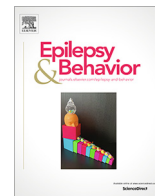




Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.



A follow-up study of patients with COVID-19 presenting with seizures

Ali A. Asadi-Pooya^{a,b,*}, Mohsen Farjoud Kouhanjani^a, Hamid Nemati^a, Amir Emami^c,
Fateme Javanmardi^c

^a Epilepsy Research Center, Shiraz University of Medical Sciences, Shiraz, Iran

^b Jefferson Comprehensive Epilepsy Center, Department of Neurology, Thomas Jefferson University, Philadelphia, PA, USA

^c Burn & Wound Healing Research Center, Department of Microbiology, Shiraz University of Medical Sciences, Shiraz, Iran



ARTICLE INFO

Article history:

Received 13 May 2021

Revised 2 June 2021

Accepted 29 June 2021

Available online 2 July 2021

Keywords:

Coronavirus

COVID-19

Epilepsy

Outcome

Seizure

ABSTRACT

Objective: We performed a follow-up study of patients with COVID-19 presenting with seizures.

Methods: All consecutive patients with seizures, who were referred to Namazee Hospital, Shiraz, Iran, with a diagnosis of COVID-19, from 10 August 2020 until 20 October 2020 were included in this longitudinal study. The clinical data were collected by the admitting physician. In a follow-up phone call to the discharged patients (after eight weeks or more), we inquired their seizure outcome.

Results: In total, 32 patients were studied; 28 patients were followed. Twelve patients (37.5%) presented with a single tonic-clonic seizure and nine (28.1%) had convulsive status epilepticus; one patient had functional (psychogenic) seizures. Ten patients (31.3%) had pre-existing epilepsy, eight others (25%) had pre-existing CNS problems (without epilepsy), one person (3.1%) had pre-existing functional seizures, and 13 individuals (40.1%) neither had epilepsy nor had other CNS problems. Eight patients (28.6%) reported experiencing seizure(s) after being discharged from the hospital; six of these had pre-existing epilepsy and one had pre-existing functional seizures. One patient, who had a newly developed ischemic brain infarction, reported experiencing recurrent seizures.

Conclusion: Seizures in patients with COVID-19 are either acute symptomatic (in about two-thirds) or an exacerbation of a pre-existing epilepsy/functional seizures (in about one-third). A thorough investigation of the underlying etiology of seizures in patients with COVID-19 is necessary. Seizure outcome in patients, who are hospitalized with COVID-19 and seizures, is generally good.

© 2021 Elsevier Inc. All rights reserved.

1. Introduction

Previous case series have provided evidence that seizure is rarely a presenting manifestation of COVID-19; it happens in less than 1% of these patients [1]. However, considering the high number of patients with COVID-19 worldwide, this may translate to thousands of patients with COVID-19 and seizures globally. Furthermore, seizure is an important and serious manifestation that may complicate the course of illness in any critically ill patient. In severely ill patients, isolated seizures may quickly escalate to generalized convulsive status epilepticus or non-convulsive status epilepticus (NCSE) which are associated with a high morbidity and mortality [2]. In such circumstances, a comprehensive investigation of the etiology of the seizure should be performed immediately [3]. The etiology of seizure(s) in many previously reported COVID-19 patients was most likely multifactorial, as many of them

had multi-organ failure, metabolic derangements, hypoxemia, fever, etc. [4]. However, some of the patients had specific neurological problems (e.g., encephalitis or cerebrovascular events) [5–10].

New-onset seizures in patients with COVID-19 have often been considered as acute symptomatic seizures [3,4]. Patients with acute symptomatic seizures do not need long-term anti-seizure medication (ASM) therapy after the period of their acute illness (i.e., about six weeks in COVID-19 patients), unless a subsequent seizure occurs [11]. However, no study has ever followed these patients to determine their seizure outcome and whether these patients experience any further unprovoked recurrent seizures after the period of their acute illness.

The aim of the current study was to investigate the seizure outcome in patients who were hospitalized with COVID-19 and seizures. We also investigated the etiology of seizures (as a presenting manifestation) in patients with COVID-19. These two objectives (i.e., clarifying the etiology and more importantly the seizure outcome) may add to the existing literature on this important issue.

* Corresponding author at: Epilepsy Research Center, Shiraz University of Medical Sciences, Shiraz, Iran.

E-mail address: aliasadipooya@yahoo.com (A.A. Asadi-Pooya).

