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ORIGINAL RESEARCH

# EEG recorded by nurses in emergency department: observational study of 100 patients with suspected seizures

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## Abstract

**Background**: Prompt electroencephalography (EEG) analysis is an essential tool to diagnose suspected seizures. However, EEG is often only available in emergency departments (EDs) during office hours, due to the lack of trained EEG professionals. The primary aim of this pilot study was to examine whether trained ED nurses were able to perform good quality EEGs and if immediate EEG recordings improved patient treatment times. **Methods**: In this retrospective observational study, we analyzed data of 100 consecutive ED nurse recorded EEGs of ED patients. Data were gathered from the hospital's electronic health records and the EEG archive. In addition to medical data, special attention was given to the median door-to-EEG time and the quality of EEGs'. **Results**: A total of 100 patients (49 females) with a mean age was 62.4 years were included in this study. The most common medical patient history was hypertension (n = 46), stroke (n = 34) and epilepsy (n = 27). The quality of each EEG recording taken by EEG-registered ED nurses was sufficient to interpret the results and set the diagnosis. Two patients were excluded from analyzing time intervals because for them EEG recording was not initially indicated at their ED visit. The median door-to-EEG time (n = 98) was 2.85 hours (the interquartile range, IQR 1.55 and 5.05) ranging between 0.28 and 20.88 hours. Abnormal EEGs were found in 76 patients. Amongst these, n = 6 were diagnosed with status epilepticus, and n = 7 were found to have new epilepsy. **Conclusions**: Our results indicate that EEG-registered ED nurses were able to record all 100 EEGs successfully. Furthermore, the median door-to-EEG time interval was shorter than reported earlier studies. Based on our results, educating and registering ED nurses to perform EEG is worthwhile to achieve prompt initiation of targeted treatments for patients with suspected seizures.

## Keywords

EEG; Emergency medicine; Emergency department; Nonconvulsive status epilepticus; Status epilepticus; Epilepsy

## 1. Introduction

In an emergency department (ED) setting, patients with altered mental status (AMS) are common. Up to 10% of patients coming to the ED have AMS, and 1.2% experience seizures while in the ED [1]. AMS is defined as altered levels of cognition, consciousness and mental status, which can appear as forms of delirium, lethargy, confusion, agitation and inappropriate behavior [2, 3]. One of the most serious underlying causes for AMS is status epilepticus (SE). If not immediately treated, SE can cause long-term neurological damage and mortality. As epilepsy is a treatable condition, early diagnosis based on prompt electroencephalography (EEG) is key to avoiding and reducing severe neurological damage and to lowering the risk of seizure recurrence [4, 5].

SE can be categorized into two major groups depending on involvement of motor activity: convulsive status epilepticus is characterized by prominent motor symptoms, while non-convulsive status epilepticus (NCSE) does not include motor symptoms [6]. Due to the lack of convulsions, diagnosis of NCSE has remained difficult. Clinical presentations vary from speech arrest, head or eye deviation, cognitive impairment to limb twitches. Due to the absence of convulsions NCSE can be diagnosed only by EEG to reveal ongoing ictal activity [7].

EEG is an essential diagnostic tool for patients with suspected seizure. Epileptiform abnormalities can be observed in up to 51% of patients with suspected seizures if EEGs are recorded during the first 24 hours of AMS. If delayed for more than 24 hours, epileptiform abnormalities are detected in only 34% of patients, increasing the risk of long-term neurological


  

injury [8]. Therefore, delayed EEG analysis leads to worse neurological outcomes and delayed initiation of appropriate medical treatment. Thus, time to EEG recording has critical implications for patient management as prompt diagnosis is crucial for starting appropriate treatment as quickly as possible [3, 9, 10].

Detection of EEG abnormalities is essential and highly time sensitive for proper patient treatment. These abnormalities include SE and NCSE, and both require quick access to EEG for ED patients for accurate diagnosis [11]. However, due to the lack of trained staff outside office hours, EEG is not available in many EDs during nights and weekends. Several studies have shown that it is possible to train previously non-EEG experts to perform diagnostic EEGs [11–15]. Most of these studies focused exclusively on ED physicians and did not include ED nurses. Thus, there is a need to explore the opportunity to enable ED nurses to record EEGs effectively and investigate the quality of the performed EEG recordings, to develop new policies aimed at shortened time-to-EEG analyses and thereby improve patient outcomes.

