



Practical Considerations When Performing Neurodiagnostic Studies on Patients with COVID-19 and Other Highly Virulent Diseases

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ABSTRACT. *The coronavirus disease 2019, SARS-COV-2 (the cause of COVID-19), has led to a worldwide shortage of personal protective equipment (PPE) and an increased stress on hospital resources, which has resulted in a spike in the anxiety of the frontline healthcare workers. News reports and information about the virus are rapidly changing. We present a case of a patient with COVID-19 who had a seizure-like spell for which an EEG was performed. In early to mid-March, there were no clear guidelines or recommendations available from neurodiagnostic-related organizations or hospitals on how to adapt procedure workflow to those with COVID-19. When caring for COVID-19 patients, as when caring for any patient with an infectious disease, it is hospital protocol to follow contact, droplet/airborne precautions by wearing appropriate PPE. However, because we knew very little about the coronavirus, this case was different. In this article, we discuss our experience with our EEG workflow and concerns for staff exposure. We then discuss our adaptations and modifications to our standard procedures and protocols. A time analysis comparing our standard EEG protocol with our modified COVID-19 protocol revealed a significant decrease in technologist exposure time (99 minutes versus 51 minutes), which theoretically would reduce the chance of virus transmission to our*

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technologist. At this critical moment in time, we hope such modifications will allow us to continue delivering high quality patient care while optimizing resource utilization and above all keeping our technologists safe.

KEY WORDS. *Coronavirus, COVID-19, EEG, neurodiagnostic testing, technologist safety.*

BACKGROUND

The coronavirus disease 2019, SARS-COV-2 (the cause of COVID-19), has led to a worldwide shortage of personal protective equipment (PPE) (Baker and Sullivan 2020; CDC March 12, 2020a) and an increased stress on hospital resources (Kamal et al. 2020; Root 2020), which has resulted in a spike in the anxiety of the frontline healthcare workers (Adams and Walls 2020). Although COVID-19 mainly affects the respiratory system, there are reports of neurological effects such as encephalopathy, encephalitis, acute cerebrovascular events (Zhou et al. 2020; Mao et al. 2020; Rabin April 1, 2020; Chen et al. 2020; Li et al. 2020; Talan March 27, 2020; Talan April 1, 2020b; Gupta et al. *in preparation*), prompting the need for neurodiagnostic testing.

The American Clinical Neurophysiology Society (ACNS) Guidelines have typically been followed as the minimum technical requirements for performing neurodiagnostic studies, including the conduction of electroencephalograms (EEGs) (ACNS Guidelines 1, 3 and 5) (Acharya et al. 2016; Kuratani et al. 2016; Sinha et al. 2016). Such guidelines acknowledge that there is “no single best method” of performing a neurodiagnostic procedure for every circumstance, but they offer “standards considered minimum for the usual clinical recording.” (Sinha et al. 2016). Given the increasing neurological sequelae in many COVID-19 positive patients (Zhou et al. 2020; Mao et al. 2020; Rabin April 1, 2020; Li et al. 2020; Talan March 27, 2020; Talan April 1, 2020b; Gupta et al. *in preparation*), it is the opinion of the authors that the use of neurodiagnostic testing may increase. It is department policy to adhere to standard infection prevention measures when performing neurodiagnostic procedures on both normal and infected patient populations (Bonner and Davidson 2020). However, the ability to perform such tests may be limited due to the highly contagious nature of the virus (CDC April 2, 2020), which ultimately led our facility to adhere to stricter airborne isolation protocols. These stricter protocols require the use of PPE, including face masks, face shields, gloves and gowns, which were of the limited supply (CDC March 31, 2020a). In this article, the authors share our experience with performing a bedside-continuous video-EEG study (cvEEG) on a patient with COVID-19, while adhering to ACNS guidelines. We then offer proposed changes to our procedures and protocols to accommodate resource limitations and the safety of EEG technologists.

CASE

A 73-year-old male presented with malaise, fever, chills, and shortness of breath in the setting of remote smoking history. Fourteen days prior to admission (PTA), he attended a spring festival. Ten days PTA, he noted a cough and fever and was tested negative for influenza and streptococcus. A few days into waiting for the COVID-19 test results, his symptoms worsened, prompting an evaluation at our hospital. He was febrile, had oxygen desaturations, a negative chest X-ray, tachycardia and was diagnosed with viral myocarditis.

He was then considered a person under investigation (PUI) for COVID-19 and was placed in an airborne isolation unit which was recently converted into a “COVID-19 ICU Unit”. He was started on plaquenil and within a day, he developed acute respiratory failure and septic shock, requiring emergent intubation and pressor support. He was sedated with propofol (30–80 mcg/kg/min) and fentanyl (75 mcg/hour) gutta (gtt, i.e., drip) and was paralyzed with cisatracurium. His test for COVID-19 returned positive. As the paralytic and sedation were being weaned, the respiratory therapist and ICU nurse noted a convulsion-like spell and a transient left facial droop. He was febrile at 101 °F. Sedation was increased, and levetiracetam was loaded. The patient was too unstable for head imaging. Teleneurology consult and cvEEG were performed.

