PLEDs and other periodic patterns of EEG in the critically ill patients: interpretation

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EEG patterns in critically ill

• Periodic and rhythmic wave forms
  – Association with neural injury?
  – How aggressively treat?

• Barriers
  – Patterns change over time
  – Given pattern: mean different things
  – Limitation of written language

• Standard terminology
  – Continuous EEG monitoring
Standardized terminology for EEG patterns in critically ill

• First version (Hirsch et al., 2005)
  – The American Clinical Neurophysiology Society (ACNS) subcommittee on Critical Care Monitoring

• Terms
  – Objective
  – Well-defined
  – Reproducible
ACNS critical care monitoring committee’s: patterns in the critically ill

• Main term no. 1 (localization)
  – Generalized (G)
  – Lateralized (L)
  – Bilateral Independent (BI)
  – Multifocal (Mf)

• Main term no. 2 (morphology)
  – Periodic discharges (PDs)
  – Rhythmic delta activity (RDA)
  – Spike-wave (includes sharp-wave) (SW)
Major modifiers

- Persistence
- Duration
- Frequency
- Sharpness
- Amplitude
- Others

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Major modifiers

**Persistence**
- % of record including the pattern
- Continuous: $\geq 90\%$ of record/epoch
- Abundant: $50-89\%$ of record/epoch
- Frequent: $10-49\%$ of record/epoch
- Occasional: $1-9\%$ of record/epoch
- Rare: $<1\%$ of record/epoch

**Duration**
- Specify typical duration of pattern if not continuous.
- When categorizing
  - Protracted: $\geq 1$ h
  - Prolonged: $5-59$ min
  - Intermediate: $1-4.9$ min
  - Brief: $10-59$ s
  - Very brief: $<10$ s
Major modifiers

**Frequency**
- Cycles/s
- Can be range

**Sharpness**
- Spiky (duration of that component [(measured at the EEG baseline] is <70 ms)
- Sharp (duration of that component 70-200 ms)
- Sharply contoured (but dose not qualify as sharp or spiky)
- Blunt
Major modifiers

**Amplitude**

- **Absoulte**
  - Very low: <20 uV
  - Low: 20-49 uV
  - Medium: 50-199 uV
  - High: ≥200 uV

- **Relative**
  - Highest of PDs to background
  - ≤2 or >2

**Others**

- Stimulus-induced versus spontaneous
- Evolving vs fluctuating vs static
- Plus (+): more ictal-appearing
  - “+F”: superimposed *fast* activity
  - “+R”: superimposed *rhythmic* or quasi-rhythmic activity
  - “+S”: superimposed *sharp* waves or *spikes*, or *sharply contoured*
Examples of appropriate terms

- Continuous 1-2/s fluctuating GPDs
- Occasional 30-60 second periods of 1.5/s SI-LRDA
- Abundant 1-3 minute periods of 0.5-1.5/s LPDs+F
- Frequent 10-second periods of 1/s BIPDs

Persistence  Duration  Frequency
<table>
<thead>
<tr>
<th>Old Term</th>
<th>New Term*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triphasic waves, most of record</td>
<td>Continuous 2/sec GPDs (with triphasic morphology can be added)</td>
</tr>
<tr>
<td>PLEDs</td>
<td>LPDs</td>
</tr>
<tr>
<td>BIPLEDs</td>
<td>BIPDs</td>
</tr>
<tr>
<td>GPEDs/PEDs</td>
<td>GPDs</td>
</tr>
<tr>
<td>FIRDA</td>
<td>Occasional brief 2/sec GRDA (if 1–10% of record); frontally predominant can be added</td>
</tr>
<tr>
<td>PLEDS+</td>
<td>LPDs+</td>
</tr>
<tr>
<td>SIRPID w/focal evolving RDA</td>
<td>SI-Evolving LRDA</td>
</tr>
<tr>
<td>Laterialized seizure, delta frequency</td>
<td>Evolving LRDA</td>
</tr>
<tr>
<td>Semirhythmic delta</td>
<td>Quasi-RDA</td>
</tr>
</tbody>
</table>

