insertion [23].

One of the three auxiliary proteins that the viral P gene codes for is the NiV V protein, which plays a critical role in the pathogenesis of the virus in hamster infections used in experiments [24]. Although two G insertions permit the production of a protein similar to that of the Sendai virus, W proteins are essential for virulence, and these proteins act by inhibiting the activation of an interferon-inducible promoter [25].

The hemagglutinin and neuraminidase activities that are characteristic of many paramyxoviruses are not displayed by either the NiV or the HeV [26]. Adsorption by the G, H, or HN proteins and the transmembrane fusion F protein mediates the interaction between paramyxoviruses and their target cells. In particular, the NiV makes use of glycoprotein G, which preys on the ephrin-B2 or, to a lesser degree, ephrin-B3 receptors.

The organs with the highest expression of Ephrin-B2 receptors include the brain, smooth muscle, lungs, placenta, and prostate. The distribution of these receptors accounts for the clinical-pathological traits seen during the disease's early symptoms.

Since the ephrin-B2 and -B3 receptors serve as vital for the movement of neurons origins during early embryogenesis, these are highly conserved throughout animal classes, having a 96% similarity to proteins [27].

The mangoes or certain fruit juices can keep the NiV alive for up to three days, and date sap stored at 22◦C can keep it alive for at least seven days. The pathogen is comparatively stable in the environment; it can survive for one hour at 70 °C and for more than 15 minutes at 100°C before becoming completely inactive due to heat. Common disinfectants like sodium hypochlorite kill the NiV virus.

3. SPREAD AND TRANSMISSION

3.1 The Transmission Mode

The Nipah virus can spread in a variety of ways, so being aware of these ways is important for comprehending how the virus spreads.

3.2 Transmission Directly from Human to Human

Restricted, but it can happen, especially in the advanced stages of the disease. Transmission can occur through close contact with bodily fluids

like blood, saliva, or respiratory secretions from an infected person.

3.3 Bats as Hosts of Reservoirs

The Nipah virus naturally lives in bats as reservoir hosts. When human beings come into contact with bat excretions, bat saliva, or partially eaten fruits, they can contract the infection [28].

3.4 Mid-Level Hosts

Pigs have been used as intermediate hosts in some outbreaks to transmit disease to humans. People can contract the disease by coming into close contact with infected pigs or by eating pork products from infected pigs.

3.5 Transmission through Nosocomial

Medical devices and surfaces that are contaminated with the Nipah virus can spread infection in healthcare settings. While tending to patients who are infected, healthcare personnel are at risk [29].

3.6 Food and Water Contamination

In certain outbreaks, the virus has been linked to the consumption of contaminated food or drink, such as date palm sap collected in containers exposed to bats [30].

3.7 Transmission by Air (Rare)

Rarely, the Nipah virus has been known to spread by respiratory droplets, particularly in medical facilities where aerosol-generating operations are carried out [31].

4. REGIONAL DISPERSION

4.1 Singapore-Malaysia

The first known epidemic of the Nipah virus occurred in 1998 in Malaysia. The state of Negeri Sembilan was the primary location of the outbreak. At first, contact with infected pigs on commercial pig farms was thought to be the source of this outbreak [32]. Humans contracted the virus from pigs. A combination of quarantine restrictions, public health efforts, and pig elimination were used to contain the outbreak. Subsequent Nipah virus outbreaks have occurred in Malaysia, and some cases have been reported in the years after the initial outbreak. The outbreak of the Nipah virus in Malaysia from September 1998 to May 1999 caused 265 cases of acute encephalitis, and 105 deaths, and almost brought down the billion-dollar pig farming sector. At first, it was thought that the Japanese encephalitis virus (JEV), which was common in these areas, was the cause of all of these outbreaks. JEV vaccination and other mosquito control measures were implemented in response to this to manage these outbreaks, but the disease continued to spread even after that. Because most of the patients were adults rather than children, the epidemiological data indicated that the causative agent for these outbreaks was different from JEV. Additionally, individuals who had received the JEV vaccination also contracted the new agent, and during animal surveillance, sick pigs with severe barking coughs were observed, and many of them died from the same illness [33]. Adult males made up the majority of those infected, and they were all closely related to pig farming. In these outbreaks, pig-to-human NiV transmissions were noted. Infected NiV areas stopped spreading after control measures, including pig elimination, pig exchanges, and avoiding pig contact, were implemented. There were also cases of the virus found in Singapore during the 1998 Nipah virus outbreak in Malaysia. The movement of infected pigs from Malaysia to Singapore was blamed for the virus's spread there. Singapore took action to stop the virus from spreading throughout the nation by implementing containment measures, such as the elimination of infected pigs [34]. 11 pig farmers in Singapore were found to be NiV positive at the beginning of March 1999, with one of them dying. Each of those farmers had a history of close contact with the infected pigs and was involved in the import of live pigs from a region of Malaysia affected by NiV. All pig imports from Malaysia were halted on March 19, 1999, and Singapore's two abattoirs were closed for inquiries and extensive cleaning [35]. The case-control study revealed that a significantly higher proportion of case-patients than control subjects had contact with live pigs. All 11 case-patients were employed at one of the two abattoirs in Singapore. The causal relationship between human Nipah virus infection in Singapore and pigs from Malaysia was established by this, as well as the nucleotide sequences of RT-PCR products isolated from the Singaporean cases being identical to Nipah virus sequences from Malaysian cases and pigs [36].

