Section: General Medicine

Original Research Article

NEUROLOGICAL MANIFESTATIONS IN COVID-19 PATIENTS ADMITTED AT A TERTIARY CENTRE DURING THE EARLY PHASE OF COVID PANDEMIC

Juby John[1], Sajad K[2], Jayachandran R[3], Rashmi KP[3]

[1]*Associate Professor, Department of Infectious Diseases, Govt. Medical College, Kottayam, Kerala, India*
[2]*Assistant Professor, Department of General Medicine, Govt. T D Medical College, Alappuzha, Kerala, India*
[3]*Associate Professor, Department of General Medicine, Govt. T D Medical College, Alappuzha, Kerala, India*

Received *: 22/03/2025*
Received in revised form *: 04/04/2025*
Accepted *: 10/04/2025*

Corresponding Author:
Dr. Rashmi KP,
Associate professor, department of General Medicine, Govt. T D Medical College, Alappuzha, Kerala, India
Email: rashmipillai195@gmail.com

DOI: 10.70034/ijmedph.2025.2.52

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2025; 15 (2); 287-293

ABSTRACT

Background: COVID-19 manifests with a wide clinical spectrum ranging from asymptomatic state to acute respiratory distress syndrome and multi organ dysfunction. Reports suggest neurological symptoms in approximately one fourth to one third of patients including symptoms related to central and peripheral nervous system and skeletal muscular damage. Commonly reported neurological symptoms include dizziness, headache, impairment of taste and smell, impaired consciousness, confusion and commonly reported complications include cerebrovascular events (CVEs), meningitis, encephalopathy, skeletal muscle injury and demyelinating disorders like Guillain-Barre syndrome. This study was aimed at estimating the prevalence and spectrum of neurological manifestations and its severity, progression, and possible outcomes in COVID-19 patients admitted in our Medical college hospital.

Materials and Methods: An Observational Descriptive Study was conducted among the patients diagnosed with COVID 19 starting from the first hospitalized case of COVID-19 in TDMC, Alappuzha (30, January 2020) till 31, July 2020. Patient's relevant information including details of history and clinical examination were collected from the medical records. Reports of laboratory investigations were reviewed. The study was approved by the institutional ethics committee of Government T D Medical College Alappuzha. Results were analysed and those with neurological manifestations were compared to those without and necessary statistical calculations were done.

Results: Total number of patients who were included in the study were 624. Mean age was 41.28. Majority of them were males (82.6%). Of these patients, 200 (32%) had at least 1 of the following underlying disorders: hypertension (123 [19.7%]), diabetes (82[13.1%]), cardiac or cerebrovascular disease (25 [4.0%]), and COPD (17 [2.7%]). The most common symptoms at on-set of illness were sore throat (135 [21.6%]), cough (133 [21.3%]), and fever (104 (16.6%). 278(44.5%) patients were totally asymptomatic. Neurologic manifestations were present in 122 patients (19.5%). Patients presenting with any neurologic manifestations were older than those without (43.5 vs. 40.73 years) and had a longer time of hospitalization (12.68 vs. 10.1 days. Among the patients who had neurological symptoms the most frequent neurologic manifestations were headaches (82, 67.2%) hypogeusia (42, 34.4%), hyposmia (41, 33.6%), dizziness (7, 5.7%), numbness (43.27%) and cerebrovascular accident (2 1.6%). Patients with cerebrovascular accidents were older than those without (both above 60 years) and both were having comorbidities. Compared to the group who did not present with neurological symptoms the group with neurological symptoms had more statistically significant Covid related symptoms like fever sore throat myalgia chest pain and diarrohea.

Conclusion: This study demonstrated the presence of significant neurological symptoms in hospitalised Covid patients who were admitted in our hospital. . Major neurological manifestation in our study was ischemic stroke which was reported in 2 patients who had prior comorbidities. There was no relation between severity of illness and neurological manifestations. Also, there was no definite relation for severity of illness with age or presence of comorbidities with development of minor neurological symptoms Physicians and neurologists should be aware that COVID-19 patients can present with neurological symptoms alone in the absence of classic flu like symptoms and even with neurological complications like acute ischemic stroke.
Keywords: Covid 19, Stroke, Neurological Complications.