*Some could have alternative new terms depending on the exact pattern.
SIRPID, stimulus-induced rhythmic, periodic, or ictal discharges.
Evolving LRDA
LRDA+S
Periodic discharges

- **PLEDs (LPDs)/GPEDs (GPDs)**

- **Mechanism**
  - Cortical isolation (Cobb et al. 1950)
  - Gray matter lesion (Gloor et al. 1968/ Raroque and Purdy, 1995)
  - A lesion anywhere (Gurer et al., 2004)

- **Clinical aspects**
  - Potentially treatable disease
  - High risk of seizures

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**TABLE 2. Correlation of timing and results of MRI in 8 study patients**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Abnormality</th>
<th>Location</th>
<th>Timing of MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diffuse atrophy</td>
<td>GWL</td>
<td>4 days after EEG</td>
</tr>
<tr>
<td>2</td>
<td>↑ T₂, W, occipital</td>
<td>GWL</td>
<td>1 mo after EEG</td>
</tr>
<tr>
<td>3</td>
<td>↑ T₂, W, occipital</td>
<td>GWL</td>
<td>7 mo after EEG</td>
</tr>
<tr>
<td>4</td>
<td>↑ T₂, W, occipital</td>
<td>GWL</td>
<td>1 day before EEG</td>
</tr>
<tr>
<td>5</td>
<td>Diffuse atrophy</td>
<td>GWL⁺</td>
<td>1 yr after EEG</td>
</tr>
<tr>
<td>6</td>
<td>Diffuse atrophy</td>
<td>GWL⁺</td>
<td>18 mo after EEG</td>
</tr>
<tr>
<td>7</td>
<td>↑ T₂, W, gyriform R anterior</td>
<td>GL</td>
<td>Same day as EEG</td>
</tr>
<tr>
<td>8</td>
<td>Extraaxial, R posterior cortex</td>
<td>I⁺</td>
<td>2 days before EEG</td>
</tr>
</tbody>
</table>

GL, gray matter; GWL, gray and white matter; I, indeterminate; ↑, increased; T₂, T₂ weighted.

⁺ Motion artifact.

PLEDs (LPDs)

- Chatrian et al. (1964)
- Spatiotemporally variable
- Controversy
  - Ictal, interictal, postictal

- Patterns
  - PLEDs-proper (class 1, 2, 3)
  - PLEDs-plus (class 4, 5)
  - Bilateral independent PLEDs (BI-PLEDs)
Subcortical PLEDs: relative stereotypic

Cortical PLEDs (n=49)

Subcortical PLEDs (n=11)

PLEDs-proper (0.7-1/s LPDs)
PLEDs-plus (0.5-1/sec LPDs+R)
PEDs-plus (0.5-1/sec LPDs+F)
BIPLEDs (BIPDs)
BIPLEDs-plus (BIPDs+F)
Etiology of PLEDs

- **PLEDs (LPDs)** (Garcia-Morales et al. *J Clin Neurophysiol* 2002;19:172-77)
  - 148/ 80,424 EEGs: 130 EEGs (enough information available)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>n (%)</th>
<th>Independent</th>
<th>Dependent</th>
<th>Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>61 (45)</td>
<td>28</td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Infectious disease</td>
<td>24 (18)</td>
<td>16</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Tumor</td>
<td>16 (11)</td>
<td>2</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Hematoma</td>
<td>14 (12)</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>15 (11.5)</td>
<td>6</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Anoxic encephalopathy</td>
<td>5 (33)</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>3 (20)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Creutzfeld-Jacob disease</td>
<td>3 (20)</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Craniocerebral trauma</td>
<td>1 (7)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Multiple sclerosis</td>
<td>1 (7)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Migraine</td>
<td>1 (7)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Aminophylline intoxication</td>
<td>1 (7)</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

- **BIPLEDs (BIPDs)**
  - Anoxia, Bilateral acute lesions, Occasionally unilateral or no lesion, **HSE**
Implication of PLEDs (LPDs)

- Seizures in PLEDs (LPDs)
  - 58-100%
  - PLEDs-proper/PLEDs-plus (Reiher et al., 1991)
    - 6% vs 74%

