Available online on 15.02.2025 at http://jddtonline.info

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

Open Access Full Text Article

Check for updates

Review Article

Recent outbreaks of Human Metapneumovirus (HMPV): Prevention, Diagnosis and Therapeutic insights

Trilochan Satapathy [1]*, Abhisek Satapathy [2], Abinash Satapathy [3], Neha Yadav [3], Manisha Chandrakar [4], Kunal Chandrakar [4]

[1]Columbia Institute of Pharmacy, Raipur, Vill-Tekari, Near Vidhansabha, Raipur-493111, Chhattisgarh, India

[2] Pt J.N.M. Medical College, Jail Rd, opp. Central Jail, Moudhapara, Raipur-492001, Chhattisgarh, India

[3] College of Veterinary Science and Animal Husbandry, Anjora, Durg-491001, Chhattisgarh, India

[4] University College of Pharmacy, Chhattisgarh Swami Vivekananda Technical University, Bhilai-491107, Chhattisgarh, India

Article Info:

Article History:

Received 10 Nov 2024
Reviewed 27 Dec 2024
Accepted 20 Jan 2025
Published 15 Feb 2025

Cite this article as:

Satapathy T, Satapathy A, Satapathy A, Yadav N, Chandrakar M, Chandrakar K, Recent outbreaks of Human Metapneumovirus (HMPV): Prevention, Diagnosis and Therapeutic insights, Journal of Drug Delivery and Therapeutics. 2025; 15(2):193-203 *DOI: http://dx.doi.org/10.22270/jddt.v15i2.7000*

Abstract

The present review aims to discuss comprehensively about the Human Metapneumovirus (HMPV) which is a respiratory pathogen belonging to the family Paramyxoviridae. Since December 2024, northern China has seen a significant rise of respiratory diseases, including HMPV, particularly among youngsters. The Chinese Center for Disease Control and Prevention stated that HMPV was responsible for 6.2% of positive respiratory disease tests and 5.4% of hospitalizations during this time. Similar increases in HMPV cases have been seen in Malaysia, Kazakhstan, India, and Italy. India verified the first instances in early January 2025, including infections in newborns. Human Metapneumovirus initially identified in 2001 in the Netherlands, HMPV is now recognized as a global cause of respiratory infections, particularly among vulnerable populations such as young children, the elderly, and immunocompromised individuals. Its potential to cause widespread outbreaks has raised concerns about its pandemic potential. Polymerase Chain Reaction (PCR) testing is considered as the most sensitive and specific approach for identifying HMPV. It entails amplifying viral RNA from respiratory specimens (such as throat swabs, nasopharyngeal swabs, and sputum samples). There are currently no licensed antiviral medications for HMPV. However, some supportive therapy may be proved as beneficial in the HMPV infections. Among these, supplemental oxygen therapy, anti-pyretics (Acetaminophen or Paracetamol), Beta-2 agonists (Albuterol etc.), corticosteroids (Prednisolone etc.), Ribavirin (its efficacy against HMPV is not well documented), hydration therapy and antibiotics are included.

Keywords: Human Metapneumovirus, Paramyxoviridae, respiratory pathogen, Polymerase Chain Reaction, oxygen therapy, corticosteroids,

*Address for Correspondence:

Trilochan Satapathy, Columbia Institute of Pharmacy, Raipur, Vill-Tekari, Near Vidhansabha, Raipur-493111, Chhattisgarh, India

Introduction:

Human metapneumovirus (HMPV) is a negative-sense, single-stranded RNA virus from the Pneumoviridae family.[1] The respiratory virus belongs to the Avian metapneumovirus subgroup C and affects mostly the upper and lower respiratory tracts. It was discovered in 2001 by a group of Dutch researchers led by Dr. R. van den Hoogen.[2] The virus was discovered during an examination into respiratory illnesses in young children. This discovery was made possible by molecular techniques, specifically reverse transcription polymerase chain reaction (RT-PCR), which enabled scientists to identify and isolate the virus from respiratory samples.[3] Prior to the identification of HMPV, severe respiratory illnesses in children and adults were frequently attributed to more well-known viruses such as Respiratory Syncytial Virus (RSV), influenza, and adenoviruses. However, a considerable proportion of these instances could not be explained, encouraging further investigation into unknown infections. Following its discovery, HMPV was rapidly identified as a major pathogen leading to respiratory diseases, particularly in newborns and the elderly.[4] It is currently recognized as one of the leading causes of viral respiratory tract infections globally. Over the last two decades, multiple investigations have established the incidence of HMPV in both hospitalized and outpatient settings.[5] The virus circulates periodically, peaking in late winter and spring, as do other respiratory viruses

such as RSV and influenza. HMPV is a member of the Paramyxoviridae family, specifically the Metapneumovirus genus, and is known to cause mild to severe respiratory infections, especially in small children, the elderly, and immunocompromised people.[6] It is a leading cause of acute respiratory illness worldwide, particularly during the winter months when respiratory infections are more common. HMPV frequently produces normal cold symptoms such as coughing, fever, nasal congestion, and wheezing, but it can also cause bronchitis and pneumonia in severe cases. In susceptible individuals with underlying medical issues, HMPV infection can result in mortality.[7] The Human Metapneumovirus (HMPV) is already in circulation worldwide, including India, as of December 2024.

Structural architecture of Human Metapneumovirus (HMPV):

HMPV has an enclosed structure and seems pleomorphic, which means it can take on a number of shapes, including spherical or slightly elongated. HMPV particles are frequently spherical or oval in shape, with a smooth or slightly jagged appearance due to glycoprotein spikes on the viral surface, when seen under an electron microscope. The spikes are visible on the exterior of the membrane, but the RNA genome is located inside. The viral particle typically measures 150-200 nm in diameter. The virus's surface is covered in spikes or glycoproteins, which are critical to its ability to infect host cells.[8] These glycoproteins include the Fusion (F) protein, which is responsible for the virus's ability to fuse with host cells. Attachment protein (G) helps the virus connect to receptors on the surface of host cells HMPV's genome is made up of single-stranded RNA, which is typical of viruses in the Paramyxoviridae family.[9]

