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Post-Acute Sequelae and Long-Term Clinical Outcomes in Hantavirus Pulmonary Syndrome Survivors

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hantavirus pulmonary syndrome; hantavirus cardiopulmonary syndrome; post-acute sequelae; long-term clinical outcomes; survivors; quality of life.

Abstract
Hantavirus pulmonary syndrome (HPS), also known as hantavirus cardiopulmonary syndrome (HCPS), is a severe rodent-borne zoonotic disease that may progress to pulmonary edema, respiratory failure, shock, and death. Although acute mortality and intensive management have been widely discussed, evidence on post-acute sequelae among survivors remains limited. This systematic review aimed to synthesize post-acute sequelae and long-term clinical outcomes in HPS/HCPS survivors. Literature searches were conducted in PubMed, ScienceDirect, PubMed Central, and publisher websites using terms related to HPS/HCPS, survivors, post-acute sequelae, follow-up, and long-term outcomes. Eligible studies were primary human studies reporting clinical outcomes after the acute phase, while reviews, animal studies, acute-only studies, and articles without follow-up data were excluded. Study selection followed PRISMA guidelines, and methodological quality was assessed using observational study quality assessment tools. From 27 identified records, 3 primary studies met the inclusion criteria. Narrative synthesis showed that survivors may experience respiratory impairment, renal sequelae, neuropsychological symptoms, reduced quality of life, and limitations in daily activities. The most consistent outcome was convalescent respiratory impairment, including exertional dyspnea and pulmonary function abnormalities. Evidence also suggests possible renal involvement and persistent physical or neuropsychological symptoms after hospital discharge. Because only three studies were included, generalizability remains limited. Nevertheless, available findings support multidisciplinary post-discharge follow-up for HPS/HCPS survivors.

INTRODUCTION

Hantavirus pulmonary syndrome (HPS), which in several studies is also referred to as hantavirus cardiopulmonary syndrome (HCPS), is a severe zoonotic disease caused by hantavirus infection. Hantaviruses are rodent-borne viruses with a global distribution and may cause two main human syndromes: hemorrhagic fever with renal syndrome and HPS/HCPS (Avšič-Županc et al., 2019; Vial et al., 2023). Human infection generally occurs through inhalation of aerosols contaminated with the urine, feces, or saliva of infected rodents, especially when individuals clean enclosed spaces or areas with rodent infestation (Basiouni et al., 2025; Ceccarelli et al., 2026). Most hantaviruses are not transmitted between humans, although Andes virus transmission between close contacts has been described (Manigold & Vial, 2014).

Clinically, HPS/HCPS may progress from nonspecific early symptoms to severe respiratory disease. Initial symptoms may include fever, headache, myalgia, and gastrointestinal complaints such as nausea, vomiting, diarrhea, or abdominal pain. In the advanced phase, patients may develop cough, shortness of breath, pulmonary edema, hypoxia, hypotension, shock, and death. HPS primarily affects the lungs and may be fatal in a substantial

proportion of infected patients (Duchin et al., 1994; Centers for Disease Control and Prevention, 2024).

HPS/HCPS is an important health concern because, although its incidence is relatively low compared with other infectious diseases, its severity and fatality remain high. Globally, hantavirus disease is distributed according to the ecology of reservoir rodents and may appear as hemorrhagic fever with renal syndrome in Europe and Asia or as HPS/HCPS in the Americas. Epidemiological reviews estimate that hantavirus infections affect approximately 30,000 people annually worldwide, while HPS/HCPS represents a smaller but more severe proportion of reported cases (Watson et al., 2014; Jonsson et al., 2010). In the United States, 890 laboratory-confirmed hantavirus disease cases were reported from the beginning of surveillance in 1993 through the end of 2023, including 859 HPS cases (Centers for Disease Control and Prevention, 2026). In the Americas, HCPS may reach a case fatality rate of up to 50%, and the Andes virus remains notable because limited person-to-person transmission has been documented (World Health Organization, 2026; Martínez et al., 2005; Martínez et al., 2020). These data emphasize that HPS/HCPS is a low-incidence but high-impact zoonotic disease with clear public health relevance, particularly in endemic areas and settings where environmental change may increase human-rodent contact (Klempa, 2009; Douglas et al., 2022).

