Physical Education, Health and Social Sciences

https://journal-of-social-education.org

E-ISSN: 2958-5996
P-ISSN: 2958-5988

A Review of Neurological Symptoms and Complication of Covid 19

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DOI: https://doi.org/10.63163/jpehss.v3i2.250

Abstract

The first case was identified in December 2019, the Human coronavirus disease 2019 (HCOV-19), caused by the severe acute respiratory syndrome coronavirus 2, spread quickly, resulting in a global pandemic. As of early 2025, the virus infected over 200 countries, with over 3.5 million cases and an estimated 165,000 to 243,000 fatalities. Largely characterized by respiratory and cardiovascular complications, recent studies highlight the wide-ranging effect of the virus on the nervous system. The neurological presentations range from mild manifestations, such as headache (in about 10–20% of patients), dizziness, and hyposmia—the most frequent peripheral nervous system symptom—to severe complications, such as encephalopathy, acute cerebrovascular disease (e.g., ischemic stroke and intracerebral hemorrhage), Guillain-Barré syndrome, and sporadic cases of acute transverse myelitis or encephalitis. Importantly, neurological deficits may occur prior to the onset of characteristic respiratory symptoms (such as fever and cough) in 20–30% of cases, making early diagnosis challenging and allowing for transmission risks in the healthcare setting.

Pathophysiologic mechanisms remain to be explored but are likely to include direct viral neuroinvasion through angiotensin-converting enzyme 2 receptors, cytokine storm induction due to systemic inflammation, and hypercoagulability with subsequent thrombotic events. Delirium and encephalopathy are more common in critically ill patients and may be due to hypoxia or multiorgan failure. Chronic neurological sequelae like cognitive impairment and postexertional fatigue are increasingly observed in "long COVID" patients, and this suggests that monitoring in the long term may be necessary.

This review consolidates current situation of the neurological spectrum of HCOV-19 and the need for early detection and multidisciplinary management. Frontline doctors and neurologists need to remain in increased suspicion of SARS-CoV-2 infection in patients with acute neurological syndromes, regardless of respiratory symptoms, to facilitate early isolation and treatment. Research is necessary to unravel the neurotropic capacity of the virus, maximize therapeutic intervention, and prevent long-term disability burden.

Key words: HCoV-19; neurological symptoms; CNS; PNS; GBS; Encephalitis.

Introduction

The fast-spreading Human coronavirus disease 2019 pandemic is caused from coronaviridae (1). Various studies have confirmed neurological complications of HCOV-19-infected patients including seizures, strokes, and decreased consciousness; such presentations seem to be occurring more frequently among patients who have experienced a more severe illness course (2). Other presentations which HCOV-19-infected patients can present with include fever, colds, sore throat, diarrhea, and other respiratory conditions. Nevertheless, the emerging evidence does appear to suggest that viral infection can trigger atypical presentations such as headaches, dizziness, seizures, strokes, anosmia, and changes of consciousness. Unlike the

requirement for a direct invasion of the central nervous system or peripheral nervous system, such presentations could be triggered by an intense systemic response to an infection by a virus outside the neurologic structure. There has been evidence suggesting SARS-CoV-2 in a position to infect directly nervous system structures, as testified by recent reports of peripheral nerve involvement, myelitis, encephalitis, and meningitis in relation to HCOV-19. However, no published systematic review seems to have made the distinction (3).

The SARS-CoV-2 has spike protein can be bound by the host cellular ACE 2 receptor, which plays a role in cell tropism (4). It has been shown that transmembrane protease serine 2 has to prime and process the S protein for host & viral cellular membranes to fuse and for entry of SARS-CoV-2. Based on current research, ACE-2 receptor is found in neurons and glial cells of different regions of the brain (5). Though no systematic and experimental investigations on SARS-CoV-2 neurotropism have been carried out, some of the mechanisms under discussion as possible entry channels for the virus to reach the brain include axonal transport and trans-synaptic transmission (6), the transcribial pathway and the hematogenous and/or lymphatic pathway (7).

The transcribial pathway of CNS invasion is marked by an initial infection of the olfactory epithelium, followed subsequently by extension to the subarachnoid space via the cribriform plate. Furthermore, axonal transport and trans-synaptic spread cases involve infection of other PN terminals and extension along the neurons. (8). In keeping with a third hypothesis, it is suggested that SARS-CoV-2 infects the organism via the lymphatic or circulatory systems, then disseminates to the CNS (9). Crossing the brain endothelial barrier can be done through either endocytosis by virally infected leukocytes or disruption of the tight junctions of brain microvascular endothelial cells or alternatively through direct infection of BMECs resulting in abluminal release of the virus into the CNS parenchyma (10). Any of these pathways is potentially capable of causing neurological disorders by directly injuring the nervous system.

