Original article

Epileptic Disord 2020; 22 (5): 548-54

The COVID-19 outbreak and approaches to performing EEG in Europe

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Received June 15, 2020; Accepted August 21, 2020

ABSTRACT – *Aims.* The coronavirus SARS-CoV-2 disease (COVID-19) pandemic affects availability and performance of neurophysiological diagnostic methods, including EEG. Our objective was to outline the current situation regarding EEG-based investigations across Europe.
Methods. A web-based survey was distributed to centres within the European Reference Network on rare and complex epilepsies (ERN EpiCARE). Responses were collected between April 9 and May 15, 2020. Results were analysed with Microsoft Excel, Python Pandas and SciPy.
Results. Representants from 47 EpiCARE centres from 22 countries completed the survey. At the time of completing the survey, inpatient video-EEGs had been stopped or restricted in most centres (61.7% vs. 36.2% for adults, and 38.3% vs. 53.2% for children). Invasive investigations and epilepsy surgery were similarly affected. Acute EEGs continued to be performed, while indications for outpatient EEGs were limited and COVID-19 triage put in place. The strictness of measures varied according to extent of the outbreak in a given country.
Conclusions. The results indicate a profound impact of COVID-19 on neurophysiological diagnostics, especially inpatient video-EEGs, invasive investigations, and epilepsy surgery. The COVID-19 pandemic may hamper care for patients in need of EEG-based investigations, particularly patients with seizure disorders. ERN EpiCARE will work on recommendations on how to rapidly adapt to such situations in order to alleviate consequences for our patients.

Key words: coronavirus, electroencephalography, epilepsy, epilepsy surgery, video-EEG

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doi:10.1684/epd.2020.1208

Novel coronavirus SARS-CoV-2 disease (COVID-19) affects health-care systems all over the world. Health-care resources available for non-COVID-19 patients, including patients in need of neurophysiological investigations, are constrained - partly shifted to COVID-19 patients and partly reduced to limit virus spread. Different regulations were implemented in different countries, reflecting continuously updated science on SARS-CoV-2, local extent and pace of the pandemic, available resources, and local traditions. Policies regarding neurophysiological investigations, including EEG, may vary.

Questions about approaches to EEG-based investigations during the COVID-19 pandemic were raised within the Clinical Neurophysiology group of the European Reference Network on rare and complex epilepsies (ERN EpiCARE). Dense e-mail communication culminated in an EpiCARE-endorsed webinar entitled "COVID-19 outbreak and policies for performing EEGs", held on April 6, 2020. A survey of approaches to EEG among EpiCARE centres was proposed.

Methods

The survey included a web-based questionnaire with 17 multiple-choice questions (comments allowed). Link to the survey was sent to all clinical neurophysiology representants within ERN EpiCARE. The representants responded at different time-points between April 9 and May 15, 2020. Forty-seven ERN EpiCARE centres from 22 countries were represented (several countries were represented by multiple centres) - see *table 1*.

Results were analysed with Microsoft Excel, Python Pandas and SciPy. For statistical evaluation, the number of COVID-19-related deaths per million at the time of survey completion in different countries (source: https://ourworldindata.org/coronavirus-source-data. Accessed 2020-05-22) was transformed into four categories based on its interquartile ranges (0.0-0.25: very low number of deaths per million; 0.25-0.5: low number of deaths per million; 0.5-0.75: high number of deaths per million; 0.75-1.0: very high number of deaths per million). The Chi-square test was used to compare categorical variables.

Results

Table 2 summarises the responses. Prior to the COVID-19 outbreak, 89.4% of centres performed both diagnostic and pre-surgical scalp video-EEGs and 63.8% performed invasive video-EEGs. Eleven centres carried out investigations only in children, three in adults, and 32 in both. At survey completion, the extent of the pandemic varied among participating countries (*figure 1*).

In most centres, inpatient scalp video-EEGs were stopped (adults: 61.7%, children: 38.3%) or reduced (adults: 36.2%, children: 53.2%). When restricted, video-EEGs were performed in "urgent situations" or only for diagnostic (*i.e.* not pre-surgical) indications. Invasive investigations were stopped in 80.0% (24/30) of centres where they were performed.