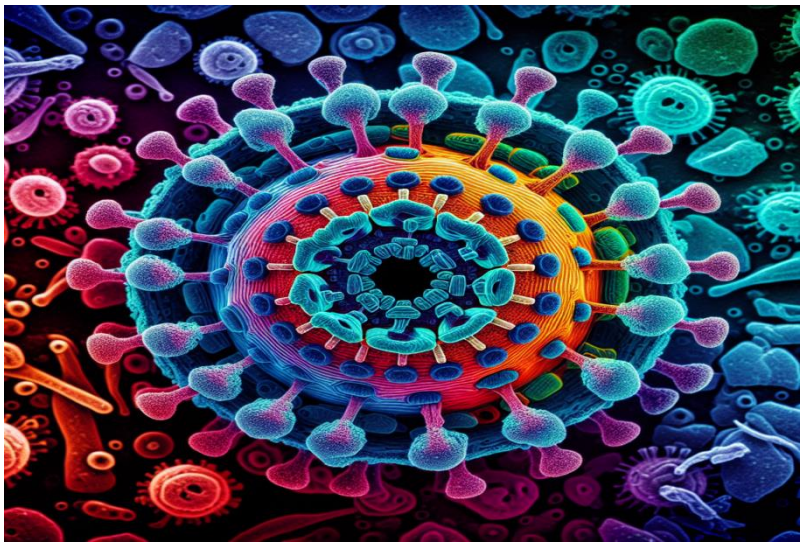

Figure 1: Electron Microscopic structure of Human Metapneumovirus (HMPV)

Epidemiology:

According to research, HMPV is a prevalent cause of respiratory infections in young children, particularly those under the age of five, as well as those with underlying health issues, such as the elderly and immunocompromised individuals. While HMPV is not as well known as RSV or influenza, it is responsible for a large number of hospitalizations and can cause consequences such as pneumonia and respiratory failure, particularly in vulnerable groups.[10]

Characteristics and Classification of Human Metapneumovirus (HMPV):

Human Metapneumovirus (HMPV) is genetically and structurally similar to RSV, but it is a separate virus with a unique genomic structure and antigenic profile. HMPV, like RSV, causes infections in the lower respiratory tract, which can result in bronchiolitis, pneumonia, or croup. However, HMPV's clinical presentation can vary greatly, with some people exhibiting mild cold-like symptoms and others developing severe respiratory distress.[11]

Table 1: Comparison between normal common cold and HMPV-infected common cold: [12, 13, 14, 15]

Feature	Normal Common Cold	HMPV-Infected Common Cold
Causative Virus	Rhinoviruses and other moderate respiratory viruses are the most common causes.	Caused by Human Metapneumovirus (HMPV), a member of the *Paramyxoviridae* family
Age Group Affected	Primarily affects children, but can also occur in adults.	Primarily affects young children, elderly, as well as immunocompromised individuals.
Incubation Period	1–3 days	3–6 days
Symptom Onset	Mild symptoms such as sneezing, a sore throat, and a runny nose appear gradually.	Gradual onset, but may involve more severe respiratory symptoms (e.g., coughing and wheezing).
Symptoms	- Nasal congestion - Sneezing - Sore throat - Mild cough - Low-grade fever (sometimes)	- Nasal congestion - Runny nose - Cough - Wheezing - Fever (common) - Sore throat (less common)
Fever	Uncommon or mild, typically below 102°F (38.9°C).	Sometimes present, can range from mild to moderate.
Cough	Usually mild and dry.	Can be more pronounced, sometimes wet or with wheezing.
Severity of Symptoms	Generally mild, self-limiting (lasts 7–10 days).	Can be mild to moderate; can escalate to bronchiolitis or pneumonia, particularly in vulnerable groups.
Duration of Illness	7–10 days	7-14 days or longer in severe cases, particularly in youngsters and the elderly.
Complications	Rare, generally resolves without complications.	Can result in problems such as bronchiolitis, pneumonia, and respiratory distress.
Transmission	Highly contagious, transmitted mostly by respiratory droplets and contact with infected surfaces.	Highly contagious, similar to the common cold, transmitted primarily by respiratory droplets and contact with infected surfaces.
Seasonality	Typically occurs year-round, with peak seasons in the fall and spring.	Seasonal, with peak circulation during late winter and early spring.
Diagnosis	Clinical diagnosis based on symptoms. Often confirmed by rapid tests or viral culture.	Diagnosed by Polymerase Chain Reaction (PCR) or viral culture from respiratory specimens.
Treatment	Symptomatic treatment (e.g., rest, hydration, over-the-counter (OTC) medications like decongestants, and analgesics).	No specific antiviral treatment; Only supportive care (hydration, oxygen, sometimes hospitalization in severe cases).
Risk of Severe Disease	Very low; complications are also rare.	Higher risk of severe respiratory illness, especially in infants, elderly, & immunocompromised individuals.
Vaccine Availability	No vaccine, but some protection from prior exposure and seasonal immunity.	No vaccine currently available, but research is ongoing.
Prevention	Good hygiene (hand washing), avoiding contact with infected individuals, and rest.	Same prevention as common cold, and additional focus on protecting high-risk groups (young children, elderly).

Mode of Transmission of HMPV Virus in Humans:

Human metapneumovirus (HMPV) is a respiratory virus that mostly affects the upper and lower respiratory tracts. The most prevalent form of transmission is by respiratory droplets produced when an infected person coughs, sneezes, or speaks. These droplets can land in people's mouths, noses, or eyes, spreading the infection. HMPV can also be transmitted through direct contact, such as shaking hands with an infected person or touching surfaces contaminated with respiratory secretions (doorknobs, shared objects).[16] Afterward, touching the face, particularly the nose, mouth, or eyes,

can help the virus enter the body. In rare situations, the virus may spread via small aerosolized particles, which are lighter and can stay suspended in the air for a longer period. This method of transmission is more common in packed, enclosed places, but it is less thoroughly studied than droplet transmission. HMPV can live on surfaces for a while, and people who touch contaminated surfaces may get the virus by touching their mouth, nose, or eyes. After exposure, symptoms usually manifest within 3 to 6 days, and infected people might be contagious for several days before and after symptoms appear, especially during the peak of their illness.[17]

General Sign and symptoms of Human Metapneumovirus (HMPV):

HMPV can induce a wide spectrum of respiratory symptoms, from mild to severe. Symptoms of the upper respiratory tract include runny nose, cough, sore throat, and nasal congestion. Lower respiratory symptoms include wheezing, trouble breathing, and signs of pneumonia. Severe instances have been recorded, particularly in small children and the elderly, and the virus can cause bronchiolitis, pneumonia, and respiratory failure.[18]

Post invasion consequence of HMPV Virus in children and elderly people:

Human Metapneumovirus (HMPV) infection can cause a variety of respiratory problems, especially in vulnerable populations including children and the elderly. While most people recover from HMPV infection with supportive treatment, the post-infection repercussions can be severe and long-lasting in some cases, particularly in the very young and elderly.[19] These implications differ according to the patient's overall health, immune condition, and the severity of the illness. Children, particularly those under the age of five, are more likely to develop serious disease due to their smaller airways, underdeveloped immune systems, and sensitivity to viral infections. Elderly people (particularly those over the age of 65 are more likely to experience serious complications due to weakening immune systems, the prevalence of chronic medical disorders (such as heart disease or diabetes), and reduced lung function. We attempted to describe the post-invasion repercussions of HMPV in youngsters and the elderly in the table below.[20]