The objective of our study was to analyze the first 100 EEGs recorded by the nurses working in the ED of Kanta-Häme Central Hospital (KHCH), Hämeenlinna, Finland. Our premise was to streamline the practical clinical work in the emergency department, toward improved patient outcomes by investigating whether EEG recordings performed by ED nurses were of sufficient quality to allow specialist physicians to analyze the EEGs reliably. Special emphasis was on patients' symptoms and medical history, the quality of EEGs, times from patients' enrollment to the ED to start of the EEG recording (door-to-EEG time), and EEG findings.

## 2. Methods

This retrospective observational study was conducted in KHCH. Data consists of the first 100 consecutive EEGs recorded for incoming patients with suspected seizures by ED professionals in the ED of KHCH after 01 January 2014. We collected data from the electronic health records and the EEG archive of the hospital. The starting point for time analysis of patient check-in and EEG procedure was set according to the timepoint of EEG availability in the ED. The study includes only patients who were admitted directly to the ED. Patients who were transferred to the ED from any of the hospital's inpatient wards were excluded.

In Finland, all nurses receive their foundational education at universities of applied sciences. In December 2013, KHCH initiated a program to train a limited number of ED nurses in the acquisition of EEG recordings. The aim of the training program was to equip ED nurses with the skills necessary to independently perform EEG recordings outside of regular office hours. The first cohort of nurses underwent a one-week training course within the clinical neurophysiology department. Each nurse in the first training group had prior work experience in the field of neurology, however none of them had previously performed an EEG recording. Training encompassed both theoretical instruction and practical sessions, initially performed on the trainees themselves as study subjects and subsequently on patients. Each EEG recording was meticulously reviewed by a specialist in clinical neurophysiology of the hospital. By January 2014, ED nurses had commenced to independently performing EEG recordings on patients under physician expert supervision.

The collected data consisted of patients' demographic data, medical history, symptoms and signs, Glasgow Coma Scale, electrocardiogram and possible imaging (head computer tomography and/or thorax x-ray), initial therapy and possible transportation of the patient from the ED. Finally, the workflow focused the development of working diagnoses in the ED, followed by patient treatment, and final diagnoses after completing therapeutic regimens. Importantly, data on the use of antiseizure medication during the treatment were collected and included information on whether patients were medicated with first-, second- or third-line antiseizure medication before or during the EEG recording (1st line drugs are benzodiazepines, 2nd line drugs include fosphenytoin, valproic acid, levetiracetam and lacosamide and 3rd line are propofol and thiopental). The enrollment time to the ED was registered and time intervals of the ED treatment periods were calculated. Furthermore, the quality of recorded EEGs, the starting time and duration of the recording, as well as the EEG findings were included in our evaluation. To address acute final outcomes, patient mortality was assessed during a 30 day after ED visit and EEG recording. In this study, we focused specifically on the quality of the EEG recordings taken by ED nurses and on the patient door-to-EEG time.

### 2.1 EEG interpretation

All 100 EEGs were taken with the EEG cap with the international 10–20 system of electrode placement. Duration time of the recordings ranged between 25–55 min.

The EEGs were reviewed, and findings were evaluated by a specialist in clinical neurophysiology (hospital's own doctor during office hours or on-call consultant during off-office hours). EEGs were classified as either normal or abnormal. Abnormal findings were categorized as follows: (1) generalized slowing, (2) focal slowing, (3) epileptiform discharge, and (4) status epilepticus (SE/NCSE). Status epilepticus was further detailed as main types of SE: generalized convulsive SE (prominent motor manifestation with impaired consciousness), focal convulsive SE (prominent motor manifestation with normal or slightly altered mental status), generalized non-convulsive SE (NCSE) (impaired consciousness without prominent motor manifestation) and focal NCSE (normal or slightly altered mental status without prominent motor manifestations).

Ensuring the quality of EEG data requires adherence to specific technical standards, including proper electrode placement, optimal impedance levels, and overall signal clarity [16]. The quality assessment involves analyzing the percentage of artifact-free segments and signal-to-noise ratios to ensure reliable results [17]. In this study our premise was to assess the practical clinical work in the emergency department, primarily based on whether the recordings were of sufficient quality for the specialist physician to reliably analyze the EEG for clinical patient evaluation.

## 2.2 Clinical characteristics

For each patient, we collected demographic data, medical history, medication, use of alcohol and smoking. Recorded symptoms included, abnormal neurological findings, Glasgow Coma Scale and data on vital signs (systolic and diastolic blood pressure, heart rate, oxygen saturation). Blood pressure (BP) values of systolic BP >140 mmHg and diastolic BP >80 mmHg were considered as elevated. Laboratory parameters were measured using standard methods. Detailed laboratory parameters are presented in **Supplementary material 1**.

