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Guidelines

Standardized computer-based organized reporting of EEG: SCORE – Second version

Sándor Beniczky [a,b,*], Harald Aurlien [c], Jan C. Brøgger [c], Lawrence J. Hirsch [d], Donald L. Schomer [e], Eugen Trinka [f,g], Ronit M. Pressler [h], Richard Wennberg [i], Gerhard H. Visser [j], Monika Eisermann [k,l,m], Beate Diehl [n], Ronald P. Lesser [o], Peter W. Kaplan [p], Sylvie Nguyen The Tich [q], Jong Woo Lee [r], Antonio Martins-da-Silva [s], Hermann Stefan [t], Miri Neufeld [u], Guido Rubboli [v], Martin Fabricius [w], Elena Gardella [a,x], Daniella Terney [a], Pirgit Meritam [a], Tom Eichele [y], Eishi Asano [z], Fieke Cox [j], Walter van Emde Boas [j], Ruta Mameniskiene [aa], Petr Marusic [ab], Jana Zárubová [ab], Friedhelm C. Schmitt [ac], Ingmar Rosén [ad], Anders Fuglsang-Frederiksen [b], Akio Ikeda [ae], David B. MacDonald [af], Kiyohito Terada [ag], Yoshikazu Ugawa [ah], Dong Zhou [ai], Susan T. Herman [e]

[a] Department of Clinical Neurophysiology, Danish Epilepsy Centre, Dianalund, Denmark
[b] Department of Clinical Neurophysiology, Aarhus University, Aarhus, Denmark
[c] Department of Neurology, Haukeland University Hospital and Department of Clinical Medicine, University of Bergen, Bergen, Norway
[d] Comprehensive Epilepsy Center, Yale University School of Medicine, New Haven, CT, USA
[e] Department of Neurology, Laboratory of Clinical Neurophysiology, Beth Israel Deaconess Medical Center, Harvard University, Boston, MA, USA
[f] Department of Neurology, Christian Doppler Klinik, Paracelsus Medical University and Centre for Cognitive Neuroscience Salzburg, Austria
[g] Institute for Public Health, Medical Decision Making & HTA, UMIT, Hall in Tyrol, Austria
[h] Department of Clinical Neurophysiology, Great Ormond Street Hospital and Clinical Neuroscience, UCL Great Ormond Street Institute of Child Health, London, UK
[i] Krembil Neuroscience Centre, Toronto Western Hospital, University of Toronto, Toronto, Ontario, Canada
[j] Department of Clinical Neurophysiology, Stichting Epilepsie Instellingen Nederland (SEIN), The Netherlands
[k] Department of Clinical Neurophysiology, Necker Enfants Malades Hospital, Paris, France
[l] INSERM U1129, Paris, France
[m] Paris Descartes University, CEA, Gif sur Yvette, Paris, France
[n] University College London, Department of Clinical and Experimental Epilepsy, Queen Square, London, UK
[o] Johns Hopkins Medical Institutions, Baltimore, MD, USA
[p] Johns Hopkins University School of Medicine, Balimore, MD, USA
[q] Department of Pediatric Neurology, University Hospital of Lille, Lille, France
[r] Department of Neurology, Brigham and Women's Hospital, Boston, MA, USA
[s] Department of Neurophysiology, Hospital Santo António and UMIB/ICBAS – University of Porto, Porto, Portugal
[t] Department of Neurology, University Hospital Erlangen, Germany
[u] Sackler School of Medicine, Tel-Aviv University, Tel-Aviv, Israel
[v] Department of Neurology, Danish Epilepsy Center, Dianalund and University of Copenhagen, Copenhagen, Denmark
[w] Department of Clinical Neurophysiology, Rigshospitalet, Copenhagen, Denmark
[x] University of Southern Denmark, Odense, Denmark
[y] Department of Neurology, Haukeland University Hospital and Department of Biological and Medical Psychology, University of Bergen, Norway
[z] Departments of Pediatrics and Neurology, Children's Hospital of Michigan, Wayne State University, Detroit, MI, USA
[aa] Department of Neurology and Neurosurgery, Center for Neurology, Vilnius University, Vilnius, Lithuania
[ab] Department of Neurology, Charles University, 2nd Faculty of Medicine, Motol University Hospital, Czech Republic
[ac] Department of Neurology, University of Magdeburg, Magdeburg, Germany
[ad] Department of Clinical Sciences, University of Lund, Lund, Sweden
[ae] Department of Epilepsy, Movement Disorders and Physiology, Kyoto University, Graduate School of Medicine Shogoin, Sakyo-ku, Kyoto, Japan
[af] Department of Neurosciences, King Faisal Specialist Hospital & Research Center, Riyadh, Saudi Arabia
[ag] Department of Neurology, Shizuoka Institute of Epilepsy and Neurological Disorders, Shizuoka, Japan
[ah] Department of Neurology, School of Medicine, Fukushima Medical University, Fukushima, Japan
[ai] Department of Neurology, West China Hospital, Sichuan University, Chengdu, Sichuan, China

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* Corresponding author at: Department of Clinical Neurophysiology, Aarhus University Hospital & Danish Epilepsy Centre, Visby Allé 5, 4293 Dianalund, Denmark.
E-mail address: sbz@filadelfia.dk (S. Beniczky).

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HIGHLIGHTS

- A revised terminology for SCORE has been developed by an IFCN taskforce.
- It has been implemented in a software tested in clinical practice on 12,160 EEGs .
- This paper summarizes the revised SCORE terminology and describes its use.

ABSTRACT

Standardized terminology for computer-based assessment and reporting of EEG has been previously developed in Europe. The International Federation of Clinical Neurophysiology established a taskforce in 2013 to develop this further, and to reach international consensus. This work resulted in the second, revised version of SCORE (Standardized Computer-based Organized Reporting of EEG), which is presented in this paper. The revised terminology was implemented in a software package (SCORE EEG), which was tested in clinical practice on 12,160 EEG recordings. Standardized terms implemented in SCORE are used to report the features of clinical relevance, extracted while assessing the EEGs. Selection of the terms is context sensitive: initial choices determine the subsequently presented sets of additional choices. This process automatically generates a report and feeds these features into a database. In the end, the diagnostic significance is scored, using a standardized list of terms. SCORE has specific modules for scoring seizures (including seizure semiology and ictal EEG patterns), neonatal recordings (including features specific for this age group), and for Critical Care EEG Terminology. SCORE is a useful clinical tool, with potential impact on clinical care, quality assurance, data-sharing, research and education.
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Contents

1. Introduction

The combination of clinically relevant signal features in an EEG recording is huge. This wide variety is typically described in free text EEG-reports. Although the International Federation of Clinical Neurophysiology (IFCN) published a glossary of terms for describing EEGs, the free-text format allows deviations from the standardized terminology. In practice, a wide variety of local terminologies flourish, where the same term is used with different meanings in different centers, and the same feature is described by different terms in different centers. This potentially contributes to the low inter-rater agreement previously described for EEG (van Donselaar et al., 1992; Stroink et al., 2006). However, when electroencephalographers have to assess specific EEG-features by choosing from a list of pre-defined terms, the inter-observer agreement is higher (Stroink et al., 2006; Gerber et al., 2008; Gaspard et al., 2014).

EEG remains the most important clinical tool for functional assessment of the central nervous system, being widely used as an essential element in the diagnostic workup of patients with epilepsy, critically ill patients, as well as patients with altered mental status and cognitive changes. Misinterpretation of EEG can affect a huge number of patients worldwide. Thus, there is a need to find computerized tools to improve the quality of EEG assessment and reporting in clinical practice, and to improve education in EEG.