Table 2: Summary of post-Invasion Consequences of HMPV in Children: [21, 22, 23, 24, 25, 26]

Consequence	Description	Impact on Children
Bronchiolitis	Inflammation and congestion of the tiny airways (bronchioles) cause difficulties breathing.	Complications are common in newborns and young children, particularly those under the age of two. Can induce serious respiratory distress, necessitating hospitalization.
Pneumonia	Lung inflammation can cause difficulties breathing, hypoxia, and lung damage.	Children, particularly those under one year old, are more likely to develop viral pneumonia from HMPV, which can lead to respiratory failure.
Asthma Exacerbation	Respiratory viruses such as HMPV can cause or exacerbate asthma in children who already have asthma or wheeze.	Children who have a history of asthma or recurrent wheeze may develop more frequent or severe asthma attacks after contracting HMPV.
Recurrent Respiratory Infections	HMPV infection may raise the chance of developing future respiratory infections.	Long-term respiratory problems, such as recurring colds, coughing, or wheezing, are possible. Children with chronic lung illness are more vulnerable
Hypoxia	Severe HMPV infections can lower oxygen levels in the lungs due to inflammation and fluid buildup.	In severe situations, children may endure protracted periods of low oxygen levels, necessitating supplementary oxygen therapy and perhaps mechanical ventilation.
Croup (Laryngotracheobronchitis)	Swelling of the larynx and trachea, resulting in a barking cough, stridor, and trouble in breathing.	Children, particularly infants and toddlers, are at risk of getting croup as a result of HMPV infection, which may necessitate urgent care or hospitalization.
Delayed Recovery	Although HMPV symptoms usually fade after a few weeks, some children may have a persistent cough or lethargy.	Recovery time can be delayed, particularly in children with pre-existing respiratory problems who may require follow-up treatment and monitoring.
Secondary Bacterial Infections	HMPV can make children more likely to develop subsequent bacterial infections such bacterial pneumonia or otitis media.	HMPV-induced immune responses may raise the incidence of secondary bacterial infections, worsening the disease's clinical outcome.

Table 3: Summary of post-Invasion Consequences of HMPV in the Elderly: [27, 28,29,30,31]

Consequence	Description	Impact on the Elderly
Pneumonia	A severe and common consequence of HMPV is lung tissue inflammation, which can escalate to respiratory failure.	A higher risk of pneumonia, which may necessitate hospitalization or ventilator assistance in severe cases. Pneumonia is the primary cause of death in older people with HMPV.
Chronic Respiratory Impairment	Prolonged respiratory issues, such as difficulty breathing and decreased lung function, can last long after the acute phase of infection.	Elderly people may develop chronic obstructive pulmonary disease (COPD)-like symptoms following infection, which can lead to long-term respiratory problems.
Exacerbation of Pre-existing Conditions	HMPV can worsen pre-existing diseases such heart failure, COPD, and asthma.	Individuals with pre-existing lung or heart diseases are more likely to experience consequences such as heart failure, worsening COPD, or severe wheezing.
Hospitalization and ICU Admission	The severity of HMPV infection increases the likelihood that elderly individuals may require hospitalization, including ICU care.	The elderly have higher rates of hospitalization and may need intensive care, especially if the infection leads to respiratory failure.
Acute Respiratory Distress Syndrome (ARDS)	Severe lung inflammation causes widespread damage, hypoxia, and the requirement for ventilator assistance.	Elderly people are more likely to develop acute respiratory distress syndrome (ARDS), which can be fatal and necessitate mechanical ventilation.
Secondary Bacterial Infections	HMPV can make older people more susceptible to secondary bacterial infections including bacterial pneumonia and sepsis.	The elderly are more likely to develop secondary infections following a viral infection, which can exacerbate the clinical course and raise the chance of death.
Cognitive Decline or Delirium	Severe infection, hospitalization, and respiratory distress can all lead to delirium or cognitive deterioration in elderly people.	Elderly individuals with severe infections may experience delirium, cognitive impairment, or worsening of pre-existing dementia symptoms during or after treatment.
Prolonged Recovery	Recovery from HMPV infection might be sluggish in older persons, resulting in prolonged weakness, weariness, and lower activity levels.	Prolonged recovery from sickness can reduce quality of life, and older persons may require additional care, rehabilitation, or physical therapy.

Post-Invasion Consequences of HMPV in Immunocompromised Persons:

Immunocompromised people—those with weaker immune systems as a result of HIV/AIDS, cancer treatments, organ transplants, or autoimmune diseases—are at a considerably increased risk of severe consequences and lengthy recovery from infections such as Human Metapneumovirus (HMPV).[32] In these cases, HMPV can cause more severe sickness, longer recovery durations, and a greater risk of subsequent infections. Immunocompromised people may be unable to eliminate the infection as effectively as those with normal immune function. This can result in prolonged viral replication and shedding, raising the risk of transmission and causing symptoms to last longer. Pneumonia is a typical side effect of HMPV infection, and in immunocompromised people, it can be significantly more severe. This causes respiratory discomfort and hypoxia (low oxygen levels in the blood). ARDS is another significant consequence in which widespread lung inflammation causes severe difficulty breathing and may necessitate mechanical support.[33] These conditions are associated with a high death risk in immunocompromised patients. The immune system's inability to adequately handle HMPV infection can lead to subsequent bacterial infections such bacterial pneumonia or sepsis. These infections complicate therapy, necessitating antibiotics or other measures, and can lengthen hospital stays and recovery times. Immunocompromised people may struggle to establish an effective immune response against HMPV. [34] This could lead to a prolonged illness and lengthier healing times, with symptoms such as chronic cough, wheezing, and exhaustion lasting weeks or months. Many immunocompromised patients have pre-existing illnesses like COPD, asthma, or interstitial lung disease. An HMPV infection can aggravate these problems, resulting in worsening symptoms, frequent hospitalizations, and more serious outcomes. In severe circumstances, HMPV can cause multi-organ dysfunction due to systemic inflammation. This is especially concerning for immunocompromised people, who may already have additional organ vulnerabilities such as liver, renal, or cardiac disorders. Infected people may develop sepsis, a life-threatening systemic inflammatory response that raises the risk of organ failure and death. Long-term sickness, frequent hospitalizations, and respiratory distress can all cause anxiety, depression, and even cognitive deterioration in immune-compromised people, especially the elderly and fragile. Recovery from such a severe sickness frequently necessitates mental health care.[35]