5. INDIA

5.1 West Bengal

Nipah virus cases have also been reported from West Bengal, an eastern Indian state; an outbreak occurred in the Nadia district in 2001 [37]. The virus in this outbreak was linked to the ingestion of raw date palm sap and intimate contact with those who were infected. Serological analyses of the infected person's serum indicated NiV; however, at first, the outbreak was thought to be caused by the measles virus [38]. Nine serum/blood samples and five urine samples were found to be positive for NiV by an IgM and IgG immunological assay, while the remaining eighteen patient samples were sent to the National Institute of Virology, Pune, for NiV detection. There were at least 43 (68%) fatalities from the sudden and extremely serious outbreak, which included 66 laboratory-confirmed cases of NiV encephalitis. The second NiV outbreak was discovered in April 2007 in the West Bengali district of Nadia, close to the Bangladeshi border, in the village of Belechuapara. Although there were only five cases in this outbreak, every infected person passed away within a week of infection, meaning that the case fatality rate was 100%.

5.2 Kerala

The southern Indian state of Kerala has seen outbreaks of the Nipah virus. Kerala's Kozhikode and Malappuram districts noticed the country's first officially recognized outbreak in 2018. Three members of the same family died at the beginning of the outbreak. The outbreak was connected to the consumption of date palm sap contaminated by fruit bats, the virus's natural reservoir, and one medical professional who assisted in treating these family members also passed away from infection. The Pteropus genus bats were sampled from the Kozhikode district and examined at the National High-Security Animal Diseases Laboratory in Bhopal for analysis. Droplet infection was the mode of infection transmission from human to human. In the state of Kerala, a pair of coastal districts, Kozhikode and Malappuram, were impacted by NiV. Thirteen deaths out of fourteen confirmed cases were reported from Kozhikode district, and three deaths out of four confirmed cases were reported from Malappuram district, according to reports from the Directorate of Health Services, Kerala. Regarding the NiV outbreak, the World Health Organization did not advise against imposing any restrictions on trade, travel, or entry screening. After June 1, 2018, there were no more recorded cases of infection, and as of July 30, 2018, Kerala was the only state where the outbreak remained under control. There were 89 laboratory-confirmed cases of NiV across all three of these outbreaks, including 67 (75.2%) fatalities [39].

The State Government of Kerala reported six laboratory-confirmed cases of Nipah virus infection between September 12 and September 15, 2023, including two fatalities. All confirmed cases, which were reported in Kerala's Kozhikode district, involved males between the ages of 9 and 45.

The first case, whose infection source is unknown, was hospitalized in late August 2023 with pneumonia and acute respiratory distress syndrome (ARDS). Shortly after being admitted, he passed away. The other five confirmed cases were close associates of the initial case, including contacts at the hospital where the initial case was treated before passing away. A person who visited the hospital for the first time was being treated while the patient died in the second instance. He died after displaying indications of pneumonia.

As of September 27, 2023, 1288 contacts of the confirmed cases-including high-risk contacts and medical personnel who provided treatment and handled sample processing have been located. For 21 days, all identified contacts are placed under quarantine. As of September 27, 2023, the four cases are still in a stable clinical state.

In response, the government established containment zones with movement limitations, social distancing, and mask-wear requirements in public areas in nine villages within the Kozhikode district. The Kozhikode district's major public events have been restricted by the government until October 1, 2023 [40]. States and districts adjacent to the alert zone were notified to increase surveillance. Containment measures, such as isolating infected individuals and launching public health awareness campaigns, were put into place in response to the outbreak.

