Clinical Neurophysiology Practice 10 (2025) 70–77

Contents lists available at ScienceDirect

Clinical Neurophysiology Practice

journal homepage: www.elsevier.com/locate/cnp

The role of EEG in the emergency department: Its contribution to the patient's diagnostic–therapeutic pathway. The EMINENCE study

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ARTICLE INFO

Keywords:
Electoencephalogram
Emergency department
Diagnostic–therapeutic pathway

ABSTRACT

Objectives: To investigate the utility of the emergency electroencephalogram(emEEG) in the diagnostic work-up of patients admitted to the Emergency Department(ED).
Methods: Data from consecutive patients admitted to the ED during a 1-year period. We evaluated the usefulness of emEEGs based on the subsequent patient clinical management.
Results: 1125 emEEGs from 1018 patients were analyzed. The overall usefulness of an emEEG was 86.7%, mainly influenced by its contribution to diagnosis(75.0%), often excluding initial working diagnosis(50.0%), and to patient management(78.0%). EmEEGs showed their best overall usefulness in Status Epilepticus(SE) and altered level of consciousness both in contributing to the final diagnosis and in patient management and therapeutic pathway. In speech and cognitive/behavioural disorders, emEEGs contributed to the diagnosis(80.6% and 79.8%, respectively), often excluding the initial suspicion of seizures/SE. Normal emEEGs contributed to diagnosis(79.0%), patient management(87.0%) and discharge to home(82.0%).
Conclusions: In ED, attending physicians have to make quick decisions about the diagnostic–therapeutic management of patients, and also the ruling out of the initial diagnosis and safely discharging the patient to home are also important goals.
Significance: This study provides valuable guidance to ED clinicians in selecting patients for an emEEG and evaluates its contribution to their diagnostic–therapeutic management.

1. Introduction

Electroencephalogram (EEG) is a reliable and non-invasive diagnostic tool that can be performed at the patient's bedside allowing the functional exploration of the brain and playing a complementary role to neuroimaging [brain computed tomography (CT) and brain magnetic resonance imaging (MRI)] in the detection of neurological disease (Praline et al., 2004; Praline et al., 2007).

EEG is particularly useful in patients with altered consciousness state due to neurological diseases such as nonconvulsive epileptic status (NCES) or metabolic/septic encephalopathy, which cannot be detected by neuroimaging (Praline et al., 2007).

Typically, pathological conditions associated with altered state of consciousness are considered emergent conditions requiring prompt diagnosis and appropriate therapeutic management (Conference de consensus sur les indications de l'EEG en urgence, 1996; Kaplan, 1999; Rodriguez Quintana et al., 2021), therefore resulting in a high demand for emergent EEG (emEEG) in clinical practice.

However, the rapid and bedside availability of this neurophysiological test, combined with its usefulness, has led to the widespread use of this diagnostic tool in clinical practice, in the absence of universally accepted guidelines (Praline et al., 2007; Rodriguez Quintana et al., 2021) and clear indications other than the management of NCES (ACEP Clinical Policies Committee Clinical Policies Subcommittee on Seizures, 2004) Clinical policy: criticalissues in the evaluation and management of adultpatientspresentino to the emergencydepartment with seizures, 2004; Bellini et al., 2024; Feyissa and Tatum, 2019; Praline et al., 2007; Varelas et al., 2003; Vignatelli et al., 2024).

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https://doi.org/10.1016/j.cnp.2025.02.010
Received 13 November 2024; Received in revised form 19 February 2025; Accepted 26 February 2025
Available online 3 March 2025

In fact, fo rother neurological conditions other than NCES, the data in the literature were scarce, limited to small samples, and heterogeneous in terms of sample selection, recruitment and setting of analysis, limiting the comparison of results (Khan et al., 2001; Lozeron et al., 2018; Praline et al., 2007; Prud'hon et al., 2024; Quigg et al., 2001; Rodriguez Quintana et al., 2021; Varelas et al., 2003; Yigit et al., 2012).

In particular, only a few studies (Bellini et al., 2024; Privitera and Strawsburg, 1994; Yigit et al., 2012) have focused their analyses on the EEGs performed in the Emergency Department (ED), a specific setting where the attending physicians usually have to make quick decisions about the diagnostic–therapeutic management of patients, often in the absence of prompt availability of some instrumental tests such as brain MRI or in the absence of a neurological/neurosurgical consultation.

This has led to a high demand for emEEGs, often related to its performance characteristics and rapid availability or to the individual experience of the treating physician rather than to its actual diagnostic power.

The main objective of the EMINENCE (**E**lectro-encephalogra**MINE**mergen**NC**yD**E**partment) study was to determine the reasons why emergency physicians ordered an emEEG and its benefits, defined as changes in the diagnostic–therapeutic management of patients or in the clinical diagnosis or changes in the subsequent discharge or hospitalisationprocess.

Finally, the study evaluated whether a correlation could be established between the diagnosis or neurological signs and symptoms on admission and emEEG abnormalities, and whether predisposing factors could be more easily related to abnormal emEEGs.

2. Materials and methods

2.1. Study design and patient selection

The EMINENCEstudy was anobservational monocentric, retrospective study conducted at the tertiary Careggi Teaching Hospital, Florence, Italy.

We included all patients older than the age of 18 years who where admitted to the ED and underwent an emEEGduring one year, from 1st of January 2023 to 31st of December 2023.