Table 4: Summary of post-Invasion Consequences of HMPV in Immunocompromised Persons [36, 37, 38]

Consequence	Description	Impact on Immunocompromised Persons
Prolonged Viral Shedding	Immunocompromised persons may suffer prolonged viral shedding, which means the virus stays in the body for a longer period of time.	Increased transmission risk: Because these patients are contagious for longer periods of time, the virus has a higher chance of spreading to others. Prolonged healing time.
Severe Pneumonia	HMPV can induce severe viral pneumonia, resulting in lung inflammation, difficulties breathing, and hypoxia.	Increased risk of pneumonia: Immunocompromised people are more likely to develop severe pneumonia, which may necessitate mechanical ventilation or even cause respiratory failure.
Acute Respiratory Distress Syndrome (ARDS)	A life-threatening illness characterized by extensive pulmonary inflammation, which leads to severe hypoxia and respiratory failure.	ARDS might develop more quickly, necessitating intense care, ventilator support, and a lengthy recovery. It has a significant mortality rate among immunocompromised patients.
Secondary Bacterial Infections	Viral infections, such as HMPV, can increase the risk of subsequent bacterial infections.	Increased risk of bacterial co-infections: Immunocompromised individuals are more likely to get secondary bacterial infections, which can exacerbate the condition and necessitate extra therapies.
Prolonged Inflammation	Persistent immunological response causes protracted inflammation in the respiratory tract.	Prolonged respiratory symptoms: Chronic inflammation can cause a persistent cough, wheezing, and exhaustion for weeks or even months, hindering rehabilitation.
Exacerbation of Underlying Conditions	HMPV can worsen pre-existing chronic respiratory disorders such COPD, asthma, and interstitial lung disease.	Individuals with underlying lung diseases are more likely to have worsening symptoms, more hospitalizations, and longer recovery times.
Impaired Immune Response to Infection	Immunocompromised people cannot mount an effective fight against the infection.	Delayed or incomplete viral clearance: Because of a weakened immune system, HMPV may remain in the body for longer periods of time, resulting in prolonged illness, complications, and an increased risk of chronic symptoms.
Organ Dysfunction (Multi-organ)	Severe viral infections can cause systemic inflammation and damage to various organs, including the liver, kidneys, and heart.	Multi-organ failure: Immunocompromised people, particularly those with underlying medical conditions, are more likely to develop multi-organ dysfunction, which can lead to sepsis or death.
Delayed Recovery	Due to decreased immunity, recovery from infection may be much slower than in immunocompetent persons.	Prolonged illness: Immunocompromised patients may experience months of weariness, weakness, and respiratory problems following the acute phase, necessitating extensive rehabilitation.
Cognitive and Psychological Effects	The stress of extended sickness, hospitalizations, and physical disability can all lead to mental health problems.	Psychological stress: Prolonged illness and recovery, combined with the physical toll of the infection, can cause depression, anxiety, and cognitive loss, particularly in elderly immunocompromised people.
Increased Mortality Risk	Because of the intensity and duration of the illness in immunocompromised people, the risk of death is increased.	Increased mortality risk: Complications such as pneumonia, ARDS, sepsis, and other organ failures dramatically raise the chance of death in highly immunocompromised people.

Diagnosis of HMPV Virus:

Human Metapneumovirus (HMPV) infection is diagnosed primarily through clinical signs, patient history, and laboratory tests. Healthcare practitioners will begin by reviewing the patient's medical history, with an emphasis on respiratory symptoms such as cough, fever, nasal congestion, and sore throat. Shortness of breath, wheezing, fatigue. Gastrointestinal problems such as diarrhea or vomiting (particularly common in youngsters). Polymerase Chain Reaction (PCR) testing is regarded as the most sensitive and specific approach for identifying HMPV.[39] It entails amplifying viral RNA from respiratory specimens (such as throat swabs, nasopharyngeal swabs, and sputum samples). PCR can accurately detect HMPV, even in instances with moderate or unusual symptoms. It

distinguishes HMPV from other respiratory viruses. Although HMPV can be cultured from respiratory specimens in specialized labs, this approach is rarely utilized in general practice because to its complexity and longer turnaround time when compared to PCR. Direct Fluorescent Antibody (DFA) Testing detects HMPV antigens in respiratory samples. It yields faster findings than PCR, but it is less sensitive and may produce false negatives if the virus load is low.[40] The Enzyme-Linked Immunosorbent Assay (ELISA) can identify viruses (antigens) or the body's immunological reaction (antibodies). It is more widely employed in research settings than in the regular diagnosis of acute infections. ELISA can be utilized for epidemiological studies or retrospective diagnosis, however it is not commonly used for acute HMPV infection.[41] Reverse transcription-polymerase chain reaction (RT-PCR) may detect HMPV-specific RNA sequences in respiratory tract samples and is widely employed for early detection, particularly during outbreaks. These imaging studies can help rule out alternative causes of respiratory distress and determine the severity of lung involvement. In severe cases of HMPV infection, the X-ray may reveal symptoms of lower respiratory tract involvement, such as lung infiltrates, but these are nonspecific. Because the symptoms of HMPV might be similar to those of other respiratory diseases (such as influenza, RSV, adenovirus, and corona virus), diagnostic testing is essential for distinction.[42] Laboratory tests can identify the precise pathogen causing the disease, allowing for more targeted therapy and isolation precautions. In some circumstances, particularly in young children or immunocompromised persons, patients may be infected with several respiratory pathogens. Molecular multiplex testing permits the detection of numerous viruses (including HMPV) from a single sample, which helps identify co-infections.[43]

Table 5: Summary of Diagnostic Methods for HMPV Virus: [41, 42, 43]

Method	Description	Advantages	Limitations
PCR	It detects viral RNA in respiratory samples.	Highly sensitive, specific, and rapid	Requires sophisticated lab equipment
Viral Culture	Cultures live virus from respiratory samples	Confirms live virus, helpful for research	Slow, requires specialized facilities
DFA	Detects viral antigens	Rapid results	Less sensitive than PCR; false negatives may occur.
ELISA	Detects antibodies or viral antigens	Can be utilized for research and retrospective diagnosis.	Less commonly used for acute diagnosis
Chest X-ray	Imaging to assess complications	Can detect complications like pneumonia	Nonspecific, does not diagnose HMPV

Preventative measures: [44, 45, 46]