The main goal of SCORE is to give electroencephalographers a computerized tool that can be used in clinical practice to assess and report EEGs. The clinically relevant features observed in the EEG recordings are selected from a software that implements the SCORE terminology. This process automatically generates a report and feeds the selected features into a database. The standardized and computerized process can potentially (1) increase inter-rater agreement; (2) contribute to quality assurance by guiding the user through the clinically relevant aspects in a context-sensitive way; (3) build a large database for clinical research; (4) constitute a valuable tool for education.

Similar approaches of standardizing feature extraction and reporting are under development for other medical specialties such as radiology, pathology and endoscopy (Morgan et al., 2014; Ellis and Srigley, 2016; Bretthauer et al., 2016).

In 2013, the first version of SCORE was published as a European consensus, endorsed both by the European Chapter of the IFCN and by the International League Against Epilepsy (ILAE) – Commission on European Affairs (Beniczky et al., 2013a). This template helped developing a unified terminology and criteria for non-convulsive status epilepticus (Beniczky et al., 2013b).

In 2013, the IFCN established an international taskforce with the objective to develop SCORE further, and to reach an international consensus for the terminology to be implemented in the computerized reporting of EEG. To increase the global outreach, information on the SCORE project was posted on the homepage of the IFCN, asking for comments and suggestions. SCORE was presented and discussed at the 14th and 15th European Congress on Clinical Neurophysiology, at the 10th European Congress on Epileptology, and at the 30th International Congress of Clinical Neurophysiology. The SCORE taskforce included members nominated by the Executive Committee of the IFCN, members of the previous, European taskforce, who actively used SCORE in clinical practice or for research and development. In addition, EEG experts who responded to the open call posted on the IFCN homepage were included.

The SCORE taskforce held three workshops (Berlin, 2014; Istanbul, 2015; Brno, 2015). Besides the workshops, the taskforce fine-tuned the scoring standards using the web-based template, running a continuously updated demonstration version of SCORE-EEG, and by mail correspondence. Before submission, SCORE has been endorsed by the Executive Committee of the IFCN.

This paper presents the structure and the terms of the revised international version of SCORE. The terms are defined according to: (1) the new, revised IFCN glossary of terms used by clinical electroencephalographers (Acharya et al., 2017), (2) the new ILAE classification of seizures and epilepsies (Fisher et al., 2017; Scheffer et al., 2017), (3) the ILAE glossary of descriptive terminology for ictal semiology (Blume et al., 2001), (4) the ILAE classification of Status Epilepticus (Trinka et al., 2015), (5) the American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology: 2012 version (Hirsch et al., 2013), (6) the American Clinical Neurophysiology Society's standardized EEG terminology and categorization for the description of continuous EEG monitoring in neonates (Tsuchida et al., 2013), and (7) the previous European version of SCORE (Beniczky et al., 2013a). The main elements of SCORE follow the sections in the standard report format of the American Clinical Neurophysiology Society (Tatum et al., 2016): History, Technical Description, EEG description, Impression and Clinical Correlation. In SCORE the corresponding sections are: Patient information and referral, Recording conditions, Findings, Diagnostic significance and Clinical comments.

Describing technical standards of EEG recording methods was beyond the scope of this paper. Those aspects are addressed in the IFCN standards for digital recording of clinical EEG (Nuwer et al., 1998).

Table 1
Indication for EEG.

Epilepsy-related indications	– clinical suspicion of epilepsy or seizure – reconsider the initial diagnosis of epilepsy – classification of a patient diagnosed with epilepsy – changes in seizure pattern – suspicion of non-convulsive status epilepticus – monitoring of status epilepticus – monitoring of seizure frequency – monitoring the effect of medication – considering stopping AED therapy – presurgical evaluation – driver's license or flight certificate
Other differential diagnostic questions	– psychogenic non-epileptic seizures – loss of consciousness – disturbance of consciousness – encephalopathy – encephalitis – dementia – cerebral vascular disease – paroxysmal behavioral changes – other psychiatric or behavioral symptoms – coma – brain death
Specific paediatric indications	– genetic syndrome – metabolic disorder – regression – developmental problems
Follow-up EEG.	
Assessment of prognosis.	
Research project.	
Other indication.	

2. Patient information and referral

To identify the patient, the following data are compulsory: name, social security number or healthcare provider number, gender and date of birth. In case social security number is not used for a security reason, an alternative number (identity string) can be entered in the report. Optional entries are: handedness, address, mother's name.

Each patient may have several recordings in the database. For each recording, information related to the referral and to the recording conditions can be inserted.

The following data can be entered for the referral: name and address of the referring physician/referring unit, indication for EEG (Table 1), diagnosis at referral (using ICD-10 codes, and for rare diseases orphanet codes) (Orphanet, 1997), seizure frequency, time since the latest seizure, medications (using the ATC WHO list). Additional metadata that can be entered here comprise basic infor-

Table 2
Modulators and procedures.

Intermittent photic stimulation	Manual eye closure
Hyperventilation	Manual eye opening
Sleep deprivation	Auditory stimulation
Sleep following sleep deprivation	Nociceptive stimulation
Natural sleep	Physical effort
Induced sleep	Cognitive tasks
Awakening	Other modulators and procedures (free text)
Medication administered during recording	
Medication withdrawal or reduction during recording	

mation on Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and functional neuroimaging (options: normal, abnormal, not performed, results not known; details can be added in free text here). Supplementary details on patient history relevant to the study can be added as free text. Internal notes, not appearing in the report, can be added.

3. Recording conditions

This section comprises administrative data (study identification number, date and time of the recording, duration of the recording, name of technologist, name of physician/supervising physician) as well as technical data related to the recording. The age of the patient is calculated automatically from the date of birth and the date of the recording.

The sensor-group is selected from a list defined in the site-settings for each EEG-lab. This is according to the new IFCN guideline on EEG electrode array (Seeck et al., 2017). The type of EEG recording is selected from the following list: standard EEG, sleep EEG, short-term video-EEG monitoring, long-term video-EEG monitoring, ambulatory recording, long term video-EEG monitoring (LTM), recording in the ICU, intraoperative monitoring. The technologist can score the alertness, orientation, and cooperation of the patient, using a multiple-choice list (awake, oriented, good cooperation, poor cooperation, disoriented, drowsy, asleep, unresponsive, comatose). The date and time for the latest meal can be specified. In case the patient has skull defect or has had brain surgery, this can be entered into the database and the location specified. Additional information related to technical description can be entered in free text.

4. Modulators and procedures

Stimulation procedures (provocation methods) and medication given or withdrawn during recordings are defined as modulators and procedures. They can be selected from a pre-defined list (Table 2). When selecting hyperventilation from the list, the user is prompted to score the quality of the hyperventilation (excellent effort, good effort, poor effort, refused the procedure, unable to do the procedure). For each observed abnormality, there is an option of specifying how they are influenced by the modulators and procedures that were done during the recording (triggered by/only during the modulator, increased by, decreased by, stopped by, or unmodified by a certain type of modulator).

Since each modulator/procedure points to a certain epoch in the recording (when they were done), they appear in the part of SCORE EEG where the other items linked to certain time-points in the recording are listed (findings). Clicking on an item in this list triggers the EEG-reader to navigate to the corresponding point in time of the recording. For example, clicking on "hyperventilation" in SCORE automatically triggers the EEG-reader to navigate to the start of the hyperventilation.