Clinical data were obtained from medical records. Demographic and clinical variables – such as gender, age, neurological symptoms and signs, the reason for ordering an emEEG, the clinical context [including a history of epilepsy or other diseases that would predispose to epileptic status (ES) or to encephalopathy], previous antiseizure medication (ASM) or other drugs or therapies that might predispose to neurological diseases assessed by an emEEG, and neuroimaging data – were included in the analysis. We also recorded electrolyte or metabolic disorders, fever or sepsis, and a history of hypertension, diabetes, dyslipidaemia, or cardiac or thyroid disease. Discharge or hospitalisation was also reported.

Finally, we recorded emEEGs performed both during and outside of normal hospital hours. We included requests for a second EEG only if they were still coming from the ED.

2.2. EEG recording and classification

The EEG was available at our institution during normal hospital hours (from 8:00 a.m. to 7:00 p.m., from Monday to Friday, and from 8:00 a.m. to 2:00 p.m. on Saturday). It was also available by calling 24 h a day outside of normal hospital hours for emergencies related to ES detection.

Standard 30-min EEG recordings were obtained using a digital machine and a EEG prewired head-cap, with 19 electrodes (Fp1-Fp2-F7-F8-F3-F4-C3-C4-T3-T4-P3-P4-T5-T6-O1-O2-Fz-Cz-Pz) positioned according to the 10–20 InternationalStandardSystem. The recordings were acquired with a sampling rate of 128 Hz. During the review, digital filters (low-pass filter = 30 to 70 Hz; time constant = 0.1 or 0.3 sec; notch filter = 50 Hz) and sensitivity gain (2 to 10 V/mm with a standard gain of 7 V/mm) were adjusted according to interpretation requirements (Scarpino et al., 2019; Scarpino et al., 2020).

The EEG recordings were usually made without drug sedation. An interpretation of the EEG results was provided by expert neurologists/neurophysiologists as soon as possible after the attending physician'srequest, depending on the rest of their daily workload; however, priority was usually givento requests coming from the ED.

The EEG recordings were then classified according to the EEG terminology of the American Clinical Neurophysiology Society's (ACNS) (Hirsch et al., 2013). The EEG descriptors considered were as follows: continuity, voltage, organisation of an anterior–posterior gradient of the background activity, presence of reactivity and spontaneous variability of the background activity, frequency, symmetry, presence of epileptic discharges andslow waves, periodic patterns,patterns with triphasic morphology, and presence of detectable EEG sleep transient patterns. Finally, the presence of patterns indicating motor or electric seizure and motor ES or NCES were also reported. Further details of the EEG description can be found in Hirsch et al. (Hirsch et al., 2013).

2.3. Outcome assessment

We evaluated the usefulness of an emEEG based on the subsequent clinical management of the patient, including the contribution of the emEEG to the diagnosis (confirming or excluding the admission diagnosis), medication changes (not just ASM)– such as initiation, dose change, and discontinuation, –discharge to home or hospital, and diagnosis at discharge. The assessment of the impact of emEEG was made by the ED attending physicians on the basis of the ED records.

2.4. Statistical analysis

Our results are reported as numbers and percentages for categorical variables and as medians (interquartile range: 25th percentile to 75th percentile) for quantitative variables. We used descriptive statistics to define our population, and compared data between groups using chi-squared tests or, for quantitative variables, the Kruskal–Wallis test. To avoid overestimating associations, Cramer V tests were used for categorical correlations. For the Cramer results, values between 0.30 and 0.49 were considered a good relationship, while values above 0.50 were considered a good association. The various statistical software applications used were GraphPad Prism v.8 (GraphPad Software, San Diego, CA), Jamovi (version 2.6.2), and Wizard for Mac (Evan Miller®). Two-tailed tests were used and p-values < 0.05 were considered significant. The Bonferroni method was used to correct for multiple analyses.

2.5. Standard protocol approvals, registrations, and patient consents

The study comforms to ethical principles and good clinical practice guidelines. Due to logistical constraints, informed consent will not be possible for all patients. A retrospective analysis of the database in which the patients were enrolled was approved by the local ethics committee (Ethics Committee Area Vasta Centro 27241, positive opinions of the ethics committee number 27241_oss).

3. Results

We included 1125 emEEGs performed on 1018 patients. During their stay in the ED, 107 patients underwent a second EEG. EmEEGs represented 25 % of the total number of EEGs performed during the same period (n = 4493 EEGs). The total number of patients admitted to the ED during the study period was 110,000, of whom 0.9 % underwent an emEEG. Most of the emEEGs (1014; 90.0 %) were performed during working hours.

The median age of the cohort was 70 years (IQR 29). Four hundred and ninety-four patients (48.5 %) were female.

Two hundred and eighty (27.4 %) subjects had preexisting epilepsy, of which 111 were of unknown aetiology and 169 were of structural aetiology. Two hundred and forty-seven (24.0 %) patients were on ASM.

Three hundred and seventy-four (36.7 %) patients had no previous brain parenchymal damage. Of the remaining 644 (62.2 %) patients, 135 (13.0 %) had previously undergone neurosurgery. The most common causes of brain damage were multi-infarct encephalopathy (204 patients, 20.0 %), brain tumour (85 patients, 8.3 %), previous ischemic stroke (74 patients, 7.2 %), hemorrhagic stroke (24 patients, 2.3 %), and previous traumatic brain injury (14 patients, 1.3 %).