- BIPLEDs (BIPDs)
  - More associated with coma and poor outcome
  - Based on small numbers
    - 18 BIPLEDs/45 PLEDs (del la Paz and Brenner, 1981)
    - 4 BIPLEDs following EPC (Snodgrass et al., 1989)

- Overall mortality rate (Fizpatrick and Lowry, 2007)
  - Overall PELDs vs BIPLEDs: 27% vs 52%

### TABLE 3. Etiology and seizures

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Seizure, n</th>
<th>No Seizure, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td>Infection</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Tumor</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Hematoma</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>9</td>
<td>6</td>
</tr>
</tbody>
</table>

PLEDs (LPDs): sometimes ictal

- Hypermetabolism (PET)
  - Handforth et al. (1994)

- Hyperperfusion (SPECT)
  - Assal et al., 2001
  - Bozkurt et al. 2002

- NCSE: 7 elderly pts
  - Terzo et al. (1986)

- EPC
  - Snodgrass et al. 1989 (8/139)
  - Baykan et al. 2000 (7/45)
  - Kuroiwa and Celesia, 1989 (13/26)

Handforth et al. *Epilepsia* 1994;35:872-81
Benign PLEDs (LPDs)

- Long–standing seizure disorders, chronic brain lesion
  - PLEDs (Westmoreland et al., 1986)
    - Tuberous sclerosis, porencephalic cyst, chronic brain abscess
  - BIPLEDs (Fushimi et al., 2003)
    - Bilateral hippocampal infarction

- Nonictal
- Without
  - Continued neuronal injury
  - Additional neurologic dysfunction
GPEDs (GPDs)

- Periodic short-interval diffuse discharges (PSIDDs)
  - 0.5-4 s
- Periodic long-interval diffuse discharges (PLIDDDs)
  - 4-30 s
- Stimulus-induced rhythmic, periodic, or ictal discharges (SIRPIDDs)
- Triphasic waves
- Suppression-burst patterns
GPEs [PSIDDs] (1/sec GPDs)
GPEDs [PLIDDDs] (GPDs)
GPEDs-plus (GPDs+F)
SIRPIIDs (SI-GRDA, SI-GPDs)

**TABLE 1. SIRPID EEG categorization**

<table>
<thead>
<tr>
<th>SIRPID subcategory</th>
<th>Number of patients (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodic, total</td>
<td></td>
</tr>
<tr>
<td>GPEDs</td>
<td>10</td>
</tr>
<tr>
<td>PLEDs</td>
<td>9</td>
</tr>
<tr>
<td>Triphasics</td>
<td>5^b</td>
</tr>
<tr>
<td>Generalized polyspikes</td>
<td>1</td>
</tr>
<tr>
<td>Multiple periodic patterns</td>
<td>4</td>
</tr>
<tr>
<td>Ictal-appearing, total</td>
<td>18</td>
</tr>
<tr>
<td>Focal</td>
<td>12</td>
</tr>
<tr>
<td>Generalized</td>
<td>7</td>
</tr>
<tr>
<td>Focal and generalized</td>
<td>1</td>
</tr>
<tr>
<td>FRDA</td>
<td>14^c</td>
</tr>
</tbody>
</table>

FRDA, frontal rhythmic delta activity; GPEDs, generalized periodic epileptiform discharges; PLEDs, periodic lateralized epileptiform discharges; SIRPIIDs, stimulus-induced rhythmic, periodic, or ictal discharges.

^a A single patient may have had more than one pattern.

^b Triphasic waves were never the only SIRPID pattern.

^c Seven had other SIRPID patterns also.