Interestingly, all neurological symptoms or diseases do not result from direct infection of nervous system structures or cells. Indirect neurotoxicity is evoked by immunomodulated pathogenesis (11), coagulation disorder, cardiovascular comorbidities like hypertension or diabetes, disrupted glucose and lipid metabolism, lung-brain cross talk disturbances like hypoxic encephalopathy, or an imbalanced gut-brain axis through gut flora disturbances during GIT SARS-CoV-2 virulence (12). 36.4% of patients from Wuhan, China, experienced symptoms associated with the central nervous system, 8.9% with the PNS, and 10.7% with skeletal muscle symptoms. A previous study on the CNS symptoms of HCOV-19 comprised six studies with unique data. To slow down the global pandemic and fill in knowledge gaps, it is required to combine the most recent and evolving research on the neurological involvement in HCOV-19 virulency (13).

This study consolidates existing literature on neurological presentation and prognosis in HCOV-19 patients and classes the findings into two broad categories: common neurological symptoms and unusual neurological complications. In addition, this review highlights the neurological symptoms, comorbidities, laboratory reports, and their results among HCOV-19-infected patients, respectively. (14).

FREQUENT NEUROLOGICAL MANIFESTATIONS OF HUMAN CORONAVIRUS-19:

The most important neurological presentations in Human Coronavirus-19 (HCOV-19) patients were headache, dizziness, taste and smell disturbances, and alterations in consciousness. They occurred in over five of the included studies and were noted in over 4% of the total studied populations. (15). The nervous disorders and effects of HCOV-19 can be categorized into two categories, as indicated in the table below.

Table 1: Manifestation and complication in Covid-19 patients

Site	Manifestation and complication
PNS	Hypogeusia
	Neuralgia
	Hyposmia
	Skeletal muscle rupture
	Guillian Barre syndrome
CNS	Ataxia
	Encephalitis
	Cerebrovascular dysfunction
	Impaired Mental activity
	Transverse myelitis
	AHNE
	Encephalopathy
	Headache
	Epilepsy
	Dizziness

CNS INVASION MECHANISM

Since HCOV-19 is believed mutated, despite the lack of experimental proof (16). The respiratory epithelium is the main target of coronaviruses, which are not predominantly neurotropic viruses. The virus RNA enters the cell and is released into the cytoplasm, where it undergoes translation and replication. The virus enters the bloodstream once the envelope protein is created and the RNA is integrated into it (17).

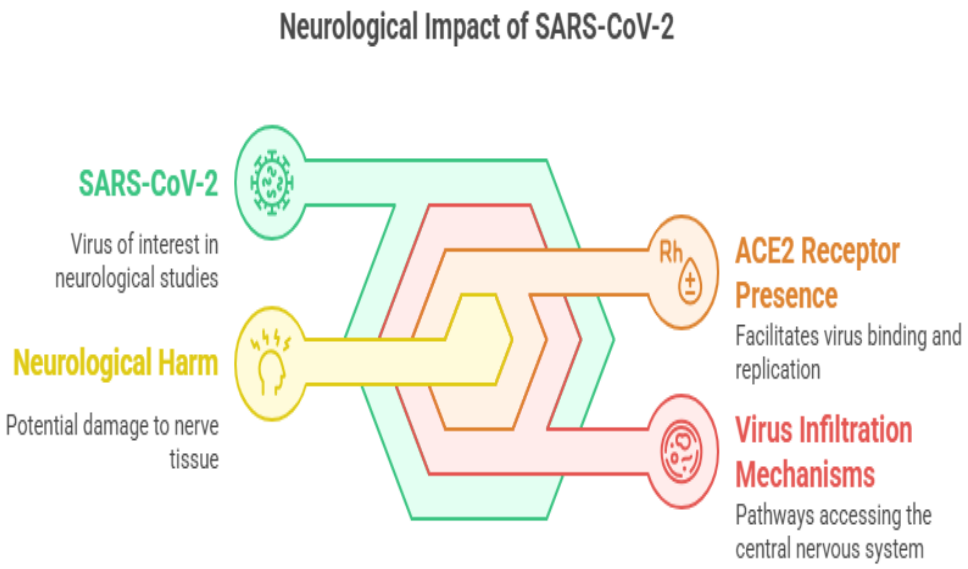


Figure 1: Neurological Impact of SARS-CoV-2

The virus can bind, replicate, and harm the nerve tissue since brain glial cells and spinal neurons contain ACE 2 receptors. Experiments on mice indicate that the coronavirus enters the nervous system via the cribriforms bone and enters the brain within 7 days. When the blood-brain barrier is broken during the disease, the virus enters the brain directly as well. Another hypothesis is that CoV enters the central nervous system through a synapse-related route following infection of peripheral nerve terminals. Since it is SARS Cov-related, we can conclude that HCOV-19 also enters the central nervous system through the above-mentioned routes. The comprehensive study of the virus and host relationship has been discussed elsewhere and is not the subject of this article. (18).