Most studies and clinical discussions regarding HPS/HCPS have focused on the acute phase, mortality, diagnosis, and supportive management in intensive care settings. There is currently no specific therapy that can cure hantavirus disease; therefore, early supportive care, close clinical monitoring, and management of respiratory, cardiac, and renal complications remain the main components for improving patient survival (World Health Organization, 2026; Brocato & Hooper, 2019). Previous trials have not established a clearly effective antiviral treatment for HCPS in the cardiopulmonary stage, while advances in intensive care, early recognition, and extracorporeal membrane oxygenation (ECMO) have contributed to improved survival in selected severe cases (Mertz et al., 2004; Wernly et al., 2011; Ulloa-Morrison et al., 2024). However, data regarding recovery after survival from the acute phase remain limited.

Several studies have shown that HPS/HCPS survivors may experience symptoms and clinical impairments after the acute phase. Gracia et al. investigated persistent respiratory symptoms and pulmonary function abnormalities among adult HPS survivors in Panama and the United States. The study demonstrated that respiratory outcomes during the convalescent period should be considered, as HPS survivors may experience pulmonary function impairment after recovery from the acute phase.

Post-acute sequelae in HPS/HCPS are not limited to the respiratory system. Pergam et al. evaluated the possibility of renal sequelae among HCPS survivors and showed that the long-term impact of this disease may involve the renal system. Therefore, follow-up of survivors should not focus solely on respiratory outcomes. Hopkins et al. also reported neuropsychological impairment in two HPS survivors, with cognitive dysfunction persisting up to one year after recovery, particularly memory impairment resembling conditions following cerebral anoxia.

A recent study by Valenzuela et al. further highlighted the importance of evaluating long-term outcomes among HCPS survivors. This multicenter cohort study in Chile involved 21 HCPS survivors with follow-up conducted 3–6 months after symptom onset. A total of 61.9%

of survivors reported incomplete recovery. The study also demonstrated a burden of physical and neuropsychological symptoms, impaired quality of life based on the EQ-5D instrument, and the need for multidisciplinary post-discharge care.

The limited availability of literature remains a major challenge in understanding post-acute sequelae and long-term clinical outcomes among HPS/HCPS survivors. The number of available studies is still small, sample sizes are relatively limited, follow-up durations vary, and the clinical outcomes assessed are not uniform. Some studies evaluate pulmonary function, while others assess renal function, neuropsychological impairment, persistent symptoms, or quality of life. These differences make it difficult to establish a comprehensive understanding of the long-term burden of HPS/HCPS.

This study aims to systematically review post-acute sequelae and long-term clinical outcomes among survivors of hantavirus pulmonary syndrome. The findings of this study are expected to provide a scientific overview of the spectrum of post-acute impairments among HPS/HCPS survivors, identify the most frequently reported clinical outcomes, and serve as a basis for developing follow-up strategies and multidisciplinary care after patients have passed the acute phase

METHOD

Study Identification

This study was a systematic literature review conducted to examine post-acute sequelae and long-term clinical outcomes among survivors of hantavirus pulmonary syndrome (HPS). In several studies, HPS is also referred to as hantavirus cardiopulmonary syndrome (HCPS); therefore, both terms were used in the search strategy to broaden the scope of relevant articles. The literature search was conducted using international journal databases, including PubMed, ScienceDirect, PubMed Central, and manual searches of publisher websites. PubMed was used because it contains biomedical literature citations from MEDLINE, life science journals, and online books, while PubMed Central was used to identify openly available full-text biomedical articles.

The literature search was conducted to identify scientific articles related to persistent symptoms, post-acute sequelae, and long-term clinical outcomes among HPS/HCPS survivors. The keywords used in PubMed and PubMed Central included “hantavirus pulmonary syndrome,” “hantavirus cardiopulmonary syndrome,” “survivors,” “post-acute sequelae,” “long-term outcomes,” “follow-up,” “quality of life,” “pulmonary dysfunction,” “renal sequelae,” “neuropsychological impairment,” and “persistent symptoms.”

In international databases, the search was performed using the following keyword combination: (“hantavirus pulmonary syndrome” OR “hantavirus cardiopulmonary syndrome” OR HPS OR HCPS) AND (“survivors” OR “convalescent” OR “follow-up”) AND (“post-acute sequelae” OR “long-term outcomes” OR “persistent symptoms” OR “quality of life” OR “pulmonary dysfunction” OR “renal sequelae” OR “neuropsychological impairment”). These keywords were selected to obtain articles that specifically discussed clinical outcomes after the acute phase among HPS/HCPS survivors.

