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ARTICLE

Neurological consultations and diagnoses in a large, dedicated COVID-19 university hospital

Consultas neurológicas e diagnósticos em um grande hospital universitário dedicado a COVID-19

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ABSTRACT

Background: More than one-third of COVID-19 patients present neurological symptoms ranging from anosmia to stroke and encephalopathy. Furthermore, pre-existing neurological conditions may require special treatment and may be associated with worse outcomes. Notwithstanding, the role of neurologists in COVID-19 is probably underrecognized. **Objective:** The aim of this study was to report the reasons for requesting neurological consultations by internists and intensivists in a COVID-19-dedicated hospital. **Methods:** This retrospective study was carried out at Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil, a 900-bed COVID-19 dedicated center (including 300 intensive care unit beds). COVID-19 diagnosis was confirmed by SARS-CoV-2-RT-PCR in nasal swabs. All inpatient neurology consultations between March 23rd and May 23rd, 2020 were analyzed. Neurologists performed the neurological exam, assessed

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Authors' contributions: Studart-Neto and Guedes: conceptualized the paper, collected data, participated in consensus meetings, analyzed data and wrote the initial draft. They contributed equally to the present work.

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Nitrini: conceptualized the paper, participated in consensus meetings, wrote and reviewed the manuscript for intellectual content, supervised the study.

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all available data to diagnose the neurological condition, and requested additional tests deemed necessary. Difficult diagnoses were established in consensus meetings. After diagnosis, neurologists were involved in the treatment. **Results:** Neurological consultations were requested for 89 out of 1,208 (7.4%) inpatient COVID admissions during that period. Main neurological diagnoses included: encephalopathy (44.4%), stroke (16.7%), previous neurological diseases (9.0%), seizures (9.0%), neuromuscular disorders (5.6%), other acute brain lesions (3.4%), and other mild nonspecific symptoms (11.2%). **Conclusions:** Most neurological consultations in a COVID-19-dedicated hospital were requested for severe conditions that could have an impact on the outcome. First-line doctors should be able to recognize neurological symptoms; neurologists are important members of the medical team in COVID-19 hospital care.

Keywords: Coronavirus Infections; COVID-19; Neurology; Seizures; Stroke; Metabolic Encephalopathy; Neuromuscular Diseases.

RESUMO

Introdução: Mais de um terço dos pacientes com COVID-19 apresentam sintomas neurológicos que variam de anosmia a AVC e encefalopatia. Além disso, doenças neurológicas prévias podem exigir tratamento especial e estar associadas a piores desfechos. Não obstante, o papel dos neurologistas na COVID-19 é provavelmente pouco reconhecido. **Objetivo:** O objetivo deste estudo foi relatar os motivos para solicitar consultas neurológicas por clínicos e intensivistas em um hospital dedicado à COVID-19. **Métodos:** Estudo retrospectivo realizado no Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brasil, um centro dedicado à COVID-19 com 900 leitos (incluindo 300 leitos para unidades de terapia intensiva). O diagnóstico de COVID-19 foi confirmado por SARS-CoV-2-RT-PCR em *swabs* nasais. Todas as interconsultas de neurologia hospitalar entre 23 de março e 23 de maio de 2020 foram analisadas. Os neurologistas realizaram o exame neurológico, avaliaram todos os dados disponíveis para diagnosticar a patologia neurológica e solicitaram exames adicionais conforme necessidade. Diagnósticos difíceis foram estabelecidos em reuniões de consenso. Após o diagnóstico, os neurologistas participaram da condução dos casos. **Resultados:** Foram solicitadas consultas neurológicas para 89 de 1.208 (7,4%) em pacientes internados por COVID-19 durante o período. Os principais diagnósticos neurológicos incluíram: encefalopatia (44,4%), acidente vascular cerebral (16,7%), doenças neurológicas prévias (9,0%), crises epilépticas (9,0%), transtornos neuromusculares (5,6%), outras lesões encefálicas agudas (3,4%) e outros sintomas leves inespecíficos (11,2%). **Conclusões:** A maioria das consultas neurológicas em um hospital dedicado à COVID-19 foi solicitada para condições graves que poderiam afetar o desfecho clínico. Os médicos na linha de frente devem ser capazes de reconhecer sintomas neurológicos. Os neurologistas são membros importantes da equipe médica no atendimento hospitalar à COVID-19.