CNS INJURY CAUSED BY A NEUROPATHOLOGICAL PROCESS:

The two primary mechanisms by which HCOV-19 damages the nervous system are hypoxic brain injury and immune-mediated CNS damage.

A. Brain Injury caused by hypoxia

Systemic hypoxia due to acute pneumonia may lead to brain damage. Peripheral vasodilation, anaerobic metabolism and buildup of toxic substances, hypoxia, and hypercarbia are involved factors. These lead to swelling of neurons and cerebral edema and damage the nervous system. (19).

B. Immune-mediated damage

Cytokine storms, i.e., excess IC and activated of T cells, macrophages, and endothelial cells, are an immediate mechanism of immune-mediated consequences. Moreover, the additional secretion of Interleukin 6 results in end organ damage, disseminated intravascular coagulation, activation of the complement and coagulation cascades, and change in vascular permeability. (20).

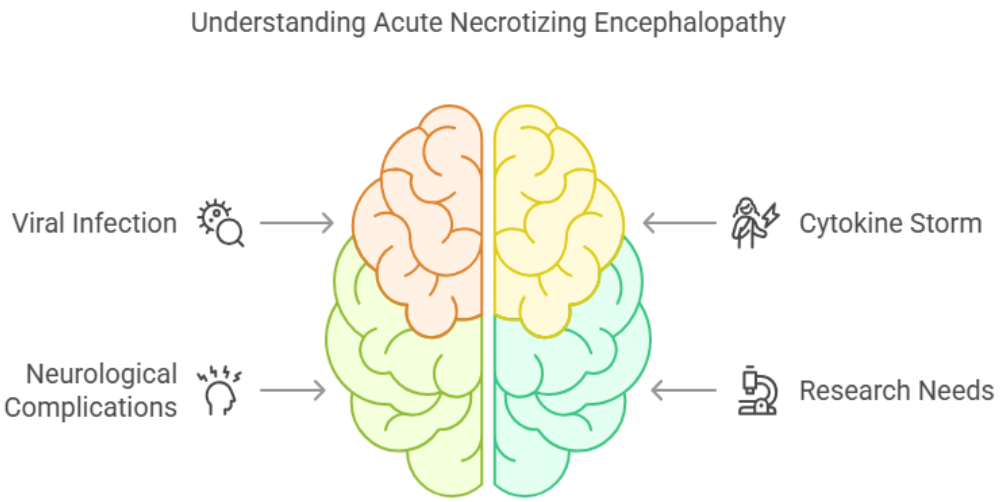
SYMPTOMS OF THE CENTRAL NERVOUS SYSTEM:

1. Encephalopathy

Though the diagnostic criteria and information were not provided, it was discovered that 40% of Mao et al.'s population presented with encephalopathy and headache (21). A 74years old male patient in the recent past admitted with fever and cough. He was discharged home after an initial diagnostic workup, which was unremarkable for any notable health issues. He returned with progressive symptoms of headache, fever, cough, and deterioration of cognition. A chest X-ray showed pneumonia; however, brain CT scan was normal except for evidence of a previous stroke. Cerebrospinal fluid polymerase chain reaction examination was negative for infection. He was discovered to be HCOV-19 positive and needed intubation for respiratory failure. The patient was treated with lopinavir/ritonavir and hydroxychloroquine, followed by broad-spectrum antibiotics (21).

2. Acute hemorrhagic necrotizing encephalopathy

The first reported US case of COVID-19-associated acute hemorrhagic necrotizing encephalopathy (AHNE) was a woman in late fifties with 3 days of fever, cough, and change in mental status. SARS-CoV-2 RNA was detected by nasopharyngeal PCR, and CSF was negative for West Nile, herpes simplex, and varicella zoster viruses. Non-contrast head CT on initial presentation revealed symmetric hypodensities in the bilateral medial thalami, and cerebral vasculature was normal on angiography. Follow-up MRI revealed hemorrhagic rim-enhancing lesions in the thalami, medial temporal lobes, and subinsular regions—a radiologic pattern consistent with AHNE. Treatment included intravenous immunoglobulins, but outcome was not mentioned (22). AHNE, a rare viral infection complication such as influenza and SARS-CoV-2, is postulated to result from cytokine storm-induced disruption of the blood-brain barrier and direct neurotropism. These mechanisms result in fulminant neuronal damage, as indicated by increased CSF biomarkers such as neurofilament light and tau proteins in comparable instances. The lack of CSF pleocytosis and delayed viral RNA detection in CSF (in other COVID-19-associated ANE instances) highlights the value of serial neurodiagnostic examinations in encephalopathic presentations. Early immunomodulatory treatment, including plasma exchange, has been variably successful in altering this rapidly evolving process



(23).