2. Methods

2.1. Patients

In this study, all consecutive patients with seizures, who were referred to and admitted at Namazee Hospital, Shiraz, Iran, with a diagnosis of COVID-19, from 10 August 2020 until 20 October 2020 were included. All the patients had a confirmed COVID-19 diagnosis by a positive result on Real-Time polymerase chain reaction testing of nasopharyngeal and oropharyngeal samples, or a probable COVID-19 diagnosis by a positive chest computerized scan (CT)/X-ray (CXR) characteristic for COVID-19 (as defined by the World Health Organization) [12].

2.2. Data collection

For any patient, who was admitted with a diagnosis of COVID-19, the following data were collected at the emergency room by the admitting physician: age, sex, and presence of fever. Other collected data were included after reviewing the patients' medical records: Real-Time polymerase chain reaction test results, chest CT scan results, CXR results, arterial blood oxygen saturation (hypoxemia was defined as saturation below 93%), the first laboratory test results, electroencephalography (EEG), brain imaging, and cerebrospinal fluid (CSF) analyses results. Underlying chronic health problems were also collected (self-declared) [i.e., renal, liver, cardiac, or neurological, and also diabetes mellitus (DM), cancer, etc.]. For the purpose of this study, pre-existing neurological problems were categorized as pre-existing epilepsy or other central nervous system (CNS) problems [e.g., pre-existing cerebrovascular accidents (CVA), multiple sclerosis (MS), Alzheimer's disease (AD), etc.]. We arbitrarily categorized the etiology of seizures as: exacerbation of a pre-existing epilepsy (or functional seizures), new CNS insults, fever, metabolic derangements, hypoxemia, meningoencephalitis, and de novo seizures in people with or without pre-existing CNS problems. The outcome (at discharge) was recorded in the database, as dead or discharged.

In a follow-up phone call interview to the discharged patients (after eight weeks or more), we inquired their seizure outcome (whether they have experienced unprovoked recurrent seizures), drug history, and any other enduring problems.

2.3. Statistical analyses

Values were presented as mean \pm standard deviation (SD) for continuous variables and as number (percent) of subjects for categorical variables. This is a descriptive study.

2.4. Standard protocol approvals, registrations, and patient consents

Shiraz University of Medical Sciences Review Board approved this study as a minimal-risk research using the data that were collected for routine clinical practice and waived the requirement for written informed consent; however, patients orally consented to be interviewed during the phone call (approval number: 22383).

2.5. Data availability statement

The data are confidential and will not be shared as per the regulations of Shiraz University of Medical Sciences.

3. Results

3.1. General characteristics of the patients

During the study period, 32 patients [20 (62.5%) women and 12 (37.5%) men] were hospitalized with seizure(s) and a diagnosis of COVID-19. The mean age (\pm standard deviation) of the patients was 22.8 (\pm 20.4) years (range: one month to 65 years; median: 14.5 years; interquartile range: 33 years). In total, three patients died at the hospital (case fatality rate = 9.4%); these were not included in the follow-up phase of the study. One other patient did not answer the phone calls and was not included in the follow-up phase of the study. Table 1 shows all the details of the studied patients.

3.2. Clinical presentations and characteristics

Twelve patients (37.5%) presented with a single tonic-clonic seizure, nine (28.1%) had convulsive status epilepticus (based on the reported length of seizures and without EEG confirmation), three (children) (9.4%) had febrile seizures, three (9.4%) presented with serial tonic-clonic seizures, three (9.4%) had tonic seizures, one had a focal clonic seizure, and one patient had functional (psychogenic) seizures (documented by ictal recording during video-EEG monitoring). Ten patients (31.3%) had pre-existing epilepsy, eight others (25%) had pre-existing CNS problems (without epilepsy), one person (3.1%) had pre-existing functional seizures, and 13 individuals (40.1%) neither had epilepsy nor had other CNS problems. Among 13 patients without any pre-existing CNS problems the presenting seizures were as follows: tonic-clonic (4), tonic (3), febrile seizure (3), status epilepticus (2), focal clonic (1).