Human Metapneumovirus (HMPV) infection prevention strategies are similar to those used to treat other respiratory viruses such as influenza and the common cold. Because there is no specific vaccine or antiviral treatment for HMPV, the primary goal is to reduce transmission and infection risk. Wash your hands frequently with soap and water for at least 20 seconds, particularly after coughing, sneezing, or touching possibly contaminated surfaces. Use a hand sanitizer with at least 60% alcohol. Avoid contacting your eyes, nose, or mouth with unwashed hands, as these are typical entrance routes for viruses. To avoid spreading respiratory droplets, always cover your mouth and nose with a tissue or your elbow when coughing or sneezing. After using tissues, discard them immediately and wash your hands. If possible, avoid those who have respiratory symptoms such as coughing, sneezing, or fever. If you have symptoms of a respiratory infection (fever, cough, shortness of breath), stay at home to limit the risk of spreading the virus. Limit your time in crowded, enclosed areas, particularly during high respiratory illness seasons. To limit the risk of virus transmission, regularly sanitize surfaces such as doorknobs, light switches, phones, keyboards, and other frequent areas. Wearing a mask can help minimize the spread of respiratory droplets in areas with inadequate ventilation or where you are likely to come into contact with sick people (e.g., healthcare settings, public transportation). Maintain a nutritious diet, exercise regularly, get adequate sleep, and manage stress to boost your immune system and lower your chances of contracting a serious illness if infected. Although the flu vaccine does not protect against HMPV, it can minimize the burden of other respiratory infections, lowering the overall risk of co-infection and consequences. Infants, young children, the elderly, and people with compromised immune systems are more likely to experience serious problems from HMPV infection. Additional care should be taken to reduce their exposure to potential sources of infection. Smoking and secondhand smoke can weaken the respiratory system, making people more susceptible to respiratory diseases like HMPV. Stay up to date on health-related guidelines, such as those from the Centers for Disease Control (CDC) or World Health Organization (WHO), especially during flu season or respiratory ailment epidemics. If someone in your household or community has been infected with HMPV, keep them away from others,

particularly vulnerable people, until they recover. If someone else is infected, make sure they rest, stay hydrated, and get medical attention if necessary, especially if their respiratory symptoms worsen.

Treatment options for HMPV Virus [47]

Human Metapneumovirus (HMPV) infection usually results in symptoms similar to those of other respiratory infections, such as the common cold, bronchiolitis, or pneumonia. There are currently no licensed antiviral medications for HMPV, thus treatment is mainly supportive. Several therapeutic techniques and interventions, however, may benefit in symptom management and prevention of repercussions, particularly in vulnerable populations. The table below highlights the available therapeutic options, their mechanisms of action, and their potential significance in HMPV infection control.

Table 6: Non-Specific and specific treatment options for HMPV Virus with their mechanism of action: [48, 49, 50]

Treatment Option	Mechanism of Action	Role in Treatment
Supportive Care (Primary Treatment)	Symptom therapy includes water, fever control (acetaminophen, ibuprofen), and cough alleviation. No direct antiviral impact.	Relieves symptoms by providing comfort and reducing the severity of fever, cough, and respiratory distress. Typically used for mild to moderate instances.
Oxygen Therapy	Supplemental oxygen: Increases blood oxygen saturation when the patient is hypoxic (poor on oxygen). There is no direct antiviral effect.	Prevents hypoxemia: Used during severe respiratory distress or when oxygen saturation falls below safe levels (e.g., <92%).
Bronchodilators (e.g., Albuterol)	Beta-2 agonists stimulate beta-2 adrenergic receptors in smooth muscle of the airways, resulting in bronchodilation.	Reduces wheezing and respiratory distress: Can be used in people who have severe wheezing, particularly youngsters or those with asthma.
Corticosteroids (e.g., Prednisone)	Anti-inflammatory action: Inhibits pro-inflammatory cytokines, reducing the immune system's inflammatory response. Can help minimize airway edema.	Used in extreme cases: In hospitalized patients with considerable inflammation or those at risk of developing pneumonia or bronchitis.
Ribavirin (Off-label use)	The nucleoside analog inhibits RNA-dependent RNA polymerase, preventing viral RNA replication. However, its efficacy against HMPV is not well documented.	Potential antiviral treatment: Used in severe or high-risk situations, such as immunocompromised patients, although not always indicated for HMPV.
Palivizumab (Monoclonal antibody, Off-label)	Neutralizes RSV and other respiratory viruses. Targets the virus's F (fusion) protein, preventing it from entering host cells. (Most commonly used for RSV).	Preventative: Primarily used for RSV, however studies on its efficacy against HMPV are continuing. Could be explored for high-risk groups.
Antipyretics (e.g., Acetaminophen, Ibuprofen etc.)	Reduces fever: Acetaminophen reduces prostaglandin synthesis in the brain, whereas ibuprofen inhibits cyclooxygenase (COX), hence decreasing inflammation and fever.	Fever control: Reduces fever and relieves symptoms.
Hydration and Fluids	Maintains fluid balance: Ensures proper hydration to avoid dehydration, which can exacerbate symptoms such as weariness and coughing. No direct antiviral impact.	Maintains fluid balance: Proper hydration prevents dehydration, which can increase symptoms like fatigue and coughing. There is no direct antiviral impact.
Mechanical Ventilation (In Severe Cases)	Positive pressure: Supports breathing by supplying air or oxygen directly into the lungs via a ventilator tube. No antiviral impact.	Life-saving in severe cases: Required for individuals with respiratory failure who cannot maintain adequate oxygen levels.
Antibiotics (If Secondary Bacterial Infection Occurs)	Antibiotics are used to treat bacterial pathogens that can cause secondary illnesses, such as pneumonia. HMPV has no antiviral impact on itself.	Treats secondary infections: Used only when there is a confirmed or suspected bacterial co-infection (e.g., bacterial pneumonia).

Indian Government advisory about HMPV Virus: [51, 52]

The Indian government has issued advice in response to recent HMPV instances recorded in the country. As of January 8, 2025, seven instances had been confirmed, with the majority affecting newborns and young children. According to Newsweek, one of the HMPV-infected kids was a three-month-old girl who was taken to Baptist Hospital in Bengaluru. According to The Hindu, a two-month-old boy in Ahmedabad, western India, contracted the HMPV virus. The ministry continued: "HMPV is already in circulation globally, including in India, and cases of respiratory illnesses associated with HMPV have been reported in various countries." The Union Health Ministry has instructed states to improve respiratory illness surveillance and increase public awareness of HMPV prevention measures. States such as Uttarakhand have issued cautions to prevent the spread of respiratory infections caused by seasonal influenza and HMPV. Health officials emphasize that, while caution is required, there is no need for concern. The Govt. has declared that HMPV is not a lethal virus and asked the public to be calm. Children under the age of three and those who are immunocompromised should exercise extreme caution.