Palavras-chave: Infecções por Coronavírus; COVID-19; Neurologia; Convulsões; Acidente Vascular Cerebral; Encefalopatias; Doenças Neuromusculares.

INTRODUCTION

In March 2020, the World Health Organization declared COVID-19 a pandemic disease with unknown consequences[1]. As of mid-May 2020, there had been almost five million reported infections, and more than 300,000 deaths worldwide caused by SARS-CoV-2[2]. Although COVID-19 was initially described as a mainly respiratory disease, accumulating evidence suggests neuropsychiatric complications play an important role in the disease[3,4]. In a Chinese retrospective cohort, impaired consciousness was observed in 7.5% of COVID-19 patients, and in 14.8% of severe cases[5]. Neurological signs are almost ubiquitous in very severe COVID-19 patients, with agitation or positive CAM-ICU findings noted in over 65% of cases[3]. COVID-19 may also be complicated by encephalopathy, headache, and stroke.

Pre-existing neurological disease is associated with increased disease severity and poorer outcome in COVID-19[6-8]. Likewise, comorbid SARS-CoV-2 infection can lead to higher rates of disability in acute neurological patients[9]. There is also an emerging concern on the potential negative impact of COVID-19 in the management of chronic neurological diseases such as Parkinson's disease[10] and epilepsy[11].

These issues underscore the importance of inpatient neurological evaluation and treatment during the pandemic. Neurology societies have highlighted the importance of reorganizing neurology consultation services for in- and outpatient clinics[12-15]. Although a few retrospective case series have described the occurrence of specific neurological symptoms and signs in COVID-19 patients[3-5], we were not able to find systematic reports of the real-life experience of consulting neurologists, other than the anecdotal editorial by Bersano and Pantoni[12].

The objective of this study was to report the main reasons for requesting neurological consultations by internists and intensivists in a COVID-19 dedicated hospital and the frequency of individual neurological diagnoses in a real-life situation over a 60-day period.

METHODS

Study design and participants

In March 2020, the Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP) was designated a COVID-dedicated tertiary referral center, with 900 beds (including three hundred Intensive Care Units – ICU – beds). Since its reorganization, a team of seven neurologists and eight neurology residents was assigned to provide on-demand consultations exclusively for COVID-19 patients.

Patients with confirmed or suspected COVID-19 requiring hospitalization underwent SARS-CoV-2 RNA detection

with throat swab real-time reverse transcription-polymerase chain reaction (RT-PCR). In high clinical suspicion PCR-negative cases, a repeat RT-PCR test was performed.

This retrospective study enrolled exclusively PCR-positive cases evaluated by the neurology inpatient consultation team between March 23rd and May 23rd, 2020. This is a real-life situation study: neurological consultations were requested at the discretion of each patient's attending physician.

Patient clinical evaluation included clinical examination, routine laboratory testing (blood cell count, biochemical analysis, liver and renal function tests, C-reactive protein, D-dimer, lactate dehydrogenase, creatine phosphokinase) and chest computed tomography (CT). Patients were divided into two groups based on the severity of the respiratory symptoms (severe and non-severe). Severe respiratory symptoms were defined as respiratory insufficiency requiring mechanical ventilation.

For each case, the reason for requesting the neurological consultation and the final neurological diagnosis were recovered from the specialist consult electronic form. Neurological evaluation consisted of neurological examination and additional ancillary tests (brain CT, Magnetic Resonance Imaging – MRI, cerebrospinal fluid – CSF – analysis), requested at the neurologist's discretion.