## 2.3 Statistics

Descriptive and frequency statistical analyses were obtained, and comparisons were made using the IBM SPSS Statistics for Windows 27.0 (IBM Corp. Armonk, NY, USA, 2020). For the analysis of time intervals, patients were excluded if EEG recording for them became indicated only during their stay in the ED but was not evident on arrival. Categorical variables are presented as number of subjects or percentages and continuous variables as mean ± standard deviation (SD) or median (interquartile range (IQR)). Comparison of continuous variables were made by a non-parametric Mann-Whitney test and dichotomic variables were analyzed by Chi-square test. A two-tailed probability value of $< 0.05$ was considered significant.

# 3. Results

## 3.1 Patients

The first 100 EEG recordings by an ED professional were performed between January 2014 and November 2016. Patient demographics and medical history are shown in Table 1. A total of 100 patients (51 male and 49 female) were studied with a mean (SD) age of 62.4 +/− 20.1 years and a range of 14 to 92 years old (Fig. 1). The age characteristics did not differ between men and women ($p = 0.223$). The most common comorbidity was arterial hypertension. Other common diagnoses were diabetes mellitus and vascular diseases, including coronary artery disease and general atherosclerosis. Twenty-seven patients had a history of epilepsy which was already being treated with anticonvulsants. Thirty-four patients had undergone one or more cerebrovascular strokes. Eleven patients had no diagnosis of any chronic disease (Table 1).

Three most frequent symptoms were convulsions/epileptic seizures, hemiparesis and/or aphasia and mental confusion and/or absence seizure. Seventeen patients were unconscious. Symptoms are presented in Fig. 2. Four patients had used alcohol on the same day they arrived in the ED.

Sixty-three patients had abnormal vital signs. Most common abnormality was elevated BP (n = 55). Abnormal laboratory blood values were found in 95 patients. Detailed laboratory findings are presented in **Supplementary material 1**.

Of the 100 evaluated patients, 10 patients died within 30 days after being seen at the ED. The mean age of the deceased patients was 78 years. Ischemic stroke was the cause of death for six patients. Each of these patients had received conservative treatment based on initially poor prognosis because of primary diseases and extensive ischemic brain damage. One patient died of a serial epileptic seizure, attributed to the late effects of a cerebral infarction. The cause of death for the other three patients was myocardial infarction (see above), multiorgan failure (heart, kidneys and liver), and death caused by prolonged alcohol abuse, respectively.

**TABLE 1. Summary of the demographics and medical history.**

| Patient data | N = 100 |
|---|---|
| Age, yr | |
| Mean (SD) | 62.4 (20.1) |
| Range | 14.0–92.0 |
| Gender | |
| Female/Male | 49/51 |
| Medical history | |
| Hypertension | 46 |
| Stroke | 34 |
| Epilepsy | 27 |
| Diabetes Mellitus | 22 |
| Cardiovascular disease* | 18 |
| Psychiatric illness** | 7 |
| Alzheimer's disease or dementia | 9 |
| Parkinson's disease | 3 |
| Attention deficit hyperactivity disorder | 1 |
| Alcohol abuse | 17 |
| Healthy | 11 |

**Coronary artery disease, peripheral artery disease; **Depression, Schizophrenia, Bipolar disorder. SD: standard deviation.*

## 3.2 Door-to-EEG time

For the group of patients receiving EEG recording performed by ED nurses, the median time from door to EEG was 2.85 (IQR 1.55 and 5.05) hours with a range of 0.28 to 20.88 hours (Fig. 3). Nine patients whose EEG recordings were delayed because of lack of trained medical personnel at the time of their arrival in the ED had a door-to-EEG time over 10 hours. Two patients were excluded from this analysis because their EEG recording became justified only after their condition deteriorated while being in the ED.

## 3.3 Quality and findings of EEG recordings

The quality of all recorded EEGs was sufficient for reliable evaluation and to achieve diagnosis. The EEG findings are shown in Table 2. Abnormalities were present in 76 of the 100 EEG recordings. There was a trend for women to have more abnormal EEG findings than for men (84% *vs.* 69%) ($p = 0.078$). Two most common EEG abnormalities were focal and generalized slowing.