Triphasic waves (GPEDs, 1-1.5/s GPDs)
Suppression-burst pattern
Etiologies of GPEDs (GPDs)

- **PSIDDs**, interval of 0.5~4.0 sec
  - Sporadic Creutzfeldt-Jakob disease

- **PLIDDs**, interval of 4-30 sec (Brenner and Schaul, 1990)
  - SSPE (subacute sclerosing panencephalitis)

- **SIRPIDs**
  - Acute neurological or systemic disease
  - Ictal pattern: 18 of 33 pts c SIRPIDs (Hirsche et al., 2004)

- **Triphasic waves** (Brenner, 2002)
  - Metabolic encephalopathies, many etiologies

- **Suppression-burst pattern**
  - Hypoxia, drug overdose, after SE, EIME, Ohtahara syndrome
### TABLE 1. Periodic patterns—EEG characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>PLEDs or BIPLEDs</th>
<th>PSIDDS</th>
<th>PLIDDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval duration</td>
<td>0.5–4 s</td>
<td>0.5–4 s</td>
<td>4–30 s</td>
</tr>
<tr>
<td>Topography</td>
<td>Unilateral (local, lateralized) or bilateral (independent)</td>
<td>Diffuse</td>
<td>Diffuse</td>
</tr>
<tr>
<td>Morphology</td>
<td>Sharp waves (includes biphasic or triphasic waves); spikes, polyspikes</td>
<td>Sharp waves (includes biphasic or triphasic waves); spikes, polyspikes</td>
<td>Complex, stereotyped; polyphasic</td>
</tr>
</tbody>
</table>

*For abbreviations, see text.

### TABLE 2. Periodic patterns—clinical features

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>PLEDs or BIPLEDs</th>
<th>PSIDDS</th>
<th>PLIDDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etiology</td>
<td>Varied; most often vascular (PLEDs)</td>
<td>Metabolic (particularly hepatic encephalopathy); anoxia</td>
<td>SSPE; toxic (anesthetics); anoxia</td>
</tr>
<tr>
<td></td>
<td>CNS infection, anoxia (BIPLEDs)</td>
<td>CJD; toxic (baclofen, lithium); NGSE</td>
<td></td>
</tr>
<tr>
<td>Seizures (F or GTC)</td>
<td>Common</td>
<td>Rare</td>
<td>Rare</td>
</tr>
<tr>
<td>Myoclonus</td>
<td>Rare</td>
<td>Common (CJD)</td>
<td>Common (SSPE)</td>
</tr>
<tr>
<td>Altered mental status</td>
<td>Common</td>
<td>Common</td>
<td>Common</td>
</tr>
</tbody>
</table>

*F, focal; GTC, generalized tonic-clonic; NGSE, nonconvulsive generalized status epilepticus. For other abbreviations, see text.
GPEDs in children with CSE and IV anesthetics

- Cortical excitation
- Herald seizure recurrence
  - Continuum of SE
  - Re-emerging ictal state

Prognosis of GPDs (GPDs)

- 37/all EEGs of adults, 8 yr at one center
  - 89.5% of 37 pts: Sz within 48 hr after detection
  - Myoclonic (35.2%), GTC (21.6%), SE (32.4%)

- Inter-GPED amplitude
  - Higher in SE, very low after anoxia
  - Suppression-burst pattern after anoxia: 100% mortality within 1 mo

- Inter-GPED interval: Mortality—PSIDD>> PLIDD

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Table 4: Aetiology and prognosis according to the EEG patterns.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Hypoxic encephalopathy</th>
<th>Metabolic and/or infectious disease</th>
<th>SSPE</th>
<th>CJD</th>
<th>Total</th>
<th>Mortality within the first month (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppression-burst</td>
<td>3</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>7</td>
<td>100(^a)</td>
</tr>
<tr>
<td>PSIDD</td>
<td>3</td>
<td>8</td>
<td>-</td>
<td>4</td>
<td>15</td>
<td>53.3</td>
</tr>
<tr>
<td>PLIDD</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>11</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>15</td>
<td>11</td>
<td>4</td>
<td>37</td>
<td>48.7</td>
</tr>
</tbody>
</table>

\(^a\) 85% within the first week.

Conclusion

- Clinically significant periodic discharges
  - PLEDs: PLEDs-proper, PLEDs-plus, BI-PLEDs
  - GPEDs: PSIDDs, PLIDDs, SIPRIDs, Triphasic waves, S-B
- Standardized terminology (ACNS)
  - LPDs, LPDs+, BIPDs
  - GPDs, GPDs with triphasic morphology
- Periodic and rhythmic discharges in critically ill
  - Neuronal injury?
  - How aggressively treat?
- Controversial EEG patterns
  - Future studies: highly desirable