Epilepsy surgery was discontinued in 63.8% of centres and reduced in 31.9%. When continued, children were more often operated on than adults. Selection criteria included urgent cases with severe seizure situation, tumours and epileptic encephalopathies. Continuing of awake epilepsy surgeries was specifically mentioned by one centre in a comment. One centre also specifically mentioned that a negative SARS-CoV-2 PCR test was mandatory before surgery.

Outpatient routine EEGs continued in 74.5% of centres, mostly with restricted indications (70.2%), often limited to "urgent cases" - judged by a clinical neurophysiologist or treating physician. Common indications included first seizure in life, an increased number of seizures or significant change from baseline status, follow-up for electrical *status epilepticus* during sleep, diagnosis and follow-up in infantile spasms, or neonatal EEGs. All centres except one implemented a triage based on asking questions about clinical symptoms of COVID-19 and risks associated with exposure (anamnestic triage); in 34.3% of centres, the patients' temperature was taken as well. In two centres, a negative SARS-CoV-2 PCR test was mandatory before EEG. Information about patients' COVID-19 status (confirmed, suspected, or no reason to suspect) in referral letter was required in two centres. Accompanying persons were generally discouraged. The majority of centres (74.5%) used personal protective equipment (PPE) during outpatient EEGs, including masks, gloves, and plastic aprons. Five centres used full PPE; the same as that worn by COVID-19 patients. Three centres reported a lack of PPE.

Hyperventilation (HV) was not performed in 42.6% centres, but was performed in 12 centres with precautions, such as the technician being at least two meters from the patient, the technician being behind a glass screen, asking the patient to wear a mask, or only testing patients with a negative SARS-CoV-2 PCR test. Several centres reported that they would consider a change in approach to HV after completing the survey. Of the centres, 74.5% reported asking patients with unknown COVID-19 status to wear a face mask. In some countries, wearing a mask in public was obligatory.

Acute EEGs were performed in all centres. Suspected non-convulsive *status epilepticus* (NCSE), infantile spasms, neonatal EEGs, encephalopathy of unknown

Table 1. List of participating centres and respondents (in alphabetical order per country).

Institution. *Country.*	**Representative**
Center for Pediatric Epilepsy, Dpt. of Pediatrics, Medical University of Vienna. *Austria*.	Martha Feucht, MD
Department of Neurology, Christian Doppler Medical Center, Paracelsus Medical University and Center for Cognitive Neuroscience, Salzburg. *Austria*.	Eugen Trinka, MD MSc
University Hospital Gasthuisberg KU Leuven. *Belgium*.	Lieven Lagae, MD PhD
EpiCARE Croatia UHC Sestre milosrdnice, Zagreb. *Croatia*.	Masa Malenica, MD PhD
Department of Neurology, School of Medicine, University Hospital Centre Zagreb. *Croatia*.	Željka Petelin Gadže, MD PhD
Epilepsy Centre, The Cyprus Institute of Neurology and Genetics, Nicosia. *Cyprus*.	Savvas Papacostas, MD
Motol University Hospital, Prague. *Czech Republic*.	Petr Marusic, MD PhD
St. Anne's University Hospital, Brno. *Czech Republic*.	Ondrej Strycek, MD
Danish Epilepsy Centre, Dianalund. *Denmark*.	Sándor Beniczky, MD PhD
Aarhus University Hospital, Aarhus. *Denmark*.	Sándor Beniczky, MD PhD
Tallin Children's Hospital, Tallin. *Estonia*.	Inga Talvik, MD PhD
Tartu University Hospital, Tartu. *Estonia*.	Ulvi Vaher, MD
Kuopio University Hospital, Kuopio. *Finland*.	Reetta Kälviäinen, MD PhD
Pediatric Epilepsy Department Lyon. *France*.	Alexis Arzimanoglou, MD
CHRU LILLE, Epilepsy Unit, Lille. *France*.	Philippe Derambure, MD PhD
Necker-Enfants Malades, Paris. *France*.	Anna Kaminska, MD PhD
Department of Epileptology, University Hospital Bonn. *Germany*.	Attila Racz, MD PhD
Epilepsy Centre, University Hospital Freiburg. *Germany*.	Andreas Schulze-Bonhage, MD
National Institute of Clinical Neurosciences, Budapest. *Hungary*.	Anna Kelemen, MD PhD
C. Munari Epilepsy Surgery Centre, Milan. *Italy*.	Laura Tassi, MD
San Paolo Hospital Epilepsy Center (DDEP), Milan. *Italy*.	Maria Paola Canevini, MD PhD
Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan. *Italy*.	Tiziana Granata, MD
Ospedale Pediatrico Bambino Gesù, Roma. *Italy*.	Luca De Palma, MD
Fondazione Istituto Neurologico Nazionale Casimiro Mondino, Pavia. *Italy*.	Valentina De Giorgis, MD
IRCCS Institute of Neurological Sciences of Bologna (INSB)-AUSL di Bologna. *Italy*.	Francesca Bisulli, MD PhD
Azienda Ospedaliero-Universitaria A. Meyer, UO Neurologia Pediatrica, Florence. *Italy*.	Carmen Barba, MD PhD
University Children's Clinical Hospital, Riga. *Latvia*.	Juģis Strautmanis, MD
Department of Neurology, Institute of Clinical Medicine, Faculty of Medicine, Vilnius University. *Lithuania*.	Rūta Mameniškienė, MD PhD
Hospital of the Lithuanian University of Health Sciences Kaunoklinikos. *Lithuania*.	Giedrė Gelžinienė, MD