3.3. The presumed etiology of seizures

All patients had available data on their body temperature (at admission), arterial blood oxygen saturation, and routine laboratory test results (i.e., blood sugar and electrolytes). Twenty-eight patients had available brain imaging and five patients had CSF analyses data. Eleven patients (34.4%) had exacerbation of their pre-existing seizures; among these, seven patients had fever and six had hypoxemia. Among eight patients with pre-existing CNS problems (without epilepsy) (3 with tumors, 2 with old CVA, one with old ischemic (vascular) changes, one with hypoxic brain damage at birth, and one with cerebral palsy and normal brain imaging), five had fever and six had hypoxemia. Two patients had newly developed ischemic brain infarctions (CVA) and one other had cerebral sinus venous thrombosis (CVT). One patient had encephalitis [CSF pleocytosis (white blood cell count: 550 – lymphocyte: 97% – polymorphonuclear leukocytes: 3%); PCR (for COVID-19 or other viruses) was not performed]. Three children had febrile seizures (that is not directly related to COVID 19). Twenty patients (62.5%) had more than one presumed etiology for their seizures. Six of patients with status epilepticus/clusters (50%) and two of those with isolated seizures (10%) had pre-existing CNS problems (without epilepsy) ($p = 0.023$).

3.4. Electroencephalography

Electroencephalography was available in 23 patients. Ten patients had normal EEGs and one had documented functional seizures (on video-EEG monitoring). Among 21 patients without pre-existing seizures, 15 people had EEGs; it was normal in six patients, three patients had normal background with focal interictal epileptiform discharges, and five patients had abnormally slow

Table 1
Characteristics of the studied patients.

	Age	Sex	Seizure type	Pre-existing Comorbidity	Fever	Hypoxemia	Brain imaging	EEG	CSF analyses	Presumed seizure etiology	Follow-up duration, days	Follow-up seizure	COVID-19 diagnosis
1	0.1	F	Focal clonic	None	No	No	1	Right temporal spikes	0	Hypocalcemia (Ca: 5.5 mg/dL)	57	No	2
2	0.5	M	TC	Epilepsy	Yes	No	0	C3, P3, C4 sharp waves	0	Exacerbation, fever	58	No	3
3	1.0	F	TC	None	Yes	Yes	2, Hydrocephalus	Normal	2	Encephalitis	57	No	3
4	1.3	F	FS	None	Yes	No	0	NA	0	Fever	81	No	2
5	2.0	F	TC	Cerebral palsy	Yes	No	2, Hypoxic brain damage	Normal	1	Fever, pre-existing condition	-	No response	3
6	2.0	F	FS	None	Yes	No	1	Normal	1	Fever	110	No	3
7	3.0	M	TC	Epilepsy	Yes	No	0	NA	0	Exacerbation, fever	56	Yes	3
8	3.5	F	Tonic	Liver and kidney disease	Yes	No	1	F3, F4 sharp waves	0	Fever, pre-existing condition	101	No	1
9	4.0	M	SE	Epilepsy	Yes	Yes	1	Normal	1	Exacerbation, fever, hypoxemia	57	Yes	3
10	5.5	F	FS	None	Yes	No	1	Normal	0	Fever	71	No	3
11	7.0	F	Tonic	None	No	Yes	1	NCSE: Spike-waves (1.5 Hz, more than 90% of the recording)	0	Hypoxemia	77	No	2
12	8.5	F	SE	Epilepsy	Yes	Yes	2, Hydrocephalus	Normal	0	Exacerbation, fever, hypoxemia	-	Expired	3
13	10.0	F	TC	Epilepsy	No	No	2, TORCH	NA	0	Exacerbation	61	No	1
14	11.0	F	Tonic	None	Yes	yes	3, recent CVA	NA	0	CVA, fever, hypoxemia, BUN: 33 mg/dL	94	Yes	3
15	11.0	F	SE	Cerebral palsy	No	No	1	NA	0	Pre-existing condition	57	No	2
16	12.0	F	TC	None	Yes	No	0	Slow background, multifocal spike-waves	0	Fever	79	No	1
17	17.0	M	TC	Heart disease	Yes	Yes	3, recent CVA	NA	0	CVA, fever, hypoxemia	125	No	3
18	26.0	F	TC	Epilepsy	Yes	No	1	Normal	0	Exacerbation, fever	75	No	2
19	26.5	M	SE	None	No	No	1	NA	0	Unknown	111	No	2
20	32.0	M	SE	Brain tumor	Yes	Yes	2, Tumor	Slow background	1	Fever, pre-existing condition	75	No	1
21	35.0	F	Serial	None	Yes	Yes	2, Old ischemic changes	Slow background, generalized frontally dominant spike-waves	0	Fever, hypoxemia, pre-existing condition	127	No	2
22	36.0	M	Functional	Functional seizures	No	No	1	Functional seizure	0	Exacerbation	89	Yes	1
23	36.0	M	Serial	Epilepsy	Yes	No	1	Normal	0	Exacerbation, fever, hypoglycemia (BS: 48 mg/dL)	74	Yes	2
24	36.0	F	SE	Diabetes mellitus	Yes	Yes	3, CVT	NA	0	CVT, fever, hypoxemia	90	No	2
25	37.0	F	Serial	Brain tumor	No	Yes	2, Tumor	Slow background, right hemisphere polymorphic delta activity	0	Hypoxemia, pre-existing condition	88	No	1
26	39.0	M	TC	Epilepsy	Yes	Yes	1	NA	0	Exacerbation, fever, hypoxemia	118	Yes	2