Figure 2: Understanding Acute Necrotizing Encephalopathy

3. Acute myelitis

Acute myelitis, and acute transverse myelitis (ATM) in specific, is a rare inflammatory disease of the spinal cord and is defined by an acute onset of motor, sensory, and autonomic impairment. The illness may be triggered by a broad variety of causes, including infections, systemic diseases, and post-infectious inflammation; some cases are related to diseases such as multiple sclerosis and neuromyelitis optica. The latest studies emphasize the absolute importance of early diagnosis by using MRI imaging and cerebrospinal fluid examination to differentiate ATM from other diseases, including Guillain-Barré syndrome (24). Treatment usually involves the use of high-dose corticosteroids, whereas other treatments, such as intravenous immunoglobulins or plasmapheresis, can be reserved for non-response. The prognosis is highly heterogeneous, with residual symptoms being the norm and complete recovery in only a minority of patients (25).

4. Encephalitis

Acute cerebrovascular dysfunction consists of a spectrum of life-threatening states of sudden disruption of cerebral perfusion with focal cerebral deficits and risk of long-term disability. The two main mechanisms are ischemic (e.g., thrombotic or embolic) arterial occlusion and hemorrhagic strokes due to vessel rupture (26). Sudden hemiparesis and aphasia to severe headache and altered mental status is a typical clinical presentation, depending on the involved brain regio. Hypertension is the single most crucial modifiable risk factor, responsible for both atherosclerosis and vessel fragility, and imaging with CT/MRI is extremely useful for differentiating subtypes of strokes and planning time-dependent intervention. Contemporary management places greater emphasis on prompt reperfusion by thrombolytic therapy for those ischemic patients eligible and operative management of hemorrhagic complications and secondary prevention measures aimed at vascular risk factors (27). Despite advancements in acute treatment, the prognosis is variable with important dependence on the percentage of ischemic penumbra salvage and timely institution of therapy. Emerging evidence further enhances the therapeutic paradigm, particularly within the areas of neuroprotection and endovascular technology, in an attempt to tackle the immense burden of cerebrovascular morbidity and mortality worldwide.

5. Headache and dizziness

The percentage of those who reported having a headache ranged from 2.0 to 66.1% (26) with 20.1% participating in the study. Data showed that headaches were more common in mild or moderate HCOV-19 patients than in severe or critical individuals. Dizziness was examined in 13 studies with 2236 HCOV-19 participants. About 7.0% of HCOV-19 patients had dizziness, with mild to moderate instances being equally classified as severe or critical cases. The reason for dizziness and vertigo, as well as for clinical distinctions between them, was not addressed in research presented. As a result, the causes for dizziness, including overall, impairment of the 8th cranial nerve, or stroke, are unclear of eight studies that made up a sample, 12.1% of 654 patients with the diagnosis of HCOV-19 manifested headache and dizziness, and no differences between cases of so-called mild and moderate, versus severe or critical, as established by the history of disease course, were revealed (27). Headache and dizziness are common but mild symptoms of various conditions. Different studies indicate that the symptoms are mild presentations that accompany the presentation of HCOV-19. The prevalence of the symptoms varies from 3.1% to 12.1% (28).

6. Smell and taste dysfunction

The incidence of the reports of taste dysfunctions and smell dysfunctions has considerably varied. A study showed the following: 88.8% of the patients experienced taste dysfunction, and 85.6% experienced smell dysfunction (29). Another study, however, identified that 5.1% and 5.6% of the patients, respectively, experienced dysfunctions in taste and smell (Mao et al., 2020). In total, general or ear, nose, and throat symptoms either occurred initially (65.4%) or

later (22.8%), before smell dysfunction started. Combined in all the studies, 59.2% of the patients experienced smell dysfunction and 50.8% experienced taste dysfunction. These dysfunctions were more frequent among HCOV-19 patients with mild or moderate disease presentations than among those with severe or critical disease courses (30).