Table 1. List of participating centres and respondents (in alphabetical order per country) (*continued*).

Institution. *Country.*	**Representative**
Mater Dei Hospital. *Malta*.	Nicola Dingli, MD MSc MRCP
L-Università ta' Malta. *Malta*.	Stephen Attard, MD MRCPCH MSc
University Medical Center Utrecht, Brain Centre Rudolf Magnus, Utrecht. *Netherlands*.	Sandra M A van der Salm, MD PhD MSc
The Children's Memorial Health Institute, Warsaw. *Poland*.	Dorota Domańska-Pakieła, MD PhD
Unidade Epilepsia Centro Hospitalar Universitário Porto. *Portugal*.	A Martins de Silva, MD PhD
CHUC - Centro Hospitalar Universitário de Coimbra. *Portugal*.	Francisco Sales, MD
Centro de Referencia de Epilepsias Refractrias, Hospital de Santa Maria, Lisbon. *Portugal*.	Carla Bentes, MD PhD
Alexandru Obregia Clinical Hospital, Bucharest. *Romania*.	Dana Craiu, MD PhD
Alexandru Obregia Clinical Hospital, Bucharest. *Romania*.	Oana Tarta-Arsene, MD PhD
Hospital Universitario y Politecnico La Fe, Valencia. *Spain*.	Vicente Villanueva, MD PhD
Hospital Del Mar-Parc de Salut Mar, Barcelona. *Spain*.	Rodrigo Alberto Rocamora Zuniga, MD PhD
Hospital Sant Joan de Deu Hospital Clinic, Barcelona. *Spain*.	Javier Aparicio Calvo, MD
Sahlgrenska University Hospital, Gothenburg. *Sweden*.	David Krysl, MD PhD
National Hospital for Neurology and Neurosurgery, University College London Hospitals NHS Foundation Trust. *UK*.	Matthew Walker, MA MB BChir PhD FRCP
Great Ormond Street Hospital for Children NHS Trust, London. *UK*.	Rachel Thornton, MD PhD
Queen Elizabeth University Hospital Campus, Glasgow. *UK*.	Sameer Zuberi, MD
Oxford University Hospitals NHS Foundation Trust, Oxford. *UK*.	Sidra Aurangzeb, MD
Oxford University Hospitals NHS Foundation Trust, Oxford. *UK*.	Mkael Symmonds, MD

cause, change in seizure type, suspected encephalitis, and first seizure in life were the most common indications.

All centres that recorded EEGs in COVID-19 patients reported use of PPE together with other precautions to minimize virus spread, *e.g.* dedicated COVID-19 EEG caps/braids, or the presence of two technicians (one interacting with the patient and the other in charge of the recording). Written local guidelines were followed. The only variable showing significant association with the number of deaths per million at time of the survey was performance of invasive investigations prior to the pandemic (chi-square = 11.79, p=0.008, DOF = 3).