Manual searching was conducted by reviewing the reference lists of relevant articles and searching publisher websites directly to identify studies that were not found through the main database search. All retrieved articles were then selected based on their titles, abstracts, and

full texts according to the predetermined inclusion and exclusion criteria. The article search, selection, and reporting process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which were used to improve the completeness of reporting in this systematic review.

Study Selection

The inclusion criteria applied in this study were original research articles written in English or Indonesian, studies conducted in humans with a history of HPS or HCPS, studies with clearly described research methods, and studies reporting clinical outcomes after the acute phase. The outcomes of interest included persistent symptoms, pulmonary dysfunction, renal sequelae, neuropsychological impairment, impaired quality of life, limitations in daily activities, ability to return to work or school, rehabilitation needs, or other clinical outcomes assessed after patients had passed the acute phase of HPS/HCPS.

Studies were excluded if they focused only on the acute phase of HPS/HCPS, acute mortality, acute diagnosis, intensive therapy without follow-up data, animal or rodent studies, virological studies without patient clinical outcomes, or articles in the form of reviews, systematic reviews, meta-analyses, editorials, comments, letters to the editor, and conference abstracts. Articles were also excluded if the study subjects were not patients with HPS/HCPS, such as studies that only discussed hemorrhagic fever with renal syndrome (HFRS), nephropathia epidemica, or hantavirus infection without pulmonary or cardiopulmonary manifestations relevant to the focus of this study.

All article titles and abstracts were systematically assessed by the researcher based on the inclusion and exclusion criteria. Articles considered relevant were then continued to the full-text review stage. At this stage, the researcher assessed the suitability of the population, study design, follow-up duration, reported clinical outcomes, and relevance of the article to the study objectives. Articles that met all criteria were included in the final synthesis, while articles that did not meet the criteria were excluded from the main analysis.

Based on the selection process, a total of 27 scientific articles were obtained from PubMed (n = 12), ScienceDirect (n = 9), and manual searches of PubMed Central and publisher websites (n = 6). After the removal of 5 duplicate articles, 22 articles underwent title and abstract screening. Twelve articles were excluded because they were not relevant to the study focus, leaving 10 articles for full-text screening. After full-text review, 3 primary research articles met the inclusion criteria and were analyzed in this systematic literature review.

Study Quality Assessment

The methodological quality of the included studies was assessed according to each study design. Observational studies were assessed using the Study Quality Assessment Tools for observational studies. Each assessment item was given a score of 1 if the criterion was fulfilled and 0 if it was not fulfilled. The total score was then classified as good if >11, moderate if 8–11, and poor if <8. Articles with good and moderate quality were considered for inclusion in the final synthesis, while articles with poor quality could be excluded from the main analysis to maintain the reliability of the review findings.

Quality assessment was conducted systematically for all articles that passed the full-text selection stage. The assessed aspects included clarity of study objectives, clarity of the study population, inclusion and exclusion criteria, adequacy of follow-up duration, outcome measurement methods, clarity of result reporting, and control of confounding factors when

available. In the context of HPS/HCPS, the quality assessment also considered the consistency between acute disease history, survivor status, timing of evaluation after the acute phase, and the type of long-term outcomes reported.

The main articles used as the basis for synthesis included studies on convalescent pulmonary dysfunction among HPS survivors, renal sequelae among HCPS survivors, and symptom burden and impaired quality of life among HCPS survivors. Gracia et al. investigated persistent respiratory symptoms and pulmonary function abnormalities among HPS survivors. Pergam et al. evaluated potential renal sequelae among HCPS survivors through prospective evaluation, laboratory testing, and 24-hour urine collection. Valenzuela et al. assessed long-term symptom burden and quality of life among HCPS survivors.

Data Analysis

The reporting method and article screening process were conducted in stages according to the PRISMA guidelines. Studies that met the inclusion criteria were then extracted and analyzed descriptively to identify post-acute sequelae and long-term clinical outcomes among HPS/HCPS survivors. Narrative synthesis was selected because the number of studies meeting the inclusion criteria was limited, sample sizes were small, study designs varied, follow-up durations were not uniform, and the clinical outcomes assessed differed across studies.