Difficult diagnosis cases were presented in a consensus meeting with the Neurology Department staff at *Hospital das Clínicas*. In cases with two or more neurological diagnoses, the final diagnosis was that of the most severe condition, or of the more plausible cause for the condition (for example: in an encephalopathy due to a confirmed stroke, the final diagnosis was stroke). Neurological diagnoses were finally classified into four main groups: encephalopathy, cerebrovascular disease, epilepsy, and neuromuscular disease. A fifth group (named "others") included diagnoses not fitting in the four other groups (*i.e.*, headache, vertigo), including management or follow-up of pre-existing neurological conditions.

Statistical analysis

All analyses were performed with the Statistical Package for Social Sciences software, version 21.0 (SPSS, IBM Statistics, Chicago, IL, USA). Categorical variables were expressed as absolute and relative frequencies and compared using Pearson's χ^2 univariate analysis. All continuous variables were expressed as mean and standard deviations and compared with Student's *t*-test or Mann-Whitney test according to normality distribution. All tests were two-tailed. Statistical significance was accepted at $p<0.05$.

Standard protocol approvals

The institutional review board approved the investigation protocol, and waived the informed consent, since this was a retrospective study, and no patient had undergone an experimental intervention.

RESULTS

During the studied period, 1,208 patients with confirmed COVID-19 were admitted to the hospital and 89 neurological consultation requests were placed (7.4%). The number of neurological consultations rose from 0.3 consults/day in the first week, to 3.6/day in the last week, representing a twelvefold increase (Figure 1).

Approximately half of the patients had severe respiratory conditions, requiring orotracheal intubation and mechanical ventilation (Table 1). Mean age of the 89 cases was 57.4+/-15.9 years, with no difference between groups; the majority of patients (61.8%) were men. Hypertension and *diabetes mellitus* were the most common comorbidities. The most prevalent typical symptoms of COVID-19 were fever, cough, and dyspnea. Anosmia and dysgeusia were rarely reported by patients. Thirty-nine patients (43.8%) had a previous neurological diagnosis (Table 1).

The main reasons for neurological consultation were: altered level of consciousness, muscle weakness, and psychomotor agitation. In eleven cases, the neurologist was called to assist in the management and follow-up of patients with pre-existing neurological diseases without acute neurological manifestations (Table 2). In some cases, two or more symptoms were reported by the clinician on neurological consultation requests. Main ancillary exams performed were brain CT (in 71 patients) and lumbar puncture (in 27 patients), while brain MRI was performed in only 15 patients (20.0%).

The most prevalent diagnoses were delirium/encephalopathy, stroke, previous neurological diseases, seizures, neuromuscular disorders, other acute brain lesions, as well as other mild nonspecific symptoms (Table 3 and Figure 2).

Associations between some reasons for neurological consultation requested by the internist and the final diagnoses established by the neurologist were found: altered level

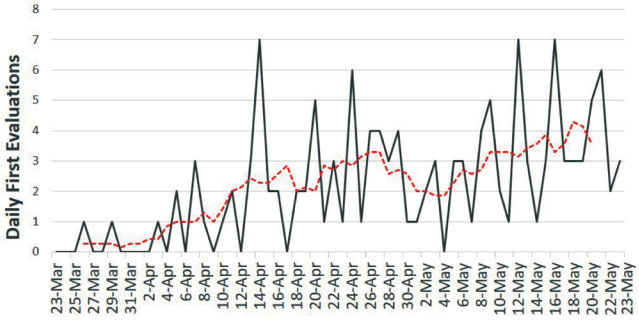

Figure 1. The solid line displays the number of patients who underwent initial neurological evaluation between March 23rd and May 23rd, 2020 at Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP). The dotted red line indicates the 7-day moving average. For any given day (D0), this number corresponds to the mean of all 7 values ranging from D-3 to D+3, and annotated on D0, and is therefore available from March 25th through May 21st.

of consciousness correlated with encephalopathy, muscle weakness with cerebrovascular disease, seizure and transient changes in consciousness with epilepsy (Table 4).