(continued on next page)

Table 1 (continued)

	Age	Sex	Seizure type	Pre-existing Comorbidity	Fever	Hypoxemia	Brain imaging	EEG	CSF analyses	Presumed seizure etiology	Follow-up duration, days	Follow-up seizure	COVID-19 diagnosis
27	45.0	M	SE	Old CVA	Yes	Yes	2, Old CVA	Normal	0	Fever, hypoxemia, hyponatremia (Na: 153 mEq/L), pre-existing condition	110	No	2
28	49.0	M	SE	Old CVA	No	Yes	2, Old CVA	Normal	0	Hypoxemia, pre-existing condition	-	Expired	2
29	51.0	F	TC	None	No	Yes	1	Left temporal spikes	0	Hypoxemia	121	No	2
30	59.0	F	TC	Brain tumor	Yes	Yes	2, Tumor	Slow background	0	Fever, hypoxemia, pre-existing condition	-	Expired	2
31	60.0	F	SE	Epilepsy	No	Yes	2, Old ischemic changes	Slow background	0	Exacerbation, hypoxemia	103	Yes	2
32	65.0	M	TC	Epilepsy	No	Yes	2, Old ischemic changes	Slow background, T5 sharp waves	0	Exacerbation, hypoxemia	111	Yes	2

Age: years; F: female; M: male; TC: tonic-clonic; FS: febrile seizure; SE: status epilepticus; Imaging (No: 0; Normal: 1; Chronic and pre-existing abnormality: 2; Acute problem: 3); CSF: cerebrospinal fluid; CSF analyses (none: 0; Normal: 1; Abnormal: 2); EEG: electroencephalography; NCSE: Non-convulsive status epilepticus; COVID-19 diagnosis (PCR: 1; CT scan: 2; CXR: 3); BUN: blood urea nitrogen; CVA: cerebrovascular accident; CVT: cerebral venous thrombosis; BS: blood sugar; Na: sodium level; Ca: Calcium level; TORCH: Congenital infection with toxoplasmosis, rubella, cytomegalovirus, herpes simplex, and other organisms; NA: not available.

background (two with interictal epileptiform discharges). One patient had NCSE.

3.5. Outcome

Twelve patients had either status epilepticus (N = 9) or clusters of seizures (N = 3); two of these died and three reported recurrent seizures after being discharged. Twenty patients had isolated seizures; one of them died (p = 0.540) and five others reported recurrent seizures after being discharged (p = 0.852). Twenty-eight patients were interviewed after being discharged from the hospital. The mean duration of their follow-up was 87 (±23) days (range: 56–127 days; median: 85 days; interquartile range: 47). Eight patients (28.6%) reported experiencing seizure(s) after being discharged from the hospital; six of these had pre-existing epilepsy and one had pre-existing functional seizures. One patient, who had a newly developed ischemic brain infarction (CVA), also reported experiencing seizures. From 20 patients, who did not have follow-up seizures, three had pre-existing epilepsy; among the remaining 17 patients (neither with pre-existing seizures nor with follow-up seizures), 10 patients (58.8%) were still taking daily ASMs. Eighteen patients did not report any enduring problems; 10 others (35.7%) reported enduring problems after being discharged from the hospital [three had respiratory difficulties, two reported occasional chest pain, two had headache, two had right sided paresis, and one adult patient had urinary incontinence (he also had glioblastoma multiforme)].

3.6. Children vs. adults

In a separate analysis, we categorized the patients according to their age (children: ≤16 years and adults ≥17 years). There were 16 patients in each group. Nine adult patients (56%) and 3 children (19%) had status epilepticus/clusters (p = 0.066). One child and two adults died (p > 0.99). Three children (19%) and five adults (31%)

reported experiencing seizure(s) after being discharged from the hospital (p = 0.705).