INTRODUCTION

Corona Virus Disease 2019 [COVID-19] caused by the novel severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) which emerged from Wuhan, Hubei Province, China in December 2019 has by now become a worldwide pandemic disease. Extensive studies have been conducted in different parts of the world since the arrival of this virus to understand the relevant information on its origin, mode of transmission, manifestations, pathogenesis, and complications.

COVID-19 manifests with a wide clinical spectrum ranging from asymptomatic state to acute respiratory distress syndrome and multi-organ dysfunction. Common symptoms include fever, cough, rhinitis, sore throat, headache, fatigue, myalgia, diarrhoea and breathlessness.[1] Although it mainly affects the respiratory system, recent published reports have suggested that neurological symptoms are common in COVID-19 just like its sister coronaviruses SARS-COV-1 and MERS-COV. In-fact COVID-19 is unique in its ability to cause a multi-organ disease, with involvement of the central and peripheral nervous system in some individuals. Indeed, a wide range of neurologic manifestations of SARS-CoV-2 infection have been recognized, and evidence of their severity and persistence is increasing.[2-6]

Furthermore, neurologic manifestations, especially encephalopathy have been associated with worse clinical outcomes in other systemic illnesses including sepsis and may even lead to significant disability.[7-11]

Reports suggest neurological symptoms in approximately one-fourth to one-third of patients including symptoms related to central and peripheral nervous system and skeletal muscular damage. Commonly reported neurological symptoms include dizziness, headache, impairment of taste and smell, impaired consciousness, confusion and commonly reported complications include cerebrovascular events (CVEs), meningitis, encephalopathy, skeletal muscle injury and demyelinating disorders like Guillain-Barre syndrome.

However, the frequency of those manifestations and associated risk factors remain unclear. We attempted to characterize the incidence of neurologic manifestations in patients with confirmed Covid-19 and identify factors associated with the development of neurologic manifestations in hospitalized patients with both severe and non-severe respiratory disease. Establishing a strong correlation between the two and recognizing the spectrum of manifestations, including the rare ones will prompt us to monitor for neurological symptoms in these patients thus avoiding delay in diagnosis and appropriate neurological management and also urge us to suspect the infection even in patients solely presenting with neurological symptoms thus facilitating early detection of the disease and prevention of deterioration or transmission of infection. Thus, this study was aimed at estimating the prevalence and spectrum of neurological manifestations and its severity, progression, and possible outcomes in COVID-19 patients admitted in our Medical College Hospital.

MATERIALS AND METHODS

An Observational Descriptive Study was conducted among the patients diagnosed with COVID 19 starting from the first hospitalized case of COVID-19 in TDMC, Alappuzha (30, January 2020) till 31, July 2020. All COVID-19 positive patients, above the age of 12 years of both gender hospitalized in corona wards in TDMC ALAPPUZHA, during the study period was taken after considering the inclusion and exclusion criteria. Patient's relevant information including details of history and clinical examination were collected from the medical records. Reports of laboratory investigations were reviewed. Patients who were recovered were interviewed telephonically for any clinical worsening at the end of 14 days after discharge. Data needed for this study were the ones routinely collected during our clinical history taking and evaluation. In view of the existing pandemic situation of COVID-19 at that time it was practically difficult to obtain informed written consent from all patients. Hence we requested to allow us a waiver of consent for this study. The study was approved by the institutional ethics committee of Government T D Medical College Alappuzha

Case Definitions

All COVID-19 positive patients, above the age of 12 years of both genders, confirmed by real-time reverse-transcription polymerase chain reaction assay from throat swab, admitted in Corona Isolation Ward in TDMC Alappuzha during the period from 30

January 2020 till 31 July 2020 were included in the study. Patients less than 12 years of age were excluded