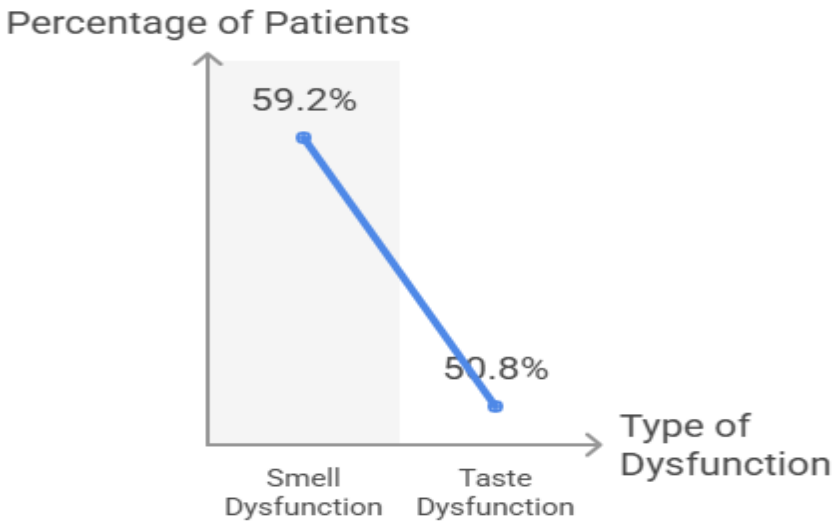


Figure 3: Prevalence of sensory dysfunction in Covid-19 patients (30)

7. Impaired consciousness

5.1% of HCOV-19 patients had disturbed consciousness, more generally described as "confusion" or "agitation," in nine studies involving 2890 patients. The range was between 1.4 (Guan et al., 2020) and 69.0% (31). Disrupted consciousness was more frequently found in patients with severe or critical HCOV-19 than in those with mild or moderate HCOV-19, as would be expected.

8. Acute cerebrovascular Dysfunction

Acute cerebrovascular events in HCOV-19 patients were reported in two cohort studies. Out of 214 hospitalized patients, 2.8% of the patients developed acute cerebrovascular events, and the majority (5 of the 6 reported cases) had severe or critical evolution of the disease, according to Mao et al. (32). In a retrospective observational study of 221 HCOV-19 patients, Li et al. reported the occurrence of 11 patients with acute ischemic stroke, 1 patient with cerebral venous sinus thrombosis, and 1 patient with cerebral hemorrhage. Patients with acute cerebrovascular events were older (71.6 ± 15.7 years vs. 52.1 ± 15.3 years), more commonly with severe HCOV-19 (84.6% vs. 39.9%), and had greater frequencies of cardiovascular risk factors, such as diabetes (46.2% vs. 12.0%), hypertension (69.2% vs. 22.1%), and history of cardio-cerebrovascular diseases in the past, Li et al. (2020) wrote. In two additional case reports, cerebral infarctions in HCOV-19 patients were described in detail (33).

9. Seizures

In case reports, one of these patients did not undergo brain MRI and CSF studies, raising doubts about the diagnosis's accuracy (34). There were no indications of acute symptomatic seizures or status epilepticus among 304 HCOV-19 patients, according to a thorough retrospective investigation (35).

10. Meningitis/encephalitis

Seven distinct cases of meningitis and encephalitis have been ascribed to HCOV-19. Two patients among them had cerebrospinal fluid that was SARS-CoV-2 positive. Although clinical details were scarce, one case of viral encephalitis from China has been described. Moreover, a case of encephalitis was described from Japan with further details. This patient had altered consciousness, SARS-CoV-2 PCR positivity in the CSF, and pathological cerebral MRI with right lateral ventriculitis and encephalitis of the predominant right mesial temporal lobe and hippocampus. However, three other cases lacked detectable SARS-CoV-2 RNA in their CSF swabs. In one case report from China, encephalitis diagnosis was unclear as a cerebral computed tomography scan was normal and no MRI scan was reported (36).

11. Oculomotor nerve palsy

It's reported that one HCOV-19 patient had oculomotor nerve palsy. The cerebral MRI revealed no evidence of SARS-CoV-2, and the CSF did not contain the virus (40).

PNS MANIFESTATIONS AND COMPLICATIONS

- **Chemosensory dysfunction and anosmia**

In a survey within the US to evaluate chemosensory dysfunction in 203 HCOV-19 negative and 59 HCOV-19 positive patients admitted from one hospital. In their research, the HCOV-19 positive group showed significantly greater taste and olfactory function disturbances i.e. loss of smell: 68% vs. 16%; loss of taste: 71% vs. 17% compared to the negative group. Most subjects in the current study were ambulatory and did not undergo hospitalization or mechanical ventilation (41). In addition, they utilized an online survey to validate the results from a large sample of Iranian 10,069 patients and presented evidence that, whereas in critical HCOV-19 patients—where transmission of the virus is most probable via the lung—in ambulatory HCOV-19 patients, transmission of the virus is probable via the nose (42). Reduced sense of smell has also been a significant problem for subjects during the past four weeks of the HCOV-19 pandemic in Iran. Of those surveyed, 83.38% reported a reduced sensation of taste, and 48.23% experienced anosmia and hyposmia. A abrupt development of anosmia occurred in 76.24% of patients. Additionally, before anosmia, the patients experienced headaches (48.6%), fever (37.3%), nasal stiffness (43.7%), and flu or cold symptoms (75.5%). However, among the 214 Chinese patients in the Mao et al. trial, 12 (5.6%) and 11 (5.1%) exhibited impaired smell and taste, respectively. The French HCOV-19 patient group did not disclose any cases of anosmia or taste impairment (42).