At this time in our hospital, PPE was being rationed. Despite the highly contagious nature of the COVID-19 (CDC April 2, 2020), the neurology team believed that the critical nature of the patient’s condition warranted an EEG, and therefore the test was ordered. All EEGs performed by our laboratory follow ACNS guidelines on EEG testing per standard protocol (Acharya et al. 2016; Kuratani et al. 2016; Sinha et al. 2016).

Many of the EEG technologists on duty at the time the test was ordered were in the high-risk category for COVID-19. Criteria that designates a staff member as high risk, per the CDC, includes people of advanced age, and those who have pulmonary, kidney, liver or cardiovascular disease, diabetes, are obese or immunocompromised, and those at any age who have a “serious underlying medical condition” (CDC March 31, 2020b).

Additionally, given the rationing of PPE, it was discouraged to have more than one EEG technologist in the room at a given time (CDC April 1, 2020a). Therefore, the decision was made that an experienced technologist, capable of troubleshooting any issues in a timely manner, perform the EEG. Thus, the EEG laboratory manager performed the routine EEG study. Below, she shares her experience:

As I walked through the doors to the new COVID-19 ICU unit, the nurses were busy just like in any ICU setting. The main difference, all the doors were shut completely. After putting on the PPE, I slid open the room door, walked in with the EEG system, and shut the door behind me. Before COVID-19, I had entered so many rooms over the years with patients in either contact, droplet and/or airborne isolation.

I performed each step of the EEG hookup as I was taught so many years ago. Measure, mark, clean, apply, glue and wrap the patient’s head. During this process I noticed that this ICU experience was different. The room had a noticeable ‘lack of activity.’ The nurses only entered

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for brief periods of time - just long enough to complete a medically necessary task. By the time I finished the hookup, I realized I had been in the room touching this patient for over an hour.

The routine EEG study was performed according our departmental policies which are based on the ACNS Guidelines. Photic stimulation and hyperventilation were not performed since the patient was comatose. The EEG machine was placed more than six feet away from the patient. Due to the nature of a diffuse encephalopathic pattern noted in this patient's EEG, the routine EEG was converted into a long-term bedside, continuous video-EEG (cvEEG) recording to assess for electrographic epileptiform abnormalities. The cvEEG recording lasted approximately 44 hours. No electrode maintenance was necessary due to preserved recording quality. Disposable EEG electrodes were used for this patient (*Ambu, Columbia, MD*).

Upon completion of the study, the EEG equipment was cleaned according to the most current hospital policy for COVID-19 infection control recommendations. This included cleaning the equipment in the room with hospital-approved Super Sani Cloth Germicidal wipes (*PDI Healthcare, Woodcliff Lake, NJ*) (EPA # 9480-4) (EPA April 2, 2020) and then by a nurse again outside the room prior to leaving the COVID unit. The equipment was then covered with a clean plastic drape and stored in a designated room for two weeks. This equipment quarantine period was chosen given the most current knowledge at the time (Lauer et al. 2020; CDC March 20, 2020); the survival period for COVID-19 on various surfaces was thought to last for days (potentially up to a week), and it was thought that an extended equipment quarantine for 14 days was reasonable. In order to minimize cross-contamination, a decision was also made by the medical directors and EEG lab managers to assign specific EEG machines for use only in COVID-19 units, following any updated sanitation protocols between patients.

DISCUSSION

It is vital to adapt processes for neurodiagnostic testing for the COVID-19 pandemic, a unique situation where infection prevention measures and patient management protocols continue to rapidly change (CDC April 1, 2020b). Some institutions may have already implemented alternative processes, but there is little to no literature published (at the time of this manuscript preparation) on these changes. Therefore, after our first experience with performing an EEG on a COVID-19 patient, we felt the need to share our experience and the changes we made to our testing protocols in order to help others, realizing this will likely be an iterative process.

At our facility, we have adopted two new protocols. The first is a protocol titled "Guidance on Neurodiagnostic Service Delivery during COVID-19 Outbreak" ([Appendix A](#)), which describes triage recommendations for suspected or confirmed COVID-19 patients based on the medical necessity of an EEG (CDC March 7, 2020). With aggressive social distancing and quarantine strategies, the objective of this protocol is to protect our patients

and staff, preserve PPE, minimize disease transmission and maintain patient throughput. Key considerations in decision-making regarding medical procedures should include:

- Urgency of procedure (medical necessity)
- Health and age of the patient
- Duration and proximity of staff exposure
- Current and projected COVID-19 cases in the facility and region causing demand for PPE
- Immediate supply of PPE available within a facility
- Staffing availability

Although it is true that some COVID-19 patients in the ICU have symptoms of a neurologic disorder, medical necessity to use EEG as a tool to guide patient treatment and management must be established. Non-urgent studies should be deferred, if possible, to a future date. EEG may be deemed necessary for cases of assessment and management of subclinical status epilepticus and cases of unexplained mental status, where EEG testing results could alter the medical management of the patient.