New epilepsy was diagnosed in seven patients while in the ED. Four of these new epilepsies were without SE, and three

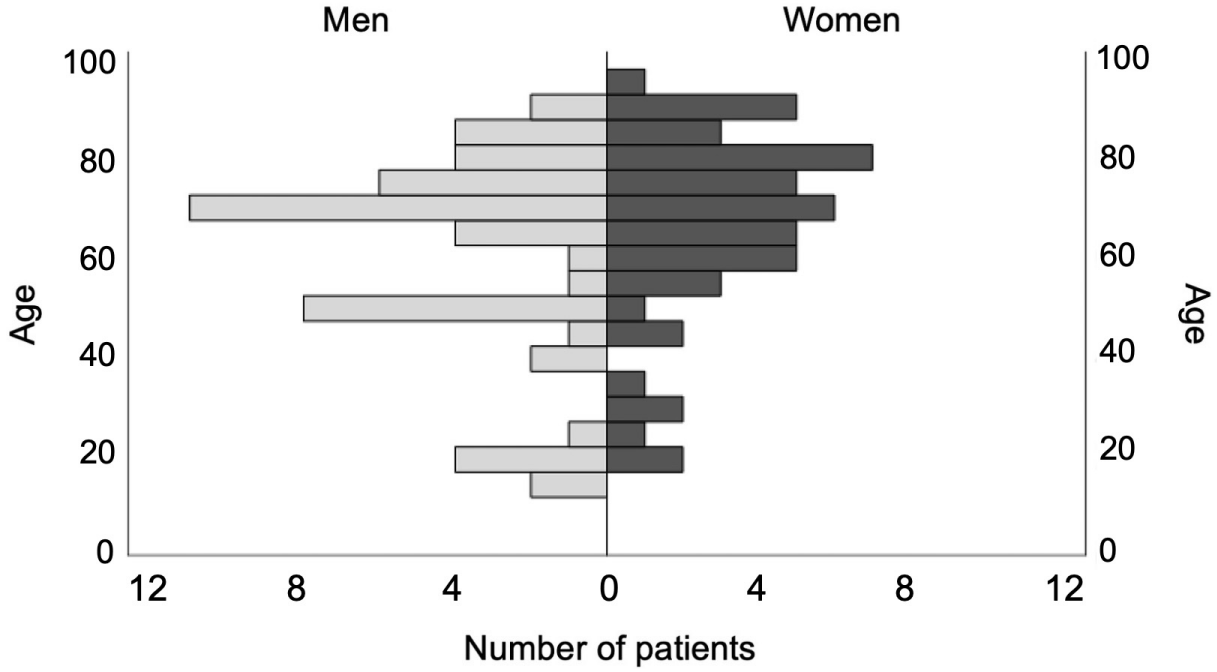


**FIGURE 1. Age distribution of the patients by gender.**

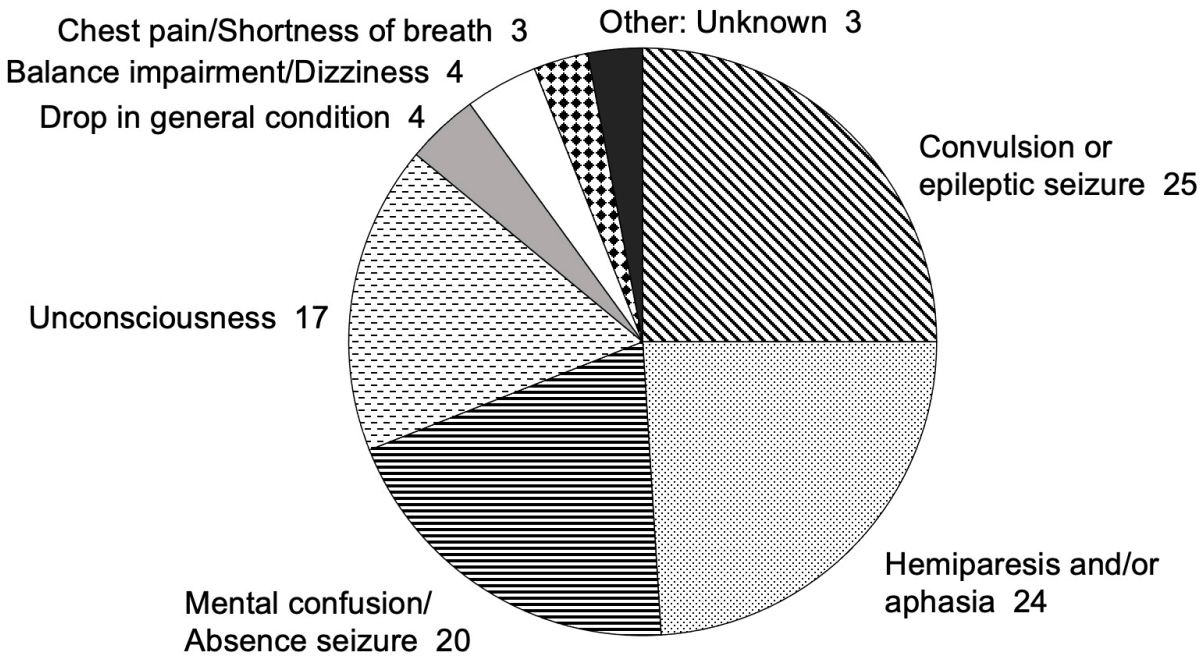


**FIGURE 2. Distribution of symptoms.**

were with NCSE. All ED diagnoses were confirmed at follow-up visit in the neurological ward. The condition of these seven patients was classified as focal epilepsy for diagnosis (Fig. 4).