The virus discovered in Kerala has been named the Indian Genotype, or I-Genotype, and is comparable to the Nipah virus strain discovered in Bangladesh, according to the National Institute of Virology (NIV), Pune.

6. CLINICAL MANIFESTATIONS

6.1 Symptoms

Human Nipah virus infections can cause mild to severe symptoms, depending on the infection [41].

6.2 Mild Saymptoms

Some Nipah virus-infected people may not show any symptoms at all, a condition known as asymptomatic infection. Some people might have mild, nonspecific symptoms that are easily confused with common illnesses like the flu. These minor symptoms could be headaches, fevers, and aches in the muscles.

6.3 Acute Respiratory infection

Acute respiratory infections caused by the Nipah virus can occasionally develop and cause symptoms like coughing, sore throats, and trouble breathing.

6.4 Encephalitis (Brain inflammation)

Encephalitis, or inflammation of the brain, is one of the main signs of a severe Nipah virus infection. Nipah virus encephalitis symptoms can include confusion, drowsiness, disorientation, and a high fever. In more severe cases, seizures and neurological symptoms may result in a coma and a reduced state of consciousness [42].

6.5 Atypical Pneumonia

Atypical pneumonia, which appears as chest pain, dyspnea, and abnormal chest X-ray findings, can be caused by a Nipah virus infection.

6.6 Gastrointestinal Symptoms

Nausea, vomiting, and diarrhoea are among the gastrointestinal symptoms that some Nipah virus infection patients may experience.

6.7 Progressive Disease

Severe Nipah virus infections can worsen quickly, resulting in multi-organ failure, respiratory distress, and severe neurological symptoms. The illness has a high death rate, with most cases ending in death days or weeks after the onset of symptoms.

6.8 Severity and Case Fatality Rate

The Nipah virus is known for its capacity to cause serious and frequently fatal illnesses, though the virus's severity and case fatality rate can vary.

6.9 Severity

The severity of a Nipah virus infection can vary, ranging from minor symptoms to a serious, potentially fatal illness. Sometimes it can be difficult to diagnose and identify an infected person because some may not show any symptoms at all or may only have mild flu-like symptoms. When the Nipah virus infection is severe, it can lead to encephalitis, which is characterized by a high fever, seizures, confusion, and a reduced state of consciousness, among other severe neurological symptoms. There may also be severe respiratory symptoms [43]. Rapid disease progression can result in multiple organ failures and death.

6.10 Case Fatality Rate

When the disease is severe, the Nipah virus infection can have a high case fatality rate. Although CFR varies from epidemic to epidemic, it has occasionally been reported to reach 40–75%. The promptness of diagnosis, the accessibility of medical care, and the overall management of the outbreak are some of the variables that can affect the case fatality rate [41].

7. DIAGNOSIS AND DETECTION

As soon as the illness manifests, the sample should be taken ideally within four to five days. The following are possible examples:

The viral transport medium will be used to collect the throat swab. Approximately 10 ml of urine in a universal sterile container, at least 5 ml of blood in a plain vial, and at least 1 ml of CSF in a sterile container.

Samples must be transported to the testing laboratory under cold chain conditions (2–8°C) and securely packaged in triple containers with advance notification.

Clean the outside of the container with a 5% Lysol solution or a 1:100 dilution of bleach before releasing the sample [44].

8. LABORATORY METHODS

8.1 Polymerase Chain Reaction (PCR)

The genetic material (RNA) of the Nipah virus can be amplified and detected using a molecular technique called PCR. Specific Nipah virus PCR assays are used to test clinical samples, such as blood, urine, throat swabs, or cerebrospinal fluid, that are obtained from suspected cases. Since PCR has such high sensitivity and specificity, it's frequently chosen for early diagnosis [45].

8.2 Serological Tests

Serum released by the host in reaction to Nipah virus infection can be identified by serological testing. You can find specific Nipah virus antibodies in the patient's blood using neutralization tests and the enzyme-linked immunosorbent assay (ELISA). In addition to determining seroprevalence in a population, these tests are useful for diagnosing past or present infections.

8.3 Virus Isolation

Trying to cultivate and spread the Nipah virus in cell culture is part of the process of virus isolation. In a laboratory setting with stringent containment protocols (usually biosafety level 4 or equivalent), clinical samples are injected into susceptible cell lines. Cytopathic effects that are specific to the virus are observed in the cells, confirming its presence.