The second adopted protocol is titled “Modified EEG Recording Process: COVID-19 Protocol” ([Appendix B](#)). This document lays out a modified EEG protocol which limits the technologist’s exposure time with the patient. These steps may seem simple, but they delineate a clear approach to performing neurodiagnostic tests on these patients. For any PUI or positive COVID-19 patient, the revised EEG protocol includes the following:

- For a neurodiagnostic test to be performed, a Medical Justification Form ([see Appendix B, Figure B1](#)) is required of the ordering patient care team, approved by the interpreting neurologist, and placed in the patient chart.
- The Manager of Neurodiagnostics and Epilepsy will determine which technologist will perform the procedure. A risk assessment of each available employee will be performed by the Manager of Neurodiagnostics and Epilepsy to determine the appropriate person to perform the procedure (CDC March 31, [2020b](#)). Experienced EEG technologists will be preferred to perform procedures on these patients as a high level of judgment and critical thinking skills, and experience in recording and assessing the waveforms are needed. Also, real time troubleshooting skills in this critical situation are necessary in providing the optimal balance between quality and efficiency while minimizing collective staff exposure. If an appropriately skilled EEG technologist is not immediately available, then performing the procedure may be delayed until one is available.
- If possible, a specific portable video-EEG system will be assigned to be used with PUI or positive patients. This system may be stored on the unit designated for such patients.
- All appropriate PPE, following the current hospital policy, will be used by the EEG technologist to complete the procedure.

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- If possible (e.g. not on a ventilator), ensure that the patient is also wearing a N95 mask.
- If the patient has received a nebulizer treatment, the study will be delayed by at least four hours, if possible, to reduce the chance of potential airborne transmission created during the nebulizer treatment (CDC April 1, 2020a).
- The portable video-EEG system will be kept outside of the patient room, if facility and workflow allow for it.
- A reduced array of disposable electrodes (ACNS March 25, 2020) will be applied with paste and tape instead of collodion; in addition, applying a head wrap will be considered to help secure the electrodes. Electrode placement will be documented in the EEG per ACNS guideline 1.
- Depending on the patient's clinical presentation, a minimum of 8 electrodes will be used with the following electrodes (see Appendix B, Figure B2) preferred due to their ease of application and relative high utility in screening for clinically relevant EEG abnormalities as shown by other authors (Gururangan et al. 2018; McKay et al. 2019; Rubin et al. 2013; Tanner et al. 2014; Westover et al. 2020).
 - Left: Fp1, F7, T7, P7, O1, C3
 - Right: Fp2, F8, T8, P8, O2, C4
 - Midline: Cz
 - EKG, Ground, and Reference
- Verbal and tactile stimulation activation procedures may be performed if clinically appropriate.
- Hyperventilation and photic stimulation activation procedures will not be routinely performed.
- At this point, the EEG technologist will exit the patient room.
- The EEG monitoring technologist will immediately start monitoring the live study remotely and annotate the EEG, marking any clinically or electrographically relevant areas. If no EEG monitoring technologist is available, then the EEG technologist will proceed with the next step and contact the interpreting physician.
- The interpreting physician will be immediately notified that the study is up and running, and the interpreting physician will immediately review the live study remotely.
- The EEG recording will be acquired for a minimum of 20 minutes.
- If the EEG must be recorded for a longer time period (i.e. converted to a cvEEG), the EEG technologist may leave the unit unless any additional electrodes are needed per interpreting physician's request or to better secure the leads. If further setup needs are required, the technologist will need to re-don PPE and reenter the patient's room to address such issues. The expectation is that the EEG technologist will infrequently need to reenter the room.

- The cvEEG will be monitored remotely by the EEG monitoring technologist and will be reviewed remotely by the interpreting physician as clinically required.
- Electrode maintenance may not be performed daily depending on EEG recording quality, PPE supply, and clinical situation.
- The cvEEG recording should be discontinued as soon as medically possible.
- EEG equipment will be cleaned following CDC guidelines (CDC April 1, 2020c).

After the first iteration of the revised procedures and protocols were completed, the authors wanted to assess the potential impact these changes might have on reducing the exposure time between the EEG technologist and the patient. A resulting time analysis was developed evaluating the timestamps for various EEG setup and takedown activities (Figure 1 and Table 1). Our standard EEG protocol requires that the setup and takedown activity be recorded on all EEGs, allowing us to do such a time analysis retrospectively. To reduce the variability, the same EEG technologist that performed the test on the COVID-19 patient also performed the modified protocol but on a healthy individual to eliminate unnecessary patient exposure. The same donning and doffing PPE and isolation protocols and procedures were followed. Donning was done outside of the patient room. Doffing was done inside the patient room.

There was an overall reduction in time exposure (99 min vs 51 min) from setup to takedown. There was a notable reduction in time during the EEG setup (76 min vs 33 min). During the setup, the majority of time reduction (60 min vs 33 min) was attributed to electrode application and running of the routine EEG. There was a slight reduction in time appreciated during the EEG takedown (10 min vs 8 min).

The difference in the EEG setup time is likely due to the reduced electrode array as well as the application with paste/tape rather than collodion. The difference in the EEG takedown time is likely due to the reduced number of electrodes that needed removal as well as the procedure to remove the electrodes (e.g. no need for collodion remover, etc.). Of note, our COVID-19 patient had relatively sparse hair compared to our healthy control, which likely underestimated the time saved in our modified protocol as compared to the standard protocol. Other limitations of this time analysis include the small sample size as we compared only one test in each category done by a single EEG technologist. We have started to collect more data and will be able to better compare the two methods in the future. The strength of this time analysis is the built-in internal control as the same technologist was utilized in both the standard and modified protocol.