Data obtained from each study were presented in an extraction table to facilitate the synthesis process. The extracted information included author and year of publication, study design, study location, sample size, type of hantavirus or HPS/HCPS diagnosis, subject characteristics, follow-up duration, type of post-acute outcomes assessed, outcome measurement methods, and main findings. The outcomes recorded included respiratory impairment, exertional dyspnea, pulmonary function abnormalities, renal sequelae, neuropsychological impairment, persistent symptoms, quality of life, activity limitations, and ability to return to work or school.

The study findings were then analyzed to identify the most commonly reported patterns of post-acute sequelae among HPS/HCPS survivors. Clinical outcomes were grouped based on organ systems and functional aspects, including respiratory outcomes, renal outcomes, neuropsychological outcomes, quality of life, and daily activities. The findings of each study were compared narratively to identify similarities and differences across studies. Due to the high heterogeneity of the articles and the limited number of primary studies, a meta-analysis was not performed.

The extracted data were synthesized narratively by emphasizing the types of sequelae reported, the duration of symptoms after the acute phase, and the clinical implications for post-discharge follow-up. The synthesis findings were grouped into several sections, including study characteristics, respiratory outcomes, renal outcomes, neuropsychological outcomes, quality of life, and limitations of the literature. This approach was used to provide a more comprehensive overview of the long-term burden of HPS/HCPS among patients who survived the acute phase.

RESULTS AND DISCUSSION

Scientific Article Selection

The literature search identified 27 scientific articles from PubMed, ScienceDirect, PubMed Central, and manual searches of publisher websites based on the predetermined search

keywords. The search results consisted of PubMed (n = 12), ScienceDirect (n = 9), and manual searches of PubMed Central and publisher websites (n = 6). After removing 5 duplicate articles, 22 articles proceeded to title and abstract screening.

The initial screening excluded 12 articles because they were not relevant to the focus of this study. Articles excluded at this stage generally discussed only the acute phase of HPS/HCPS, acute mortality, diagnosis, intensive therapy without follow-up data, virological studies, animal or rodent studies, or articles that did not report post-acute clinical outcomes among survivors. A total of 10 articles were then continued to full-text screening for more comprehensive assessment. After full-text review, 3 primary research articles met the inclusion criteria and were analyzed in this systematic literature review.

The article selection process based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines is presented in Figure 1. The methodological quality assessment results of all articles that met the inclusion criteria are presented in Table 1. A case report on neuropsychological impairment after HPS was not included as a primary article because of its case report design; however, it was used as supporting literature in the discussion because it reported persistent cognitive impairment up to one year after recovery from HPS.