8.4 Imaging Studies

To determine the degree of organ involvement, radiological imaging tests like brain scans or chest X-rays may be carried out, particularly in cases of encephalitis or respiratory symptoms.

8.5 Differential Diagnosis

Differentiating the Nipah virus from other diseases, such as other viral encephalitis, influenza, or pneumonia, is crucial because the symptoms of Nipah virus infection can overlap with those of other illnesses.

9. CHALLENGES IN DIAGNOSIS

9.1 Non-Specific Symptoms

Particularly in mild or early cases, the early symptoms of a Nipah virus infection can be non-specific and resemble those of other common illnesses like respiratory infections or influenza. Because of this, it may be difficult to distinguish the Nipah virus from other illnesses using just clinical symptoms [46].

9.2 Limited Awareness

Healthcare professionals and the public might not be well-informed about the Nipah virus in areas where outbreaks are uncommon. This may cause a delay in the diagnosis and treatment.

9.3 High Containment Laboratory Requirements

The Nipah virus is potentially fatal and highly contagious. High-containment laboratories, such as biosafety level 4 (BSL-4) or comparable facilities, are required to perform diagnostic work. Since these labs are scarce in many areas, it is logistically difficult to perform diagnostic testing quickly.

9.4 Post-Mortem Examinations

Post-mortem exams might be required in cases of severe Nipah virus infection to confirm the diagnosis. However, getting the family's permission can be difficult, and conducting a post-mortem examination safely is a complicated and demanding procedure.

9.5 Rapid Spread

Nipah virus outbreaks can spread rapidly, so it is essential to identify and isolate cases as soon as possible to keep them contained. Post-diagnosis complications may lead to additional viral transmission.

10. EARLY DIAGNOSIS

10.1 Prompt Medical Care

Early diagnosis enables prompt initiation of supportive care and medical care, which can increase an infected person's chances of survival. It is essential to act quickly in severe cases of Nipah virus infection to manage complications and give the right care [47].

10.2 Preventing Transmission

Because the Nipah virus is extremely contagious, early diagnosis aids in the isolation of afflicted individuals and stops the virus from spreading to

medical personnel and the general public. It is possible to put containment measures in place swiftly to stop the disease from spreading.

10.3 Public Health Measures

Early case detection enables public health officials to quickly contain outbreaks. To lower the possibility of subsequent cases, this involves tracking down contacts, keeping an eye on them, and placing anyone who may have come into contact with the virus in quarantine.

10.4 Public Awareness

Early case detection and public awareness of the Nipah virus increase awareness among medical professionals and the general public, which aids in the search for more cases and possible infection sources.

10.5 Improved Healthcare Practices

Every outbreak offers a chance to increase knowledge about the virus, enhance medical procedures, and develop more advanced diagnostic and therapeutic approaches for similar outbreaks in the future.

10.6 Treatment and Management

10.6.1 Anti-viral therapies

For the treatment of Nipah virus infection, there are no approved medications or specific antiviral therapies. Research is still being done, though, on possible antiviral medications and therapeutic approaches. A few methods and studies are being conducted about antiviral treatments for the Nipah virus [48].

10.7 Ribavirin

In certain Nipah virus cases, ribavirin-a broad-spectrum antiviral drug-has been administered. Its effectiveness in treating Nipah virus infection is still unknown, though, and it is not thought of as a specific virus treatment.

10.8 Passive Immunotherapy

Convalescent plasma or monoclonal antibodies made from people who have recovered from Nipah virus infection are used in passive immunotherapy. These antibodies may aid in improving the patient's immune response and neutralizing the virus. Monoclonal antibody treatments are still being researched.

10.9 Antiviral Drug Development

The Nipah virus has been tested in vitro (in the lab) against several antiviral medication candidates, some of which have shown promise. As these drug candidates are still in the early phases of development, more animal model and clinical trial testing and validation are necessary.

11. SUPPORTIVE CARE

11.1 Infection Control Measures

Patients who have been diagnosed or suspected of having the Nipah virus should be kept apart from other patients and healthcare personnel to stop the virus from spreading. It is imperative to implement stringent measures for controlling infections, such as the use of personal protective equipment (PPE).

11.2 Intensive Medical Care

Intensive care units (ICUs) are frequently needed to treat patients with severe Nipah virus infections. In the intensive care unit (ICU), supportive care may involve respiratory distress management, intravenous fluid administration, and careful monitoring of vital signs.

