

신경계중환자실에서 지속뇌파감시



이 현 조

울산의대 신경과

Continuous EEG monitoring of neurocritical patients

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- Indication
 - Guidelines
 - New indications: preliminary studies (ICP, encephalopathy and reactivity)
 - A possible new strategy: ZHELPS2B
- Impact on outcomes
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- Reduced montage
 - High specificity but insufficient sensitivity
 - A need in the clinical practice
- Training for the interpretation
 - Inter-rater reliability of ICU EEG terminology
 - qEEG, raw EEG

Guidelines for the Evaluation and Management of Status Epilepticus



Situation	Rationale	Grade
Sz without return to baseline >10 min	NCSz after CSz 18-50%	Class I, level B
Coma, including post-cardiac arrest	NCSz 20-60%	Class I, level B
EDs or PDs on initial 30 min EEG	NCSz 40-60%	Class I, level B
TBI, SAH, ICH	NCSz 20-30%	Class I, level B

Situation	Strength	Evidence
Should be initiated within 1 h of SE onset if ongoing seizures are suspected	Strong	Low
Should be at least 48 h in comatose patients to evaluate for NCSz	Strong	Low
Transfer to a facility that can offer cEEG monitoring (RSE)	Strong	Very low
The person reading EEG in the ICU setting should have specialized training in cEEG interpretation, including the ability to analyze raw EEG as well as quantitative EEG tracings	Strong	Low

Systematic Review
Recommendations on the use of EEG monitoring in critically ill patients: consensus statement from the neurointensive care section of the ESICM



Etiology	Situation	Objective	Strength	Evidence
Generalized convulsive SE	Do not return to baseline within 60 min after ASD	Detect NCSz	Strong	Low
Refractory SE	Concern for ongoing seizure activity	Detect NCSz	Strong	Low
TBI/SAH/ICH	Unexplained alteration in consciousness	Detect NCSz	Strong	Low
Cardiac arrest	Persistent coma	Detect NCSz	Strong	Low
Encephalitis	Unexplained alteration in consciousness	Detect NCSz	Strong	Low
Acute ischemic stroke	Unexplained alteration in consciousness	Detect NCSz	Weak	Very low
SAH	Patients in whom clinical examination is unreliable	Detect ischemia	Weak	Low
Cardiac arrest	Persistent coma	Prognostication	Weak	Low
All ICU patients	Unexplained alteration in consciousness	Prognostication	Weak	Low
Encephalitis	Unexplained alteration in consciousness	Prognostication	Weak	Very low


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Consensus Statement on Continuous EEG in Critically Ill Adults and Children, Part I: Indications




Etiology	Situation	Objective
Generalized convulsive SE	Do not return to baseline within 30 min after ASD Not showing clear signs of improvement within 10 min	Detect NCSz
Acute supratentorial brain injury	Unexplained-alteration mental status Requirement for pharmacological paralysis (e.g. TH, ECMO)	Detect NCSz
All ICU patients	PDs	Detect NCSz
SE	Monitor the response of Sz/SE treatment	Detect NCSz
SAH	Patients in whom clinical examination is unreliable Before the highest risk window to establish a baseline recording (e.g. as soon as the aneurysm is secured) Should include qEEG analysis	Detect ischemia
High-dose sedation	Monitoring of sedation (e.g. Coma therapy in TBI, RSE)	Monitoring
Cardiac arrest	Persistent coma	Prognostication
Severe TBI, SAH	Standard EEG vs. 7	Prognostication

[illegible]



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Neuroimaging



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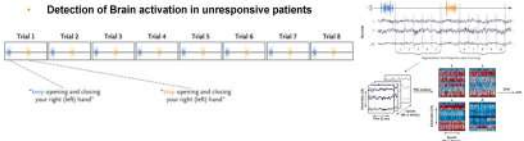
Indication: preliminary studies