4. Discussion

In the current study, we observed that seizures (as a presenting manifestation) in patients with COVID-19 are either acute symptomatic seizures (62.5%) or exacerbation of a pre-existing epilepsy/functional seizures (34.4%); only rarely a seizure heralds the beginning of an epileptic process (3.1%). Furthermore, a recent study showed that while seizures and status epilepticus could be encountered in patients with COVID-19, their occurrence did not correlate with the patients' functional outcome [13]. Our observation is consistent with that in previous studies [4,14] and it has important clinical implications. First, a thorough investigation of the underlying etiology of the seizure should be performed immediately and an appropriate treatment strategy should be implemented to resolve that cause and to prevent further escalation of seizures. Our observation that more patients with status epilepticus/clusters had pre-existing CNS problems (without epilepsy) than those with isolated seizures is important and the treating physician should pay more immediate attention to patients with COVID-19 who have any pre-existing CNS problems. Also, as with other acute symptomatic seizures, there is no need for long-term ASM therapy in patients with COVID-19 and seizure, after the period of the acute illness, unless a subsequent seizure happens. Since the period from the onset of COVID-19 symptoms to death may range from 6 days to 6 weeks, it is reasonable to continue the ASM for about 6 weeks and then taper and discontinue the drug rapidly in 1–2 weeks [3]. In spite of this, we observed that many patients continued to take their ASM(s) for longer times. It is necessary to educate the treating healthcare professionals to limit the use of unnecessary ASMs and to avoid their many adverse effects.

In rare instances, seizures in patients with COVID-19 could be attributed to specific CNS pathologies; one of our patients had encephalitis and three others had cerebrovascular events. Neu-

retrograde and neuro-invasive capabilities of coronaviruses have been described before. Severe acute respiratory syndrome (SARS)-coronavirus-2 (SARS-CoV2) RNA was detected in the CSF in a few patients before [6,10]; however, many other studies that tested for this had negative results [4]. Furthermore, a recent systematic review revealed a pooled incidence of 1.7% for ischemic CVA in the setting of COVID-19 infection [15]. Another systematic review concluded that cerebral venous thrombosis in the context of COVID-19 is rare, but there seems to be an increased relative risk of the condition [16]. In any patient with COVID-19 and seizures it is necessary to request a brain imaging study, as soon as possible, to detect any potentially life-threatening condition such as CVT. It is also desirable to have CSF analyses of patients with COVID-19 and seizures; however, how a diagnosis of encephalitis might change the disease course and also the management plan in these patients should be investigated and clarified in future studies.

In a recent study, we observed that patients with epilepsy were not susceptible to contracting COVID-19 more than that in other individuals. Furthermore, COVID-19 in patients with epilepsy was not associated with a poorer prognosis [17]. In the current study, the seizure outcome in patients, who were hospitalized with COVID-19 and seizures, were generally good. Only rarely the presenting seizure may herald the development of epilepsy in the future (in one patient with CVA in the current study). However, patients with epilepsy, who contract COVID-19, may experience an exacerbation of their seizures for a variety of reasons (e.g., fever, hypoxemia, etc.). It may be necessary to order a Real-Time polymerase chain reaction testing of nasopharyngeal and oropharyngeal samples for COVID-19 in any patient who comes to the emergency department with pre-existing epilepsy and seizure exacerbation during this pandemic.

5. Limitations

This was a single center study with a small sample size. We acknowledge that subtle, non-convulsive seizures, in patients presenting with alteration of mental status, may have been missed without EEG monitoring. Another limitation was the nature of the follow-up (self-reported outcome); some patients might have missed minor seizures or even severe unwitnessed seizures. Finally, the length of the follow-up was short.

6. Conclusion

Seizures (as a presenting manifestation) in patients with COVID-19 are either acute symptomatic seizures (in about two-thirds) or an exacerbation of a pre-existing epilepsy/functional seizures (in about one-third). A complete investigation of the underlying etiology of the seizure in patients with COVID-19 is necessary. Seizure outcome in patients, who are hospitalized with COVID-19 and seizures, is generally good and COVID-19 does not add to the risk of developing epilepsy in the future unless a significant brain insult (e.g., CVA) happens.

7. Declarations

Acknowledgments: Shiraz University of Medical Sciences supported this study.