Two hundred and thirty-eight (23.3 %) patients were admitted to the ED with metabolic or electrolyte disorders. 267 (26.2 %) patients had fever or sepsis, and 43 (4.2 %) patients were admitted after drug abuse.

Brain CT was performed in 952 (93.5 %) patients and showed acute pathology in 72 patients (7.5 %), of which cerebral ischemia was the most common type of brain damage (24 patients, 33.0 %).

Thirty-one (3.0 %) patients underwent lumbar puncture, of whom four had results consistent with a central nervous system (CNS) infection.

The demographic characteristics of the patients are shown in Table 1.

Neurological examinations on admission revealed cognitive/behavioural impairment in 355 (34.8 %) patients, involuntary movements in 347 (34 %) patients, altered level of consciousness state in 268 (26.3 %) patients, and speech disorder in 261 (25.6 %) patients, whereas 675 (66.2 %) patients showed a resolution of the symptoms that led to the admission to the ED.

Three hundred and twenty-two (31.6 %) patients were subsequently admitted to hospital, 6 (0.6 %) patients refused admission to hospital, and the remaining 690 (67.8 %) patients were discharged home after their ED visit.

An EEG recording and interpretation were performed by the neurologist/neurophysiologist with at median time of 90 min (IQR 80 min) after the ED attending physician's request.

The most common clinical indications for an emEEG were witnessed seizures (218, 21.4 %) or a suspected seizures (169, 16.6 %), loss of consciousness with or without head trauma or falls of unknown dynamics (140, 13.7 %), altered mental status (81, 7.9 %) (including both as a single indication and when in differential diagnosis with other clinical conditions), transient ischemic attack (TIA) (79, 7.7 %), ischemic or hemorrhagic stroke (65,6.3 %) (especially when in differential diagnosis with seizure or post-critical state; 86, 8.4 %), ES (33, 3.2 %) (including both as a single indication and when in differential diagnosis with other clinical conditions), falls of unknown dynamics with or without mild head trauma (31, 3 %), global amnesia (26, 2.5 %), and mild head trauma (11, 1.1 %).

Table 1
Patient's Demographic Characteristics.

Patients, n	1018
Age year, median (IQR)	70 (IQR 29)
Female gender, n (%)	494 (48.5 %)
Previous Epileptic Seizures	280 (27.4 %)
Unknown aetiology	111 (10.9 %)
Structural aetiology	169 (16.6 %)
Antiseizures drugs	247 (24.2 %)
Under-dosed Antiseizures drugs	62 (6.0 %)
Fever	126 (12.3 %)
Sepsis	141 (13.8 %)
Metabolic disturbance	84 (8.2 %)
Electrolyte disturbance	154 (15.1 %)
Drug abuse	44 (4 %)
Previous Neurological history	644 (62.2 %)
Stroke	98 (9.6 %)
Neurosurgery	135 (13.0 %)
Cardiac disorders	194 (19.1 %)
Diabetes	167 (16.4 %)
Dyslipidemia	257 (25.2 %)
Thyroid disease	121 (11.8 %)
Brain CT	952 (93.5 %)
Recent CT Lesions	72 (7.5 %)
Lumbar Puncture	31 (3.0 %)
Positive	4 (12.9 %)
Home discharge	690 (67.8 %)
Hospitalization	322 (31.6 %)
Hospitalization Refused	6 (0.6 %)

CT: Computer Tomography.

In 625 (61.4 %) cases, a single clinical indication for an emEEG was proposed, whereas in 299 (29.0 %) cases, a differential diagnosis between two clinical conditions was reported. In the remaining 93 (9.1 %) cases, no defined clinical indication was given, and patients underwent an emEEG depending on the presence of some neurological symptoms or signs, such as cognitive/behavioural impairment (65, 69.8 %) and speech disorders (26, 27.9 %).

An alluvial plot showing the most frequent discharge diagnosis (at least 5 % of the total number of patients with each reported initial diagnosis) compared with the most frequent admission diagnosis in patients who underwent emEEGs is shown in Fig. 1.

For example, patients with an initial diagnosis of suspected seizure were discharged with different final diagnosis such as confirmed seizure, loss of consciousness, global amnesia, head trauma or 'other diagnosis'.

EmEEGs were useful in 883 (86.7 %) patients. It influenced the initial diagnosis in 770 (75.6 %) patients, in particular, confirmed the clinical diagnostic suspicion in 189 (18.5 %), and excluded in 515 (50.5 %). The neurophysiological test influenced management decisions in 803 (78.8 %) patients and treatment in 362 (35.5 %).

In 66 (8.5 %) patients, the detection of abnormalities (such as focal slow waves or background slowing), on an emEEG, although not directly confirming or excluding the initial diagnosis, prompted the emergency physician to perform further instrumental or biochemical investigations thus contributing to reaching the correct final diagnosis.

In addition, in terms of management decisions, even in patients with normal emEEG, the test was useful in 317 (96.9 %) cases because of changes in the clinical behaviour [i.e. discharge of the patient home (n = 269, 82.2 %), contribution to discharge diagnosis (n = 259, 79.2 %), and patient management (n = 287, 87.7 %)].

In Table 2, the usefulness of emEEG, understood as a contribution to the diagnosis and the diagnostic–therapeutic management,is reported according to each initial diagnosis at admission.