★ **Delirium detection & cognitive outcome**



- Transition from non-delirium to delirium: Beta power HR 0.7 (0.5-0.9)
- Transition from delirium to non-delirium: Beta power HR 1.5 (1.2-2.1)

	Relative delta power (2 - 4 Hz) Td1-Pd1		Relative power (2 - 4 Hz) Td1-Pd1	
	Correlation coefficient (95% CI)	P-value	Correlation coefficient (95% CI)	P-value
Identification of delirium (2002)	0.39 (0.20 - 0.42)	<0.001	0.36 (0.28 - 0.43)	<0.001
Severity of delirium (2004 & 408)	0.38 (0.20 - 0.42)	<0.001	0.46 (0.33 - 0.58)	<0.001
Attention level (score 12 of 20) (3 & 40)	0.27 (0.17 - 0.37)	<0.001	0.33 (0.23 - 0.43)	<0.001
Level of consciousness (2002)	-0.20 (-0.38 - -0.10)	<0.001	-0.35 (-0.49 - -0.19)	<0.001

★ **Detection of Brain activation in unresponsive patients**



Reuter T. 2013, Cassiani L. 2013

			
Current practice			
Area	Responses	2009 Mixed	2014 Adult
EEG availability	All time 24/7, in house & on call	63%	86%
	Limited additional hours	25%	11%
	Only standard weekday hours	12%	3%
Remote reading	Possible for all/most records	35%	53%
	Possible for some records	43%	42%
	Not possible	22%	5%
cEEG	Yes	34%	52%
cEEG pts/month	< 5	58%	12%
	6-20	29%	30%
	>20	13%	30%


cEEG resources	2014
Almost always available	83%
Insufficient EEG techs	15%
Insufficient EEG machines	13%
Insufficient neurophysiologists	4%

Current practice

Topic	do not know (%)	do know (%)
COVID-19 vaccine	1%	1%
Medical data communication	32%	56%
Food	47%	61%
Water	48%	59%
AI diagnosis	51%	68%
DR	54%	81%
Telemedicine	56%	65%
AI monitoring	58%	73%
Healthcare insurance	67%	82%
Healthcare data communication	70%	85%


Legend: do not know (blue), do know (red)

Source: NH, 2022, January 1, 2024



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Indication: new strategies?