Table 3
Findings: main folders.

Modulators and procedures
Background activity
Sleep and drowsiness
Interictal findings
Rhythmic and periodic patterns in critically ill patients
Episodes
Physiologic patterns
Patterns of uncertain significance
EEG artifacts
Polygraphic channels
Trend analysis

Diagnostic significance.

Table 4
Posterior dominant rhythm.

Property	Scoring options
Significance	Normal No definite abnormality Abnormal
Frequency	Values (numbers) typed in.
Frequency asymmetry	Symmetrical # Hz lower on the left side (value typed in) # Hz lower on the right side (value typed in)
Amplitude	Low (<20 μV) Medium (20–70 μV) High (>70 μV)
Amplitude asymmetry	Symmetrical Right < Left Left < Right
Reactivity to eye opening	Yes Reduced left side reactivity Reduced right side reactivity Reduced reactivity on both sides
Organization	Normal Poorly organized Disorganized Markedly disorganized
Caveat	No Only open eyes during the recording Sleep-deprived Drowsy Only following hyperventilation
Absence of PDR	Artifacts Extreme low voltage Eye-closure could not be achieved Lack of awake period Lack of compliance Other causes (+ free text)

5. Findings

All normal and abnormal EEG features are listed under "findings". This contains folders with pre-defined terms that characterize the EEG features. Since the variety of features that occurs in EEG is huge, the list is long. Nevertheless, the user only has to open the folders with the features that are seen in the assessed EEG. Thus, the user does not spend time on features that are not seen in the assessed EEG recording. The structured list with main folders containing the main types of EEG graphoelements (Table 3) makes it easy to find the EEG features observed in the recording.

6. Background activity

The following EEG features are listed under background activity: posterior dominant rhythm (PDR), mu rhythm, other organized rhythms, and special features.

PDR is the most often scored EEG feature in clinical practice. Therefore, a short-key to this feature is available, which directly opens the terms that can be chosen for characterizing the PDR (Table 4).

When scoring other organized rhythms, the spectral frequency range can be selected (delta, theta, alpha, beta, gamma) and frequency and amplitude values can be entered. Then, location and effect of modulators can be scored, and the significance selected (normal, no definite abnormality, or abnormal).

Special features contains scoring options for the background activity of critically ill patients: continuous background activity,

nearly continuous background activity, discontinuous background activity, burst-suppression, burst-attenuation, suppression and electrocerebral inactivity.

7. Sleep and drowsiness

Features related to sleep and drowsiness patterns, relevant in the context of clinical EEG recordings (not polysomnography) are scored here. For longer recordings (long-term video-EEG monitoring, LTM) the architecture of sleep can be evaluated (normal/abnormal). In case normal sleep patterns are seen, the achieved sleep stages can be selected (drowsiness; N1-3; REM).

Normal sleep-graphoelements (sleep spindles, vertex waves, K-complexes, saw-tooth waves, and positive occipital sharp transients of sleep (POSTS), hypnagogic hypersynchrony) and their location can be selected. In case there is abnormal asymmetry or absence of physiological sleep graphoelements, the significance of this finding (“abnormal”) is scored.

Additional options are: drowsiness, hypnagogic or hypnopompic hypersynchrony, sleep-onset REM period (SOREMP), non-reactive sleep activity. It also can be specified that sleep was not recorded.

When sleep or drowsiness is scored, it is automatically registered in the list of modulators, and, when scoring abnormal graphoelements, the effect on that graphoelement can be selected.

8. Interictal findings

All abnormal graphoelements are scored under the sub-section of interictal findings, except for those that belong to the background activity, rhythmic and periodic patterns in critically ill patients, and episodes (e.g. seizures). The steps of scoring interictal findings follows the logical thinking of clinical neurophysiologists. First, the name and morphology of the graphoelement are specified, followed by location, features related to time and the effect of modulators.

Epileptiform interictal activity and abnormal interictal rhythmic activity are the main categories. All others are grouped under special patterns. Table 5 shows the names and morphology of the interictal findings. Periodic discharges in non-critically ill patients should be scored here.

Location of the graphoelements is scored by selecting the regions where the negative potentials are observed on the scalp: laterality (left, right, midline, bilateral, diffuse) and region (frontal, central, temporal, parietal, occipital). A location is considered diffuse when it occurs asynchronously over large areas of both sides of the head. The location maximum can be specified by denoting the electrode sites where the peak negativity is observed. “Bilateral synchronous” is the preferred term for generalized. When bilateral location is selected, the user can choose one of the following options for bilateral synchrony: asynchronous, primary bilateral synchronous, secondary bilateral synchronous, and bilateral synchronous – not further specified. In addition, amplitude asymmetry can be scored for bilateral graphoelements (symmetric, left < right, right < left).

When the same type of interictal graphoelement is seen independently in two different locations, they are scored separately (i.e. in two different entries). When the same interictal graphoelement is observed bilaterally and at least in three independent locations, the user can opt for scoring them using one entry, and choosing “multifocal” as a descriptor of the locations of the given interictal graphoelements, optionally emphasizing the involved, and the most active sites.

When propagation within the graphoelement is observed, first the location of the onset region is scored. Then, clicking “propagation” opens a new window for scoring the location of the propagation.

In case source-imaging is done, the results are scored at sublobar level: frontal (perisylvian-superior surface; lateral; mesial; polar; orbitofrontal), temporal (polar; basal, lateral-anterior; lateral-posterior; perisylvian-inferior surface), central (lateral convexity; mesial; central sulcus –anterior surface, central sulcus – posterior surface; opercular), parietal (lateral-convexity; mesial; opercular), occipital (lateral; mesial, basal) and insula.

Time-related features are summarized in Table 6. It is important to estimate how often an interictal abnormality is seen in the

Table 5
Names and morphology of interictal findings.

Name	Morphology
Epileptiform interictal activity	Spike Spike-and-slow-wave Runs of rapid spikes Polyspikes Polyspike-and-slow-wave Sharp-wave Sharp-and-slow-wave Slow sharp-wave High frequency oscillation (HFO) Hypsarrhythmia - classic Hypsarrhythmia - modified
Abnormal interictal rhythmic activity	Delta activity Theta activity Alpha activity Beta activity Gamma activity Polymorphic delta Frontal intermittent rhythmic delta activity (FIRDA) Occipital intermittent rhythmic delta activity (OIRDA) Temporal intermittent rhythmic delta activity (TIRDA)

Special patterns:
Periodic discharges not further specified (PDs).
Generalized periodic discharges (GPDs).
Lateralized periodic discharges (LPDs).
Bilateral independent periodic discharges (BIPDs).
Multifocal periodic discharges (MfPDs).
Extreme delta brush.
Burst suppression.
Burst attenuation.

Table 6
Time-related features.

Name of time-related feature	Choices for scoring
Mode of appearance	Random Periodic Variable
Discharge pattern	Single discharges Rhythmic trains or bursts Arrhythmic trains or bursts Fragmented
Incidence *(for single discharges)*	Only once Rare (less than 1/h) Uncommon (1/5 min to 1/h) Occasional (1/min to 1/5min) Frequent (1/10 s to 1/min) Abundant (>1/10 s)
Prevalence *(for trains/bursts)*	Rare (<1%) Occasional (1–9%) Frequent (10–49%) Abundant (50–89%) Continuous (>90%)

Table 7
Effect of the intermittent photic stimulation.