CONCLUSIONS

These are trying times presenting with unprecedented circumstances which require us to alter how we care for our patients. The increased neurological sequelae seen with COVID-19 will likely increase the need for neurodiagnostic studies, such as EEG. Our experience

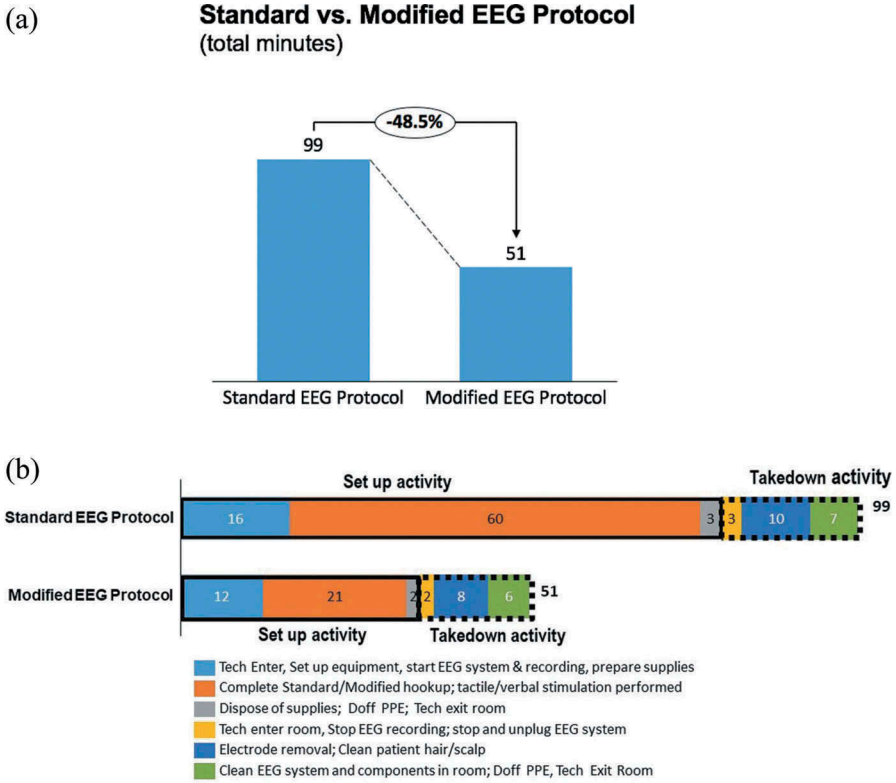


FIG. 1. Time analysis.

with performing a cvEEG following our standard procedures and protocols lead to increased concern of potentially unnecessary patient exposure time. The modified protocols and procedures have limited the studies to be done only on selected patients. In addition, for these studies, the authors believe the modifications will lead to a reduced exposure time without a clinically relevant compromise in EEG quality. Based on previous studies, the reduced electrode array has been shown to have high specificity but limited sensitivity (Gururangan et al. 2018; McKay et al. 2019; Rubin et al. 2013; Tanner et al. 2014; Westover et al. 2020). The electrode choice is an evolving process for us, and additional electrodes could be applied as needed. Other options to consider are the use of subhairline arrays, disposable EEG caps or bands. The authors want to emphasize that the modifications will likely continue to evolve with experience. We hope that this manuscript stimulates ideas and collaboration. In the end, our goal is to continue to deliver high quality patient care while decreasing patient exposure times and optimizing resource utilization; this will allow us to not only take care of patients but take care of each other as well. Stay safe.

Table 1. Time analysis.

Standard EEG Protocol on 1ST COVID Patient			
Standard EEG (Collodion)	Process activity	Time per activity (min)	Cumulative exposure time (min)
Hookup process	Tech enter room , set up equipment, start EEG system & recording, prepare supplies	16	16
	Full 10/20 Collodion hookup completed; verbal/tactile stimulation performed	60	76
	Dispose of supplies; doff PPE; Tech exit room	3	79
Removal process	Tech enter room , stop EEG recording; stop and unplug EEG system	3	82
	Electrode removal; clean patient hair/scalp	10	92
	Clean EEG system and components in room; doff PPE, Tech exit room	7	99
Total Tech Exposure Time			99
MODIFIED PROCESS TO DECREASE TECH EXPOSURE TIME			
Modified EEG (Paste/Tape)	Process activity	Time per activity (min)	Cumulative exposure time (min)
Hookup process	Tech enter room , set up equipment, start EEG system & recording, prepare supplies	12	12
	Modified 10/20 Paste/Tape hookup completed; verbal/tactile stimulation performed	21	33
	Dispose of supplies; doff PPE; Tech exit room	2	35
Removal process	Tech enter room , stop EEG recording; stop and unplug EEG system	2	37
	Electrode removal; clean patient hair/scalp	8	45
	Clean EEG system and components in room; doff PPE, Tech exit room	6	51
Total Tech Exposure Time			51

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Acharya JN, Hani AJ, Thirumala PD, Tsuchida TN. 2016. American clinical neurophysiology society guideline 3: A proposal for standard montages to be used in clinical EEG. J Clin Neurophysiol. Aug;33(4):312–316.