Conclusion and future strategies to fight against HMPV Virus:

Human Metapneumovirus (HMPV) is not a novel disease; it has been identified as a major cause of respiratory illness since its discovery in 2001. While it normally produces mild cold-like symptoms, it can cause serious respiratory distress in sensitive populations such as small children, the elderly, and immunocompromised people. The current increase in HMPV cases highlights the importance of attention, especially given the increased global awareness about respiratory viruses following COVID-19. HMPV, on the other hand, is less contagious and less severe than Severe Acute Respiratory Syndrome Corona virus 2 (SARS-CoV-2) , and the vast majority of cases resolve without sequelae. Public health interventions like as enhanced hygiene, respiratory etiquette, and surveillance systems have proven beneficial in limiting its spread. Research into HMPV vaccines is ongoing. Advances in mRNA and other vaccination technologies may speed up the development of preventive interventions. A vaccination would be especially beneficial for high-risk populations. Enhanced diagnostic technologies can aid in the early detection and distinction of HMPV from other respiratory viruses such as influenza and RSV, allowing for timely and focused therapies. Strengthened global surveillance systems can provide early warnings of epidemics, particularly in areas with high HMPV prevalence. Data sharing between countries can help us better understand the virus's behavior. Governments are likely to include HMPV into normal public health monitoring and response plans, assuring readiness for potential future surges. Continuous respiratory health education programs, with a focus on basic preventative measures, will be crucial in reducing HMPV transmission. HMPV currently lacks specific antiviral therapies, therefore management is mostly supportive. Research into effective treatments is a major priority. Environmental and socioeconomic factors, such as population density and access to healthcare, may have an impact on the virus's spread throughout countries. With the correct investments in public health infrastructure, research, and global collaboration, HMPV outbreaks can be effectively managed, reducing their impact on health systems and communities. While the virus is unlikely to cause a pandemic, it will continue to be monitored and managed as part of global health initiatives.

List of abbreviations Used:

CDC: Centers for Disease Control	OTC: Over-the- counter
COPD: Chronic obstructive pulmonary disease	PCR: Polymerase Chain Reaction
COX: Cyclooxygenase	RNA: Ribo nucleic acid
DFA: Direct Fluorescent Antibody	RSV: Respiratory Syncytial Virus
ELISA: Enzyme-Linked Immunosorbent Assay	RT-PCR: Reverse transcription polymerase chain reaction
HMPV: Human metapneumovirus	(SARS-CoV-2): Severe Acute Respiratory Syndrome Corona virus 2WHO: World Health Organization
IMA: Indian Medical Association	

Conflict of interest: The authors declare no conflict of interest.

Acknowledgement: We are thankful to the Principal, Columbia Institute of Pharmacy, Raipur (C.G.), Principal, Pt J.N.M. Medical College, Jail Rd, opp. Central Jail, Moudhapara, Raipur-492001, Chhattisgarh, India and Dean, College of Veterinary Science and Animal Husbandry, Anjora, Durg-491001, Chhattisgarh, India for providing necessary facilities to complete this review article.

Funding: We do not receive any kind of funding from any source for this review article.

Author's contribution: Dr. Trilochan Satapathy: Conception and Preparation of content

Abhisek Satapathy: Editing the content

Abinash Satapathy and Neha Yadav: Grammar and English language correction

Manisha Chandrakar, Kunal Chandrakar: Review the content

Ethical Approval: Not applicable

References:

1. Shafagati N, Williams J. Human metapneumovirus-what we know now. F1000Research. 2018; 7. https://doi.org/10.12688/f1000research.12625.1 PMid:29744035 PMCid:PMC5795268

2. Van den Hoogen B. Human Metapneumovirus: Discovery, Characterization and Associated Disease.

3. Jeong S, Park MJ, Song W, Kim HS. Advances in laboratory assays for detecting human metapneumovirus. Annals of Translational Medicine. 2020 May; 8(9). https://doi.org/10.21037/atm.2019.12.42 PMid:32566634 PMCid:PMC7290561

4. Panda S, Mohakud NK, Pena L, Kumar S. Human metapneumovirus: review of an important respiratory pathogen. International journal of infectious diseases. 2014 Aug 1; 25: 45-52. https://doi.org/10.1016/j.ijid.2014.03.1394 PMid:24841931 PMCid:PMC7110553

5. Davis CR, Stockmann C, Pavia AT, Byington CL, Blaschke AJ, Hersh AL, Thorell EA, Korgenski K, Daly J, Ampofo K. Incidence, morbidity, and costs of human metapneumovirus infection in hospitalized children. Journal of the Pediatric Infectious Diseases Society. 2016 Sep 1; 5(3):303-311. https://doi.org/10.1093/jpids/piv027 PMid:26407261 PMCid:PMC5125451

6. Crowe JE, Williams JV. Paramyxoviruses: respiratory syncytial virus and human metapneumovirus. Viral Infections of Humans: Epidemiology and Control. 2014:601-627. https://doi.org/10.1007/978-1-4899-7448-8_26 PMCid:PMC7121911

7. Xie Z, Zhu Z, Xu J, Mao N, Cui A, Wang W, Wang Y, Zhang Z, Xia B, Wang H, Sun Z. Seasonal and Genetic Characteristics of Human Metapneumovirus Circulating-Henan Province, China, 2017-2023. China CDC Weekly. 2024 May 5; 6(20):450. https://doi.org/10.46234/ccdcw2024.087 PMid:38846360 PMCid:PMC11150164

8. Robinson CC. Respiratory viruses. Clinical virology manual. 2009 Jun 5:201-248. https://doi.org/10.1128/9781555815974.ch17 PMid:19419406 PMCid:PMC6932397

9. Bossart KN, Broder CC. Paramyxovirus entry. Viral Entry into Host Cells. 2009.

10. Boivin G, Abed Y, Pelletier G, Ruel L, Moisan D, Cote S, Peret TC, Erdman DD, Anderson LJ. Virological features and clinical manifestations associated with human metapneumovirus: a new paramyxovirus responsible for acute respiratory-tract infections in all age groups. The Journal of infectious diseases. 2002 Nov 1;186(9):1330-1334. https://doi.org/10.1086/344319 PMid:12402203

11. Papenburg J, Boivin G. The distinguishing features of human metapneumovirus and respiratory syncytial virus. Reviews in medical virology. 2010 Jul;20(4):245-260. https://doi.org/10.1002/rmv.651 PMid:20586081