Overall, the emEEG showed background slowing in 370 (36 %) patients, background asymmetry in 161 (15.8 %), focal slowing in 219 (21.5 %), bilateral slowing in 137 (13.4 %), epileptic discharges in 190 (19 %), rhythmic/periodic discharges in 56 (5.5 %), triphasic waves in 23 (2.3 %), motor seizures in 2 (0.2 %), nonconvulsive seizures in 5 (0.49 %), motor ES in 9 (0.8 %), and NCES in 23 (2.2 %). Three hundred and twenty-seven (32.1 %) patients had normal emEEGs on admission.

Table 3 presents a comprehensive list of emEEG characteristics and abnormalities according to the most common diagnosis on patient admission.

When the discharge diagnosis was compared with the most common admission neurological signs or symptoms [cognitive/behavioural impairment (34.6 %), involuntary movements (33.9 %), and speech disorder (20.4 %), understood both as a single neurological sign or symptom or in association with other admission signs and symptoms], we observed that 90 (25.4 %) patients admitted to the ED with cognitive/behavioural impairment had a final diagnosis of seizure or suspected seizure. A final diagnosis of ES or seizure was made in 264 (76.3 %) patients presenting to the ED with involuntary movements. A final diagnosis of ES, seizure or suspected seizure was made in 71 (34.1 %) patients presenting to the ED with a speech disorder.

Table 4 shows the usefulness of emEEG in terms of its contribution to the diagnosis and the diagnostic–therapeutic management according to the most common neurological signs and symptoms on admission.

Taking into account these most common neurological signs and symptoms on admission, seizures or ES were reported in 31 (8.9 %) patients with involuntary movements, in 12 (5.7 %) patients with speech disorders, and in 15 (4.2 %) patients with cognitive/behavioural

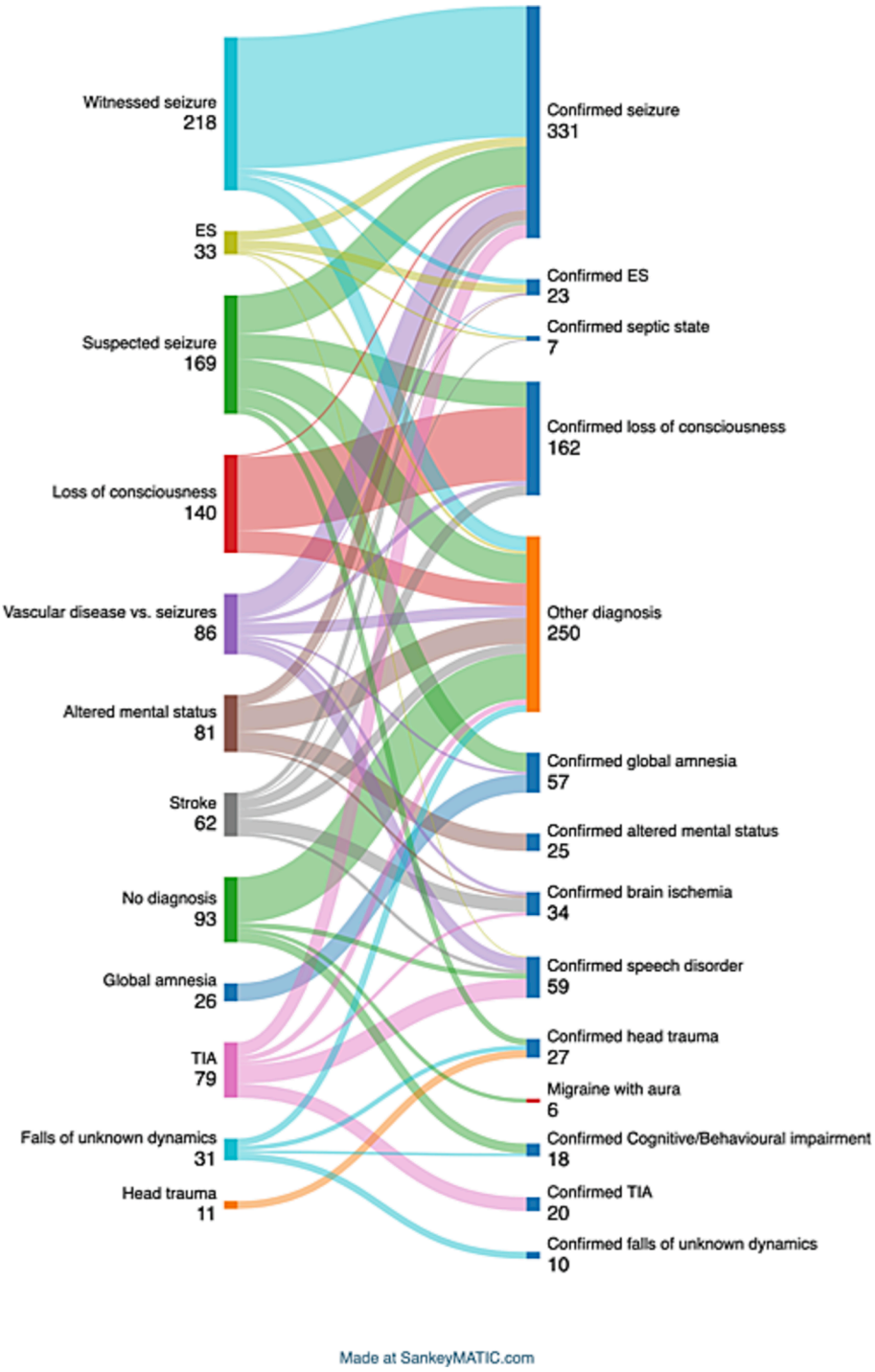

Fig. 1. Sankey diagram showing the relationship between the most frequent discharge diagnosis (at least 5% of the total number of patients with each reported initial diagnosis) and the most frequent admission diagnosis in patients who underwent emEEGs.