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- Adams JG, Walls RM. Published online 2020 Mar 12. Supporting the health care workforce during the COVID-19 global epidemic. *JAMA*. doi:10.1001/jama.2020.3972.
- American Clinical Neurophysiology Society (ACNS). 2020 Mar 25. *COVID-19 resources*. ACNS.org. [accessed 2020 Mar 31]. <https://www.acns.org/practice/covid-19-resources>.
- Baker P, Sullivan E 2020 Mar 17. *U.S. Virus plan anticipates 18-month pandemic and widespread shortages*. The New York Times. [accessed 2020 Apr 2]. <https://www.nytimes.com/2020/03/17/us/politics/trump-coronavirus-plan.html>.
- Bonner AM, Davidson P. 2020. Infection Prevention: 2020 review and update for neurodiagnostic technologists. *Neurodiagn J*. 60(1):11–35.
- Centers for Disease Control and Prevention (CDC). 2020a. *Healthcare supply of personal protective equipment*. Last reviewed: March 12, 2020. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/healthcare-supply-ppe-index.html>.
- Centers for Disease Control and Prevention (CDC). *Interim infection prevention and control recommendations for patients with suspected or confirmed coronavirus disease 2019 (COVID-19) in healthcare settings*. Last reviewed: 2020a Apr 1. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html>.
- Centers for Disease Control and Prevention (CDC). *Prepare your practice for COVID-19*. Last reviewed: 2020a Mar 31. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html>.
- Centers for Disease Control and Prevention (CDC). *Coronavirus disease 2019 (COVID-19) for healthcare professionals*. Last reviewed: 2020b Apr 1. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/caring-for-patients.html>.
- Centers for Disease Control and Prevention (CDC). *How COVID-19 Spreads*. Last updated 2020b Apr 2. CDC.gov. [accessed 2020 Apr 2]. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fcoronavirus%2F2019-ncov%2Fprepare%2Ftransmission.html.
- Centers for Disease Control and Prevention (CDC). *People who are at higher risk for severe illness*. Last updated: 2020b Mar 31. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-at-higher-risk.html>.
- Centers for Disease Control and Prevention (CDC). *Cleaning and disinfecting your facility*. Last updated 2020c Apr 1. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/prepare/disinfecting-building-facility.html>.
- Centers for Disease Control and Prevention (CDC). *Interim clinical guidance for management of patients with confirmed coronavirus disease (COVID-19)*. Last updated: 2020c Mar 20. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/clinical-guidance-management-patients.html>.
- Centers for Disease Control and Prevention (CDC). *Interim U.S. guidance for risk assessment and public health management of healthcare personnel with potential exposure in a healthcare setting to patients with coronavirus disease (COVID-19)*. 2020d Mar 7. CDC.gov. [accessed 2020 Apr 2]. <https://www.cdc.gov/coronavirus/2019-ncov/hcp/guidance-risk-assessment-hcp.html>.
- Chen T, Wu D, Chen H, Yan W, Yang D, Chen G, Ma K, Xu D, Yu H, Wang H, et al. 2020. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. *BMJ*. Mar;26(368):m1091.
- Environmental Protection Agency. *List N: disinfectants for use against SARS-CoV-2*. Last updated 2020 Apr 2. [accessed 2020 Apr 3]. <https://www.epa.gov/pesticide-registration/list-n-disinfectants-use-against-sars-cov-2>.
- Gupta PK, Caccamo A, Haines S, Mentreddi A, Sawhney H, Chan F. (in preparation). Electroencephalographic findings in a COVID-19 patient with a febrile convulsive event.
- Gururangan K, Razavi B, Parvizi J. 2018. Diagnostic utility of eight-channel EEG for detecting generalized or hemispheric seizures and rhythmic periodic patterns. *Clin Neurophysiol Pract*. Mar;26(3):65–73.
- Kamal R, Kurani N, McDermott CC *How prepared is the US to respond to COVID-19 relative to other countries?* Peterson-KFF Health System Tracker. 2020 Mar 27. [accessed 2020 Apr 2]. <https://www.healthsystemtracker.org/chart-collection/how-prepared-is-the-us-to-respond-to-covid-19-relative-to-other-countries/#item-start>.