- Posterior stimulus-dependent response
- Posterior stimulus-independent response, limited to the stimulus-train
- Posterior stimulus-independent response, self-sustained
- Generalized photoparoxysmal response, limited to the stimulus-train
- Generalized photoparoxysmal response, self-sustained
- Activation of pre-existing epileptogenic area
- Unmodified

Table 8
Modifier terms for Rhythmic or Periodic Patterns in critically ill patients (RPPs).

Morphology	Superimposed activity *(for PDs and RDA)*	Fast activity (+F) Rhythmic activity (+R) *(for PDs only)* Sharp waves or spikes (+S) *(for RDA only)*
	Sharpness *(for PDs and SW)*	Spiky (<70 ms, measured at the baseline) Sharp (70–200 ms) Sharply-contoured Blunt
	Number of phases *(for PDs and SW)*	1; 2; 3; >3
	Triphasic morphology *(for PDs and SW)*	Yes No
	Absolute amplitude *(for PDs, RDA, SW)*	Very low (<20 μV) Low (20–49 μV) Medium (50–199 μV) High (≥200 μV)
	Relative amplitude *(for PDs)*	≤2 >2
	Polarity *(for PDs and SW)*	Positive Negative Tangential/horizontal dipole Unclear
Time-related features	Prevalence *(for PDs, RDA and SW)*	Rare (<1%) Occasional (1–9%) Frequent (10–49%) Abundant (50–89%) Continuous (>90%)
	Frequency *(for PDs, RDA and SW)*	Typical frequency (+ enter numerical value) Frequency range (minimum and maximum)
	Duration *(for PDs, RDA and SW)*	<10 s: very brief 10–59 s: brief 1–4.9 min: intermediate 5–59 min: long >1 h: very long
	Onset *(for PDs, RDA and SW)*	Sudden (progressing from absent to well developed within 3 s) Gradual
	Dynamics *(for PDs, RDA and SW)*	Evolving Fluctuating Static

PDs: Periodic Discharges, RDA: Rhythmic Delta Activity, SW: Spike-and-wave or Sharp-and-wave.

recording. This is scored differently, depending on the type of discharge-pattern. For single discharges, this is scored as incidence (how often it occurs/time-epoch); for trains or bursts this is scored as prevalence (the percentage of the recording covered by the train/burst). Besides the choices listed in Table 6, additional data can be entered for periodic graphoelements (duration of the time-interval between the discharges), rhythmic patterns (duration and frequency) and arrhythmic patterns (duration).

For each described graphoelement, the influence of the modulators can be scored. Only modulators present in the recording are shown as options. Eye-closure sensitivity is also scored here. For most modulators, the selection-choices are: unmodified, increased, decreased, stopped by, triggered by/only during the modulator. For sleep, two additional choices are available: continuous during non-REM sleep (and free text option for entering spike-wave index) and change of pattern during sleep (+ free text). The effect of Intermittent Photic Stimulation (IPS) is scored according to the terminology (Table 7) proposed by Kasteleijn-Nolst Trenité et al. (2001). When IPS has a modulatory effect on the graphoelement, the frequency of the stimulation can be entered.

9. Rhythmic or periodic patterns in critically ill patients (RPPs)

RPPs are scored according to the 2012 version of the American Clinical Neurophysiology Society's Standardized Critical Care EEG Terminology (Hirsch et al., 2013).

First, the name of the graphoelement is selected ("main term 2"): Periodic Discharges (PDs), Rhythmic Delta Activity (RDA), Spike-and-wave or Sharp-and-wave (SW). Scoring the location of the graphoelement as described above generates "main term 1": bilateral synchronous and symmetric (G, for "generalized"), lateralized (L), bilateral independent (BI), multifocal (Mf). These choices generate the name of the scored RPP (main term 1 + 2).

The "modifier" terms are scored as morphology and time-related features (Table 8). The effect of modulators is scored as described above, thus specifying whether the pattern is spontaneous or "stimulus-induced (SI)". These choices are added to the name of the graphoelement (added to main term 1 + 2).

In case any clinical correlate occurs time-locked to the RPPs, it is described attached to the RPP-entry, using the scoring-template for semiology (see below).

10. Episodes

Clinical episodes are named using the terms specified in Table 9 and Supporting Document 1. Epileptic seizures are named using the current ILAE seizure classification (Fisher et al., 2017; Beniczky et al., 2017).

The template for scoring episodes emphasizes the importance of the electro-clinical correlation and the dynamic evolution of the seizures. Three consecutive phases are defined: initial, subsequent and postictal. For short seizures, only the initial phase needs to be completed (for example myoclonus and typical absence). The semiologic and the electrographic ictal findings are scored in chronological order (i.e. in order of their appearance during the seizure), within each phase.

Semiology is described according to the ILAE Glossary of Descriptive Terminology for Ictal Semiology (Blume et al., 2001). The names of semiologic findings are listed in Tables 10 and 11. In case semiologic features are recorded by polygraphic channels (for example myoclonus by surface EMG or ictal tachycardia – by ECG) this is also added here (see also section on polygraphic channels). Besides the name, the semiologic finding can also be characterized by the somatotopic modifier (i.e. the part of the body where it occurs). In this respect, laterality (left, right, symmetric, asymmetric, left > right, right > left), body part (eyelid, face, arm, leg, trunk, visceral, hemi-) and centricity (axial, proximal limb, distal limb) can be scored.

Ictal EEG activity is scored by choosing the name of the ictal pattern (Table 12). Then location and source analysis (if done) can be scored as described for the interictal patterns. Numerical values for frequency and amplitude of the ictal patterns can be added, and spatiotemporal dynamics can be scored (evolution in morphology; evolution in frequency; evolution in location). A separate list of names is available for postictal patterns (suppression, low frequency activity, periodic epileptiform discharges, increase in the interictal epileptiform discharges, no observable change).

Table 9
Names of episodes.

Epileptic seizure (Seizure-types in the current ILAE seizure classification – see supporting document 1)
Psychogenic non-epileptic seizure (PNES)
Electroencephalographic seizure
Sleep-related episodes
• Arousal (normal)
• Benign sleep myoclonus
• Confusional arousal
• Cataplexy
• Periodic Limb Movement in Sleep (PLMS)
• REM-sleep Behavioral Disorder (RBD)
• Sleep-walking
Pediatric episodes
• Hyperekplexia
• Jactatio capitis nocturna
• Pavor nocturnus
• Stereotypical behavior
Paroxysmal motor events
Syncope
Other (+ name in free text)

Additional clinically relevant features related to episodes can be scored under "timing and context" (Table 13). When multiple stereotypical episodes occur (for example several stereotypical seizures during long-term video-EEG monitoring), these can be scored under the same entry. In this case, the number of stereotypical episodes is specified in "timing and context". Even small variations in the semiological or EEG findings can be scored this way (by specifying the number of episodes in which the finding was observed).

At the end, the effect of modulators and procedures on the scored episode is specified. If "medication administered during the recording" is entered as a modulator, one can score the clinical and EEG effect of the medication. Seizures related to photic stimulation are scored using the proposed scale of photoparoxysms (Table 7). Facilitating factors (alcohol, awakening, catamenial, fever, sleep, sleep-deprivation, other) and provoking factors (hyperventilation, reflex + free text, other + free text) can be scored here.

11. Physiologic patterns and patterns of uncertain significance

The electroencephalographer can score physiologic patterns and patterns of uncertain significance when considered of clinical importance (for example to emphasize that a pattern resembling an abnormal finding is in fact normal. The list of these patterns is listed in Table 14.