A total of six patients experienced SE during EEG recording. All of these patients had NCSE, one of which was classified as generalized NCSE and five as focal NCSE. Additionally, in one patient's recording clinical status epilepticus had receded and the EEG indicated a postictal state (Table 2). Two EEG examples are presented in **Supplementary material 2**.

### 3.4 Diagnoses

The diagnoses are summarized in Fig. 4. The most common diagnoses were epilepsy/recurrent seizures, and second most common were other neurological diagnoses. Eleven previously healthy patients without previous neuro pathology were diagnosed as follows: unspecified tonic-clonic seizures (n = 5), transient ischemic attacks (n = 2), alcohol abuse (n = 2), focal aware epileptic seizure (n = 1), and unspecific symptoms without epilepsy after head trauma (n = 1).

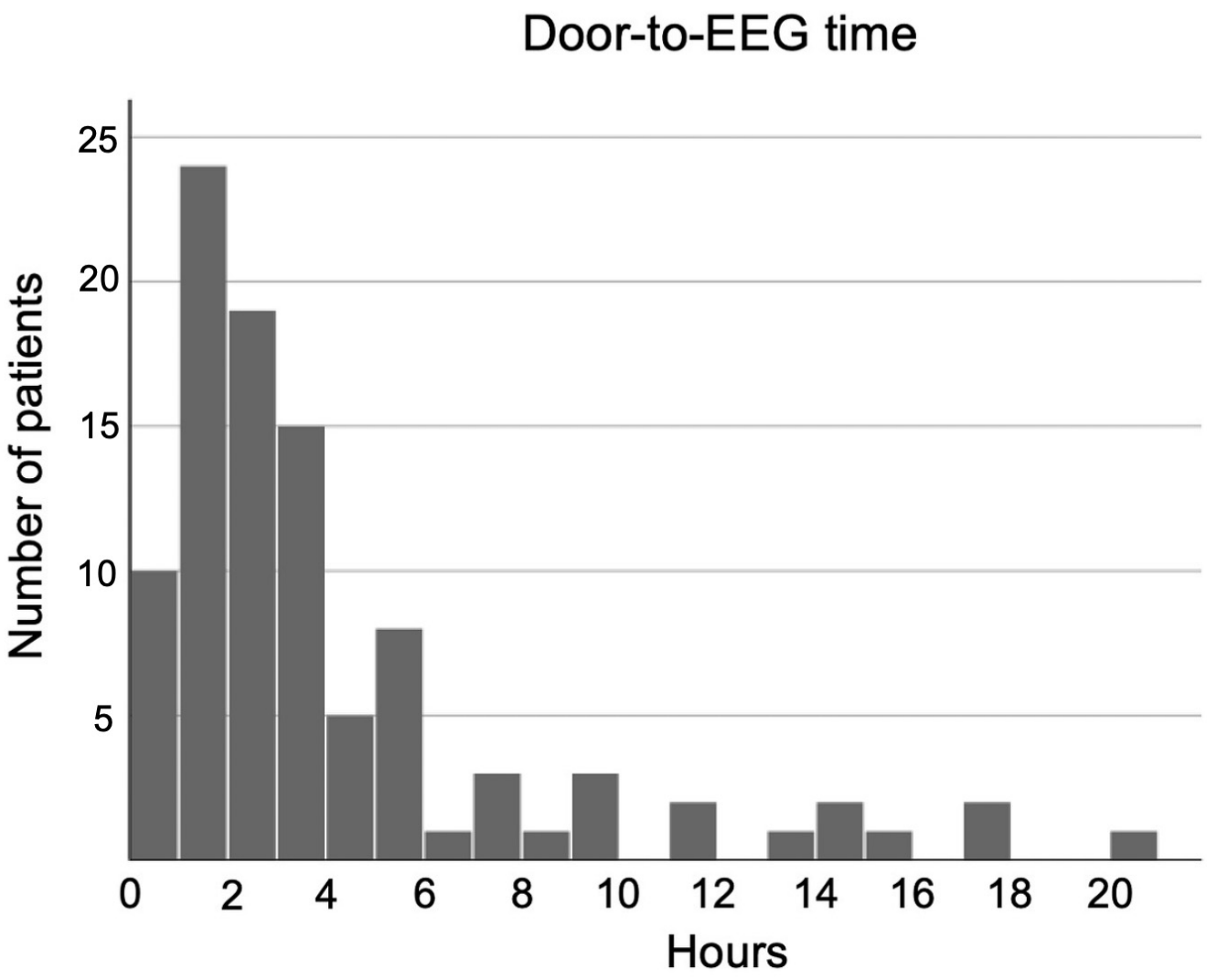


**FIGURE 3. Door-to-EEG time.** EEG: electroencephalography.

**TABLE 2. Findings of 100 EEG recordings.**

| | N = 100 |
|---|---|
| Evaluation | |
| Normal | 24 |
| Abnormal | 76 |
| Generalized slowing | 48 |
| Focal slowing | 50 |
| Epileptiform discharge | 28 |
| SE | 6 |
| Generalized or focal convulsive SE | 0 |
| Focal NCSE | 5 |
| Generalized NCSE | 1 |

*NCSE: non-convulsive status epilepticus; SE: status epilepticus.*

### 3.5 Medical treatment

Of the evaluated 100 patients, 49 patients were given antiseizure medication before or during the EEG registration. First-line antiseizure medication was given to 42 patients. Second-line antiseizure medication were given to 29 patients, and one patient received third-line antiseizure medication. The six SE patients were medicated as follows: first-line medication (n = 2), second-line medication (n = 2), first-line followed by second-line medication (n = 1). One patient displayed unclear symptoms and hence did not receive any antiseizure medication. This patient had no history of neurological disease, and the EEG was taken later after other cause for the observed symptoms were ruled out.

## 4. Discussion

This observational study had two key findings. Firstly, after proper education, ED nurses were able to perform good quality EEG recordings by themselves. Secondly, through this practice a short median door-to-EEG time of less than 3 hours on average was achieved already for the first 100 patients evaluated and treated according to this new protocol.

This study is part of a continuum, where we aim to develop and improve the processes of our ED and emergency medicine in its entirety [18–22]. Based on age, the patient population of our study was comparable to patient cohorts reported in other