Discussion

The results demonstrate profound impact of COVID-19 on EEG-based diagnostics, which, due to absent, delayed or incomplete investigations, may add to previously described negative effects of lockdown in patients with seizure disorders (Lai *et al*., 2005). On the other hand, allowing "business as usual" would increase the risk of infection exposure not only in patients, but also in health-care personnel, with possible serious and long-lasting consequences. It is important to emphasize that health-care personnel (in this case, mainly EEG technicians and nurses), some of whom are in a high-risk COVID-19 category (Haines *et al*., 2020), are exposed as the first line, and maximal care should therefore be given to protecting them. Finding optimal trade-off between these two sides of the problem is challenging, especially given the rapid and variable development of the pandemic in different countries.

According to the survey, inpatient video-EEGs were severely affected, particularly in pre-surgical and invasive investigations, especially in adults. Epilepsy surgery was negatively influenced as well. In those centres where epilepsy surgery continued, (selected)

Table 2. Summary of responses.

Were EEG-based investigations performed prior to the COVID-19 pandemic?	
In both children and adults	32 (68.1%)
In children only	11 (23.4%)
In adults only	3 (6.4%)
Were video-EEG investigations performed prior to the COVID-19 pandemic?	
Both diagnostic and presurgical video-EEG	42 (89.4%)
Mainly or exclusively diagnostic video-EEG	3 (6.4%)
Mainly or only presurgical video-EEG	2 (4.3%)
Were invasive video-EEG investigations performed prior to the COVID-19 pandemic?	
Yes	30 (63.8%)
No	17 (36.2%)
Is inpatient video-EEG for adults continuing during the COVID-19 pandemic?*	
No	29 (61.7%)
Yes – but reduced (some patient selection applied)	17 (36.2%)
Yes – no change compared to before pandemic	1 (2.1%)
Is inpatient video-EEG for children continuing during the COVID-19 pandemic?	
No	18 (38.3%)
Yes – but reduced (some patient selection applied)	25 (53.2%)
Yes – no change compared to before pandemic	3 (6.4%)
Is invasive video-EEG continuing during the COVID-19 pandemic?*$	
No	24 (80.0%)
Yes – but reduced (some patient selection applied)	5 (16.7%)
Yes – no change compared to before pandemic	1 (3.3%)
Is epilepsy surgery performed during the COVID-19 pandemic?*	
No	32 (68.0%)
Yes – but reduced (some selection applied)	15 (31.9%)
Is routine outpatient EEG continuing during the COVID-19 pandemic?*	
No	12 (25.5%)
Yes – but reduced (some selection applied)	33 (70.2%)
Yes – no change compared to before pandemic	2 (4.3%)
Do you perform COVID-19 triage before outpatient EEG?*$	
No	1 (2.9%)
Yes – we perform outpatient EEGs only after anamnestic triage	23 (65.7%)
Yes – anamnestic triage, and taking patients' temperature before the EEG recording	12 (34.3%)
Yes – we perform outpatient EEGs only in patients who tested negative for COVID-19	2 (5.7%)
Are accompanying persons included as part of the COVID-19 triage for outpatient EEG*$	
No	4 (11.4%)
Yes – we allow only persons following anamnestic triage to enter the outpatient department / EEG lab	18 (51.4%)
Yes – following anamnestic triage and taking a person's temperature before the EEG recording	14 (29.8%)
Yes – we allow only persons who tested negative for COVID-19 to enter the outpatient department / EEG lab	1 (2.9%)
Do you perform hyperventilation during EEG?	
No	20 (42.6%)
Yes – same as before	15 (31.9%)
Yes – but precautions are taken	12 (25.5%)
Do you ask patients with unknown COVID-19 status to wear a face mask during EEG recording?	
No	12 (25.5%)
Yes	35 (74.5%)

*At the time of survey (which was different for individual responders, see also *figure 1*). $Percent of centres where invasive investigations were performed before the outbreak (*n*=30). $Percent of centres where outpatient EEGs continued to be performed (*n*=35).