Besides the name of the pattern, the location can be scored as described above.

12. EEG artifacts

When relevant for the clinical interpretation, artifacts can be scored by specifying the type (Table 15) and the location. It is important to score the significance of the described artifacts: recording is not interpretable, recording of reduced diagnostic value, does not interfere with the interpretation of the recording.

13. Polygraphic channels

Changes observed in polygraphic channels can be scored: EOG, Respiration, ECG, EMG, other polygraphic channel (+ free text), and their significance logged (normal, abnormal, no definite abnormality). Additional features for polygraphic channels are listed in Table 16.

Table 10
Names of ictal semiologic findings.

No observable manifestation	
Motor or behavioral arrest	
Dyscognitive	
Elementary motor	Myoclonic jerk
	Negative myoclonus
	Clonic
	Jacksonian March
	Epileptic spasm
	Tonic
	Dystonic
	Postural
	Versive
	Tonic-clonic (without figure-of-four; with figure-of-four – extension in the left/ right elbow)
	Astatic
	Atonic
	Eye blinking
	Subtle motor phenomena (+ free text)
	Other elementary motor (+ free text)
Automatisms	Mimetic
	Oroalimentary
	Dacrystic (crying)
	Gelastic
	Manual
	Gestural
	Hypermotor
	Hypokinetic
	Other automatism (+ free text)
Sensory	Cephalic aura or headache
	Visual
	Auditory
	Olfactory
	Gustatory
	Epigastric
	Somatosensory
	Autonomic (Viscerosensitive)
	Other sensory (+ free text)
Experiential	Affective or emotional
	Hallucinatory
	Illusory
	Mnemonic: Déjà vu/Jamais vu
	Other experiential (+ free text)
Language related	Vocalization
	Verbalization
	Dysphasia
	Aphasia
Autonomic	Pupillary
	Hypersalivation
	Respiratory or apnoeic
	Cardiovascular
	Gastrointestinal
	Urinary incontinence
	Genital
	Vasomotor
	Sudomotor
	Thermoregulatory
	Other autonomic (+ free text)
Semiologic findings recorded by polygraphic channels	EOG
	Respiration
	ECG
	EMG
	Other polygraphic channel (+ free text)
Other semiologic finding (+ free text)	

14. Trend analysis

Results of amplitude-integrated EEG analysis can be scored under "Trend analysis". The following patterns can be scored: continuous activity, burst-suppression, low-voltage activity, seizure activity, artifacts. Sleep-wake cycling can be scored using the fol-

Table 11
Names of postictal semiological findings.

No observable clinical manifestation	Unconscious
Quick recovery of consciousness	Aphasia or dysphasia
Behavioral change	Hemianopia
Impaired cognition	Nose wiping
Dysphoria	Headache
Anterograde amnesia	Unilateral myoclonic jerks
Retrograde amnesia	Paresis (Todd's palsy)
Postictal sleep	Other unilateral motor phenomena (+ free text)

Table 12
Ictal EEG activity.

No observable change
Obscured by artifacts
Polyspikes
Fast spike activity or repetitive spikes
Low voltage fast activity
Polysharp-waves
Spike-and-slow-waves
Polyspike-and-slow-waves
Sharp-and-slow-waves
Rhythmic activity
Slow wave of large amplitude
Irregular delta or theta activity
Burst-suppression pattern
Electrodecremental change
DC-shift
High frequency oscillation (HFO)
Disappearance of ongoing activity
Other ictal EEG pattern (+ free text)

Table 13
Timing and context of clinical episodes.

Consciousness	Not tested Affected Mildly affected Not affected
Awareness of the episode	No (The patient is not aware of the episode) Yes (The patient is aware of the episode)
Clinical – EEG temporal relationship	Clinical start, followed by EEG start by # seconds (numerical value entered) EEG start, followed by clinical start by # seconds (numerical value entered) Simultaneous
Number of stereotypical episodes during the recording	Numerical value entered
State at the start of episode	From sleep From awake
Duration of the episode	Numerical value entered >30 min but not precisely determined (status epilepticus)
Duration of the postictal phase	Numerical value entered
Prodrome	No Yes (+ free text)
Tongue biting	No Yes

lowing choices: yes (identified), no (not identified), unspecified state changes, unknown.

15. Diagnostic significance

The last mandatory step of the scoring is interpretation of the diagnostic significance. Ideally, until this step the electroencephalographer is blinded to the clinical data, to remain unbiased. After extracting and scoring the EEG-features, they are evaluated in the clinical context to score the diagnostic significance. Three main categories are available: Normal recording, abnormal recording, and no definite abnormality. For abnormal recordings, in keeping with the clinical information, the specific diagnostic yield of EEG can be scored, as shown in Table 17. Epilepsies can be further classified, according to the ILAE classification: focal, generalized, combined generalized and focal, and unknown (Scheffer et al., 2017) and, when possible, syndrome classification can be selected (Supporting Document 2).

Several items of diagnostic significance can be selected for abnormal recordings.

Table 14
Patterns that are not considered abnormal.

Physiologic patterns	Patterns of uncertain significance
Rhythmic activity Slow alpha variant rhythms	Sharp transient Wicket spikes
Fast alpha variant rhythms Frontocentral theta activity	Small sharp spikes (Benign Epileptiform Transients of Sleep)
Lambda waves	Rhythmic temporal theta burst of drowsiness
Posterior slow waves in youth	Ciganek rhythm (midline central theta)
Diffuse low frequency activity induced by hyperventilation	6 Hz spike-and-slow-wave 14 and 6 Hz positive bursts
Photic drive response	Rudimentary spike-wave-complex
Photomyogenic response (orbitofrontal photomyoclonus)	Slow-fused transient Needle-like occipital spikes of the blind
Arousal pattern	Subclinical Rhythmic EEG Discharges in Adults
Frontal arousal rhythm	(SREDA)
Other (+ free text)	Temporal slowing in elderly subjects Breach rhythm Other (+ free text)

Table 15
EEG Artifacts.

Biological artifacts	Non-biological artifacts
Eye blinks	50 or 60 Hz
Eye movements (horizontal, vertical)	Induction or high frequency
Nystagmus	Dialysis
Chewing artifact	Artificial ventilation artifact
Sucking artifact	Electrode pops
Glossokinetic artifact	Salt bridge artifact
Rocking or patting artifact	Other artifact (+ free text)
Movement artifact	
Respiration artifact	
Pulse artifact	
ECG artifact	
Sweat artifact	
EMG artifact	

16. The neonatal template

For patients younger than 3 months a specific neonatal template is used for scoring. Gestational age is entered; postmenstrual age, chronological age and corrected age are automatically calculated in accordance with the American Academy of Pediatrics policy statement on age terminology in the perinatal period (Engle, 2004).

The American Clinical Neurophysiology Society standardized EEG terminology and categorization for the description of continu-

ous EEG monitoring in neonates is implemented in SCORE (Tsuchida et al., 2013). A specific neonatal module replaces the description of the background activity: neonatal ongoing activity. Two new folders with neonatal features are added to SCORE: transient patterns and rhythmic activity. The content of the neonatal template differs depending on the postmenstrual age (<30 weeks vs. >30 weeks).

