In December 2019, the first cases of what we now know as COVID-19, caused by the novel coronavirus SARS-CoV-2, were reported. The virus rapidly spread globally and was declared a pandemic in March 2020. As we go to press, the US is the most affected country with over 6 million cases and over 184,000 deaths. Infection with SARs-CoV-2 can be asymptomatic, but when symptoms occur, a typical presentation consists of pulmonary symptoms, shortness of breath, cough, and fever. Less common presentations continue to be reported with some regularity and demonstrate multisystem involvement. More severe infections requiring hospitalization may also involve acute respiratory distress syndrome, acute cardiac events, and multiorgan failure. Furthermore, growing experience with COVID-19 has shown significant involvement throughout the nervous system. There have been 2 proposed mechanisms of neuroinvasion. The first possible mechanism posits that the virus enters through transneuronal propagation via the olfactory system. The second potential mechanism proposes dissemination through viremia. Neural involvement secondary to a coronavirus is not entirely novel; both neurotropism and neuroinvasion by coronaviruses have been described in humans previously.

**Neurologic Findings Associated with COVID-19**

Central nervous system (CNS) manifestations of COVID-19 were noted early in the pandemic. Very early on, researchers in China reported neurologic signs and symptoms in up to 25% of patients. As we gain more experience with COVID-19, the full breadth of neurologic manifestations is coming into clearer focus. Neurologic manifestations reported to date are wide ranging and can involve the nervous system diffusely. There have been reports of encephalopathy, stroke, anosmia/dysgeusia, dizziness, headache, Guillen-Barre Syndrome, Miller Fisher Syndrome, skeletal muscle injury/myalgia, seizures, and acute hemorrhagic necrotizing encephalopathy. In addition, a variety of epileptic phenotypes have been described, including new-onset seizure, convulsive seizure, myoclonic seizures, status epilepticus, and new-onset refractory status epilepticus (NORSE). Seizures and status epilepticus are not unexpected findings in those who are critically ill and require care in an intensive care unit (ICU). It follows that, depending on case presentations, seizures and status epilepticus may be expected and secondary to organ failure and dysfunction or a result of direct brain injury owing to infection, parainfectious insult, or stroke.

**Reported EEG Findings Associated with COVID-19**

The EEG data gathered to date are disproportionately low in comparison to the total volume of cases because of concerns for the health and safety of neurodiagnostic personnel and the need to conserve personal protective equipment (PPE) during the pandemic. Emerging data are further limited because of recording methodologies. Neurophysiologists and critical care physicians have increasingly turned to caps and other recording equipment that allows rapid application without the need for extensive training in electrode application, often using limited montages with fewer electrodes. As a result, reported EEG findings at this time should be viewed as preliminary and subject to change when expanded indications and routine application methods can be implemented safely.

Despite the limitations of methodology, however, associated EEG changes reported early in the pandemic are also wide ranging and consistent with varied EEG findings known to occur with severe CNS insults and diseases requiring critical care. Simply put, acute encephalopathy of multifactorial origin has been recognized in patients with COVID-19; and the EEG patterns commonly seen with acute encephalopathy and sedation are represented in the
documented cases. Because hypoxia and periods of anoxia are a prominent complication of COVID-19, the EEG correlates of anoxic injury have also been reported. In the available published case series, altered mental status seems to be the most common indication for EEG in cases of COVID-19, and a seizure like event was less commonly the indication for monitoring.⁵,⁶,⁸ The available case series consistently show generalized EEG findings more commonly than focal EEG findings. In 2 small series, generalized slowing was the most common finding.⁵,⁶ Generalized slowing is nonspecific and consistent with an encephalopathy that may reflect primary CNS insult or systemic disease.

Additional EEG findings reported include generalized periodic discharges, lateralized periodic discharges, bilateral independent periodic discharges, triphasic waves, focal seizure, focal status epilepticus, myoclonic status epilepticus, voltage suppression, and isoelectric EEG consistent with brain death.⁴,⁶ These varied patterns are similar to other EEG findings in patients requiring ICU-level care associated with multiorgan dysfunction and infectious or parainfectious inflammatory processes.⁶ The theory that encephalopathic seizure and EEG changes result directly from SARS-CoV-2 infection, rather than from the toxic metabolic effects of multiorgan failure, is supported by the finding of a periodic pattern in the absence of metabolic disorder or other typical explanation consistent with the hypothesis of a progressive neurologic process secondary to SARS-CoV-2.⁶ Lastly, there are a few reports of de novo status epilepticus, described as prolonged seizure with an initial clinical correlate followed by electroclinical dissociation before progression to super-refractory status epilepticus consistent with NORSE.⁴ This also raises concern for a direct infectious or parainfectious insult to the brain parenchyma.

**Utility of EEG in COVID-19**

There is potential for increased utility of EEG in the management of patients with COVID-19. In a small case series 5 of 8 patients with neurologic involvement had a fatal outcome, supporting the idea that neurologic manifestations are associated with more severe cases.⁵ This is confounded, however, by the finding that patients with significant neurologic involvement commonly had normal imaging.⁹ This leads to the hypothesis that EEG could be used to evaluate prognosis as explored in a case series in which baseline EEG was compared to EEG poststimulus using both interpreter’s analysis of raw and quantitative EEG that showed patients who went on to have a good cerebral performance score did not show evidence of encephalopathy.⁴ The EEG of patients with COVID-19 who went on to die was compared to EEG poststimulus using both interpreter's analysis of raw and quantitative EEG that showed patients who went on to have a good cerebral performance score did not show evidence of encephalopathy.⁴ Nonetheless this is an intriguing area for further investigation.

There are even fewer data regarding EEG findings in patients with pre-existing epilepsy; in few observed, EEG findings in the context of COVID-19 were noted to be different from EEG findings prior to infection, which suggests novel pathology.⁵

**Summary and Conclusions**

Early data demonstrate there is increased EEG seizure frequency for those requiring ICU-level care for COVID-19, new-onset seizure can be associated with COVID-19, altered mental status can be due to status epilepticus in patients with COVID-19, and status epilepticus and NORSE can be presenting symptoms of COVID-19. So far, the EEG findings described in patients with COVID-19 appear to be commensurate with associated systemic or neurologic insult and past experience in treating patients with similar indications. To date there are no pathognomonic EEG findings associated with COVID-19. However, experience with EEG in COVID-19 is still preliminary and ordering patterns combined with available resources are influencing data collection. In addition to staffing and PPE concerns, ordering patterns are also a potential source of bias in data collection. As experience with COVID-19 grows and EEG can be done safely, we can expect increasing data as EEG ordering patterns return to baseline and EEGs are performed routinely for patients with unexplained altered mental status. Previous experience with EEG in critical care situations would suggest there is a high burden of subclinical seizures currently undetected that we will soon discover as capability to record long-term EEG studies expands.

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