Statistical Analysis

We analysed the data using SPSS (IBM Statistics for Windows, Trial Version 26.0 Armonk NY IBM Corp) software. For baseline data, mean and standard deviations (SD) were used for normally distributed data and median and range for data that were not normally distributed. Categorical variables were expressed as counts and percentages. Proportions for categorical variables were compared using the chi square test. The significant P value was kept less than 0.05

RESULTS

Total number of patients who were included in the study were 624.They were selected consecutively. Among them 50 % were in the age group of 21-40 years (312 patients).Mean age was 41.28.Majority of them were males (82.6%).Of these patients, 200 (32%) had at least 1 of the following underlying disorders: hypertension (123 [19.7%]), diabetes (82[13.1%]), cardiac or cerebrovascular disease (25 [4.0%]), and COPD (17 [2.7%]). The most common symptoms at on-set of illness were sore throat (135 [21.6%]), cough (133 [21.3%]), and fever (104 (16.6%).278(44.5%) patients were totally asymptomatic. The percentage of co morbidity and the percentage of general symptoms are shown graphically. Figure 1 represents the percentage of co morbidity and figure 2 the percentage of general symptoms.

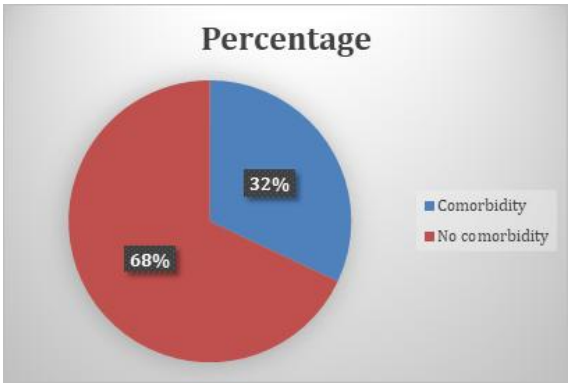

Figure 1 percentage of comorbidity

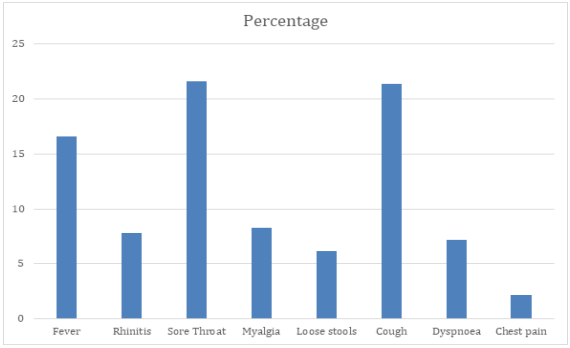

Figure 2 percentage of general symptoms

Neurologic manifestations were present in 122 patients (19.5%). Patients presenting with any neurologic manifestations were older than those without (43.5 vs. 40.73 years) and had a longer time of hospitalization (12.68 vs. 10.1 days). Majority of patients with neurologic symptoms presented with those symptoms at the time of admission itself. Among the patients who had neurological symptoms the most frequent neurologic manifestations were headaches (82, 67.2%) hypogeusia (42, 34.4%), hyposmia (41, 33.6%), dizziness (7, 5.7%), numbness (43.27%) and cerebrovascular accident (2 1.6%). Patients with cerebrovascular accidents were older than those without (both above 60 years) and both were having comorbidities. One of them developed ataxic hemiparesis during the course of hospital stay while the other patient presented with cerebrovascular accident. No cases of Guillain-Barre syndrome or acute demyelinating encephalomyelitis (ADEM) were identified. The percentage of neurological symptoms are depicted in table 1 and represented graphically as pie chart in figure 3 and bar chart in [Figure 4]