Neonatal ongoing activity is scored in four consecutive steps: alertness → behavioral state → properties → graphoelements. First alertness can be scored (awake; asleep). When both alertness types are present in the recording, ongoing activity is scored separately for the two types (i.e. in two different entries). Features of the behavioral state(s) corresponding to the chosen type of alertness are specified in the next step. For "awake" these are: quiet, moving, upset, crying (multi-select). For "asleep", two features can be scored under behavioral state: (1) type of sleep (for >30 weeks: active, quiet, transitional, spontaneous, drug-induced; for <30 weeks: spontaneous, drug-induced) and (2) sleep-wake cycling (yes, no, unspecified). Then, under "properties", specific features of the neonatal ongoing activity can be scored: continuity, synchrony, variability, reactivity, amplitude, and significance (Table 18). Graphoelements that are part of the ongoing activity, during the entered type of alertness, can be selected in the next step: monorhythmic delta, delta brushes, rhythmic temporal theta, and if postmenstrual age >30 weeks also frontal sharp-waves (encoches frontales) and anterior slow dysrhythmia. Location of the graphoelements can be scored as described above. Several graphoelements can be added to each type of alertness.

Transient patterns (negative sharp transients, positive sharp transients) can be further specified by location (as described above), time-related features, and significance of the transient pattern (normal for age, no definite abnormality, not normal for age). The content of the time-related features is the same as described under interictal patterns, with the exception of incidence, which is scored as follows: only once, uncommon (<1 per 5 min), occasional (1 per 5 min – 1 per minute), frequent (1 per 1 min – 1 per 10 s), abundant (>1 per 10 s).

Table 16
Polygraphic channels.

Respiration sensors	Apnoea Hypopnoea Apnoea-hypopnoea index (numerical value entered) Periodic respiration Tachypnoea (numerical value for cycles / minute) Oxygen saturation (+ free text) Other (+free text)
ECG	Normal rhythm Arrhythmia Asystolia Bradycardia (numerical value for frequency) Extrasystole Ventricular Premature Depolarization Tachycardia (numerical value for frequency) Other (+ free text) QT period (+ free text) ECG not recorded
EMG	Myoclonus Negative myoclonus Myoclonus – rhythmic (numerical value for frequency) Myoclonus – arrhythmic Myoclonus – synchronous Myoclonus – asynchronous PLMS (Periodic Limb Movements in Sleep) Spasm Tonic contraction Asymmetric activation of EMG – right first Asymmetric activation of EMG – left first Other (+ free text) Side and name of muscle

Table 17
Diagnostic significance – abnormal recording.

Epilepsy (further scored according to the current ILAE classification – see supporting document 2)	Psychogenic non-epileptic seizures (PNES) Other non-epileptic clinical episode
Status epilepticus (further scored according to the new ILAE classification - Trinka et al. (2015))	Focal dysfunction of the central nervous system Diffuse dysfunction of the central nervous system
Continuous spikes and waves during slow sleep (CSWS) or electrical status epilepticus in sleep (ESES)	Coma Brain death EEG abnormality of uncertain clinical significance

Table 18
Properties scored for the neonatal ongoing activity.

Continuity	Normal continuity Normal discontinuity (insert values for burst duration and suppression duration) Tracé alternant *(only for "asleep" and > 30 weeks)* (insert values for burst duration and suppression duration) Excessive background discontinuity (insert values for burst duration and suppression duration) Burst-suppression *(only for > 30 weeks)* (insert values for burst duration and suppression duration) Electrocerebral inactivity
Synchrony	Mostly synchronous Mostly asynchronous
Variability (lability)	No Yes Unclear
Reactivity	No Yes Unclear
Amplitude	Normal Borderline low Borderline high Abnormal low Abnormal high
Significance	Considered normal for age No definite abnormality Considered not normal for age

Rhythmic activity is the third specific folder of the neonatal template. One can select rhythmic activity (delta, theta, alpha, beta, gamma) and brief rhythmic discharges. Location and time-related-features are scored as described above.

The other SCORE-folders, containing interictal findings, rhythmic and periodic patterns in critically ill patients, episodes, patterns of uncertain significance, EEG artifacts, polygraphic channels, and trend analysis are available for neonates too. However, the classification of the epileptic seizure is different: it contains a specific neonatal module, with the latest classification of neonatal seizures, as currently proposed by the ILAE taskforce: myoclonic, clonic, spasm, tonic, automatisms, hypomotor, autonomic, mixed, unknown, electrographic.

17. Generating the report

While selecting and scoring the EEG-features (Table 3) from the pre-defined lists as described above, the report is automatically generated containing all selected items including diagnostic significance. Before electronically signing the report, the electroencephalographer can add a short free text for "Summary of the findings" and "Clinical Comments".

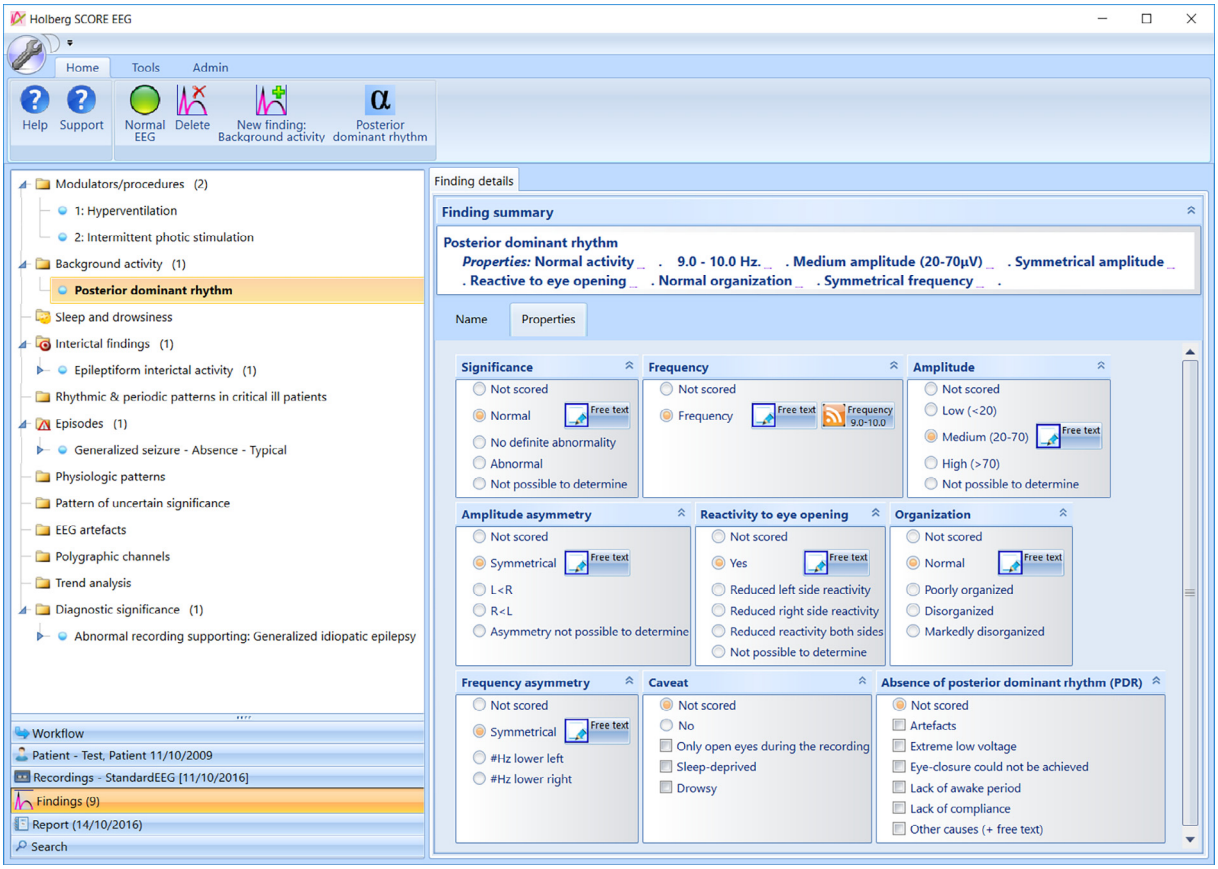


Fig. 1. Graphical user interface of SCORE. To the left, the main navigation chart and the folders with the findings. This screen-shot shows scoring of the Posterior Dominant Rhythm (PDR). In the windows listed under "Properties" scorings of the PDR-features is done by clicking on the items, and by entering numerical data (for frequency). The selected items are shown in the box located above the scoring windows.