Role of the funding source: Shiraz University of Medical Sciences had no role in the study design, analysis, and interpretation of data, in the writing of the report, and in the decision to submit the paper for publication.

Author Contributions: Ali A. Asadi-Pooya, M.D.: Designed and conceptualized the study; analyzed the data; drafted and revised the manuscript.

Others: Data collection and revision of the manuscript.

Availability of data and material: The data used in this study are confidential and will not be shared.

Conflict of Interest Disclosures: Ali A. Asadi-Pooya, M.D.: Honoraria from Cobel Daruo, RaymandRad, Sanofi, and Tekaje; Royalty: Oxford University Press (Book publication). Others: none.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.yebeh.2021.108207>.

References

- [1] Keshavarzi A, Janbabaei G, Kheyrafi L, Ghavamabad LH, Asadi-Pooya AA. Seizure is a rare presenting manifestation of COVID-19. *Seizure* 2021;86:16–8.
- [2] Ch'ang J, Claassen J. Seizures in the critically ill. *Handb Clin Neurol* 2017;141:507–29.
- [3] Asadi-Pooya AA. Seizures associated with coronavirus infections. *Seizure* 2020;79:49–52.
- [4] Asadi-Pooya AA, Simani L, Shahisavandi M, Barzegar Z. COVID-19, de novo seizures, and epilepsy: a systematic review. *Neurol Sci* 2021;42:415–31.
- [5] Lyons S, O'Kelly B, Woods S, Rowan C, Brady D, Sheehan G, et al. Seizure with CSF lymphocytosis as a presenting feature of COVID-19 in an otherwise healthy young man. *Seizure* 2020;80:113–4.
- [6] Moriguchi T, Harii N, Goto J, Harada D, Sugawara H, Takamino J, et al. A first case of meningitis/encephalitis associated with SARS-Coronavirus-2. *Int J Infect Dis* 2020;94:55–8.
- [7] Klein DE, Libman R, Kirsch C, Arora R. Cerebral venous thrombosis: A typical presentation of COVID-19 in the young. *J Stroke Cerebrovasc Dis* 2020;29:104989.
- [8] De Stefano P, Nencha U, De Stefano L, Mégevand P, Seeck M. Focal EEG changes indicating critical illness associated cerebral microbleeds in a Covid-19 patient. *Clin Neurophysiol Pract* 2020;5:125–9.
- [9] Bolaji P, Kukoyi B, Ahmad N, Wharton C. Extensive cerebral venous sinus thrombosis: a potential complication in a patient with COVID-19 disease. *BMJ Case Rep* 2020;13:e236820.
- [10] Haddad S, Tayyar R, Risch L, Churchill G, Fares E, Choe M, et al. Encephalopathy and seizure activity in a COVID-19 well controlled HIV patient. *IDCases* 2020;21:e00814.
- [11] Bergey GK. Management of a first seizure. *Continuum (Minneapolis)* 2016;22(1 Epilepsy):38–50.
- [12] WHO-2019-nCoV-Surveillance_Case_Definition-2020.2-eng.pdf/ accessed on 25 March 2021.
- [13] Danoun OA, Zillgitt A, Hill C, Zutshi D, Harris D, Osman G, et al. Outcomes of seizures, status epilepticus, and EEG findings in critically ill patient with COVID-19. *Epilepsy Behav* 2021;118:107923.
- [14] Emami A, Fadakar N, Akbari A, Lotfi M, Farazdaghi M, Javanmardi F, et al. Seizure in patients with COVID-19. *Neurol Sci* 2020;41:3057–61.
- [15] Parsay S, Vosoughi A, Khabbaz A, Sadigh-Eteghad S. The incidence and mortality ratio of ischemic cerebrovascular accidents in COVID-19 cases: a systematic review and meta-analysis. *J Stroke Cerebrovasc Dis* 2021;30:105552.
- [16] Baldini T, Asioli GM, Romoli M, Carvalho Dias M, Schulte EC, Hauer L, et al. Cerebral venous thrombosis and severe acute respiratory syndrome coronavirus-2 infection: A systematic review and meta-analysis. *Eur J Neurol*, 2021. doi:10.1111/ene.14727. Online ahead of print.
- [17] Asadi-Pooya AA, Emami A, Akbari A, Javanmardi F. COVID-19 presentations and outcome in patients with epilepsy. *Acta Neurol Scand* 2021;143:624–8.