12. Jayaweera JA, Noordeen F, Kothalaweala S, Pitchai FN, Rayes ML. A case series on common cold to severe bronchiolitis and pneumonia in children following human metapneumovirus infection in Sri Lanka. BMC Research Notes. 2018 Dec; 11:1-5. https://doi.org/10.1186/s13104-018-3239-3 PMid:29444701 PMCid:PMC5813322

13. Walsh EE, Peterson DR, Falsey AR. Human metapneumovirus infections in adults: another piece of the puzzle. Archives of internal medicine. 2008 Dec 8;168(22):2489-2496. https://doi.org/10.1001/archinte.168.22.2489 PMid:19064834 PMCid:PMC2783624

14. Wilkesmann A, Schildgen O, Eis-Hübinger AM, Geikowski T, Glatzel T, Lentze MJ, Bode U, Simon A. Human metapneumovirus infections cause similar symptoms and clinical severity as respiratory syncytial virus infections. European journal of pediatrics. 2006 Jul; 165:467-475. https://doi.org/10.1007/s00431-006-0105-4 PMid:16607540

15. El Sayed Zaki M, Raafat D, El-Metaal AA, Ismail M. Study of human metapneumovirus-associated lower respiratory tract infections in Egyptian adults. Microbiology and immunology. 2009 Nov; 53(11):603-608. https://doi.org/10.1111/j.1348-0421.2009.00162.x PMid:19903260

16. Crowe Jr JE. Human metapneumovirus as a major cause of human respiratory tract disease. The Pediatric infectious disease journal. 2004 Nov 1;23(11):S215-S221. https://doi.org/10.1097/01.inf.0000144668.81573.6d PMid:15577576

17. Costa-Filho RC, Saddy F, Costa JL, Tavares LR, Castro Faria Neto HC. The Silent Threat of Human Metapneumovirus: Clinical Challenges and Diagnostic Insights from a Severe Pneumonia Case. Microorganisms. 2025 Jan 2; 13(1):73. https://doi.org/10.3390/microorganisms13010073 PMid:39858840 PMCid:PMC11767637

18. Arruda E, Cintra OA, Hayden FG. Respiratory tract viral infections. Tropical Infectious Diseases. 2006:637. https://doi.org/10.1016/B978-0-443-06668-9.50064-8 PMCid:PMC7152450

19. Proença-Modena JL, Acrani GO, Snider CB, Arruda E. Respiratory viral infections. Tropical Infectious Diseases: Principles, Pathogens and Practice. 2011:378. https://doi.org/10.1016/B978-0-7020-3935-5.00058-6 PMCid:PMC7149827

20. Haas LE, Thijsen SF, Van Elden L, Heemstra KA. Human metapneumovirus in adults. Viruses. 2013 Jan 8;5(1):87-110. https://doi.org/10.3390/v5010087 PMid:23299785 PMCid:PMC3564111

21. Esposito S, Mastrolia MV. Metapneumovirus infections and respiratory complications. InSeminars in respiratory and critical care medicine 2016; 37)4):512-521). Thieme Medical Publishers. https://doi.org/10.1055/s-0036-1584800 PMid:27486733 PMCid:PMC7171707

22. Rudd PA, Thomas BJ, Zaid A, MacDonald M, Kan-o K, Rolph MS, Soorneedi AR, Bardin PG, Mahalingam S. Role of human metapneumovirus and respiratory syncytial virus in asthma exacerbations: where are we now?. Clinical Science. 2017 Jun 30; 131(14):1713-1721. https://doi.org/10.1042/CS20160011 PMid:28667069

23. Ditt V, Lüsebrink J, Tillmann RL, Schildgen V, Schildgen O. Respiratory infections by HMPV and RSV are clinically indistinguishable but induce different host response in aged individuals. PloS one. 2011 Jan 26; 6(1):e16314. https://doi.org/10.1371/journal.pone.0016314 PMid:21298115 PMCid:PMC3027670

24. Alter SJ, Bennett JS, Koranyi K, Kreppel A, Simon R. Common childhood viral infections. Current problems in pediatric and adolescent health care. 2015 Feb 1; 45(2):21-53. https://doi.org/10.1016/j.cppeds.2014.12.001 PMid:25703483

25. Bhattacharya S, Agarwal S, Shrimali NM, Guchhait P. Interplay between hypoxia and inflammation contributes to the progression and severity of respiratory viral diseases. Molecular Aspects of Medicine. 2021 Oct 1; 81:101000. https://doi.org/10.1016/j.mam.2021.101000 PMid:34294412 PMCid:PMC8287505

26. Robinson CC. Respiratory viruses. Clinical virology manual. 2009 Jun 5:201-248. https://doi.org/10.1128/9781555815974.ch17 PMid:19419406 PMCid:PMC6932397

27. Clementi N, Ghosh S, De Santis M, Castelli M, Criscuolo E, Zanoni I, Clementi M, Mancini N. Viral respiratory pathogens and lung injury. Clinical microbiology reviews. 2021 Jun 16;34(3):10-128. https://doi.org/10.1128/CMR.00103-20 PMid:33789928 PMCid:PMC8142519

28. Veronese A, Ursic T, Bizjak Vojinovic S, Rodman Berlot J. Exploring Clinical Predictors of Severe Human Metapneumovirus Respiratory Tract Infections in Children: Insights from a Recent Outbreak. Microorganisms. 2024 Mar 23; 12(4):641. https://doi.org/10.3390/microorganisms12040641 PMid:38674586 PMCid:PMC11052206

29. Falsey AR, Erdman D, Anderson LJ, Walsh EE. Human metapneumovirus infections in young and elderly adults. The Journal of infectious diseases. 2003 Mar 1; 187(5):785-790. https://doi.org/10.1086/367901 PMid:12599052

30. Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome: advances in diagnosis and treatment. Jama. 2018 Feb 20; 319(7):698-710. https://doi.org/10.1001/jama.2017.21907 PMid:29466596

31. Piukovics K. Epidemiology of most frequent infectious complications in immunocompromised patients: focusing on bacteraemia, CMV and HHV-6 infections in haematological patients, and following autologous stem cell transplantation (Doctoral dissertation, Szegedi Tudomanyegyetem (Hungary)).