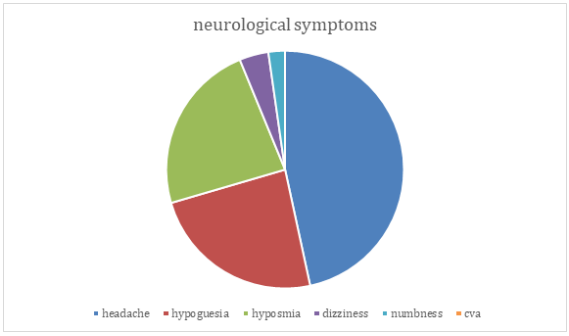

Figure 3 pie chart percentage of neurological symptoms

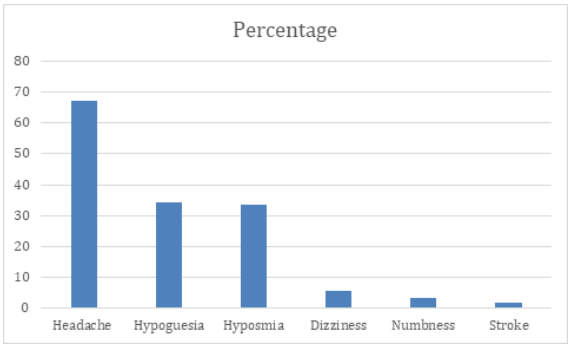

Figure 4: bar chart percentage of neurological symptoms

None of the patients with neurological patients were critically ill and there was no need of any ICU care or ventilator support in these patients. None of the patients in this group received plasma therapy which was a prevalent form of treatment at that point of time and there was no mortality in this group. Patients who developed serious neurological manifestations like cerebrovascular accidents had to stay more in the hospital compared to the patients with those who had minor symptoms. Headache, dizziness, dysgeusia, and anosmia together accounted for 95.8% of all

neurologic manifestations of Covid-19. The median number of neurologic manifestations per patient was 3. Patients were subdivided into two groups based on the presence or absence of neurological symptoms and the two groups were analysed. The main differences between the groups are summarized in the following [Table 2].

Table 1: count and percentage of neurological symptoms

Neurological Symptom	Number	Percentage
Headache	82	67.2
Hyposmia	41	33.6
Hypogeusia	42	34.4
Dizziness	7	5.7
Numbness	4	3.27
Stroke	2	1.6

Table 2: comparative features of neuro group and non neuro group

	Neuro	Non-neuro
Total	122 19.5	502 80.4
Age av	43.5	40.73
Sex m/f	99/23	417/85
Hsp stay av	12.28	10.1
Headache	82 67.2	0
Hyposmia	41 33.6	0
Hypoguesia	42 34.4	0
Dizzines	7 5.7	0
Ataxia/cva	2 1.6	0
Numbness	4 3.27	0
Fever	36 29.5	68 13.54
Rhinitis	14 11.47	35 6.9
Sore throat	42 34.42	93 18.5
Cough	33 27	100 19.9
Myalgia	25 20.4	27 5.3
Dyspnoea	17 13.94	28 5.5
Loose stools	14 11.47	25 4.9
Chest pain	8 6.55	6 1.1
Comorbid	47 38.52	153 30.4
DM	18 14.75	64 12.7
HTN	24 19.67	99 19.7
CVA	0	1 0.1
COPD	6 4.91	11 2.1
CAD	6 4.91	18 3.5
CKD	1 0.8	2 0.3
COMP	12 9.83	11 2.1
PLASMA	0	5 0.9
d dim>500	6 4.9	9 1.7
Ferr>400	4 3.27	7 1.3
ICU	0	2 0.3
Mech vent	0	1 0.1
Oxygen	7 5.7	14 2.7
Antibiot	66 54.09	181 36
Antiviral	20 16.39	47 9.3
Anticoag	8 6.55	13 2.5
Steroids	20 16.39	29 5.7
hcqs	1 0.8	5 0.9

Patients who had neurological symptoms were predominantly male (81.1%). There was no history of any previous neurological diseases in these set of patients. Previous co morbidity was not a statistically significant factor for presenting with neurological symptoms in Covid patients when compared to the group who did not have neurological symptoms (P value 0.08). Diabetes mellitus (P value 0.55) Hypertension (P value 0.99) previous COPD (P value 0.09) previous CAD (P value 0.49) CKD (P value0.54) were found not to have any significant statistical association with development of neurological symptoms. However both the patients who developed serious neurological symptoms like cerebrovascular accidents had co morbidities. There were no patients with a past history of malignancy in the group of patients who presented with neurological symptoms.