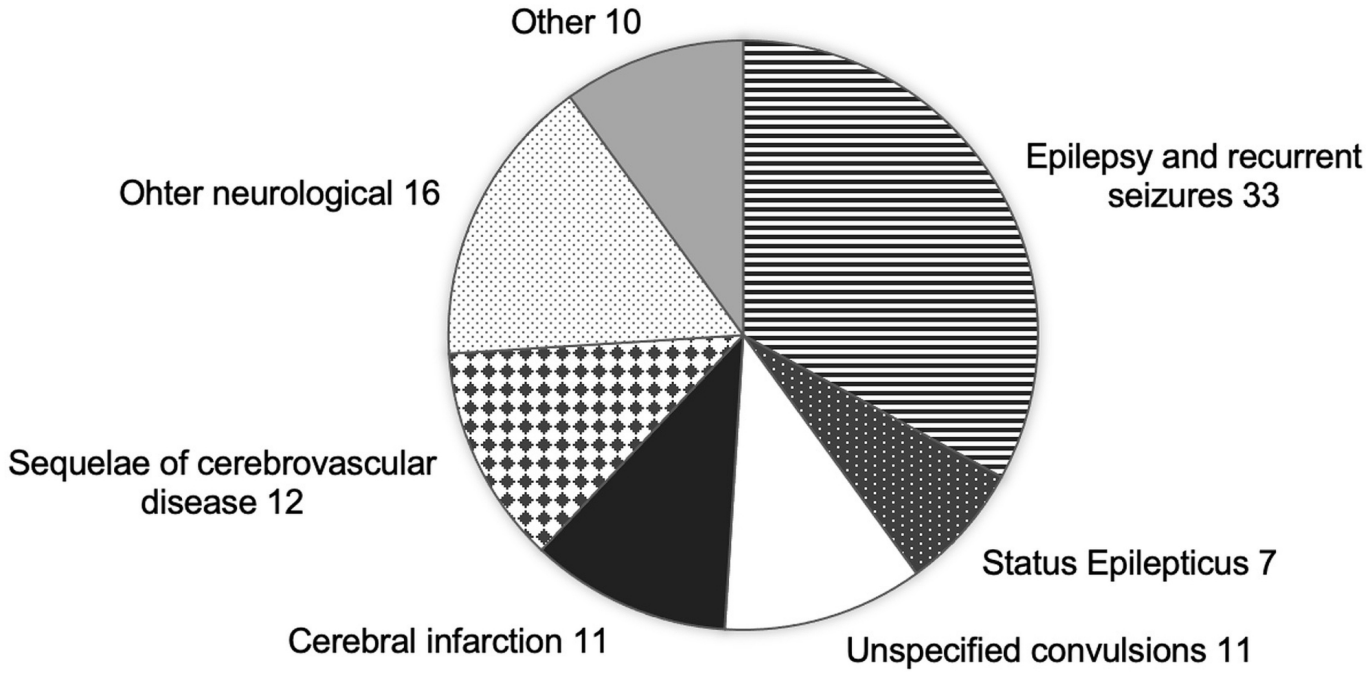


**FIGURE 4. Summary of diagnoses.**

studies [7, 23, 24]. The differences observed between genders on EEG findings might be explained based on a relatively small patient group of the study [25].

Previous patient history of epilepsy in our study resembled that of an earlier study [26]. In our patients, six had NCSE. The prevalence of NCSE was slightly higher than in other similar studies, where the prevalence ranged from 3% to 5% [15, 27]. One study reported a prevalence of NCSE of 9.3% [3], which is slightly higher than the prevalence in our study. This difference could be explained by a smaller sample size. The decisive diagnosis of NCSE cannot be made without EEG analysis, and the finding of NCSE impacts acute patient management and directs patients care immediately in the correct direction towards saving patient's lives. Most previous studies in which EEG is performed by non-experts have relied on emergency department physicians or research assistants (medical students with no previous experience of EEG), and two studies have relied on emergency department nurses [11–15]. Our findings of the diagnostic value of the EEGs, performed essentially without delay, are in line with the previous studies and seem to suggest that it is not necessary to exclusively bind physicians to the actual EEG registration in the ED setting.

One study [28] listed the indications for EEG in their entire institution. That study found that convulsions of patients treated in the intensive care unit accounted for 26% of indications, which was similar to our findings in our hospital's ED. In our study, EEG was examined without any exclusion criteria according to symptoms to allow for unbiased evaluation of EEG profiles likely related to a patient's presentation. In this way, our investigation differs from some other studies [4, 7, 8, 29].

Earlier studies have reported a median delay for EEG performance between 3.85 h to 22.03 h [4, 13, 25, 29] post patient arrival in the ED. All of these reported delay intervals were considerably longer than in our study. The stated reasons for long delays were the lack of trained staff, not giving SE patients in the highest priority of triage, and unavailability to access EEG equipment [4, 25, 29]. We have taken all of these aspects into account when developing our protocol, and our results show that it