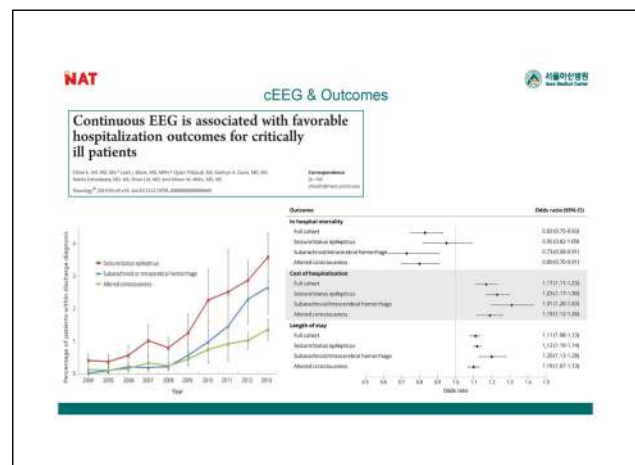
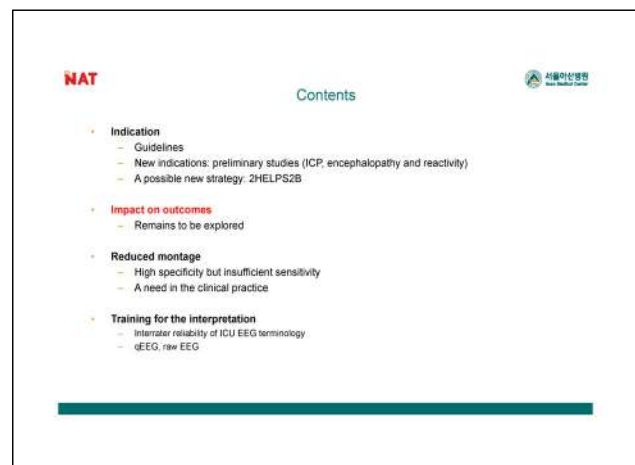
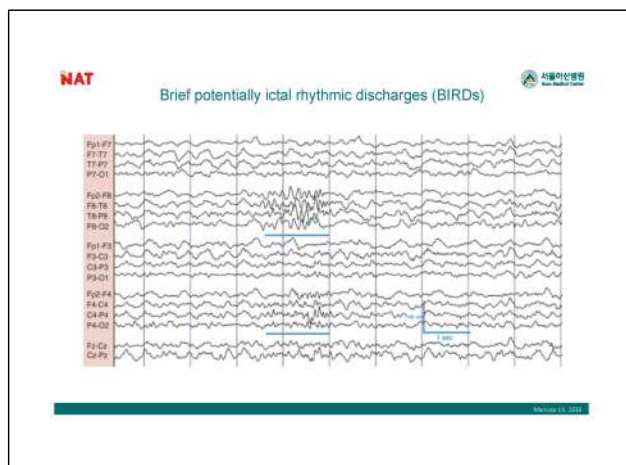
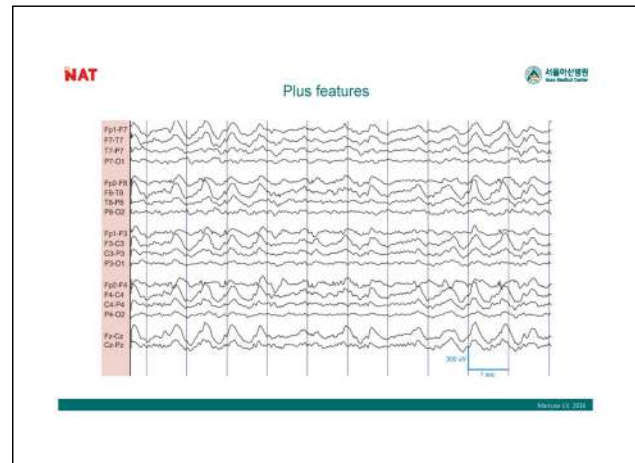
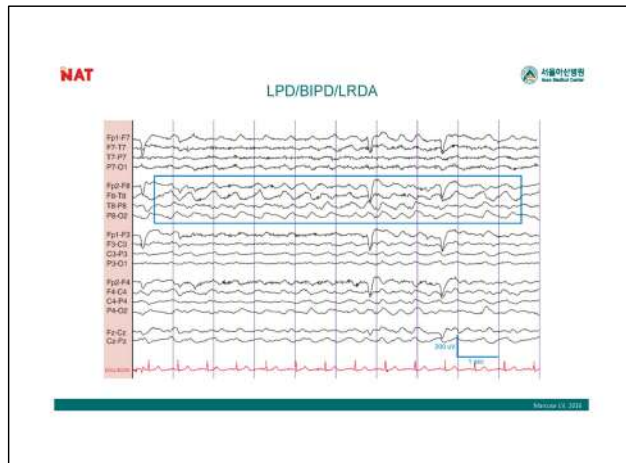