Compared to the group who did not present with neurological symptoms the group with neurological symptoms had more statistically significant Covid related symptoms. Fever(P value 0.00002),Sore throat(P value 0.00013)Myalgia(P value 0,00001) Dyspnoea(P value 0.001)Loose stools(P value0.007) and Chest pain(P value 0.0003) were the significant Covid related symptoms which were seen more in the group with neurological symptoms. Cough (P value 0.08) and Rhinitis (P vale 0.09) were similarly seen

in both the groups. Laboratory investigations were done in both the groups and the only statistically significant association was with a D dimer>500(P value 0.043). Ferritin value more than 400 was not statistically significant (P value 0.15) association. Most of the patients in both the groups were treated symptomatically. Patients in the group with neurological symptoms received more antibiotics (P value 0.0002) antivirals (p value 0.025) anticoagulants (P value 0.028) and steroids (P value 0.0009).Oxygen therapy was similar in both the groups (P value 0.1) Discharge functional outcome and mortality was not significantly different between those with and without any neurologic manifestations. No single neurologic manifestation, besides cerebrovascular accident was significantly associated with worse discharge functional outcome.

DISCUSSION

The study period taken for the study was in the early phase of Covid Pandemic. During the initial months of Covid pandemic most of the patients in the state of Kerala were travellers from foreign countries. As the days progressed Covid cases increased in rest of the country,[12] and the patients included those who were travellers from rest of the country to Kerala. Most of these travellers were belonging to the working class and students. This could explain the comparatively lower age group and the male predominance seen in this study. A similar trend was seen in other medical colleges of Kerala at that point of time.[13]

Kerala was managing Covid patients with strict vigilance during the early days of pandemic. This was recognised by W H O and also by various governments. Travellers who came from overseas and interstate travellers were regularly quarantined and tested with RTPCR for the presence of SARSCOV2 Antigens.[14] This strategy lead to detecting many asymptomatic patients in the districts of Kerala. T D Medical College is the only government owned tertiary hospital in the district of Alappuzha which is one of the most densely populated districts of Kerala. Hence during early part of pandemic most of the Covid positive patients were admitted to government T D Medical college. This could explain the presence of a large number of asymptomatic patients in the study sample. This pattern continued till the end of May and during the months of June 2020 onwards local transmission of Covid cases occurred.[15]

As part of containment strategy during early part of the Covid pandemic patients were discharged only after a negative RTPCR report. Hence the hospital stay duration of many patients were prolonged. But our study could demonstrate the need of prolonged hospitalisation in those with neurological symptoms. The study population in our group had varied neurological manifestations starting from headache which was the commonest symptom followed by hypogeusia and hyposmia.[2] patients in the study population developed cerebrovascular accident. There were no cases with encephalopathy or seizures or sensory deficits though there were patients who were complaining of numbness. The varied presentation of neurologic findings is possibly due to involvement of entire nervous system (peripheral and central) by this disease.[16-18] Coronaviruses can invade nervous tissues, involving macrophages, microglia, astrocytes,[19] and cause nerve damage not only through direct infection pathways (both circulatory and neuronal) but also through secondary hypoxia, immune-mediated injuries, attack to enzymes involved in the renin-angiotensin system, and other mechanisms.[16] Indeed, COVID-19 viral load has been found in the brain tissue samples of patients who died during the pandemic.[17,20]

The findings in our study are consistent with the various studies which were conducted in various parts of the world.[4,21,22] The incidence of cerebrovascular accidents varied in various studies. It was as low as 1.5 % and 3 % in some studies.[23,24] It was around 5.7% in a neurological review study,[22] and it was around 21% in studies at neurological centres.[28] This shows that incidence of cerebrovascular accidents were reported more from neurological centres than general hospitals. The incidence of serious neurological issues were considerably low in our study when compared to other major studies. This again is due to the peculiarity of the study population who were young mostly asymptomatic and without major co morbidities. There is growing evidence that the COVID-19 pandemic is having several important implications for stroke.[26,27] Covid 19 infection itself predisposes patients to a lot of thrombotic complications which includes stroke.[28,29]

hyposmia and hypogeusia were noted in significant number of our patients. These findings are in line with previous reports,[30] which have suggested that these symptoms are due to direct effects of the virus on the olfactory system,[31] and gustatory receptors.[32] Coronaviruses may also enter the brain through the olfactory tract in the early stages of infection.[33] Interestingly, anosmia and ageusia can be an early sign of infection, a sign of a milder form of infection and can occur during and after the general symptoms.[34]