is possible to effectively decrease the delay of EEG performance. This is a breakthrough protocol for patients benefit. According to multiple earlier studies, emergency EEG should be taken within 24 hours [4, 8, 24, 25, 29, 30]. In these studies, the delay to EEG recording had been studied, but the performers had been either neurologists or EEG technicians, while in our study specifically trained ED nurses recorded the EEGs. We are convinced that a short delay to EEG analysis can be achieved by a combination of successful training programs for ED professionals, proper shift planning, and simultaneous prioritization of patients in the triage. The number of trained nurses is critical to cover most shifts. In our study, trained staff was present in all shifts, with the exception of those 9 out of 98 EEG recordings, where the delay was over 10 hours. By not requiring a dedicated technician to set up the EEG, trained ED professionals can minimize any delay of door-to-EEG time.

Our findings of abnormal EEGs in 75% of patients are slightly higher than in earlier studies, where abnormal EEG recordings were seen in 57 to 70% of patients [8, 24, 26, 27, 31]. Among the observed EEG abnormalities, the most frequent finding was slowing. These results align with those reported in prior studies [27, 31]. SE was present in 6 EEG recordings, and together 48 patients were given either first- or second-line antiseizure medication before or during the EEG registration. We assume that without these 1st and 2nd line drugs, more status epilepticus would have been found in EEGs and was hence avoided by applying our procedure.

In our study, quality of every EEG record was high and allowed for clear interpretation. Every record was sufficient for reliable evaluation to achieve a proper analysis of the EEG recordings. These results differ from some of the previous

studies, where EEGs ranging from 5–14% had to be excluded from evaluation because of excessive artifacts [7, 26, 31]. In a few studies, where the use of EEG in the ED has been evaluated, the EEG machines were either 2-channel EEGs [11] or Rapid Response EEGs [13, 15]. In our study, all recordings were done with a conventional EEG machine, which might have been one reason for more reliable results. Also, some of the reported EEG results and findings might have been overlooked when using other than conventional EEG [7, 32].