DISCUSSION

In this study, 89 neurological consults were analyzed, requested among 1,208 COVID-19 patients admitted to a single University-based tertiary referral hospital dedicated to severe COVID-19 patient care (7.4% of total cases). In this setting, patients were evaluated by neurologists with the same

Table 1. Clinical features of patients with COVID-19 evaluated by the Neurology team between March 23rd and May 23rd, 2020 at Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP).

Characteristics	Nonsevere respiratory condition	Severe respiratory condition	Total	p-value
Number of patients	44	45	89	
Age, mean (SD), y	57.7 (16.2)	56.9 (15.8)	57.4 (15.9)	0.811
Gender				
Female	15 (34.1%)	19 (42.2%)	34 (38.2%)	0.515
COVID-19 symptoms				
Fever	24 (60%)	33 (76.7%)	57 (68.7%)	0.155
Cough	30 (75%)	29 (67.4%)	59 (71.1%)	0.478
Dyspnea	22 (56.4%)	37 (84.1%)	59 (71.1%)	0.008
Myalgia	5 (12.8%)	13 (29.5%)	18 (21.7%)	0.108
Fatigue	15 (38.5%)	14(31.8%)	29 (34.9%)	0.645
Diarrhea	5 (12.8%)	3 (6.8%)	8 (9.6%)	0.465
Anosmia	3 (8.1%)	5 (11.4%)	8 (9.9%)	0.570
Dysgeusia	0	3 (9.4%)	3 (4.8%)	0.135
Comorbidities				
Hypertension	23 (59.0%)	28 (65.1%)	51 (62.2%)	0.651
Diabetes	12 (30.8%)	19 (44.2%)	31 (37.8%)	0.257
Heart disease	8 (20.5%)	9 (20.9%)	17 (20.7%)	0.590
Malignancy	4 (10.3%)	4 (9.1%)	8 (9.6%)	1.000
Chronic renal disease	11 (28.2%)	6 (14.0%)	17 (20.7%)	0.172
Lung disease	5 (12.8%)	5 (11.6%)	10 (12.2%)	1.000
Smoking	8 (18.2%)	10 (22.2%)	18 (20.2%)	0.376
Previous neurological disease				
Cerebrovascular disease	7 (16.7%)	9 (20.9%)	16 (18.8%)	0.782
Epilepsy	8 (18.2%)	3 (6.7%)	11 (12.4%)	0.253
Dementia	4 (9.5%)	4 (9.1%)	8 (9.3%)	1.000
Outcome				
Death	2 (5.0%)	12 (27.3%)	14 (16.7%)	0.008

Table 2. Reason for Neurological Consultation in patients with COVID-19 between March 23rd and May 23rd, 2020 at Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP).

Symptom (reported by the internist)	Nonsevere respiratory condition	Severe respiratory condition	Total	p-value
Altered level of consciousness	17 (38.6%)	18 (40.0%)	35 (39.3%)	0.534
Psychomotor agitation	8 (18.2%)	4 (8.9%)	12 (13.5%)	0.166
Slow awakening from sedation	0	5 (11.1%)	5 (5.6%)	0.029
Focal neurological signs	2 (4.5%)	1 (2.2%)	3 (3.4%)	0.491
Muscle weakness	6 (13.6%)	10 (22.2%)	16 (18.0%)	0.219
Vertigo	1 (2.3%)	1 (2.2%)	2 (2.2%)	0.747
Headache	3 (6.8%)	0	3 (3.4%)	0.117
Seizure and transient changes in consciousness	3 (6.8%)	4 (8.9%)	7 (7.9%)	0.513
Seizure in epileptic patient	4 (9.1%)	1 (2.2%)	5 (5.6%)	0.173
Movement disorder*	2 (4.5%)	4 (8.9%)	6 (6.7%)	0.349
Management or follow-up of pre-existing neurological disease	6 (13.6%)	5 (11.1%)	11 (12.4%)	0.484

*Myoclonus, nonspecific psychomotor agitation.