Patients with co-morbidities had increased incidence of neurological symptoms in many studies.[21,35] In our study there were no statistically significant associations with various co morbidities and neurologic manifestations. This could be due to the predominantly young and working class profile of patients who were enrolled in this study. Both the patients who developed cerebrovascular accidents had both diabetes mellitus and hypertension. This could point to the association to comorbidities to serious neurological manifestations which was the pattern seen in many other studies.[21] A raised D dimer value >500 was found to have statistically significant association with neurologic symptoms.

This finding is similar to the findings of many studies.[21]

Various studies have shown that neurological manifestations are more in those presenting with symptomatic Covid than the asymptomatic group. Our study also has shown that the incidence of fever, sore throat, myalgia, dyspnoea loose stools and chest pain were high in the group which presented with neurological manifestations. In many of the studies myalgia was considered as a neurological symptom too. Though this finding is statistically significant this is compounded by a large number of asymptomatic patients in the group without neurologic symptoms.

CONCLUSION

This study demonstrated the presence of significant neurological symptoms in hospitalised Covid patients who were admitted in our hospital. Major neurological manifestation in our study was ischemic stroke which was reported in 2 patients who had prior comorbidities. Cough, sore throat and fever were the main non-neurological symptoms reported. There was no relation between severity of illness and neurological manifestations. Also, there was no definite relation for severity of illness with age or presence of comorbidities with development of minor neurological symptoms. Physicians and neurologists should be aware that manifestations of COVID-19 are not limited to the respiratory system. COVID-19 patients can present with neurological symptoms alone in the absence of classic flu like symptoms and even with neurological complications like acute ischemic stroke. Neurological complications, particularly encephalitis and stroke, can cause lifelong disability, with associated long-term care needs and potentially large health, social, and economic costs. Hence, it is important to suspect COVID-19 and test for it in such patients so as to take appropriate protective measures and to provide apt treatment.

Limitations

There are many limitations for the study. The study was conducted in the early part of pandemic where majority of patients were having a non-severe disease and presented late to health care system. This factor led to the inclusion of large number of asymptomatic patients in the study group. The pandemic of COVID-19 is still continuing and evolving day by day. Many different strains have appeared till now. Our study was conducted during the initial phase of COVID surge in Kerala. During our study period patients in category C were comparatively less and also major neurological manifestations were fewer. But as the cases rose in the later part of year, many patients presenting with major neurological manifestations had increased. Unfortunately, we could not include them in this study.

Since our study was mainly a retrospective study, many important data required for the study could not be collected and analysed. Also, inflammatory markers (CRP, Ferritin, D-dimer, IL-6) were done conservatively in most patients as most of our study population belonged to low socio-economic status and could not afford the cost of the same. MRI Brain and CSF study could not be done in patients with neurological manifestations due to logistic reasons.