- Kuratani J, Pearl PL, Sullivan L, Riel-Romero RM, Cheek J, Stecker M, San-Juan D, Selioutski O, Sinha SR, Drislane FW, et al. 2016. American clinical neurophysiology society guideline 5: minimum technical standards for pediatric electroencephalography. *J Clin Neurophysiol.* Aug;33(4):320–323.
- Lauer SA, Grantz KH, Bi Q, Jones FK, Zheng Q, Meredith HR, Azman AS, Reich NG, Lessler J. 2020 Mar 10. The incubation period of coronavirus disease 2019 (COVID-19) from publicly reported confirmed cases: estimation and application. *Ann Intern Med.* doi:10.7326/M20-0504. [Epub ahead of print].
- Li YC, Bai WZ, Hashikawa T. 2020 Feb 27. The neuroinvasive potential of SARS-CoV2 may play a role in the respiratory failure of COVID-19 patients. *J Med Virol.* doi:10.1002/jmv.25728. [Epub ahead of print].
- Mao L, Wang M, Chen S, He Q, Chang J, Hong C, Zhou Y, Wang D, Li Y, Jin H, et al. Neurological manifestations of hospitalized patients with COVID-19 in Wuhan, China: a retrospective case series study. 2020 Feb 25. *Medrxiv.org.* [accessed 2020 Apr 3]. <https://www.medrxiv.org/content/10.1101/2020.02.22.20026500v1>.
- McKay JH, Feyissa AM, Sener U, D'Souza C, Smelick C, Spaulding A, Yelvington K, Tatum WO. 2019. Time is brain: the use of EEG electrode caps to rapidly diagnose nonconvulsive status epilepticus. *J Clin Neurophysiol.* Nov;36(6):460–466.
- Rabin RC *Some coronavirus patients show signs of brain ailments.* The New York Times. 2020 Apr 1. [accessed 2020 Apr 3]. <https://www.nytimes.com/2020/04/01/health/coronavirus-stroke-seizures-confusion.html>.
- Root A *Covid-19 hospitalizations rise in U.S. as global million-case mark nears.* 2020 Mar 30. *Barrons.com.* [accessed 2020 Apr 2]. <https://www.barrons.com/articles/covid-19-hospitalizations-rise-in-u-s-as-global-million-case-mark-nears-51585570472>.
- Rubin MN, Jeffery OJ, Fugate JE, Britton JW, Cascino GD, Worrell GA, Hocker SE, Wijdicks EF, Rabinstein AA. 2013. Efficacy of a reduced electroencephalography electrode array for detection of seizures. *Neurohospitalist.* Jan;4(1):6–8.
- Sinha SR, Sullivan L, Sabau D, San-Juan D, Dombrowski KE, Halford JJ, Hani AJ, Drislane FW, Stecker MM. 2016. American clinical neurophysiology society guideline 1: minimum technical requirements for performing clinical electroencephalography. *J Clin Neurophysiol.* Aug;33(4):303–307.
- Talan J COVID-19: *neurologists in Italy to colleagues in US: look for poorly-defined neurologic conditions in patients with the coronavirus.* *Neurology Today.* 2020a Mar 27. [accessed 2020 April 3]. <https://journals.lww.com/neurotodayonline/blog/breakingnews/pages/post.aspx?PostID=920>.
- Talan J *First case report of acute necrotizing encephalopathy associated with COVID-19.* *Neurology Today.* 2020b Apr 1. [accessed 2020 Apr 3]. <https://journals.lww.com/neurotodayonline/blog/breakingnews/pages/post.aspx?PostID=926>.
- Tanner AE, Särkelä MO, Virtanen J, Viertiö-Oja HE, Sharpe MD, Norton L, Davies-Schinkel C, Young GB. 2014. Application of subhairline EEG montage in intensive care unit: comparison with full montage. *J Clin Neurophysiol.* Jun;31(3):181–186.
- Westover MB, Gururangan K, Markert MS, Blond BN, Lai S, Benard S, Bickel S, Hirsch LJ, Parvizi J. 2020 Feb 7. Diagnostic value of electroencephalography with ten electrodes in critically ill patients. *Neurocrit Care.* doi:10.1007/s12028-019-00911-4. [Epub ahead of print].
- Zhou L, Zhang M, Gao J, Wang J. 2020 Mar 24. Sars-Cov-2: underestimated damage to nervous system. *Travel Med Infect Dis.* 101642. doi:10.1016/j.tmaid.2020.101642. [Epub ahead of print].

APPENDIX A. GUIDANCE ON NEURODIAGNOSTIC (EEG) SERVICE DELIVERY DURING COVID-19 OUTBREAK

Version 1.0 – March 26, 2020

Neurodiagnostic Service (EEG and Long Term Video EEG)

Updates & Versioning

Version	Date/Time	Summary of Updates
1	3/26/20	Initial Document Created
2	4/4/20	Details of Key Considerations Updated
3		
4		
5		
6		
7		

PURPOSE

This guidance is intended to clarify the protocol for performance of Neurodiagnostic Procedures (extra operative EEG and Evoked Potential procedures) during the COVID –19 outbreak for procedures being performed on patients who are:

- under investigation for COVID-19 (PUI)
- COVID-19 confirmed patients

Intended for:

- Hospital Leadership
- Physicians

PROCEDURE

1. Only studies deemed medically essential will be performed on a Patient Under Investigation (PUI) or patient with positive COVID-19 status.
2. If the procedure is thought to be medically essential, the requesting physician should complete the Surgical or Medical Justification for Procedure Form.
3. Hospital medical staff, neurologist attending/reading, and Neurodiagnostics (EEG/EMU) medical director should weigh the value of the procedure vs other key considerations.
4. Only orders that have been vetted and approved with the “Medical Justification Form” and by the Neurology consultant/EEG Reader will be performed.