Table 3. Final neurological diagnoses of COVID-19 patients evaluated by the Neurology team between March 23rd and May 23rd, 2020 at Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP).

Neurological diagnosis	Nonsevere respiratory condition	Severe respiratory condition	Total
Diffuse encephalopathy	20 (45.5%)	20 (44.4%)	40 (44.4%)
Stroke	5 (11.4%)	6 (13.3%)	11 (12.3%)
Cerebral venous thrombosis	1 (2.3%)	1 (2.2%)	2 (2.2%)
Intracranial hemorrhage	1 (2.3%)	1 (2.2%)	2 (2.2%)
Acute non-vascular structural encephalic lesions*	1 (2.3%)	2 (4.4%)	3 (3.4%)
Seizure in epileptic patient	2 (4.5%)	2 (4.4%)	4 (4.5%)
Acute symptomatic or provoked seizure	2 (4.5%)	2 (4.4%)	4 (4.5%)
Peripheral neuropathy	0	3 (6.7%)	3 (3.4%)
Rhabdomyolysis	2 (4.5%)	0	2 (2.2%)
Pre-existing neurological disease	4 (9.1%)	4 (8.9%)	8 (9.0%)
Others**	6 (13.6%)	4 (8.9%)	10 (11.2%)

*Wernicke encephalopathy and central pontine myelinolysis (01 case), acute disseminated encephalomyelitis (01 case), and Posterior Reversible Encephalopathy Syndrome (01 case).

**Headache, vertigo, syncope, somatoform disorder, primary psychosis.

training; more difficult cases were discussed in a weekly consensus meeting with the neurology department staff.

More than half of these complications (65.1%) were severe or potentially severe, consisting of encephalopathy, acute cerebrovascular disease, and non-vascular acute encephalic lesions, some of which can cause serious neurological sequelae. These severe complications were seen both in patients who required mechanical ventilation and in those with less severe degrees of the disease.

In the early stage of the COVID-19 pandemic, Mao et al. reported the occurrence of neurological manifestations in 214 patients admitted to three COVID-19 dedicated hospitals in Wuhan, China[5]. In a retrospective analysis of medical records, the authors found that 78 (36.4%) of the patients had central or peripheral nervous system involvement. Manifestations ranged from mild, such as anosmia and headache, to stroke and encephalopathy. Although the reported frequency in the Wuhan study was high, severe central nervous system (CNS) diagnoses (acute cerebrovascular diseases and impaired consciousness) were reported in 28.2% of these 78 patients.

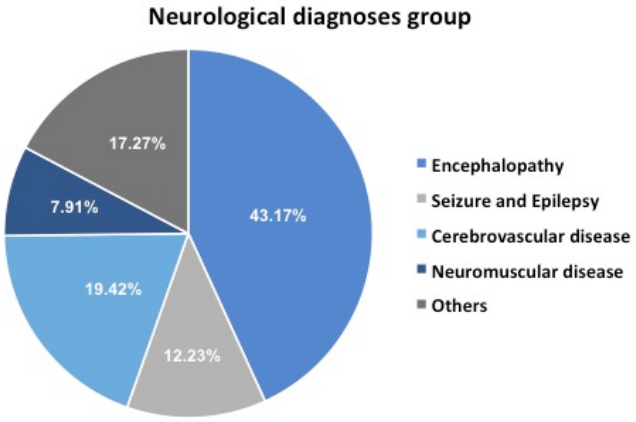

Figure 2. Graphic distribution of neurological diagnoses by disease group in the period between March 23rd and May 23rd, 2020 at Instituto Central do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Brazil (ICHC-HCFMUSP). Group "Others" included "management or follow-up of previous neurological disease", headache, vertigo, syncope, somatoform disorder, and primary psychosis.