18. Follow-up diagnoses for longitudinal studies

For each patient, follow-up diagnostic entries can be added, specifying the date and the follow-up diagnoses in the same categories as in diagnostic significance. Based on these data, diagnostic accuracy parameters can be determined.

19. The SCORE EEG software

A software implementing the SCORE terminology has been developed by a group of programmers at Holberg EEG AS, under the supervision of one of the authors (HA). First, the software implemented the European version (Beniczky et al., 2013a). Then the software was modified to the second, revised version, based on the structure and terminology provided by the IFCN taskforce. Throughout this process, an online demonstration-version was available for the members of the taskforce, for testing the implemented revisions. Between 2013 and 2016 about 10 man-years of development was performed to establish the current software, including the functionality to integrate with electronic health record systems (HL7) in the advanced version.

The revised version of SCORE contains 537 main terms ("names"); 308 of them are unchanged compared to the previous version. At present, 776 features are available for further characterizing the main terms; 314 of them are unchanged compared to the previous version.

SCORE-EEG has been used in clinical practice in Haukeland University Hospital Bergen, Oslo University Hospital, Danish Epilepsy Centre Dianalund, Aarhus University Hospital, Stichting Epilepsie Instellingen Nederland (SEIN), Beth Israel Deaconess Medical Center, and University Health Network Toronto Western Hospital. 12,160 EEG recordings have been described and reported using SCORE EEG. After the training phase when clinicians became familiar with the software, the time spent on reporting EEGs was the same, and for some even shorter compared to reporting in free-text formats. In two of the institutions that implemented SCORE-EEG in clinical practice, the integration with the electronic healthcare records (EHR) of the hospitals has also been tested, and it worked well. A direct file-based import of reports from a user-defined file share into the EHR system can be used if the EHR system is not compatible with HL-7 or where local policy is preventing this. Alternatively standard copy paste functionality can be used to copy the reports from SCORE EEG to the EHR system.

SCORE-EEG is installed in the IT environment of the hospitals. Each user logs on using an individual user name and password. The communication between the SCORE EEG software and the servers is encrypted, and the activity of each user is logged and traceable.

When opening a new recording in SCORE, an empty matrix is generated, where, for all features the item "not scored" is selected as default. The active choice "not possible to determine" is also available (to avoid redundancy, this choice is not added to the tables in this paper). For all items free-text can be added. Figs. 1 and 2 show the graphical user interface for scoring, and Fig. 3 shows an example of a generated report. SCORE-EEG helps the user to avoid omitting clinically relevant features, by presenting for each condition a list of specific items that have potential clinical relevance, thus guiding the user through the process of systematic assessment and reporting of EEGs. For example, when a seizure is

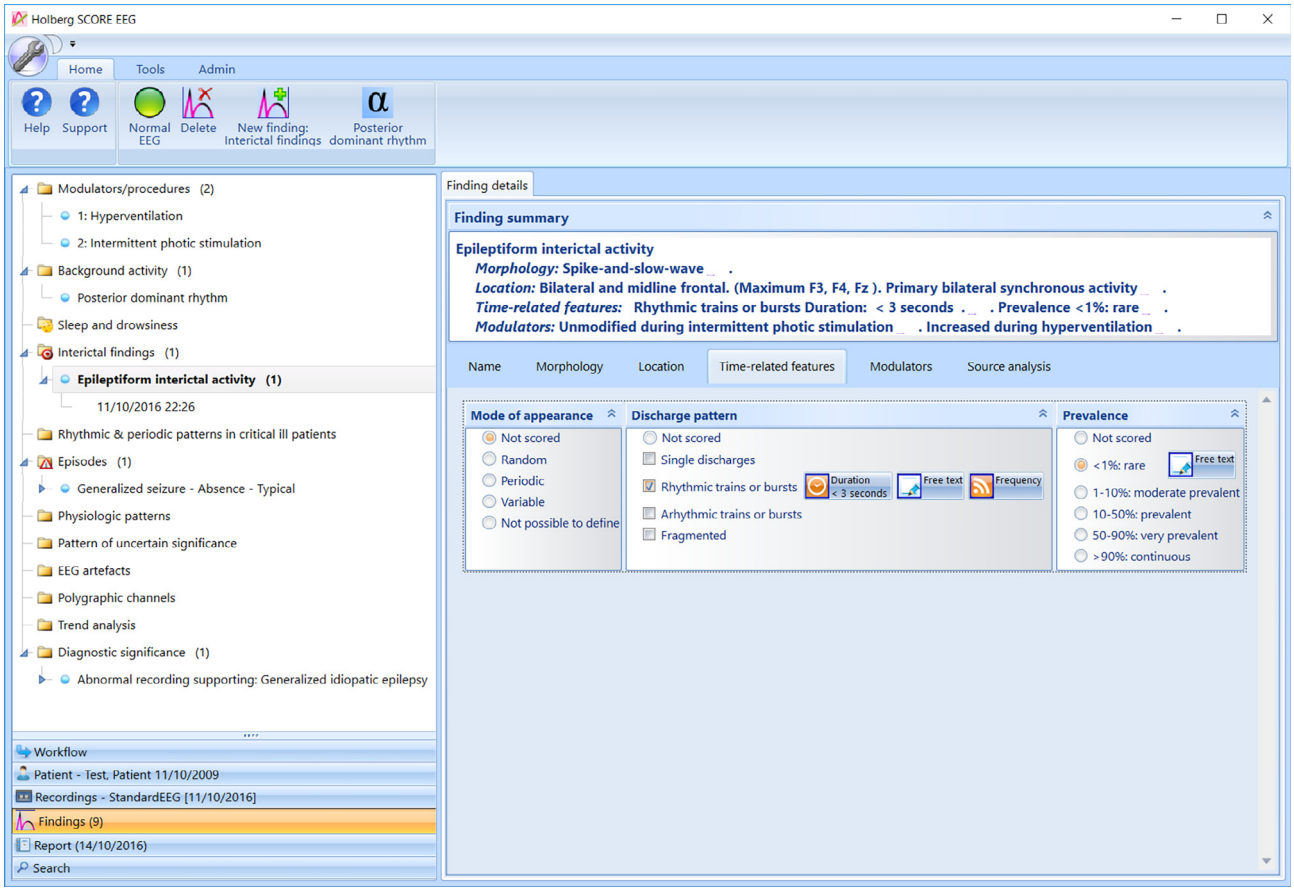


Fig. 2. Graphical user interface showing scoring the time-related features of an epileptiform discharge. The properties are grouped for this type of EEG abnormality, as follows: morphology, location, time-related features, modulators, source analysis.

scored, the software presents all aspects that can be relevant for the assessed seizure, and the report cannot be generated before the relevant items are addressed by the user. Since the terms and features in SCORE are fixed items, the use of standardized terminology is enforced by the structure of the system.