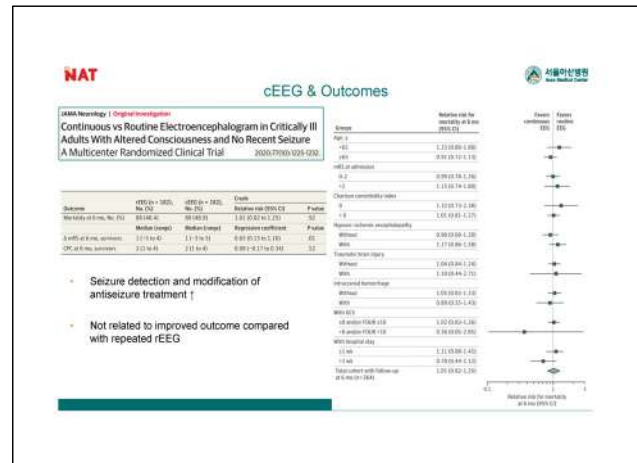
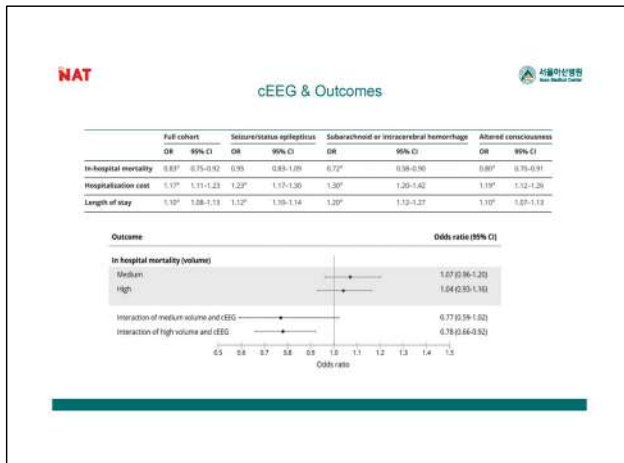
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- ▶ **No validated approaches for abnormal EEG patterns (Ictal-interictal continuum)**
 - Physician preference
 - Intuition resources
- ▶ **ZHELPS2B**
 - Score 0~7
 - Seizure risk in critically ill patients

Risk Factor	Points
Frequency > 20x *	1
Spontonic Epileptic Form Discharges	1
LPDS/POLUCA	1
Plus Features *	1
Prior Seizure	1
Brief Ictal Rhythmic Discharge	2
	Total Score
Total Score:	0 1 2 3 4 5 >6
Seizure Risk:	<5% 12% 27% 50% 73% 88% >95%

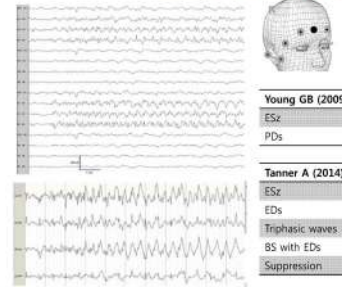
Class A, 2022





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Montage: standard vs. simplified

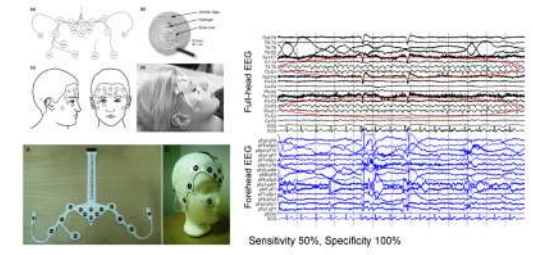


Young GB (2009)	Sensitivity	Specificity
ESz	68%	98%
PDs	39%	92%

Tanner A (2014)	Sensitivity	PPV
ESz	54%	100%
EDs	60%	81%
Triphasic waves	24%	83%
BS with EDs	55%	55%
Suppression	32%	46%

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Montage: standard vs. simplified

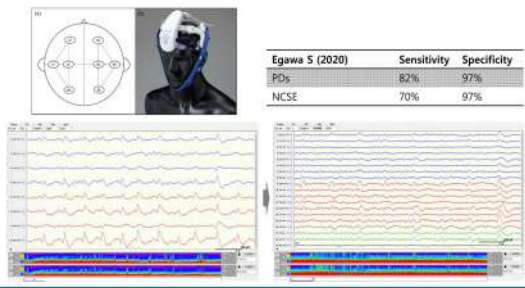


Sensitivity 50%, Specificity 100%

Muller-Mass A. 2011

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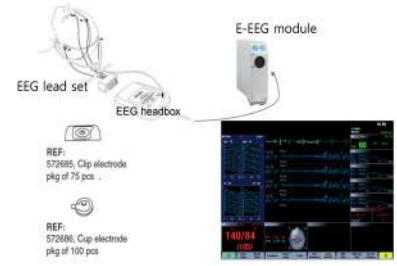
Montage: standard vs. simplified