REFERENCES

1. Zhu N, Zhang D, Wang W, et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med 2020;20:727–733.
2. Berger JR. COVID-19 and the nervous system. J Neurovirol 2020;26:143–148.
3. Ellul MA, Benjamin L, Singh B, et al. Neurological associations of COVID-19. Lancet Neurol;19(9):767–783 (2020). https://dio.org/10.1016/S1474-4422(20)30221-0
4. Koralnik IJ, Tyler KL. COVID-19: a global threat to the nervous system. Ann Neurol 2020;88:1–11.
5. Leonardi M, Padovani A, McArthur JC. Neurological manifestations associated with COVID-19: a review and a call for action. J Neurol 2020;267:1573–1576.
6. Nath A. Neurologic complications of coronavirus infections. Neurology 2020;94:809–810.
7. Paterson RW, Brown RL, Benjamin L, et al. The emerging spectrum of COVID-19 neurology: clinical, radiological and laboratory findings. Brain 2020. https://dio.org/10.1093/brain/awaa240
8. Varatharaj A, Thomas N, Ellul MA, et al. Neurological and neuropsychiatric complications of COVID-19 in 153 patients: a UK-wide surveillance study. Lancet Psychiatry 2020;7(10):875–882.
9. Carfì A, Bernabei R, Landi F; Group ftGAC-P-ACS. Persistent symptoms in patients after acute COVID-19. JAMA 2020;324:603
10. Gofton TE, Young GB. Sepsis-associated encephalopathy. Nat Rev Neurol 2012;8:557–566
11. Pandharipande PP, Girard TD, Jackson JC, et al. Long-term cognitive impairment after critical illness. N Engl J Med 2013;369:1306–1316
12. Rath RS, Dixit AM, Koparkar AR, Kharya P, Joshi HS. COVID-19 pandemic in India: A Comparison of pandemic pattern in Selected States. Nepal J Epidemiol. 2020;10(2); 856-864. DOI: 10.3126/nje.v10i2.28960
13. Varghese B, Shajahan S, Anilkumar H. et al. Symptomatology and epidemiologic characteristics of COVID 19 patients in Kerala, India. J Evolution Med Dent Sci 2020;9(46):3411-3417, DOI: 10.14260/jemds/2020/749
14. Chathukulam J, Tharamangalam J. The Kerala model in the time of COVID19: Rethinking state, society and democracy. World Dev. 2021 Jan; 137:105207. doi: 10.1016/j.worlddev.2020.105207. Epub 2020 Sep 23. PMID: 32989341; PMCID: PMC7510531
15. Jayesh S and Shilpa Sreedharan Analysing the Covid-19 Cases in Kerala: A Visual Exploratory Data Analysis Approach SN Comprehensive Clinical Medicine (2020) 2:1337–1348 https://doi.org/10.1007/s42399-020-00451-5
16. Wu Y, Xu X, Chen Z, Duan J, Hashimoto K, Yang L, et al. Nervous system involvement after infection with COVID-19 and other coronaviruses. Brain Behav Immun 2020; 1591: 18–22. https://doi.org/10.1016/j.bbi.2020.03.031. CrossrefWeb of Science®Google Scholar
17. Puelles VG, Lutgehertmann M, Sperhake MT, et al. Multiorgan and renal tropism of SARS-CoV-2. N Engl J Med 2020. https://doi.org/10.1056/NEJMc2011400. CrossrefPubMedWeb of Science®Google Scholar
18. Li YC, Bai WZ, Hashikawa T. The neuroinvasive potential of SARS-CoV-2 may play a role in the respiratory failure of COVID-19 patients. J Med Virol 2020; 92: 552– 555. https://doi.org/10.1002/jmv.25728. Wiley Online LibraryCASPubMedWeb of Science®Google Schola
19. Al-Obaidi MMJ, Bahadoran A, Wang SM, Manikam R, Raju CS, Sekaran SD. Disruption of the blood brain barrier is vital