In case SCORE is integrated with the EEG reader, snapshots with typical examples of the scored features can be included into the report.

Recordings can be marked ("flagged") for studies or for teaching database.

The scoring standard was translated from English into 14 languages, and implemented in SCORE-EEG: Azerbaijani, Chinese, Czech, Danish, Dutch, Georgian, German, Norwegian, Portuguese, Russian, Spanish, Swedish, Turkish and Ukrainian. Eight other languages are under translation. Regardless of the language used, the codes in the database are the same. One can score a report in one language and convert the report into another language.

The free version of the SCORE-EEG software and guidance for users can be requested from the following home-page: http://holbergeeg.com. SCORE-EEG automatically generates report based on the items selected by the user during the scoring process, and it saves the scored features in a local database.

20. Conclusion and Future perspectives

The SCORE system has been developed by an international panel of experts, under the auspices of the IFCN. The structured template, containing standardized terminology, assists the electroencephalographers in extracting clinically relevant features and reporting them using a software. This process leads to an automatically generated report, and in the same time, it feeds the features into a database. The template guides the user through the logical steps of characterizing EEG phenomena (name, morphology, location, time-related features, modulators). Specific modules are available for scoring the electro-clinical features of seizures, for neonatal recordings (including features specific for this age group), and for Critical Care EEG. The feasibility of SCORE was tested in clinical practice on 12,160 EEG recordings.

The present version still has several limitations. Inter-observer agreement using this system has not been systematically investigated yet. Although the general opinion of the centers that implemented SCORE was, that after gaining experience with using the software, the time spent on reporting EEGs was not longer (or even shorter) than writing or dictating free text reports, this aspect has not been systematically addressed so far.

At present SCORE-EEG generates local databases in the centers where it is implemented. Development of multi-center, national and international databases will be a powerful tool to promote clinical EEG research. For example, SCORE incorporates all recommended elements of the scalp EEG module of the Epilepsy Common Data Elements (CDE) recommended for clinical research by the US National Institutes of Health (NIH)/National Institute of Neurological Disorders and Stroke (NINDS). Future development will include development of the "forced choice" modules required for clinical research EEG scoring.

SCORE will facilitate quality improvement efforts for reporting EEG and epilepsy monitoring. Difficult or controversial EEGs can be reviewed in quality improvement conferences, with the findings

EEG REPORT 11/10/2016

Unit Name

Institution Name

HOSPITAL LOGO

REFERRAL FROM

Name: Dr Test, Doc Test
Institution: Institution Test
Address: Road 2
1234 Postal Place

PATIENT - PERSONAL INFORMATION

Name: Test, Patient
Identity string: 111009-12345
Address: Test Road 1
Date of birth: 11/10/2009

Age at study time 7 years old

STUDY INFORMATION

Study ID: 1 Local study ID: 1111x16 Technician: Nologist, Tech

Start: 11/10/2016 09:15 Stop: 11/10/2016 09:45 Duration: 30 minutes Recorded: 30 minutes

EEG type Standard EEG
Indication for EEG Classification of a diagnosed patient with epilepsy
Last seizure <1 day
Medication at referral N03AX09 lamotrigine
Alertness Awake, Oriented, Good cooperation
Sensor group 10-20 and inferior row

MODULATORS AND PROCEDURES

Hyperventilation
Properties: Good effort of hyperventilation .
Intermittent photic stimulation

FINDINGS

Background activity

Posterior dominant rhythm

Properties: Normal activity. 9.0 - 10.0 Hz.Medium amplitude (20-70μV). Symmetrical amplitude. Reactive to eye opening. Normal organization. Symmetrical frequency.

Interictal findings

Epileptiform interictal activity

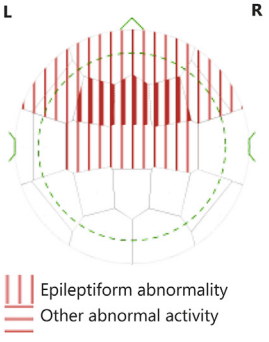
Morphology: Spike-and-slow-wave.
Location: Bilateral and midline frontal. (Maximum F3, F4, Fz). Primary bilateral synchronous activity.
Time-related features: Rhythmic trains or bursts Duration: < 3 seconds. Prevalence <1%: rare.
Modulators: Unmodified during intermittent photic stimulation. Increased during hyperventilation.

Episodes

Generalized seizure - Absence - Typical

Timing & context: Consciousness affected. Is not aware of the episode. Simultaneous Clinical and EEG start. Awake at seizure start. Seizure duration: 12 seconds.

Semiology
1: Motor or behavioural arrest
1: Eye blinking
Properties: Bilateral eyeblinking.
EEG
Ictal EEG activity
Morphology: Spike-and-slow-waves.
Location: Bilateral and midline frontal, central. (Maximum F3, F4, Fz). Symmetrical amplitude. Primary bilateral synchronous activity.
Properties: 3.0 Hz.



SUMMARY OF THE FINDINGS

Interictal: bi-frontal, synchronous, 3 Hz spike-and-slow-waves.
Ictal: Typical absence

DIAGNOSTIC SIGNIFICANCE

Abnormal recording supporting: Generalized idiopathic epilepsy

CLINICAL COMMENTS

In keeping with the history, the electroclinical findings indicate childhood absence epilepsy.

Tech Nologist Technician | One Doc, Physician (signed) | Dr Two Doc, Supervising physician

Test, Patient 111009-12345 1111x16 11/10/2016 Page: 1 / 1

Fig. 3. Example of a report generated with the SCORE-EEG software.

clearly marked for efficient review. Since each EEG can be scored multiple times by different readers, local laboratories can assess their own interrater reliability by having all neurophysiologists and/or trainees score a group of EEGs selected by EEG type or by a particular EEG finding. For national and international quality improvement, standardized SCORE reports could be de-identified and automatically submitted to neurophysiology accrediting organizations. These accrediting organizations should be encouraged to adopt SCORE's standardized terminology and develop systems for HIPAA-compliant data transmission.

SCORE is a valuable educational tool. The web-based educational program of the ILAE (Virtual Epilepsy Academy) used a SCORE-based educational template. The new, VIIth edition of *Niedermeyer's Electroencephalography* will use a SCORE-based educational platform to provide readers with samples scored by experts, with the possibility to score the samples themselves, and later to compare them with the experts' scorings.

The current version of SCORE represents a broad international consensus, and includes a wide variety of terms. Future studies on inter-rater agreement are necessary to estimate the reliability of the various terms in SCORE. After building up a large international database, one could consider removing the terms that are never used and those that fail to achieve a substantial inter-observer agreement. SCORE was designed as a dynamic system, allowing for updates (renaming or removing existing items, inserting new items) without losing data from the earlier versions. Considering the increasing knowledge in this field, we consider that revisions at regular intervals (5 years) are necessary.

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Declaration of interest

Harald Aurlien is shareholder and Chief Medical Officer in Holberg EEG AS. Jan Brøgger and Tom Eichele are shareholders in Holberg EEG AS. Donald L. Schomer is the editor of the *Niedermeyer's Electroencephalography* textbook. Akio Ikeda received grants from GlaxoSmithKline K.K., Nihon Kohden Corporation, Otsuka Pharmaceuticals Co., and UCB Japan Co., Ltd. The other authors do not have any conflict of interest.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.clinph.2017.07.418.

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