KEY CONSIDERATIONS

1. Length and proximity of EEG staff exposure: For patients with known or suspected COVID-19 infection, we have seen conflicting guidance as to whether droplet precautions are sufficient or whether higher-level “airborne precautions” are necessary. EEG technologists can typically take 30 minutes to 1 hour to set up and 20 minutes to remove leads while in close proximity to a patient’s head/face. For long term EEG, the possibility of multiple entrances over time to a patient room is a consideration as well. Please refer to “Revised EEG Recording Process” for a modified process and procedures in performing an EEG on a patient.
2. Current and projected COVID-19 cases in the facility and region: Adhere to current hospital recommendations at the time of study.
3. Supply of PPE available to the facilities in the system: Adhere to current hospital recommendations at the time of study.
4. Staffing availability: The Epilepsy Program Manager or Manager of Neurodiagnostics and Epilepsy will determine which Technologist will perform the procedure. A risk assessment of each available employee will be performed by the Epilepsy Program Manager or Manager of Neurodiagnostics and Epilepsy to determine the appropriate person to perform the procedure (CDC March 31, 2020). Experienced EEG Technologists will be preferred to perform procedures on these patients as a high level of judgement/critical thinking skills, experience in recording the waveforms, and assessing the criticality of the situation is needed in this setting to provide the highest quality, most efficient patient care and decrease staff exposure time to the patient. If for some reason an appropriate EEG Technologist is not available, then performing the procedure may be delayed until an appropriate EEG Technologist is available.
5. Urgency of procedure: For a neurodiagnostic test to be performed, a Medical Justification form (Figure 1) needs to be filled out by the ordering patient care team, approved/cleared by the interpreting neurologist, and placed in the patient chart.
6. Health and age of the patient, especially given the risks of concurrent COVID-19 infection during recovery.

We will update these recommendations as further guidance is issued.

APPENDIX B. REVISED EEG PROCEDURES DURING A COVID-19 OUTBREAK

Modified EEG Recording Process COVID-19 Protocol

Version 2.0, April 3, 2020

Version 1.0, March 26, 2020

This protocol is to guide the Neurodiagnostic Service Line with the steps/actions needed to complete a procedure on a patient who is presumptive positive (i.e. Patient Under Investigation (PUI)) or positive for any pandemic outbreak, including but not limited to the COVID-19. Adhere to the following steps as best as possible when performing EEG or cEEG procedures, realizing that deviations may arise for patient specific reasons:

- For a neurodiagnostic test to be performed, a Medical Justification Form (Figure B1) needs to be filled out by the ordering patient care team, approved by the interpreting neurologist, and placed in the patient chart.
- The Manager of Neurodiagnostics and Epilepsy will determine which technologist will perform the procedure. A risk assessment of each available employee will be performed by the Manager of Neurodiagnostics and Epilepsy to determine the appropriate person to perform the procedure (CDC March 31, 2020b). Experienced EEG technologists will be preferred to perform procedures on these patients as a high level of judgment and critical thinking skills, and experience in recording and assessing the waveforms are needed. Also, real time troubleshooting skills in this critical situation are necessary in providing the optimal balance between quality and efficiency while minimizing collective staff exposure. If an appropriately skilled EEG technologist is not immediately available, then performing the procedure may be delayed until one is available.
- If possible, a specific portable video-EEG system will be assigned to be used with PUI or positive patients. This system may be stored on the unit designated for such patients.
- All appropriate PPE, following the current hospital policy, will be used by the EEG technologist to complete the procedure.
- If possible (e.g. not on a ventilator), ensure that the patient is also wearing a N95 mask.
- If the patient has received a nebulizer treatment, the study will be delayed by at least four hours, if possible, to reduce the chance of potential airborne transmission created during the nebulizer treatment (CDC April 1, 2020a).
- The portable video-EEG system will be kept outside of the patient room, if facility and workflow allow for it.

Surgical or Medical Justification for Procedure Form

I Dr. _____ MD/DO need to perform on ___/___/___

The following procedure _____

On patient _____

D.O.B ___/___/___

The reason this procedure is urgent or cannot be postponed is _____

The condition the patient has that must be addressed in an urgent manner is: _____

Signed

On date: ___/___/___

FIG. B1. Medical justification form.

- A reduced array of disposable electrodes (ACNS March 25, 2020) will be applied with paste and tape instead of collodion; in addition, applying a head wrap will be considered to help secure the electrodes.
- A minimum of 8 electrodes will be used, with the following electrodes (Figure B2) preferred due to their ease of application and relative high utility in screening for clinically relevant EEG abnormalities as shown by other authors (Gururangan et al. 2018; McKay et al. 2019; Rubin et al. 2013; Tanner et al. 2014; Westover et al. 2020).
 - Left: Fp1, F7, T7, P7, O1, C3
 - Right: Fp2, F8, T8, P8, O2, C4