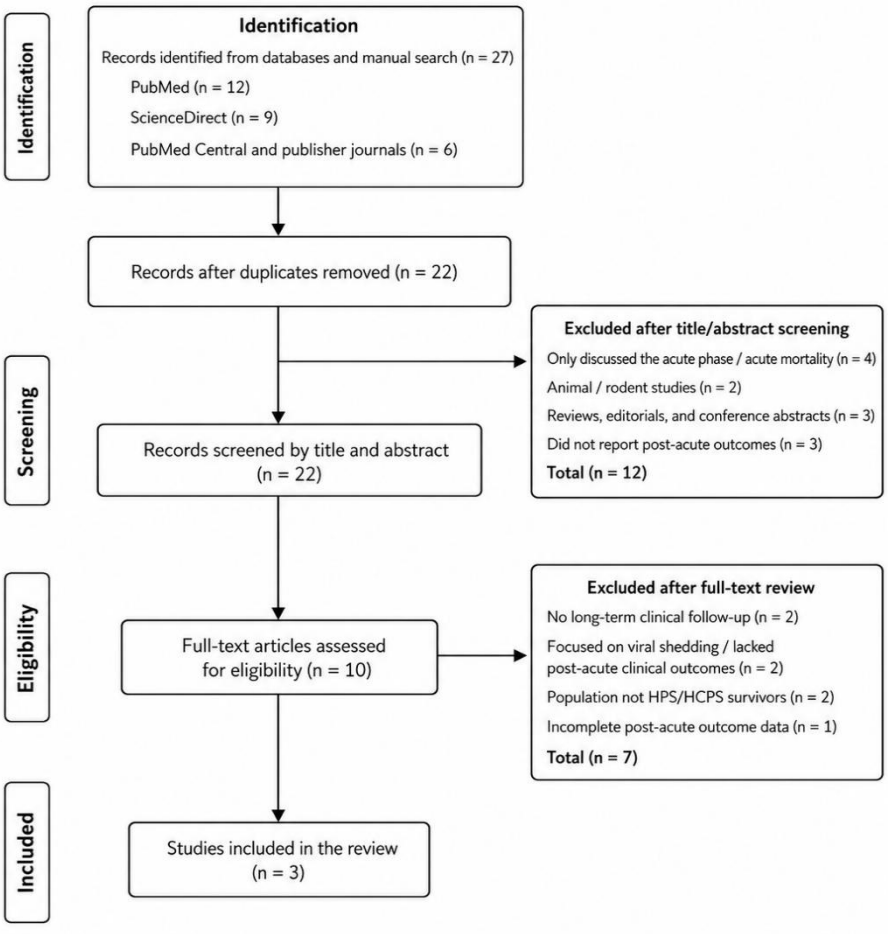

Figure 1. PRISMA Flow Diagram of Article Selection

Study Characteristics

The studies that met the inclusion criteria consisted of observational and cohort studies assessing clinical outcomes after the acute phase among survivors of hantavirus pulmonary syndrome (HPS) or hantavirus cardiopulmonary syndrome (HCPS). In general, the analyzed studies did not focus on acute mortality, but rather on the condition of survivors after passing the critical phase, including persistent symptoms, pulmonary function, renal function, quality of life, daily activity impairment, and the need for further care.

The study conducted by Gracia et al. assessed pulmonary dysfunction during the convalescent period after HPS in Panama and the United States. This study involved 14 HPS survivors caused by Choclo virus in Panama and 9 HPS survivors caused by Sin Nombre virus in New Mexico. Evaluation was conducted using a respiratory symptom questionnaire and pulmonary function testing up to 8 years after acute infection. The study reported that exertional dyspnea persisted for 1–2 years after acute infection in 43% of survivors in Panama and 77% of survivors in New Mexico. Reported pulmonary function abnormalities included reduced midexpiratory flow, increased residual volume, and decreased pulmonary diffusion capacity.

The study conducted by Pergam et al. assessed the possibility of renal sequelae among HCPS survivors. This was a prospective study involving 30 HCPS survivors who were periodically evaluated through clinical examinations, laboratory tests, and 24-hour urine collection. The main outcomes assessed were proteinuria and decreased creatinine clearance. The results showed that 18 of 30 survivors underwent more than one evaluation, and some survivors showed proteinuria during follow-up.

The most recent study by Valenzuela et al. assessed long-term symptom burden and quality-of-life impairment among survivors of Andes virus-associated HCPS in Chile. This study involved 21 HCPS survivors, consisting of 11 patients who required extracorporeal membrane oxygenation (ECMO) and 10 non-ECMO patients. Evaluation was conducted 3–6 months after symptom onset using self-reported recovery assessment, symptom questionnaires, and the EQ-5D quality-of-life instrument. A total of 13 of 21 survivors, or 61.9%, reported incomplete recovery, and all participants reported at least one persistent symptom at follow-up.

In general, the study populations consisted of patients who had passed the acute phase of HPS/HCPS and survived after treatment. The reported subject characteristics included sample size, age, sex, type of hantavirus, severity of acute disease, need for mechanical ventilation or ECMO, and duration of follow-up after acute infection. Variations in these characteristics may influence the long-term clinical outcomes reported in each study.

The main outcomes evaluated in the included studies varied according to the focus of each study. Gracia et al. focused on respiratory outcomes, particularly exertional dyspnea and pulmonary function test results. Pergam et al. focused on renal outcomes, particularly proteinuria and changes in renal function. Valenzuela et al. focused on persistent symptom burden, quality of life, daily activity impairment, and social and functional reintegration after HCPS. These differences indicate that the long-term impact of HPS/HCPS is multisystemic and not limited to pulmonary impairment.

The follow-up duration also varied across the included articles. Gracia et al. conducted evaluations up to several years after acute infection, Pergam et al. performed annual follow-up

evaluations, while Valenzuela et al. conducted evaluations 3–6 months after symptom onset. Differences in follow-up duration are one source of variation in the interpretation of findings across studies. In addition, outcome measurement methods also differed, ranging from symptom questionnaires, pulmonary function testing, laboratory tests and 24-hour urine collection, to the EQ-5D quality-of-life instrument. Therefore, the findings were synthesized narratively and were not continued to quantitative meta-analysis.