property of neurotropic viral infection of the central nervous system. Acta Virol 2018; 62: 16– 27. https://doi.org/10.4149/av_2018_102. CrossrefCASPubMedWeb of Science®Google Scholar
20. Bernard-Valnet R, Pizzarotti B, Anichini A, et al. Two patients with acute meningo-encephalitis concomitant to SARS-CoV-2 infection. Eur J Neurol 2020. https://doi.org/10.1111/ene.14298. Wiley Online LibraryWeb of Science®Google Scholar
21. Mao L, Jin H, Wang M, et al.: Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China [IN PRESS]. JAMA Neurol. 2020, 10.1001/jamaneurol.2020.1127
22. Whittaker A, Anson M, Harky A. Neurological manifestations of COVID-19: A systematic review and current update. Acta Neurol Scand 2020; 142: 14– 22. https://doi.org/10.1111/ane.13266. Wiley Online LibraryCASPubMedWeb of Science®Google Schola
23. Klok F, Kruip M, van der Meer N, Arbuos M, Gommers D, Kant K. Incidence of thrombotic complications in critically ill ICU patients with COVID-19. Thromb Res. 2020; S0049-3848(20): 30120– 30121. Google Scholar
24. Lodigiani C, Lapichino G, Carenzo L, Cecconi M, Ferrazzi P, Sebastian T. Venous and arterial thromboembolic complications in COVID-19 patients admitted to an academic hospital in Milan, Italy. Thromb Res. 2020; 191: 9- 14. CrossrefCASPubMedWeb of Science®Google Scholar
25. E. Moro, A. Priori, E. Beghi, R. Helbok, L. Campiglio, C. L. Bassetti, E. Bianchi, L. F. Maia, S. Ozturk, F. Cavallieri, M. Zedde, J. Sellner, D. Bereczki, M. Rakusa, G. Di Liberto, A. Sauerbier … See all authors European journal of neurology. https://doi.org/10.1111/ene.1440
26. Markus HS, Brainin M. COVID-19 and stroke – a global World Stroke Organization perspective. Int J Stroke. 2020; 29: 1747493020923472. https://doi.org/10.1177/1747493020923472. Google Scholar
27. Beyrouti R, Adams ME, Benjamin L, et al. Characteristics of ischaemic stroke associated with COVID-19. J Neurol Neurosurg Psychiatry 2020; jnnp-2020-323586. https://doi.org/10.1136/jnnp-2010-323586. Web of Science®Google Scholar
28. Hess DC, Eldahshan W, Rutkowski E. COVID-19-related stroke. Transl Stroke Res 2020; 7: 1– 4. https://doi.org/10.1007/s12975-020-00818-9. Google Scholar
29. Oxley TJ, Mocco J, Majidi S, et al. Large-vessel stroke as a presenting feature of COVID-19 in the young. NEJM 2020; 382: 60. https://doi.org/10.1056/NEJMc2009787. CrossrefPubMedWeb of Science®Google Scholar
30. Lechien JR, Chiesa-Estomba CM, De Siati DR, et al. Olfactory and gustatory dysfunction as a clinical presentation of mild-to-moderate forms of the coronavirus disease (COVID-19): a multicenter European study. Eur Arch Otorhinolaryngol 2020; 6: 1– 11. https://doi.org/10.1007/s00405-020-05965-1. Google Scholar
31. Bulfamante G, Chiumello D, Canevini MP, et al. First ultrastructural autoptic findings of SARS-Cov-2 in olfactory pathways and brainstem. Minerva Anesthesiol 2020; 86: 678– 679. https://doi.org/10.23736/S0375-9393.20.14772-2. CrossrefPubMedWeb of Science®Google Scholar
32. Vaira LA, Salzano G, Fois AG, Piombino P, De Riu G. Potential pathogenesis of ageusia and anosmia in COVID-19 patients. Int Forum Allergy Rhinol. 2020. https://doi.org/10.1002/alr.22593. Wiley Online LibraryWeb of Science®Google Scholar
33. Desforges M, Le Coupanec A, Dubeau P, et al. Human coronaviruses and other respiratory viruses: underestimated opportunistic pathogens of the central nervous system? Viruses 2020; 12: 14. https://doi.org/10.3390/v12010014. CrossrefGoogle Scholar
34. Lechien JR, Chiesa-Estomba CM, Place S, et al. Clinical and epidemiological characteristics of 1,420 European patients with mild-to-moderate coronavirus disease 2019. J Intern Med 2020. https://doi.org/10.1111/joim.13089. Wiley Online LibraryPubMedWeb of Science®Google Schola
35. Li Y, Wang M, Zhou Y, Chang J. Acute cerebrovascular disease following COVID-19: a single center, retrospective, observational study. Available at SSRN: https://ssrn.com/abstract=3550025 March 3, 2020.