Another study applying a similar methodology to that used in Wuhan[5] found neurological manifestations in 512 (57.4%) of 841 patients in two COVID-19 hospitals in Spain[4]. Severe manifestations of CNS involvement, using the same disease categorization used in the present study, were described in 36.5% of the cases[4].

In an observational case series, Helms et al. recorded neurological manifestations in 58 consecutive patients admitted to the hospital due to COVID-19-related acute respiratory distress syndrome, in Strasbourg, France. All patients were treated in ICUs. Agitation was noted in 69% of the patients when neuromuscular blockade was discontinued. Diffuse corticospinal tract signs were observed in 67% of patients. The severity of the neurological manifestation in these cases with acute respiratory failure was even higher than in our sample[3].

The lower frequency and the greater severity of neurological involvement that we found were most likely due to case ascertainment, similarly to the real-life situation, in which neurologists are called to evaluate patients who present signs or symptoms that concern internists or intensivists. Therefore, a bias toward potentially more serious and, therefore, less frequent manifestations was present in our study.

Our data also revealed that neurological manifestations are frequent both in cases that required mechanical ventilation, as well as in less severe ones. The fact that more serious

Table 4. Association between reason for neurological consultation and final diagnosis by disease group.

Reason for Neurological consultation	Final diagnosis by disease group					p-value
	Encephalopathy	Seizure and Epilepsy	Cerebrovascular disease	Neuromuscular disorder	Others	
Altered level of consciousness	28 (80.0%)	1 (2.9%)	4 (11.4%)	1 (2.9%)	1 (2.9%)	<0.001
Psychomotor agitation	7 (58.3%)	1 (8.3%)	2 (16.7%)	1 (8.3%)	1 (8.3%)	0.925
Slow awakening from sedation	4 (80.0%)	0	1 (20.0%)	0	0	0.562
Focal neurological signal	1 (33.3%)	0	2 (13.3%)	0	0	0.215
Muscle weakness	3 (18.8%)	0	7 (43.8%)	5 (31.3%)	1 (6.3%)	<0.001
Vertigo	0	0	1 (50.0%)	0	1 (50.0%)	0.403
Headache	0	0	0	0	3 (100%)	0.004
Seizure and transient changes in consciousness	4 (57.1%)	3 (42.9%)	0	0	0	0.011
Seizure in epileptic patient	0	4 (80.0%)	0	0	1 (20.0%)	<0.001
Movement Disorder	4 (66.7%)	0	1 (16.7%)	0	1 (16.7%)	0.808
Management or follow-up of pre-existing neurological disease	3 (27.3%)	0	1 (9.1%)	2 (18.2%)	5 (45.5%)	0.001

neurological conditions, such as stroke and encephalopathy, were equally frequent in more and in less severe patient groups was unexpected.

Neurological manifestations in COVID-19 can be due to indirect nervous system involvement resulting from systemic diseases, such as hypoxia, uremia, coagulopathy, and critical care neuropathy, due to the invasion of the CNS by SARS-CoV-2, or caused by other mechanisms such as inflammatory and immune-mediated (including post-infectious) reactions.

Factors that support an indirect (systemic) mechanism for neurological complications of SARS-COV2 infection, such as encephalopathy, are the absence of SARS-CoV2 genetic material in the CSF, and the lack of signs of brain involvement on neuroimaging (CT and MRI) in the vast majority of cases in which these tests were obtained[16]. More recently, postmortem pathological examination of brain specimens obtained from 18 patients who died from COVID-19 failed to demonstrate inflammatory changes indicative of encephalitis or changes related to a direct viral effect and disclosed only hypoxic changes[17].