No	Author (Year)	Study Design	Location	Sample Size	Type of Hantavirus / Diagnosis	Follow-up Duration	Main Outcome	Main Findings
1	Gracia et al. (2010)	Descriptive observational study among HPS survivors	Panama and United States	23 HPS survivors	Choclo virus in Panama and Sin Nombre virus in New Mexico	Up to 8 years after acute infection	Persistent respiratory symptoms and pulmonary function	Exertional dyspnea may persist for 1–2 years after acute infection. Pulmonary function abnormalities included reduced midexpiratory flow, increased residual volume, and decreased pulmonary diffusion capacity.
2	Pergam et al. (2009)	Prospective observational study	United States	30 HCPS survivors	HCPS after recovery from the acute phase	First follow-up at a median of 7.4 months after hospital discharge, followed by annual evaluations	Renal sequelae, proteinuria, and renal function	Some survivors showed proteinuria during follow-up. This finding suggests that the post-acute impact of HCPS may involve the renal system.
3	Valenzuela et al. (2025)	Multicenter observational follow-up study	Chile	21 HCPS survivors	Andes virus-associated HCPS	3–6 months after symptom onset	Persistent symptoms, quality of life, activity function, and rehabilitation needs	A total of 61.9% of survivors reported incomplete recovery. All participants reported at least one persistent symptom, with physical and neuropsychological complaints found in both ECMO and non-ECMO groups.

Note: HPS = hantavirus pulmonary syndrome; HCPS = hantavirus cardiopulmonary syndrome; ECMO = extracorporeal membrane oxygenation; EQ-5D = EuroQol-5 Dimensions.

This review shows that post-acute sequelae and long-term clinical outcomes among survivors of hantavirus pulmonary syndrome (HPS) or hantavirus cardiopulmonary syndrome (HCPS) may involve various clinical aspects, particularly respiratory function, renal function, neuropsychological symptoms, quality of life, and the ability to perform daily activities. Although the number of articles meeting the inclusion criteria remains limited, the emerging pattern of findings indicates that the success of HPS/HCPS management should not be assessed solely based on patient survival during the acute phase. Survivors may continue to experience persistent symptoms after passing the critical phase; therefore, post-discharge monitoring is an important component of care for patients with HPS/HCPS. The study by Gracia et al. demonstrated persistent respiratory symptoms and pulmonary function abnormalities among adult HPS survivors, while Pergam et al. showed the possibility of renal sequelae among HCPS survivors.

Respiratory outcomes were the most consistently reported findings in the analyzed studies. Gracia et al. evaluated HPS survivors in Panama and the United States to document persistent respiratory symptoms and pulmonary function abnormalities after the acute phase. Their findings indicated that HPS/HCPS may result in convalescent respiratory impairment, such as exertional dyspnea and changes in pulmonary function parameters. This condition may be related to the acute disease process of HPS/HCPS, which is characterized by increased pulmonary capillary permeability, pulmonary edema, hypoxia, and impaired gas exchange. Therefore, even after patients have survived the acute phase, recovery of pulmonary function may take a longer period and require further clinical evaluation.

In addition to the respiratory system, renal sequelae are also an important aspect that should be considered. Pergam et al. evaluated potential renal sequelae among HCPS survivors and concluded that renal sequelae may occur after HCPS infection. This finding is important because HPS/HCPS is often understood as a disease that predominantly affects the pulmonary and cardiovascular systems, although its systemic impact may also involve the kidneys. Therefore, renal function testing, urinalysis, or proteinuria monitoring may be considered among HPS/HCPS survivors, particularly in patients with severe acute manifestations or abnormal findings during hospitalization.

Neuropsychological symptoms also emerged as long-term outcomes requiring attention. Hopkins et al. reported that two HPS survivors experienced cognitive impairment immediately after acute hospitalization and continued to show cognitive dysfunction at one-year follow-up after recovery. The reported impairment resembled conditions following cerebral anoxia, particularly memory impairment. Although this study was not included as a primary article because of its case report design, its findings remain relevant as supporting literature because they indicate the possibility of long-term neurocognitive effects after HPS.

A recent study by Valenzuela et al. expanded the understanding of long-term symptom burden among HCPS survivors. The study assessed HCPS survivors with and without the need for extracorporeal membrane oxygenation (ECMO) and found that the most frequently reported symptoms at three months included fatigue, motor impairment, hair loss, insomnia, anxiety, dyspnea, memory impairment, sensory disturbances, and nightmares. These findings indicate that the post-acute burden of HCPS is multidimensional, involving physical, respiratory, neurological, psychological, and quality-of-life-related symptoms.