Egawa S (2020)	Sensitivity	Specificity
PDs	82%	97%
NCSE	70%	97%

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Montage: standard vs. simplified



EEG lead set

EEG headbox

E-EEG module

REF: 572685, Clip electrode plug of 75 pcs

REF: 572686, Cup electrode plug of 100 pcs

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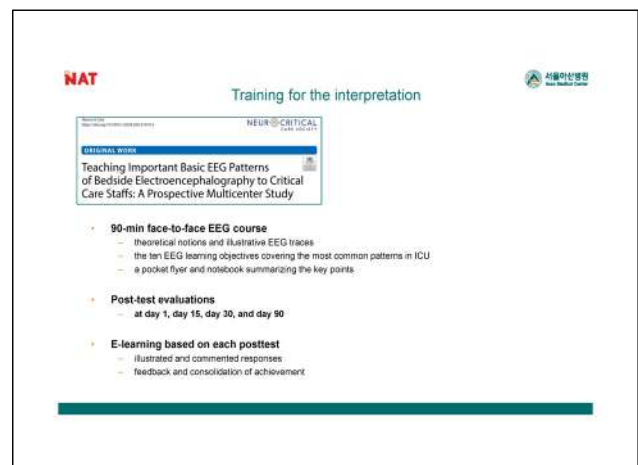
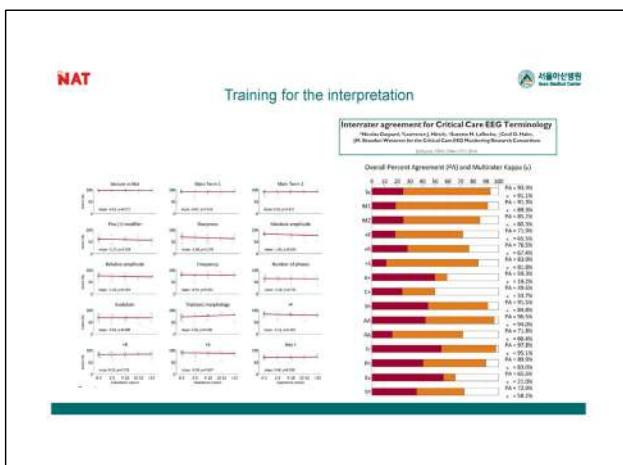
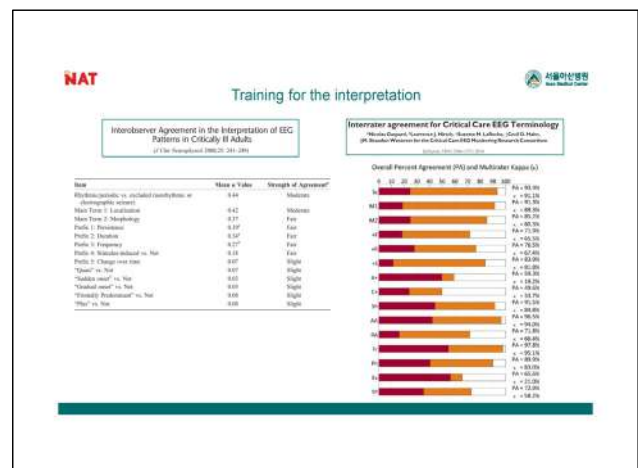
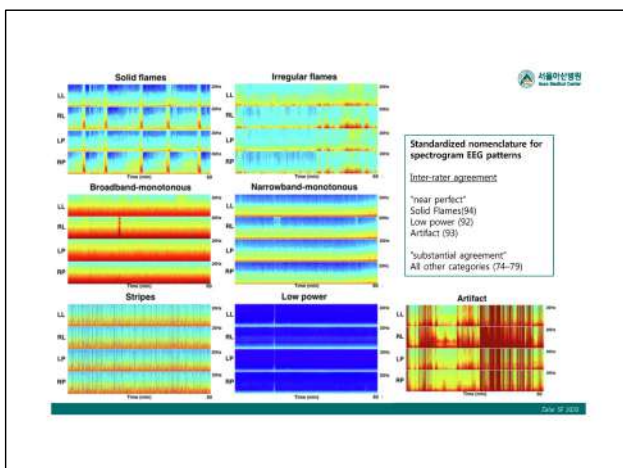
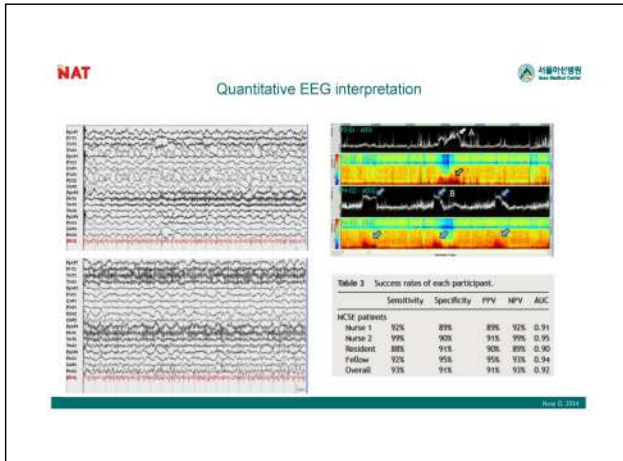
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Training for the interpretation