32. Ballegeer M, Saelens X. Cell-Mediated Responses to Human Metapneumovirus Infection. Viruses. 2020 May 14;12(5):542. https://doi.org/10.3390/v12050542 PMid:32423043 PMCid:PMC7290942

33. Van Den Hoogen BG, Osterhaus DM, Fouchier RA. Clinical impact and diagnosis of human metapneumovirus infection. The Pediatric infectious disease journal. 2004 Jan 1; 23(1):S25-S32. https://doi.org/10.1097/01.inf.0000108190.09824.e8 PMid:14730267

34. Wilkesmann A, Schildgen O, Eis-Hübinger AM, Geikowski T, Glatzel T, Lentze MJ, Bode U, Simon A. Human metapneumovirus infections cause similar symptoms and clinical severity as respiratory syncytial virus infections. European journal of pediatrics. 2006 Jul; 165:467-475. https://doi.org/10.1007/s00431-006-0105-4 PMid:16607540

35. Karimi Z, Chenari M, Rezaie F, Karimi S, Parhizgari N, Mokhtari-Azad T. Proposed pathway linking respiratory infections with depression. Clinical Psychopharmacology and Neuroscience. 2022 May 5;20(2):199. https://doi.org/10.9758/cpn.2022.20.2.199 PMid:35466092 PMCid:PMC9048006

36. Wilkesmann A, Schildgen O, Eis-Hübinger AM, Geikowski T, Glatzel T, Lentze MJ, Bode U, Simon A. Human metapneumovirus infections cause similar symptoms and clinical severity as respiratory syncytial virus infections. European journal of pediatrics. 2006 Jul; 165:467-475. https://doi.org/10.1007/s00431-006-0105-4 PMid:16607540

37. Kukavica-Ibrulj I, Hamelin ME, Prince GA, Gagnon C, Bergeron Y, Bergeron MG, Boivin G. Infection with human metapneumovirus predisposes mice to severe pneumococcal pneumonia. Journal of virology. 2009 Feb 1;83(3):1341-1349. https://doi.org/10.1128/JVI.01123-08 PMid:19019962 PMCid:PMC2620891

38. Maitre NL, Williams JV. Human metapneumovirus in the preterm neonate: current perspectives. Research and reports in neonatology. 2016 Jul 28:41-49. https://doi.org/10.2147/RRN.S76270 PMid:27891060 PMCid:PMC5120728

39. Jeong S, Park MJ, Song W, Kim HS. Advances in laboratory assays for detecting human metapneumovirus. Annals of Translational Medicine. 2020 May;8(9). https://doi.org/10.21037/atm.2019.12.42 PMid:32566634 PMCid:PMC7290561

40. You HL, Chang SJ, Yu HR, Li CC, Chen CH, Liao WT. Simultaneous detection of respiratory syncytial virus and human metapneumovirus by one-step multiplex real-time RT-PCR in patients with respiratory symptoms. BMC pediatrics. 2017 Dec; 17:1-7. https://doi.org/10.1186/s12887-017-0843-7 PMid:28347279 PMCid:PMC5368990

41. Boivin G, Mazzulli T, Petric M, Couillard M. Diagnosis of viral infections. Clinical virology. 2009 Feb 27:265-294. https://doi.org/10.1128/9781555815981.ch13

42. Stefanidis K, Konstantelou E, Yusuf GT, Oikonomou A, Tavernaraki K, Karakitsos D, Loukides S, Vlahos I. Radiological, epidemiological and clinical patterns of pulmonary viral infections. European Journal of Radiology. 2021 Mar 1;136:109548. https://doi.org/10.1016/j.ejrad.2021.109548 PMid:33485125 PMCid:PMC7808729

43. Jeong S, Park MJ, Song W, Kim HS. Advances in laboratory assays for detecting human metapneumovirus. Annals of Translational Medicine. 2020 May; 8(9). https://doi.org/10.21037/atm.2019.12.42 PMid:32566634 PMCid:PMC7290561

44. De Zwart A, Riezebos-Brilman A, Lunter G, Vonk J, Glanville AR, Gottlieb J, Permpalung N, Kerstjens H, Alffenaar JW, Verschuuren E. Respiratory syncytial virus, human metapneumovirus, and parainfluenza virus infections in lung transplant recipients: a systematic review of outcomes and treatment strategies. Clinical Infectious Diseases. 2022 Jun 15;74(12):2252-2260. https://doi.org/10.1093/cid/ciab969 PMid:35022697 PMCid:PMC9258934

45. Bosis S, Esposito S, Niesters HG, Crovari P, Osterhaus AD, Principi N. Impact of human metapneumovirus in childhood: comparison with respiratory syncytial virus and influenza viruses. Journal of medical virology. 2005 Jan; 75(1):101-104. https://doi.org/10.1002/jmv.20243 PMid:15543589

46. Abinash Satapathy, Neha Yadav, Trilochan Satapathy, Kalpana Sen, Shailesh Sahn, Ayushi Gupta, Bharti Pradhan, Shiv Kumar Bhardwaj. H9N2: A Mysterious Avian Influenza Virus: A Global Threat for Respiratory Pneumonia. Research journal of Pharmacology and Pharmacodynamics.Apr 2024;16(2):127-133. https://doi.org/10.52711/2321-5836.2024.00023

47. Ison MG. Antiviral treatments. Clinics in chest medicine. 2017 Mar 1;38(1):139-153. https://doi.org/10.1016/j.ccm.2016.11.008 PMid:28159156 PMCid:PMC7131036

48. Quizon A, A Colin A, Pelosi U, A Rossi G. Treatment of disorders characterized by reversible airway obstruction in childhood: are anti-cholinergic agents the answer?. Current pharmaceutical design. 2012 Jul 1;18(21):3061-3085. https://doi.org/10.2174/1381612811209023061 PMid:22564300

49. Kitanovski L, Kopriva S, Pokorn M, Dolnicar MB, Rajic V, Stefanovic M, Jazbec J. Treatment of severe human metapneumovirus (hMPV) pneumonia in an immunocompromised child with oral ribavirin and IVIG. Journal of pediatric hematology/oncology. 2013 Oct 1; 35(7):e311-e313. https://doi.org/10.1097/MPH.0b013e3182915d2d PMid:23669731

50. Boivin G, Caouette G, Frenette L, Carbonneau J, Ouakki M, De Serres G. Human respiratory syncytial virus and other viral infections in infants receiving palivizumab. Journal of clinical virology. 2008 May 1; 42(1):52-57. https://doi.org/10.1016/j.jcv.2007.11.012 PMid:18164233 PMCid:PMC7172843

51. Deval H, Kumar N, Srivastava M, Potdar V, Mehta A, Verma A, Singh R, Kavathekar A, Kant R, Murhekar M. Human metapneumovirus (hMPV): an associated etiology of severe acute respiratory infection in children of Eastern Uttar Pradesh, India. Access Microbiology. 2024 Sep; 6(9):000829-v4. https://doi.org/10.1099/acmi.0.000829.v4 PMid:39268186 PMCid:PMC11391948

52. Shafagati N, Williams J. Human metapneumovirus-what we know now. F1000Research. 2018; 7. https://doi.org/10.12688/f1000research.12625.1 PMid:29744035 PMCid:PMC5795268