The findings of Valenzuela et al. also showed that long-term sequelae did not occur only among patients who required ECMO. Persistent symptoms were reported in both ECMO and non-ECMO groups, although several complaints, such as motor impairment and palpitations, were more commonly found in the ECMO group. This suggests that the severity of the acute phase may influence symptom burden after recovery; however, patients who did not receive ECMO may still experience persistent symptoms. Post-discharge monitoring should therefore not be limited only to patients with the most severe acute disease, but should also be provided to all HCPS survivors who experience symptoms after hospital discharge.

Clinically, the findings of this review indicate that HPS/HCPS survivors require a broader follow-up approach that is not limited to respiratory evaluation. Follow-up assessments may include evaluation of pulmonary function, renal function, neuropsychological symptoms, sleep quality, anxiety, activity capacity, and quality of life. A multidisciplinary approach may involve infectious disease specialists, pulmonologists, nephrologists, physical medicine and rehabilitation specialists, psychologists or psychiatrists, and primary care services for long-term monitoring. This approach is important because post-acute symptoms may affect the patient's ability to return to work, school, or daily activities.

From a methodological perspective, the interpretation of this review should be approached with caution. The number of primary studies meeting the inclusion criteria was limited, consisting of only three main research articles. In addition, study design, study location, sample size, type of hantavirus, follow-up duration, and assessed clinical outcomes differed across studies. Gracia et al. focused on pulmonary function, Pergam et al. focused on renal outcomes, while Valenzuela et al. focused on symptom burden and quality of life. These differences make the findings difficult to compare directly across studies and explain why quantitative meta-analysis was not appropriate for this review.

Another limitation is the lack of a standardized definition of post-acute sequelae in HPS/HCPS. Follow-up duration varied from several months to several years after acute infection. The instruments used also differed, ranging from symptom questionnaires, pulmonary function testing, laboratory tests, 24-hour urine collection, to quality-of-life instruments. These differences make the overall description of the long-term burden of HPS/HCPS less uniform. Therefore, the findings of this review should be understood as an initial overview of the pattern of post-acute sequelae rather than a definitive conclusion regarding the prevalence of each outcome.

Despite these limitations, this review provides important evidence that HPS/HCPS may leave long-term effects among survivors. Respiratory outcomes were the most consistent findings; however, the available evidence also suggests the possibility of renal sequelae, neuropsychological impairment, persistent symptoms, and decreased quality of life. These findings support the need for further research using prospective designs, larger sample sizes, longer follow-up durations, and standardized assessment instruments. Such studies are needed to clarify the long-term burden of HPS/HCPS and to help develop more targeted follow-up recommendations for survivors.

Overall, post-acute sequelae and long-term clinical outcomes among HPS/HCPS survivors remain underexplored but have important clinical implications. HPS/HCPS should not only be viewed as an acute disease with a high risk of mortality, but also as a disease that may cause multisystem effects after survival. Post-discharge monitoring, rehabilitation, and

quality-of-life assessment should be considered as part of the management of HPS/HCPS survivors.

CONCLUSION

Post-acute sequelae and long-term clinical outcomes among survivors of hantavirus pulmonary syndrome (HPS) or hantavirus cardiopulmonary syndrome (HCPS) indicate that clinical effects may persist after patients have passed the acute phase. The findings of this review show that HPS/HCPS survivors may experience convalescent respiratory impairment, renal sequelae, neuropsychological symptoms, decreased quality of life, and limitations in daily activities. The most consistently reported outcome was respiratory impairment, particularly exertional dyspnea and pulmonary function abnormalities after the acute phase.

The number of studies discussing post-acute sequelae and long-term outcomes among HPS/HCPS survivors remains limited, with small sample sizes, variable follow-up durations, and differences in the clinical outcomes assessed. Therefore, narrative synthesis was more appropriate than quantitative meta-analysis. Nevertheless, the available evidence suggests that HPS/HCPS should not only be viewed as an acute disease with a high risk of mortality, but also as a disease that may cause multisystem effects after survival.

Post-discharge monitoring among HPS/HCPS survivors should consider the evaluation of pulmonary function, renal function, neuropsychological symptoms, quality of life, and the patient's ability to return to daily activities. Further studies with prospective designs, larger sample sizes, longer follow-up durations, and standardized assessment instruments are needed to clarify the long-term burden of HPS/HCPS and to support the development of multidisciplinary follow-up strategies for survivors.

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