- Recommendation
 - Professionals trained to read cEEG tracings
 - A certified neurophysiologist
 - Electroencephalographers
 - A person had specialized training in cEEG interpretation, including the ability to analyze raw EEG as well as quantitative EEG tracings
- Training Non-experts
 - Urgent bedside diagnosis & management
 - Physicians and nursing healthcare professionals should receive appropriate training
 - Mainly focused on quantitative EEG interpretation
 - ACNS Critical Care EEG terminology : improved interrater agreement?



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Training for the interpretation



Objectives	Definitions
Background frequency	Posterior dominant 'alpha' rhythm or delta, theta, beta rhythms. Physiological variations during sleep were considered in case of any change in background EEG activity according to sleep stage and mild sleep transients (K-complexes essentially).
Asymmetry	Any variation of amplitude or background frequency > 1 Hz between both hemispheres.
Reactivity	Any change in cerebral EEG activity to stimulation and included amplitude or frequency accentuation or attenuation of activity, but also stimulus-induced rhythmic reactivities.
Effects of sedation on EEG frequency/amplitude	Any change of background frequency after sedation with or without superimposed fast activity.
Burst suppression	EEG frequency continuity lasting more than 50% of the EEG epoch and consisting of alternance of attenuation or suppression with burst of various forms and amplitude.
Paroxysmal EEG patterns	Graphoelements of sudden onset and abrupt termination distinguishing from background activity of 50% of amplitude.
Periodic patterns	Generalized, lateralized, or multifocal paroxysmal EEG patterns with relatively uniform morphology occurring intermittently at an approximately and/or regular rate with a quantifiable inter-discharge interval.
Rhythmic activities	Any paroxysmal EEG pattern or regular waves with relatively uniform morphology occurring repeatedly without quantifiable inter-discharge interval. Rhythmic activities were considered as occurs when they demonstrated being repetitive at > 2 cycles/sec and/or associated with spatio-temporal evolution, not reactive to stimulation and lasted at least 10 seconds.
Artifacts	Extracerebral source present in EEG recordings, such as electrocardiographic, myoelectric, oculographic EEG contaminants.
Isoelectric EEG	Entirety suppression of the record (electrocerebral inactivity).