In our study, there were 33 final epilepsy diagnoses of which seven were new epilepsy cases. Two previous studies reported final epilepsy diagnoses with considerably higher frequency than in our study. Those studies reported epilepsy diagnoses in 53% and 52% of patients [8, 29]. This could be explained by differences in patients' inclusion criteria while other studies included only patients with suspected NCSE. The highest percentage of epilepsy reported in previous studies can also be explained by the inclusion criteria where all patients had to have first-time convulsion seizures [8]. Two other studies reported epilepsy diagnoses in 20% [4] and SE diagnoses in 24% of patients [7]. These results could be explained by the small number of patients [7] and the patients' inclusion criteria that limited the evaluation to only patients with first time seizure [4].

The strengths of our study is that only two people systematically collected patient data, as well as high quality and precise information that was gathered. We reached an exceptionally short door-to-EEG interval and high quality in the performance of EEG, which is at least partly due to the special EEG training in addition to a high-level basic education of nurses in our study. The implementation of the new protocol was done systematically. We are highly encouraged and we will study the attitudes and motivation of nurses in relation to new tasks in this context.

There are some limitations in this study, most of them are due to the nature of observational retrospectivity of the study. One limitation is the relatively small patient size of the study, which limits the interpretability and generalizability, although it is comparable to earlier studies [4, 7, 13, 15, 23, 26, 28–30]. Our evaluation had no control group to compare the results as this was an observational study. Another limitation is the retrospective design causing of the risk of reporting bias. Because of the retrospective character, we had no influence on what information was collected of the patients following their ED evaluation, and some laboratory variables were taken from only a few but not all patients, which is why they were not included in the results of this study. On the other hand, retrospective setting is the way to research how treatment protocols function in the clinical reality, without affecting the results through an observer effect.

To the best of our knowledge, this is the first study analyzing the impact of trained ED nurses performing conventional EEG on the quality of EEG recordings and door-to-EEG time for patients. Only one publication was found that included door-to-EEG-time as a major readout as in our study [30], which is why our research together with EEG quality and performance by trained ED nurses represents a pioneering contribution to this field. As the utility and need for emergent EEG in ED has been studied widely, our study shows that there is a need for a larger study to examine the effectiveness of trained staff to routinely perform conventional EEG in ED and evaluate established examination practices, aimed at optimizing current approaches and patient outcomes.

Based on our research findings, we believe that the training of ED nurses and the implementation of their tasks are clinically reproducible across other ED services with strong background knowledge and appropriate training protocols. Due to the time-sensitive nature of EEG abnormalities, early detection and prompt initiation of appropriate treatment are crucial. In future studies, we will further investigate the training processes for ED nurses and evaluate the impact of 24-hour EEG availability on patient care and clinical outcomes.

## 5. Conclusions

In this pilot study, we focused on the first 100 consecutive EEG recordings performed by ED nurses after they completed a specific training program for these skills. In conclusion, EEGs were successfully recorded, and short door-to-EEG times were achieved. We are continuing our research to find out what impact our new protocol and the new role of nurses have had on their professional image and the prognosis of patients.

### ABBREVIATIONS

AMS, Altered Mental Status; BP, Blood Pressure; ED, Emergency Department; EEG, Electroencephalography; IQR, Interquartile Range; KHCH, Kanta-Häme Central Hospital; NCSE, Non-Convulsive Status Epilepticus; SD, Standard Deviation; SE, Status Epilepticus.

### AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

### AUTHOR CONTRIBUTIONS

AP—designed the study; takes responsibility for the paper as a whole. AL and RM—organized the data collection. MH and TS—were on their part organizing the EEG training of ED nurses. MH, VH, HP, TA and AP—participated substantially in interpretation of the data. AL—carried out statistical analyses. All authors drafted the article, critically revised it, and approved it. All authors attest to meeting the four ICMJE.org authorship criteria: (1) Substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work; AND (2) Drafting the work or revising it critically for important intellectual content; AND (3) Final approval of the version to be published; AND (4) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

According to Finnish legislation and principles of the Ethics Committee of Tampere University Hospital, due to the retrospective form of the study, informed consent was not required from the participants. Patient data collection was conducted with the permission of and according to the guidelines of the Ethics Committee of Tampere University Hospital (Registry number: R21056R, date: 16 April 2021) and Kanta-Häme Central Hospital (Research permission: KHSHP/791/13.00.01/2021, date: 07 May 2021).

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.signavitae.com/mre-signavitae/article/1897893630072242176/attachment/Supplementary%20material.docx.

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