impairment. Epileptic discharges were reported in 118 (34.1 %) patients with involuntary movements, in 38 (18.2 %) with speech disorders, and in 42 (11.8 %) with cognitive/behavioural impairment, whereas rhythmic/periodic discharges were reported in 37 (10.6 %) patients with involuntary movements, in 21 (10.0 %) with speech disorders, and in 20 (5.6 %) with cognitive/behavioural impairment.

Among the demographic characteristics of the patients, previous neurosurgical intervention (n = 120 of 134 patients, 89.5 %), sepsis (n = 114 of 129 patients, 88.3 %), metabolic disturbance (n = 74 of 83 patients, 89.1 %), electrolyte disturbance (n = 127 of 154 patients, 82.4 %), fever (n = 101 of 126 patients, 80.1 %), and previous brain parenchymal damage without previous neurosurgery (n = 284 of 336 patients, 76.8 %) were the most common predisposing factors for an abnormal EEG.

4. Discussion

According to our results, the overall usefulness of an emEEG performed in patients admitted to the ED was 86.7 %, mainly influencing its contribution to the diagnosis (75 %), often excluding clinical diagnostic suspicion (50 %), and patient management (78 %).

In 8.5 % of the patients, the detection of abnormalities on the

Table 2
Usefulness of Emergency EEG, understood as contribution to the diagnosis and to the diagnostic-therapeutic management, according to each initial diagnosis on admission.

Patient's Clinical Management	Diagnosis contribution	Diagnosis confirmed	Diagnosis Ruled Out	Management decision	Treatment
Cramer's V	0.36	0.45	0.63	0.39	0.37
INITIAL DIAGNOSIS ON ADMISSION					
Witnessed seizures (n = 218)	128 (58.7)	90 (41.2)	21 (9.6)	156 (71.5)	68 (31.2)
Suspected seizures (n = 169)	96 (56.8)	29 (17.1)	51 (30.0)	117 (69.2)	44 (26.0)
TIA (n = 79)	68 (86.0)	0 (0.0)	64 (81.0)	117 (69.2)	44 (26.6)
Stroke (n = 65)	56 (86.1)	5 (7.6)	48 (73.8)	57 (87.6)	34 (52.3)
Vascular disease vs seizures (n = 86)	56 (65.1)	18 (20.9)	30 (34.8)	60 (69.7)	34 (39.5)
Loss of consciousness (n = 140)	123 (87.8)	5 (3.5)	109 (77.8)	116 (82.8)	21 (15.0)
Altered mental status (n = 81)	67 (82.7)	8 (9.8)	57 (70.3)	65 (80.2)	49 (60.0)
Epileptic status (n = 33)	27 (81.8)	20 (60.0)	3 (9.0)	25 (75.7)	24 (72.7)
Falls of unknow dynamics (n = 31)	26 (83.8)	1 (3.2)	21 (67.7)	25 (80.6)	6 (19.3)
Global amnesia (n = 26)	26 (100 %)	0 (0.0)	26 (100)	25 (96.1)	0 (0.0)
Head trauma (n = 11)	11 (100 %)	0 (0.0)	11 (100)	10 (90.9)	2 (18.1)
No diagnosis (n = 93)	80 (86.0)	11 (11.8)	68 (73.1)	76 (81.7)	36 (38.7)

TIA: Transient Ischemic Attack.

Table 3
Emergency EEG characteristics and abnormalities according to the most frequent diagnosis on patient's admission.

	Frequency	Reactivity	Topography	Symmetry	Major delta slow Bilateral	Major delta slow Focal	Seizures/ ES	Epileptic discharges	Periodic Discharges
Cramer's V	0.34	0.32	0.49	0.23	0.26	0.27	0.35	0.32	0.24
INITIAL DIAGNOSIS ON ADMISSION									
Witnessed Seizures (n = 218)	98 (44.9)	74 (33.9)	73 (33.4)	48 (22.0)	49 (22.4)	63 (28.8)	14 (6.4)	89 (40.8)	24 (11.0)
Suspected Seizures (n = 169)	65 (38.4)	40 (23.6)	41 (24.2)	44 (26.0)	17 (10)	30 (17.7)	(2.9)	29 (17.1)	4 (2.3)
TIA (n = 79)	22 (27.8)	4 (5.0)	4 (5.0)	3 (3.7)	5 (6.3)	11 (13.9)	0 (0.0)	0 (0.0)	0 (0.0)
Stroke (n = 65)	28 (43.0)	16 (24.6)	17 (26.1)	12 (18.4)	10 (15.3)	17 (26.1)	1 (1.5)	5 (7.6)	4 (6.1)
Vascular disease vs seizures (n = 86)	35 (40.6)	17 (19.7)	17 (19.7)	15 (17.4)	11 (12.7)	29 (33.7)	4 (4.6)	15 (17.4)	3 (3.4)
Loss of consciousness (n = 140)	28 (20)	9 (6.4)	11 (7.8)	7 (5.0)	11 (7.8)	13 (9.2)	0 (0.0)	9 (6.4)	1 (0.7)
Altered mental status (n = 81)	69 (85.1)	62 (76.5)	62 (76.5)	18 (22.2)	31 (38.2)	19 (23.4)	1 (1.2)	11 (13.5)	7 (8.6)
Epileptic Status (n = 33)	23 (69.6)	19 (57.5)	19 (57.5)	11 (35.4)	8 (24.2)	17 (51.5)	12 (36.3)	20 (60.6)	10 (30.3)
Falls Of Unknow Dynamics (n = 31)	14 (45.1)	6 (19.3)	6 (19.3)	3 (9.6)	5 (16.1)	6 (19.3)	0 (0.0)	1 (3.2)	0 (0.0)
Global Amnesia (n = 26)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (7.6)	2 (7.6)	0 (0.0)	0 (0.0)	0 (0.0)
Head Trauma (n = 11)	4 (36.3)	2 (18.1)	2 (18.1)	2 (18.1)	2 (18.1)	1 (9.0)	0 (0.0)	0 (0.0)	0 (0.0)
No Diagnosis (n = 93)	38 (40.8)	19 (20.4)	20 (21.5)	16 (17.2)	24 (25.8)	12 (12.9)	2 (2.1)	11 (11.8)	3 (3.2)