- **Guillain barre syndrome**

Up to now, China, Iran, and Italy have reported eight cases of HCOV-19-associated GBS. Zhao et al. described the first case of GBS in a 61-year-old woman who had visited Wuhan City, China. Within a single day, she recovered from acute weakness and severe fatigue in both legs. Demyelinating polyneuropathy was indicated by electromyography. Following IVIG treatment, she subsequently experienced respiratory difficulty. Her HCOV-19 test was positive. She contaminated eight individuals, consisting of 2 neurologists and 6 nurses who were isolated but HCOV-19 PCR-negative, along with two of her relatives.

The author concluded that thrombocytopenia and lymphopenia at admission were in line with a para-infectious pattern of GBS due to HCOV-19 according to the history of travel. After her quarantine and antiviral treatment, she recovered completely from her motor functions.

A male patient who presented with quadriplegia and bilateral facial paralysis from ascending paralysis also presented with fever, cough, and intermittent dyspnea (43). He was treated with IVIG. In the scientists' opinion, GBS ought to be taken as a neurological consequence of HCOV-19 because respiratory involvement is prevalent in the virus and might make it possible to develop GBS. As per Virani and others, a 54-year-old American individual had GBS. As his paralysis in the ascending manner increased, he had respiratory issues. There was no bowel or bladder issue. There were no reflexes, and the MRI spine was normal. There was a history of

diarrhea before the abrupt onset of weakness. His HCOV-19 test was positive. He was treated with IVIG and antimalarial drugs (44).

In 2020, presented with a co-incidental relationship to a patient with GBS who presented with HCOV-19 symptoms in the hospital. Miller Fisher syndrome, characterized by positive GD1b-IgG antibodies, and polyneuritis cranialis were both described by Gutiérrez-Ortiz. CSF SARS-CoV-2 PCR on both patients was negative (45).

- **Other manifestations**

Additionally, one person each experienced epilepsy and ataxia, and five others had neuralgia, however further details were not given (46).

Conclusion

The main organs affected by HCOV-19 are the cardiovascular and respiratory systems. Neurological involvement is not rare and can have severe consequences if it is not identified and treated very early. These issues are usually observed in patients who are actually very sick, and sometimes they can even appear before respiratory symptoms or be the sole symptoms of HCOV-19 patients. Hence, a high suspicion index is needed to treat and prevent such occurrences as quickly as possible. Recording the functional outcomes after neurological problems is also important as well as accurately gathering data on both acute and chronic neurological problems from across the globe.

References

Ahmad, I., & Rathore, F. A. (2020). Neurological manifestations and complications of HCOV-19: A literature review. Journal of clinical neuroscience, 77, 8-12.

Asadi-Pooya, A. A., & Simani, L. (2020). Central nervous system manifestations of HCOV-19: a systematic review. Journal of the neurological sciences, 413, 116832.

Karuppan MKM, Nair M, Devadoss D, Lakshmana MK, Chand HS. SARS-CoV-2 Infection in the Central and Peripheral Nervous System-Associated Morbidities and Their Potential Mechanism. Molecular neurobiology. 2021 Jan 13;58(6):2465–80.

Baig, A. M., Khaleeq, A., Ali, U., & Syeda, H. (2020). Evidence of the HCOV-19 virus targeting the CNS: tissue distribution, host–virus interaction, and proposed neurotropic mechanisms. ACS chemical neuroscience, 11(7), 995-998.

Baig, A. M., Khaleeq, A., Ali, U., & Syeda, H. (2020). Evidence of the HCOV-19 virus targeting the CNS: tissue distribution, host–virus interaction, and proposed neurotropic mechanisms. ACS chemical neuroscience, 11(7), 995-998.

Cain, M. D., Salimi, H., Diamond, M. S., & Klein, R. S. (2019). Mechanisms of pathogen invasion into the central nervous system. Neuron, 103(5), 771-783.

Chahrour, M., Assi, S., Bejjani, M., Nasrallah, A. A., Salhab, H., Fares, M., ... & Fares, M. Y. (2020). A bibliometric analysis of HCOV-19 research activity: a call for increased output. Cureus, 12(3).

Chen, R., Wang, K., Yu, J., Chen, Z., Wen, C., & Xu, Z. (2020). The spatial and cell-type distribution of SARS-CoV-2 receptor ACE2 in human and mouse brain. bioRxiv 2020.04. 07.030650.

Chen, T., Wu, D. I., Chen, H., Yan, W., Yang, D., Chen, G., ... & Ning, Q. (2020). Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. bmj, 368.