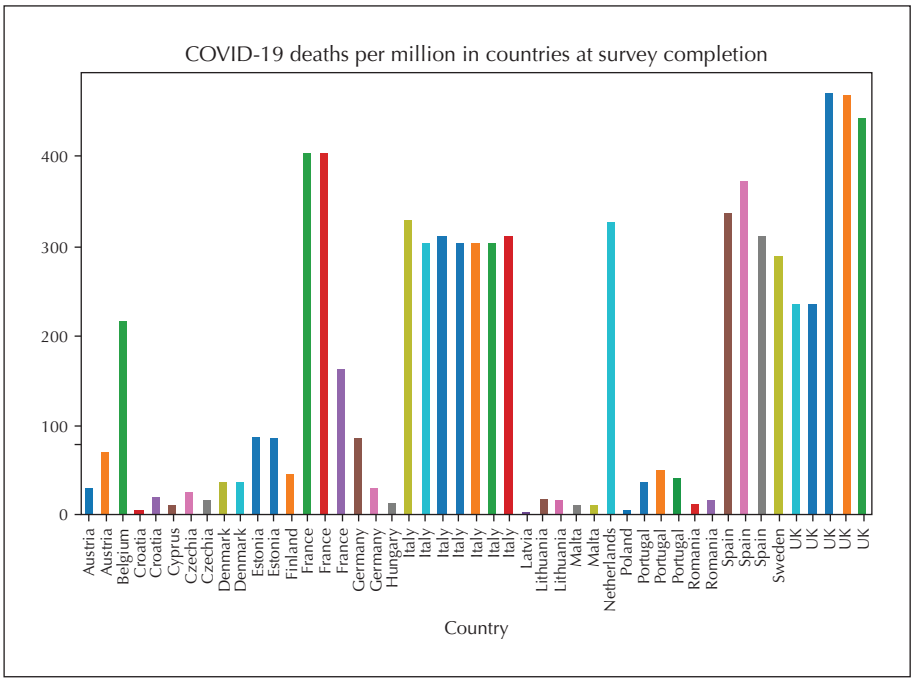

Figure 1. COVID-19-related deaths per million population in different participating countries at the time of completing the survey. Note that different centres from individual countries completed the survey at different timepoints which results in several bars per country. Source: https://ourworldindata.org/coronavirus-source-data Accessed 2020-05-22.

children were more often operated on than adults. Centres performing invasive investigations prior to the pandemic were over-represented in the survey (particularly from those countries experiencing a higher number of COVID-19-related deaths) and reduction of invasive investigations was therefore particularly pronounced.

Several expert statements and guidelines have been published regarding the approach for patients with epilepsy and EEG during the COVID-19 pandemic (French *et al*., 2020; Gelisse *et al*., 2020; Haines *et al*., 2020; San-Juan *et al*., 2020), including continuously updated information from the American Academy of Clinical Neurophysiology (https://www.acns.org/practice/covid-19-resources), the International League Against Epilepsy (https://www.ilae.org/news-and-media/news-about-ilae/news-from-ilae-about-covid-19) and the ERN EpiCARE (https://epi-care.eu/covid-19-and-epilepsy-ern-epicare-recommendations), in several EU languages. Although some variability of policies was seen among the centres participating in the survey (*e.g.* regarding the stringency of protective measures and PPE), the general approaches tended to be similar among the centres and were in line with published recommendations, including active choice to use face masks, restriction of accompanying persons, and performance of screening/triage. A dividing issue among the centres at the time of the survey was the approach to HV, with more than half of the centres performing HV without change. Current ACNS guidelines clarify this point stating that HV is not recommended in COVID-19-positive patients or patients under investigation, while in others, HV should be performed only when a high diagnostic yield is likely.

Our study indicates that the COVID-19 pandemic may be an opportunity for development of shared guidelines that could help to facilitate and standardize approaches in the event of future emergencies. □

Supplementary data.

Summary didactic slides are available on the www.epilepticdisorders.com website.

Acknowledgements and disclosures.

We hereby thank all representatives from all participating centres (see *table 1*) for their enthusiasm, valuable comments and for readily taking part in the survey. Many thanks to Judit Germuska and Nicola Openshaw-Lawrence for great support and for the assistance with the survey.

None of the authors have any conflict of interest to declare.

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TEST YOURSELF

(1) How did the COVID-19 pandemic affect EEGs across Europe?

A. Not at all
B. Elective and invasive recordings stopped or were significantly reduced
C. All EEGs stopped
D. Most centres continue to perform acute EEGs

(2) According to the survey, how did the centres approach EEG hyperventilation?

A. No change compared to the time before the pandemic
B. All centres stopped performing EEG hyperventilation
C. More than half of the centres continued to perform EEG hyperventilation in selected patients
D. About 40% of centres stopped performing EEG hyperventilation

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".