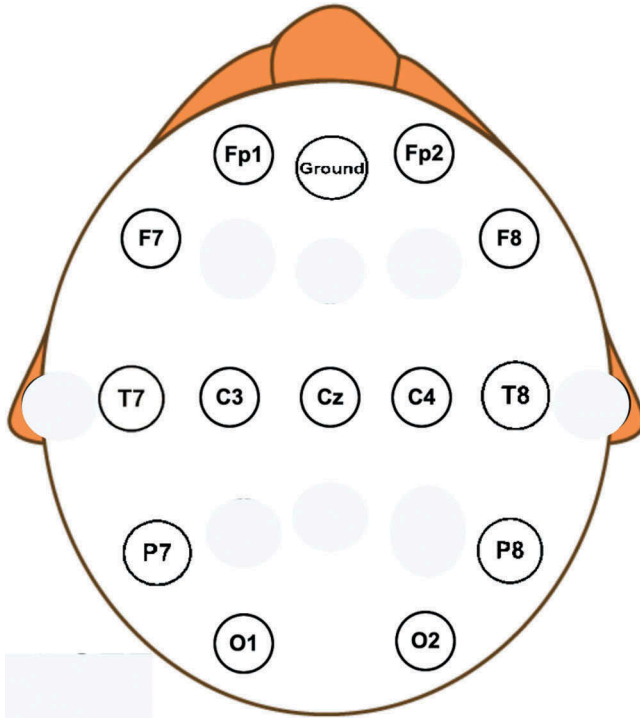


FIG. B2. Proposed reduced electrode array.

- Midline: Cz
- EKG, Ground, and Reference
- The process of performing the 10/20 system of measurement may be abbreviated for electrodes being placed. Electrode placement will be documented in the EEG per ACNS guideline 1.
- Verbal and tactile stimulation activation procedures may be performed if clinically appropriate.
- Hyperventilation and photic stimulation activation procedures will not be routinely performed.
- At this point, the EEG technologist will exit the patient room.
- The EEG monitoring technologist will immediately start monitoring the live study remotely and annotate the EEG, marking any clinically or electrographically relevant areas. If no EEG monitoring technologist is available, then the EEG technologist will proceed with the next step and contact the interpreting physician.

- The interpreting physician will be immediately notified that the study is up and running, and the interpreting physician will immediately review the live study remotely.
- The EEG recording will be acquired for a minimum of 20 minutes.
- If the EEG must be recorded for a longer time period (i.e. converted to a cvEEG), the EEG technologist may leave the unit unless any additional electrodes are needed per interpreting physician's request or to better secure the leads. If further setup needs are required, the technologist will need to re-don PPE and reenter the patient's room to address such issues. The expectation is that the EEG technologist will infrequently need to reenter the room.
- The cvEEG will be monitored remotely by the EEG monitoring technologist and will be reviewed remotely by the interpreting physician as clinically required.
- Electrode maintenance may not be performed daily depending on EEG recording quality, PPE supply, and clinical situation.
- The cvEEG recording should be discontinued as soon as medically possible.
- EEG equipment will be cleaned following CDC guidelines (CDC April 1, 2020 c).

References:

1. American Clinical Neurophysiology Society (ACNS). *COVID-19 Resources*. March 25, 2020b. ACNS.org. Accessed March 31, 2020. Retrieved from: <https://www.acns.org/practice/covid-19-resources>
2. Centers for Disease Control and Prevention (CDC). *People who are at higher risk for severe illness*. Last updated: March 31, 2020b. CDC.gov. Accessed: April 2, 2020. Retrieved from: <https://www.cdc.gov/coronavirus/2019-ncov/need-extra-precautions/people-at-higher-risk.html>
3. Centers for Disease Control and Prevention (CDC). *Interim Infection Prevention and Control Recommendations for Patients with Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings*. Last reviewed: April 1, 2020a. CDC.gov. Accessed April 2, 2020. Retrieved from: <https://www.cdc.gov/coronavirus/2019-ncov/infection-control/control-recommendations.html>
4. Centers for Disease Control and Prevention (CDC). *Cleaning and Disinfecting Your Facility*. Last updated April 1, 2020c. Accessed April 2, 2020. Retrieved from: <https://www.cdc.gov/coronavirus/2019-ncov/prepare/disinfecting-building-facility.html>
5. Gururangan K, Razavi B & Parvizi J. Diagnostic utility of eight-channel EEG for detecting generalized or hemispheric seizures and rhythmic periodic patterns. *Clin Neurophysiol Pract*. 2018 Mar 26;3:65–73.
6. McKay JH, Feyissa AM, Sener U, D'Souza C, Smelick C, Spaulding A, Yelvington K, Tatum WO. Time Is Brain: The Use of EEG Electrode Caps

- to Rapidly Diagnose Nonconvulsive Status Epilepticus. *J Clin Neurophysiol*. 2019 Nov;36(6):460–6.
7. Rubin MN, Jeffery OJ, Fugate JE, Britton JW, Cascino GD, Worrell GA, Hocker SE, Wijdicks EF, Rabinstein AA. Efficacy of a reduced electroencephalography electrode array for detection of seizures. *Neurohospitalist*. 2013 Jan;4(1):6–8.
 8. Tanner AE, Särkelä MO, Virtanen J, Viertiö-Oja HE, Sharpe MD, Norton L, Davies-Schinkel C, Young GB. Application of subhairline EEG montage in intensive care unit: comparison with full montage. *J Clin Neurophysiol*. 2014 Jun;31(3):181–6.
 9. Westover MB, Gururangan K, Markert MS, Blond BN, Lai S, Benard S, Bickel S, Hirsch LJ, Parvizi J. Diagnostic value of electroencephalography with ten electrodes in critically ill patients. *Neurocrit Care*. 2020 Feb 7. doi: 10.1007/s12028-019-00911-4. [Epub ahead of print]