On the other hand, case reports and small case series provided evidence of direct CNS involvement in COVID-19 infection. Moriguchi et al., in Japan, reported a meningoencephalitis case with medial temporal lobe lesions on MRI, in which SARS-CoV-2 was detected in the CSF by RT-PCR[18]. In the previously cited study by Helms et al., leptomeningeal enhancement was noted on MRI in 8/13 patients, and bilateral frontotemporal hypoperfusion was noted in all 11 patients who underwent perfusion MRI[3]. In another report, MRI showed a subtle hyperintensity in the olfactory bulbs and cortical hyperintensity in the right gyrus rectus, consistent with local invasion and direct brain parenchymal lesion by SARS-CoV-2 in a case with anosmia[19]. Most remarkable was the documented finding of the presence of SARS-CoV-2 in neurons and endothelial cells in the frontal lobe of a case of COVID-19 on electronic microscopy, which was confirmed by detection of SARS-CoV-2 genetic material in the brain with RT-PCR[20]. In that case, PCR for SARS-CoV-2 was negative in the CSF.

SARS-CoV-2 encephalopathy may be also caused by acute necrotizing encephalopathy[21,22] and encephalitis related to an exaggerated inflammatory reaction in the CNS, with high cytokine and other inflammatory mediators levels in the CSF[23,24], probably related to a hyperinflammatory systemic reaction against SARS-CoV-2, with a breakdown of the blood-brain barrier. Alternatively, encephalitis may be caused by a CNS-specific inflammatory response[23,24]. Acute disseminated encephalomyelitis (ADEM) has been reported in SARS-CoV-2 patients, indicating a probable virally triggered immune-mediated mechanism leading to CNS inflammatory lesions[25,26].

In our study, the occurrence of neurological manifestations in cases with less severe COVID-19 systemic disease, may indicate that neurological symptoms, at least in part of our cases, occurred regardless of systemic involvement, and that neurological symptoms are probably due to heterogeneous causes. Further studies are needed to elucidate the precise mechanism underlying the neurological manifestations of SARS-CoV-2[27], which will contribute to the development of more rational therapeutic interventions and, possibly, reduce the severity of the impact of SARS-CoV-2 in the nervous system.

The limitations of our study are those of a retrospective study. The history of COVID-19 pre-admission symptoms and neurological symptoms, for instance, was frequently obtained from relatives of critically ill or confused patients and could be prone to recall bias. Some potentially relevant clinical and demographical information, such as the prevalence of obesity or angiotensin-converting enzyme inhibitors, were not available. Our patient population originated from neurology consultation requested by internists, which corresponds to 7.4% of the total COVID-19 population in our hospital. This makes our study inadequate to evaluate the total prevalence of specific signs and diagnoses in the general COVID-19 population. Perception of the need for a neurological evaluation, especially in severely ill patients, may have varied among different medical teams. Of note, the daily number of requests for neurological consultations increased along the study period, probably reflecting an increased awareness of the frequency and severity of neurological manifestations of SARS-CoV-2 infection, as well as of the importance of neurology specialized care for this patient population. Like all studies carried out in COVID-19 dedicated hospitals, there were restrictions on the availability of MRI, CT, electroencephalography, CSF, electroneuromyography, and neuropathological examinations. Also, the purpose of this work was not to evaluate the details of each case to establish the pathophysiology of stroke, encephalopathy, seizures, and other neurological conditions, which we intend to do in forthcoming manuscripts. Along the same lines, neuroimaging and CSF findings are also being prepared for future communications.

The main conclusions of this study are:

- Severe neurological complications that require neurologist interventions are relatively common in COVID-19 patients.
- These complications are equally frequent in patients with severe respiratory failure, who require respiratory assistance, and less severely ill patients, without significant respiratory symptoms.
- Neurologists should be part of the medical team of COVID-19 in dedicated hospitals, and internists must be trained to recognize signs of neurological complications and to appropriately request neurology consultations in such cases.

Future studies are needed to further understand the pathophysiology of nervous system manifestations in SARS-CoV-2 patients, so that more effective therapeutic interventions can be implemented to prevent and minimize severe neurological complications.

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