11.3 Management of Complications

Serious side effects from the Nipah virus include multi-organ dysfunction, respiratory failure, and encephalitis (brain inflammation). It might be required to use interventions to treat these issues, such as mechanical ventilation for respiratory distress.

11.4 Neurological Support

For the management of symptoms such as seizures and altered mental status, patients suffering from encephalitis may need specific neurological care and interventions.

11.5 Nutritional Support

Sufficient nourishment is crucial for the recovery of the patient. If the patient is unable to eat or drink, nutrition may be given through enteral (tube) feeding or intravenous (IV) feeding.

Table 1. Development of vaccines for Nipah Virus

Vaccine	Species	Efficacy
Vaccine virus vector	Syrian hamster	Protection from lethal challenges after a single vaccination
Canary pox virus vector	Pig	Protection from lethal clinical disease after two vaccinations
VSVΔG	Ferret	Protection from the heterologous lethal challenge after a single vaccination
Adeno-associated virus vector	Syrian hamster	Protection from lethal challenges after a single vaccination
Measles virus	Syrian hamster	Protection from lethal challenges after two vaccination
sG_{NIV}	Cat	Protection from clinical disease after three vaccinations
sG_{HeV}	Cat	Protection from clinical disease after two vaccinations

11.6 Psychological Support

A Nipah virus infection can cause a great deal of emotional distress for patients and their families. Counseling and psychological support may be helpful.

11.7 End-of-Life Care

It may be necessary to provide end-of-life care in severe cases with a poor prognosis. This involves giving patients and their families dignity and comfort.

12. VACCINE DEVELOPMENT

12.1 Sub-unit Vaccines

Numerous Nipah virus experimental subunit vaccines have been created, and preclinical research has indicated that they may be effective. Instead of employing live viruses, these vaccines elicit an immune response using viral proteins. To evaluate safety and effectiveness, a few subunit vaccines have moved on to early-stage clinical trials [49].

12.2 Recombinant Vaccines

Recombinant vaccines aim to elicit an immune response using genetically modified viruses or viral proteins. Researchers have looked into the possibility of Nipah virus recombinant vaccines.

12.3 Prevention and Control

To manage and contain Nipah virus outbreaks and stop the virus from spreading throughout communities and healthcare facilities, public health measures are crucial. A Nipah virus infection can be avoided by staying away from raw date palm sap and limiting contact with infected pigs and bats in endemic areas. In areas where livestock serve as intermediate hosts, preventing infection in them may be a successful approach. It entails keeping bat roosting trees and fruit trees away from livestock farms and grazing areas that could be contaminated with viruses. It is best practice for staff to wear personal protective equipment (PPE) such as masks, gloves, protective goggles, gowns, and boots if an outbreak is suspected. These items need to be carefully cleaned and sanitized after each use. The intended staff's hygiene is another crucial point [50].

12.4 Surveillance and Early Detection

It is important to have surveillance systems in place to keep an eye out for any possible Nipah virus cases or outbreaks. Timely intervention depends on early detection [51].

12.5 Case Isolation

To stop the Nipah virus from spreading, those who have been diagnosed with or suspected of having it should be isolated. Strict infection control in hospital settings and community quarantine of close contacts are examples of isolation methods.

12.6 Contact Tracing

To stop secondary cases, it's critical to identify and keep an eye on people who have had close

contact with confirmed cases. Finding possible sources of infection and isolating people who might be virus incubators are two benefits of contact tracing.

12.7 Infection Control Precautions

When providing care for patients who have a suspected or confirmed Nipah virus infection, healthcare professionals and caregivers should wear personal protective equipment (PPE) to prevent virus exposure.

12.8 Educational Campaigns

Campaigns for public awareness are crucial in informing the public about the dangers of the Nipah virus and offering advice on how to prevent it, such as avoiding contact with sick animals and avoiding date palm sap.

12.9 Community Engagement

Involving the community is essential to controlling outbreaks. Interacting with local communities can promote cooperation and trust, make contact tracing easier, and guarantee that people seek medical attention as soon as possible.

13. ANIMAL CONTROL MEASURES

It is important to limit contact with potentially infected animals in areas where animal outbreaks of the Nipah virus have been linked. This can include eliminating contaminated animals from the farm, altering farming methods, and refraining from eating raw date palm sap that has been contaminated by bats.

13.1 Surveillance and Monitoring

An essential part of managing and containing Nipah virus outbreaks is surveillance and monitoring. These initiatives support early identification, monitoring the virus's transmission, and putting the right public health measures in place.