TIA: Transient Ischemic Attack; ES: Epileptic Status.

Table 4
Usefulness of Emergency EEG, understood as contribution to the diagnosis and to the diagnostic-therapeutic management, according to the most frequent neurological signs and symptoms on admission.

Patient's Clinical Management	Diagnosis contribution	Diagnosis confirmed	Diagnosis ruled out	Management decision	Treatment
Cognitive/Behavioural Impairment (n = 353)	282 (79.8)	59 (16.7)	198 (56.0)	143 (40.5)	143 (40.5)
Involuntary movements (n = 346)	216 (62)	126 (36)	59 (17)	254 (73.0)	122 (35)
Speech Disorder (n = 258)	208 (80.6)	52 (20.1)	139 (53.8)	208 (80.6)	137 (53.1)

emEEG, such as focal slow waves or background slowing, although not directly confirming or excluding the initial diagnosis, led the emergency physician to perform further instrumental or biochemical investigations, which led to the correct final diagnosis.

ES and altered consciousness state were the initial diagnoses for which the emEEG was most useful overall, contributing to the final diagnosis (81.8 % and 82.7 %, respectively), patient management (75.7 % and 80.2 %) and therapeutic pathway (72.7 % and 60.0 %). More specifically, an emEEG usually confirmed the clinical suspicion of an ED diagnosis (60.0 %), whereas it often excluded this suspicion in patients with an initial diagnosis of altered states of consciousness (70.3 %), and also suggested another diagnosis [i.e. septic or metabolic encephalopathy (14.8 %)].

Furthermore, even when a normal emEEG was detected, its usefulness was reported in 97 % of the patients, influencing the contribution to the diagnosis (79 %), patient management (87 %), and home discharge (82 %).

The term 'emergency' refers to a life-threatening pathological condition that requires immediate treatment. Neurological disorders causing altered states of consciousness are usually included in the emergent conditions, and many of these (i.e. NCES, metabolic or septic encephalopathy, encephalitis) could be detected by an emEEG.

The usefulness of emEEG in clinical practice is well-established. Specifically, emEEG is beneficial during the first 24–48 h after the

onset of neurological symptoms, not only for the clinical management of ES or NCES and ASM changes, but also in patients with loss of consciousness, acute ischemic lesions, altered mental status or mental confusion, even in the setting of normal neuroimaging (Mañez Miro et al., 2018; Praline et al. 2007; Yigit et al., 2012, Varelas et al., 2003, Rodriguez Quintana et al., 2021). However, universally accepted recommendations are still lacking, except for NCES and motor ES (ACEP Clinical Policies Committee Clinical Policies Subcommittee on Seizures, 2004; Feyissa and Tatum, 2019; Praline et al., 2007; Varelas et al., 2003; Vignatelli et al., 2024).

The lack of guidelines on the use of an emEEG is mainly due to the scattered data in the literature and to the heterogeneity of sample selection, recruitment, and setting, which makes it difficult to compare the reported results.

The small sample size analysed was a limitation of most of the previous studies (Praline et al., 2007; Khan et al., 2001; Quigg et al., 2001; Rodriguez Quintana et al., 2021; Varelas et al., 2003; Yigit et al., 2012).

The recruitment of the chosen sample was another limitation of the studies. In fact, there is no widely accepted definition of the emEEG (Varelas et al., 2003). In previous studies, this definition included all the EEGs performed outside hospital hours (Quigg et al., 2001) or any EEG performed to exclude NCES with'24-hours-a-day, 7-days-a-week' availability and after approval by the neurologist or neurosurgery (Khan et al., 2001). In other cases, an emEEG was defined as any EEG requested on an emergency basis and performed within 1 h of the emergency physician's request (Varelas et al., 2003), resulting in a large heterogeneous sample recruitment.

In addition, the setting chosen in most studies (Khan et al., 2001; Praline et al., 2007; Quigg et al., 2001; Varelas et al., 2003) included intensive care units (ICUs), resulting in several emEEGs ordered for brain death detection or prognostic purposes regarding the neurological outcome of patients after severe brain injuries (Scarpino et al., 2018; Scarpino et al., 2021). When the ICU setting was not involved, inpatient wards were included, often resulting in emEEG requests from neurology and neurosurgery wards, where attending physicians had more expertise in selecting neurophysiological tests (Rodriguez Quintana et al., 2021).