Chen, T., Wu, D. I., Chen, H., Yan, W., Yang, D., Chen, G., ... & Ning, Q. (2020). Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. bmj, 368.

Chen, X., Laurent, S., Onur, O. A., Kleineberg, N. N., Fink, G. R., Schweitzer, F., & Warnke, C. (2021). A systematic review of neurological symptoms and complications of HCOV-19. Journal of neurology, 268, 392-402.

Deng, Y., Liu, W., Liu, K., Fang, Y. Y., Shang, J., Zhou, L., ... & Liu, H. G. (2020). Clinical characteristics of fatal and recovered cases of coronavirus disease 2019 in Wuhan, China: a retrospective study. Chinese medical journal, 133(11), 1261-1267.

Desforges, M., Le Coupanec, A., Dubeau, P., Bourgouin, A., Lajoie, L., Dubé, M., & Talbot, P. J. (2019). Human coronaviruses and other respiratory viruses: underestimated opportunistic pathogens of the central nervous system?. viruses, 12(1), 14.

Duong, L., Xu, P., & Liu, A. (2020). Meningoencephalitis without respiratory failure in a young female patient with HCOV-19 infection in Downtown Los Angeles, early April 2020. Brain, behavior, and immunity, 87, 33.

Filatov, A., Sharma, P., Hindi, F., & Espinosa, P. S. (2020). Neurological complications of coronavirus disease (HCOV-19): encephalopathy. Cureus, 12(3).

Guan, W. J., Liang, W. H., Zhao, Y., Liang, H. R., Chen, Z. S., Li, Y. M., ... & He, J. X. (2020). Comorbidity and its impact on 1590 patients with HCOV-19 in China: a nationwide analysis. European Respiratory Journal, 55(5).

Guan, W. J., Ni, Z. Y., Hu, Y., Liang, W. H., Ou, C. Q., He, J. X., ... & Zhong, N. S. (2020). Clinical characteristics of coronavirus disease 2019 in China. New England journal of medicine, 382(18), 1708-1720.

Gutiérrez-Ortiz, C., Méndez-Guerrero, A., Rodrigo-Rey, S., San Pedro-Murillo, E., Bermejo-Guerrero, L., Gordo-Mañas, R., ... & Benito-León, J. (2020). Miller Fisher syndrome and polyneuritis cranialis in HCOV-19. Neurology, 95(5), e601-e605.

He, J., Cheng, G., Xu, W., Zhang, L., & Zeng, Z. (2020). Diagnosis and treatment of an elderly patient with secondary cerebral infarction caused by HCOV-19. Nan Fang yi ke da xue xue bao= Journal of Southern Medical University, 40(3), 351-352.

Helms, J., Kremer, S., Merdji, H., Clere-Jehl, R., Schenck, M., Kummerlen, C., ... & Meziani, F. (2020). Neurologic features in severe SARS-CoV-2 infection. New England Journal of Medicine, 382(23), 2268-2270.

Henry, B. M., De Oliveira, M. H. S., Benoit, S., Plebani, M., & Lippi, G. (2020). Hematologic, biochemical and immune biomarker abnormalities associated with severe illness and mortality in coronavirus disease 2019 (HCOV-19): a meta-analysis. Clinical Chemistry and Laboratory Medicine (CCLM), 58(7), 1021-1028.

Hoffmann, M., Kleine-Weber, H., Schroeder, S., Krüger, N., Herrler, T., Erichsen, S., ... & Pöhlmann, S. (2020). SARS-CoV-2 cell entry depends on ACE2 and TMPRSS2 and is blocked by a clinically proven protease inhibitor. cell, 181(2), 271-280.

Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., ... & Cao, B. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The lancet, 395(10223), 497-506.

Jiang, Fang, et al. "Review of the clinical characteristics of coronavirus disease 2019 (HCOV-19)." Journal of general internal medicine 35 (2020): 1545-1549.

Lechien, J. R., Chiesa-Estomba, C. M., De Siati, D. R., Horoi, M., Le Bon, S. D., Rodriguez, A., ... & Saussez, S. (2020). Olfactory and gustatory dysfunctions as a clinical presentation of mild-to-moderate forms of the coronavirus disease (HCOV-19): a multicenter European study. European Archives of Oto-rhino-laryngology, 277(8), 2251-2261.

Levinson, R., Elbaz, M., Ben-Ami, R., Shasha, D., Levinson, T., Choshen, G., ... & Paran, Y. (2020). Anosmia and dysgeusia in patients with mild SARS-CoV-2 infection. MedRxiv, 2020-04.

Li, B., Yang, J., Zhao, F., Zhi, L., Wang, X., Liu, L., ... & Zhao, Y. (2020). Prevalence and impact of cardiovascular metabolic diseases on HCOV-19 in China. Clinical research in cardiology, 109, 531-538.