13.2 Case Surveillance

Identification and systematic tracking of suspected and confirmed cases of Nipah virus infection is known as case surveillance. Cases, including clinical and epidemiological data, must be reported, and recorded by public health agencies and healthcare facilities.

13.3 Laboratory Surveillance

An essential part of Nipah virus surveillance is laboratory testing. Using particular diagnostic techniques, clinical samples (blood, urine, and respiratory secretions) from suspected cases are tested to confirm the virus's presence.

13.4 Animal Surveillance

It is essential to monitor animal populations, especially those of fruit bats. The Nipah virus naturally lives in fruit bats. To detect the virus, samples from bats and other animals may be collected as part of surveillance.

13.5 Syndromic Surveillance

Syndromic surveillance is keeping an eye out for symptom clusters or particular health syndromes, like encephalitis, respiratory distress, or atypical pneumonia, which could be signs of an infection with the Nipah virus.

13.6 Enhanced Monitoring in High-Risk Areas

High-risk variables (such as bat populations and pig farming) or areas with a history of Nipah virus outbreaks may have stricter surveillance and monitoring systems in place.

13.7 Research and Monitoring of Reservoirs

To comprehend the ecology and dynamics of the virus's transmission, more research is required into the Nipah virus's natural reservoirs, especially fruit bats.

13.8 Quarantine and isolation

Procedures for isolation and quarantine are essential for controlling and containing Nipah virus outbreaks. These steps assist in stopping the virus's spread and safeguarding those who might be susceptible to infection [52].

14. ISOLATION OF CONFIRMED OR SUSPECTED CASES

14.1 Hospital Isolation

People who have been diagnosed with or are suspected of having the Nipah virus should be kept apart in a medical facility, such as an intensive care unit (ICU) or isolation ward.

14.2 Strict Infection Control

To prevent exposure to the virus, healthcare workers must rigorously follow infection control protocols, which include carrying the proper personal protective equipment (PPE).

14.3 Airborne Precautions

Using N95 respirators or other higher-level respiratory protection is one example of the precautions that should be taken when flying, especially when conducting aerosol-generating operations.

14.4 Restricted Visitors

Only authorized healthcare personnel should be able to enter the isolation area, and access should be restricted. It is best to keep non-essential staff, visitors, and other patients away from the isolation area.

15. QUARANTINE OF CLOSE CONTACTS

15.1 Identifying Contacts

Through contact tracing, close contacts for cases that have been confirmed should be found. Direct or close proximity to a confirmed case is considered close contact, especially if there is a possibility of respiratory secretion exposure [53].

15.2 Home Quarantine

In-home quarantines for close contacts are common. They should be told to stay indoors and not come into contact with people for a predetermined amount of time, usually the 14 days that the Nipah virus takes to incubate.

15.3 Monitoring

Health officials or medical professionals may keep an eye out for symptoms like fever, respiratory issues, or neurological indications in people under quarantine.

16. CONCLUSION

In conclusion, the Nipah virus continues to pose a serious risk to public health, and our knowledge of this zoonotic infection is still developing. Even though a great deal of progress has been made in understanding the virus's origins and dynamics of transmission, numerous obstacles still exist. The Nipah virus, which is mainly carried by fruit bats, has periodically spread throughout South and Southeast Asia, causing serious neurological and respiratory symptoms in people. Its high death rate serves as a clear warning that it can spark severe epidemics. Community education, infection control strategies, surveillance, and early detection have been the main focuses of efforts to contain and prevent Nipah virus outbreaks. Though none of the potential Nipah virus vaccines or treatments have gained regulatory approval yet, there has been encouraging progress in recent years. These developments are important first steps toward a broader approach to fight Nipah virus infections. It is crucial to carry out more research on the genomic variability of the virus and the ecological elements that affect events that spread from bats to humans. It is impossible to exaggerate the significance of international cooperation and readiness for many new infectious diseases. The Nipah virus is still a persistent and unpredictable threat, even though it does not always make news. To guarantee prompt action in the event of future Nipah virus epidemics, the global health community has to allocate resources towards research, monitoring, and developing capacity. This emphasizes the need for an aggressive "One Health" approach that incorporates environmental, animal, and human health, particularly given climate change and the rise in human-wildlife contact. We can better reduce the risks posed by the Nipah virus and other emerging pathogens, ultimately preserving public health and global wellbeing, by encouraging interdisciplinary collaboration and strengthening healthcare infrastructure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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