Finally, Yigit et al., (Yigit et al., 2012), Privitera et al., (Privitera and Strawsburg, 1994) and Bellini et al. (Bellini et al., 2024) limited their analyses to the ED setting, however focusing only on epileptic disorders.

In the current study, we recruited all consecutive patients admitted to the ED of our hospital who underwent emEEG, including both the neurophysiological tests recorded during the daily clinical practice and those performed outside hospital hours with a median time of recording and interpretation of EEG results of 1 h and 30 min after the request of the emergency physician.

The power of this study was mainly represented by the large sample analysed and the chosen setting, which limited the evaluation of emEEGs only among to those performed in the ED.

Indeed, the ED was a unique setting in which attending physicians usually had to make rapid decisions about the diagnostic–therapeutic management of patients, often in the absence of immediate availability of some instrumental tests such as brain MRI, or prior neurological or neurosurgical consultation. At the same time, they had to make decisions about the subsequent discharge or hospitalisation process of the patients. For all these reasons, not only confirming but also the ruling out the initial diagnosis could be of great importance in this particular clinical setting for correct subsequent patient management.

These specific work needs that characterise the ED have usually resulted in a high demand for emEEG in the clinical practice, often related to the performance characteristics and the rapid availability of this neurophysiological test or related to the individual's experience of the ED attending physicians rather than to its actual diagnostic power or a logical clinical approach.

The widespread use of emEEGs in this clinical context, in the absence of accepted guidelines, has often led to over-prescription, misuse, and reduced diagnostic power and specificity. This high demand for emEEG in the clinical practice is a major challenge, especially in first and second level hospitals where resources are limited, and there is an urgent need for highly qualified personnel.

According to our results, witnessed or suspected seizures, loss of consciousness, altered mental status, TIA, stroke (especially when in differential diagnosis with seizures or post-critical state), ES, falls of unknown dynamics, global amnesia, and mild head trauma were the most common initial diagnoses for an emEEG request.

Even when a diagnostic suspicion other than seizures (i.e. TIA or stroke diseases) was assessed on admission, an emEEG was often necessary to exclude ES or epileptic seizures as the cause of the neurological symptoms presenting to the ED, especially when neuroimaging did not reveal any acute pathology. In a minority of cases, particularly in patients with altered mental status due to drug abuse, metabolic or electrolyte disturbances, fever, or sepsis, an emEEG was needed to detect clinical conditions other than ES or epileptic seizures (i.e. septic or metabolic encephalopathy or encephalitis).

Fig. 1 shows the thirteen most common discharge diagnoses among the patients included in the analysis. Transient neurological deficits not better characterised, sensory disturbance, dizziness, global sickness not better defined and metabolic disturbance represented instead the most common final diagnoses among the 250 patients discharged with "other diagnosis".

As shown in Fig. 1, the majority (85.7 %) of patients with witnessed seizures, had their initial diagnosis confirmed on discharge from the ED. The remaining number of patients discharged with a final diagnosis of seizure came mainly from suspected seizure (38.1 %), ES (9.0 %), altered mental status (9.7 %), and from patients with a differential diagnosis between vascular disease and epileptic seizure on admission (22.9 %). At the same time, patients with a final diagnosis of ES had a witnessed seizure (34.7 %), ES (52.1 %), altered mental status (4.3 %), and a differential diagnosis between vascular disease and epileptic seizure as a diagnosis on admission (8.6 %).

When a vascular disease was the only initial diagnosis, a greater number of patients with TIA as the admission diagnosis were discharged with seizure (24.0 %) compared with those with stroke (11.2 %). When loss of consciousness was the only initial diagnosis (therefore not in the differential diagnosis with seizure), the admission diagnosis was confirmed in most cases (75.0 %), and only in a very small number of patients, a diagnosis of seizure was performed (2.1 %). Finally, none of the patients admitted with an initial diagnosis of global amnesia, falls of unknown dynamics, or mild head trauma as a single diagnosis, or those admitted to the ED without a specific diagnostic suspicion were discharged with a diagnosis of seizure or ES.

From the analysis of our data, ES and altered consciousness state were the initial diagnoses for which the emEEG showed the best overall usefulness for the final diagnosis (81.8 % and 82.7 %, respectively) and to patient management (75.7 % and 80.2 %) and therapeutic pathway (72.7 % and 60.0 %). More specifically, an emEEG usually confirmed the clinical suspicion of ES (60.0 %), while it often excluded it in patients with an initial diagnosis of altered consciousness state (70.3 %), and sometimes suggested another diagnosis [i.e. septic or metabolic encephalopathy (14.8 %)].

In patients with loss of consciousness or with a suspected vascular diagnosis (TIA or stroke), emEEG was useful both in ruling out epileptic seizures (77.8 % and 81.0 % – 73.8 %, respectively) and in patient management.

For witnessed or suspected seizures, the contribution of emEEG to the diagnosis was just over 50 % [a result consistent with previous literature (Bellini et al., 2024; Zawar et al., 2022)], confirming the diagnosis (41.2 %) in witnessed seizures and predominantly excluding it in the cases of suspected seizures (30.0 %).