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Training for the interpretation



	Pretest evaluation		Day-1 posttest evaluation		Day-15 evaluation		Day-30 evaluation		Day-90 final evaluation	
	n	Median [IQR]	n	Median [IQR]	n	Median [IQR]	n	Median [IQR]	n	Median [IQR]
EEG availability										
Routine EEG	103	3 [2-4]	95	7 [5-8]	90	7 [5-8]	81	7 [5-8]	73	9 [8-9]
Implementation phase (SSG)	74	2 [2-3]	53	6 [5-7]	36	6 [4-7]	34	7 [6-7]	18	8 [7-8]
No EEG but surgical EEG	73	1 [2-3]	43	7 [5-8]	34	6 [5-7]	22	7 [7-8]	17	8 [8-9]
EEG staff performance										
Senior internist	30	1 [2-4]	24	7 [5-8]	20	6 [5-8]	18	6 [7-8]	13	8 [8-9]
Fellow	24	3 [2-4]	20	8 [7-9]	18	7 [6-8]	16	6 [7-8]	12	8 [8-9]
Resident	35	1 [2-4]	42	7 [6-8]	34	7 [5-8]	26	7 [6-8]	23	9 [7-8]
Medical student	44	3 [2-3]	37	7 [6-8]	29	6 [4-8]	23	8 [7-8]	19	9 [8-10]
Nurse	97	2 [2-3]	70	6 [5-7]	59	6 [4-7]	44	7 [6-8]	39	8 [7-8]

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Training for the interpretation



	Percentages (95% CI)				
	Pretest evaluation	Day-1 posttest evaluation	Day-15 evaluation	Day-30 evaluation	Day-90 final evaluation
Background EEG frequency	17.6 (12.9-22.3)	79.3 (74.2-84.3)	62.5 (56.5-68.5)	95.3 (92.6-97.9)	89.8 (86.0-93.6)
Symmetric EEG	41.7 (35.1-47.3)	36.8 (30.8-42.8)	76.3 (71.0-81.3)	16.5 (11.8-21.3)	16.3 (10.8-26.0)
EEG reactivity	9.6 (5.9-13.3)	64.8 (58.8-70.7)	48.1 (41.9-54.3)	72.4 (66.9-78.0)	70.4 (64.7-76.1)
Effects of sedation on EEG frequency/amplitude	39.6 (33.5-45.7)	67.4 (61.5-73.2)	70.6 (64.8-76.8)	37.0 (31.0-43.0)	67.0 (60.9-73.2)
Burst suppression EEG pattern	24.0 (18.7-29.3)	96.4 (94.0-98.7)	68.1 (62.3-73.9)	98.4 (96.9-100)	80.2 (74.1-86.3)
Paroxysmal EEG patterns	24.6 (18.7-29.3)	59.1 (52.9-65.2)	24.4 (19.0-29.7)	66.9 (61.3-72.6)	94.4 (91.6-97.3)
Periodic/pseudo-periodic EEG pattern	43.6 (37.4-49.8)	80.8 (75.9-85.7)	58.7 (52.8-64.6)	91.3 (87.8-94.8)	42.9 (36.4-49.8)
Rhythmic activities	56.8 (50.6-62.9)	73.6 (68.1-79.1)	93.1 (89.9-96.1)	77.9 (72.8-83.1)	86.1 (81.8-90.4)
EEG artifacts	0	52.8 (46.6-59.1)	73.8 (68.3-79.2)	76.4 (71.1-81.6)	91.7 (88.2-95.1)
Isoelectric EEG	19.6 (14.7-24.3)	43.0 (36.9-49.2)	66.3 (60.4-72.1)	86.6 (82.4-90.8)	89.8 (86.0-93.6)

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Summary



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