Li, L. Q., Huang, T., Wang, Y. Q., Wang, Z. P., Liang, Y., Huang, T. B., ... & Wang, Y. (2020). COVID-19 patients' clinical characteristics, discharge rate, and fatality rate of meta-analysis. Journal of medical virology, 92(6), 577-583.

Li, Y. C., Bai, W. Z., & Hashikawa, T. (2020). The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. Journal of medical virology, 92(6), 552-555.

Li, Y., Li, M., Wang, M., Zhou, Y., Chang, J., Xian, Y., ... & Hu, B. (2020). Acute cerebrovascular disease following HCOV-19: a single center, retrospective, observational study. Stroke and vascular neurology, 5(3).

Lu, L., Xiong, W., Liu, D., Liu, J., Yang, D., Li, N., ... & Zhou, D. (2020). New onset acute symptomatic seizure and risk factors in coronavirus disease 2019: a retrospective multicenter study. Epilepsia, 61(6), e49-e53.

Mao, L., Jin, H., Wang, M., Hu, Y., Chen, S., He, Q., ... & Hu, B. (2020). Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. JAMA neurology, 77(6), 683-690.

Mehta, P., McAuley, D. F., Brown, M., Sanchez, E., Tattersall, R. S., & Manson, J. J. (2020). HCOV-19: consider cytokine storm syndromes and immunosuppression. The lancet, 395(10229), 1033-1034.

Moriguchi, T., Harii, N., Goto, J., Harada, D., Sugawara, H., Takamino, J., ... & Shimada, S. (2020). A first case of meningitis/encephalitis associated with SARS-Coronavirus-2. International journal of infectious diseases, 94, 55-58.

Netland, J., Meyerholz, D. K., Moore, S., Cassell, M., & Perlman, S. (2008). Severe acute respiratory syndrome coronavirus infection causes neuronal death in the absence of encephalitis in mice transgenic for human ACE2. Journal of virology, 82(15), 7264-7275.

Palasca, O., Santos, A., Stolte, C., Gorodkin, J., & Jensen, L. J. (2018). TISSUES 2.0: an integrative web resource on mammalian tissue expression. Database, 2018, bay003.

Pilotto, A., Odolini, S., Masciocchi, S., Comelli, A., Volonghi, I., Gazzina, S., ... & Padovani, A. (2020). Steroid-responsive severe encephalopathy in SARS-CoV-2 infection. medRxiv.

Poyiadji, N., Shahin, G., Noujaim, D., Stone, M., Patel, S., & Griffith, B. (2020). HCOV-19–associated acute hemorrhagic necrotizing encephalopathy: imaging features. Radiology, 296(2), E119-E120.

Sedaghat, Z., & Karimi, N. (2020). Guillain Barre syndrome associated with HCOV-19 infection: a case report. Journal of Clinical Neuroscience, 76, 233-235.

Sun, C., Zhang, X. B., Dai, Y., Xu, X. Z., & Zhao, J. (2020). Clinical analysis of 150 cases of 2019 novel coronavirus infection in Nanyang City, Henan Province. Zhonghua jie he he hu xi za zhi= Zhonghua Jiehe he Huxi Zazhi= Chinese Journal of Tuberculosis and Respiratory Diseases, 43(6), 503-508.

Tu, H., Tu, S., Gao, S., Shao, A., & Sheng, J. (2020). The epidemiological and clinical features of HCOV-19 and lessons from this global infectious public health event. J Infect, 81(1), 1-9.

Tveito, K. (2020). Cytokinstormer ved HCoV-19?. Tidsskrift for Den norske legeforening.

Virani, A., Rabold, E., Hanson, T., Haag, A., Elrufay, R., Cheema, T., ... & Bhanot, N. (2020). Guillain-Barré syndrome associated with SARS-CoV-2 infection. IDCases, 20, e00771.

Wan, Y. (2020). Shang J. Graham R, RS Baric RS, Li F. Receptor recognition by the novel coronavirus from Wuhan: an analysis based on decade-long structural studies of SARS coronavirus. J. Virol, 94(7).

Wang, L., Cai, J., Luo, H., Guan, H., Wang, H., Huang, C., & Zhou, F. (2020). A case of coronavirus disease 2019 with tuberculous meningitis. Chinese Journal of Neurology, E004-E004.

Wei, H., Yin, H., Huang, M., & Guo, Z. (2020). The 2019 novel cornoavirus pneumonia with onset of oculomotor nerve palsy: a case study. Journal of neurology, 267, 1550-1553.

Wong, S. H., Lui, R. N., & Sung, J. J. (2020). Covid-19 and the digestive system. Journal of gastroenterology and hepatology, 35(5), 744-748.