With global amnesia and mild head trauma as the only initial diagnosis, the emEEG ruled out the suspected epileptic seizure in 100 % of the patients. Moreover, none of the patients showed specific EEG abnormalities such as epileptic discharges, periodic discharges, seizures or

ES, or triphasic waves; rather, most of these patients had normal EEGs, suggesting that in subjects with these two initial clinical diagnoses, an emEEG recording may not be indicated because of non-specificity.

Patients presenting to the ED with falls of unknown dynamics had emEEG characteristics similar to those of patients with global amnesia and mild head trauma. Only one patient with pre-existing epilepsy had epileptic discharges, suggesting that emEEG is indicated in patients with this initial diagnosis only if there is a positive history of epilepsy.

Finally, when there was no defined clinical indication on admission and patients underwent an emEEG, depending on the presence of some neurological symptoms or signs such as cognitive/behavioural impairment and speech disorders, the usefulness of this neurophysiological test was mainly related to ruling out suspected epileptic seizures (73.1 %) and management decisions (81.7 %).

In terms of EEG characteristics, background slowing was the most common EEG abnormality, observed in 36 % of patients, particularly those with altered mental status or clinical suspicion of epileptic seizures. This slowing was also associated with abnormal reactivity and topography. Focal slowing was seen in 21.5 % of patients and was more common in patients with ES (51.5 %). Epileptic discharges were reported in 19 % of the patients, particularly in those with ES (60.6 %) and with witnessed seizures (40.8 %). Rhythmic/periodic discharges and triphasic waves were reported in only 5.5 % and 2.3 % of the patients, respectively, especially in subjects with ES (30.3 %) and altered mental status (14.8 %). Both motor and nonconvulsive seizures as well as motor and NCES were overall reported in a total of 3.8 % of the patients, particularly in those with an admission diagnosis of ES (36.3 %).

A normal emEEG was reported in 32.1 % of the patients, especially when global amnesia was the diagnosis on admission to the ED.

When considering neurological signs and symptoms on admission, cognitive/behavioural impairment (34.6 %), involuntary movements (33.9 %), and speech disorder (20.4 %) were the most common causes of presentation to the ED requiring an emEEG. On discharge from the ED, involuntary movements were the neurological admission sign associated with a more frequent final diagnosis of ES or seizure (76.3 %), followed by speech disorder (34.1 %) and cognitive/behavioural impairment (25.4 %). Both seizures or ES and epileptic or rhythmic/periodic discharges on the emEEG were reported mainly in patients with involuntary movements, followed by patients with speech disorders.

Furthermore, the contribution of an emEEG to the diagnosis was 80.6 % and 79.8 % when speech disturbance and cognitive/behavioural impairment were the presenting neurological symptoms, respectively, excluding the initial suspicion of seizures or ES in 53.8 % and 56.0 % of the patient, respectively. In the case of speech disturbance, emEEG was also useful for patient management in 80.6 % of cases. When involuntary movements were considered as an admission signs, the usefulness of an emEEG in contributing to the diagnosis was lower compared to the other two most common neurological symptoms on admission (62.0 %) but, in this case, it confirmed the initial suspicion of seizures or ES (36.0 %). However, in 73 % of the cases the emEEG was useful for patient management.

From the analysis of our data, TIA and involuntary movements were the initial diagnosis and the neurological sign on admission, respectively, that were more frequently discharged as seizures compared to the percentage of emEEGs confirming an epileptic origin of the neurological symptomatology leading to the ED access.

Our study has some limitations. Given the retrospective nature of the research, clinical and instrumental information was collected from medical records and may have been incomplete. Another limitation was the retrospective assessment of the impact of emEEG, which was performed by the researchers themselves using patient records. Although the impact of the emEEG on the diagnostic–therapeutic management of patients in the ED was measured by a different researcher (the ED attending physician) than the one who interpreted the emEEGs (the neurologist physician), the inherent bias associated with subjective interpretations should be acknowledged.

Furthermore, this study was conducted in a tertiary hospital where at least two or three neurophysiological technicians and one EEG expert neurologist/neurophysiologist per day were exclusively dedicated to the recording and interpreting emEEGs during their working hours. We were aware that this daily work organisation made it possible to meet the large number of emEEG requests in clinical practice, many of which came from the ED, and thus to collect the current large sample of patients. We were also aware that this daily work organisation could not be extended to primary and secondary hospitals, where the availability of emEEG is limited. In addition, our sample, recruited in a tertiary teaching hospital, included mainly complex and severe cases that may not fully represent the spectrum of cases in smaller hospitals, limiting the generalisability of our work.

In summary, this study, which included a large sample of subjects and limited the evaluation of emEEGs performed only in the ED, attempted to identify the reasons why ED attending physicians ordered an emEEG and the clinical conditions or neurological signs and symptoms on admission that indicated its greatest usefulness. This usefulness was defined as changes in management or therapeutic decisions, changes in clinical diagnosis, and change sin the patient's discharge or hospitalisation process. Our study provided evidence to suggest recommendations for the daily clinical practice of emEEGs, particularly in a specific setting such as the ED. The development of these recommendations following well-established methodological tools and no longer limited only to the management of ES, would be of great importance especially for primay and secondary hospitals where the availability of emEEG is limited and where resources are scarce in front of the need of highly qualified personnel.

Multicentre prospective studies analysing large samples and restricting the evaluation of emEEGs performed in the ED setting are needed to increase the robustness and generalisability of our findings.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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