# Mnemonics for the use and interpretation of amplitude-integrated electroencephalography in newborn infants

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# ABSTRACT

An electroencephalography (EEG) has always been considered a specialized field, whose use and interpretation requires training. For this reason, access to these monitoring studies has been restricted to neurologists and neurophysiologists. Newborn infants admitted to the neonatal intensive care unit (NICU) require neurophysiological monitoring to establish their diagnosis and prognosis, so a simple and accessible tool is required for NICU staff. Such features have been covered by amplitude-integrated electroencephalography (aEEG), which, through simple visual patterns of brain activity, allows to approach neurological conditions. The objective of this study is to help with the management of mnemonics that facilitate the identification of normal and pathological visual patterns in an aEEG. Although simple in appearance, this nomenclature is intended to create an easy-to-understand idea of basic concepts for the use and interpretation of neurophysiological monitoring with aEEG.

*Keywords:* electroencephalography; interpretation of computed assisted imaging, methods; neurological disease.

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An electroencephalogram (EEG) is a necessary test approach in newborn infants (NBIs) with neurological disorders because it allows to assess for abnormal brain electrical activity. Although a conventional EEG (cEEG) is noninvasive, the need for specialized staff to place the numerous electrodes and interpret the EEG tracing is an obstacle for its use. Currently, an alternative that may be used in the neonatal intensive care unit (NICU) is an amplitudeintegrated electroencephalography (aEEG). It is an easy and affordable test that may be performed by NICU staff after a brief training period. The routine use of aEEG allows for an early approach and prognosis in multiple conditions;<sup>1</sup> however, for its correct use, it is essential that the NICU staff know how to recognize the different electrical patterns, whether normal or pathological, in order to prevent diagnostic errors.

Mnemonics refers to the process of mental association to facilitate memory, derived from the Ancient Greek word *mnēmonikos*, which means "of memory" or "relating to memory." The objective of this study is to help with the management of concepts that facilitate the identification of normal and pathological visual patterns in an aEEG. Although simple in appearance, this nomenclature is intended to create an easy-to-understand idea of basic concepts for the use and interpretation of neurophysiological monitoring with aEEG.<sup>2</sup>

# **ELECTRODE PLACEMENT**

The location of electrodes is based on the International 10–20 system, which relies on several craniometric points; therefore, training is required to be able to use this system.<sup>3</sup>

Brain monitoring with an aEEG can be performed with hydrogel, gold cup, or needle electrodes. Most devices use 1 or 2 channels, although full-montage devices are also available. The original montage chosen by Maynard in the 1960s was 1 channel in the parietal region (left/P3-right/P4). This setup prevented artifacts resulting from manipulation and was located over the vascular watershed brain regions, which are highly susceptible to damage by systemic hypoperfusion. The disadvantage of using a single channel is that it does not allow to differentiate interhemispheric changes. A 2-channel montage (C3-P3 and C4-P4) may be used in different clinical settings to observe interhemispheric asymmetries and increase the diagnostic sensitivity of the device, e.g., in neonatal arterial

ischemic stroke.<sup>4</sup> Frontal leads are used less frequently, due to the relative absence of electrical activity in frontopolar regions.<sup>5</sup>

#### Rule of 3

The objective of this method is to place the electrodes without having special training. This "rule of 3" play on words is helpful because, after locating the central point, you first have to measure 3 cm to the left and right, and then 3 cm to the back on each side, thus generating an interhemispheric distance of 6 cm and an intrahemispheric distance of 3 cm.6 The first step is to draw 2 imaginary lines, 1 on the midline and the other on the middle of both ears: where these lines cross is located the vertex point (Cz); from this point we apply the "rule of 3," measuring 3 cm to the left, where C3 will be located, and 3 cm to the right, where C4 will be located. Finally, measure 3 cm to the back from C3 and C4, where P3 and P4 will be located, respectively (Figure 1). The "rule of 3" may be used in late preterm and term NBIs.

An alternative method is to use the eyeballs as a guide, drawing 2 imaginary lines in the middle of the eyeballs and then a line in the middle of both ears; where these lines cross, C3 (left) and C4 (right) will be located. Then, measure 3 cm to the back from the central points in order to establish the location of P3 and P4 (*Figure 2*). This option is preferable in preterm NBIs or infants with microcephaly.

### **ORIGIN OF aEEG TRACING**

All EEGs record the difference in electrical potential between 2 scalp locations. This signal reflects the current flow between different regions of the cortex and contains positive and negative voltage values, which fluctuate over time. The raw EEG signal is amplified and closely filtered to attenuate electrical activity below 2 Hz and above 15 Hz, minimizing artifacts (sweating, muscle activity, and environmental electrical interference). The signal is subsequently rectified (negative voltages are converted into positive voltages) and the peak-to-peak amplitudes are measured in microvolts (µV) peak-to-peak (µV p-p). The final result is plotted on a semi-logarithmic scale (linear from 0  $\mu$ V to 10  $\mu$ V p-p, and on a logarithmic scale from 10  $\mu$ V to 100  $\mu$ V p-p), to highlight the lowest voltage activity. The aEEG tracing is displayed on a highly compressed time scale, at a rate of 6 cm/h; this allows to obtain easily recognizable visual patterns.<sup>3</sup>

#### FIGURE 1. Rule of 3



Two imaginary lines are drawn, 1 on the midline (yellow) and the other on the middle of both ears (purple); where these lines cross is located the central point or vertex (Cz). From this point, we apply the "rule of 3," measuring 3 cm to the left, where C3 will be located, and 3 cm to the right, where C4 will be located. Finally, measure 3 cm to the back from C3 and C4, where P3 and P4 will be located, respectively.

Source: Personal files of César G. Sánchez-Acosta.

#### FIGURE 2. Rule of 3



Two imaginary lines are drawn in the middle of the eyeballs (yellow lines), and then a line is drawn in the middle of both ears (purple); where these lines cross, C3 (left) and C4 (right) will be located. Then, 3 cm are measured to the back from the central points in order to establish the location of P3 and P4. Source: Personal files of César G. Sánchez-Acosta.

#### **aEEG BACKGROUND PATTERNS**

The age at onset and the minimum and maximum amplitude values for the different background patterns are mentioned in *Table 1.*<sup>7</sup>

Continuous pattern (C): It appears as a "snake," where the wider bandwidth represents quiet sleep (QS) and the narrower bandwidth corresponds to active sleep/wakefulness (AS/W) (*Figure 3-a*).<sup>8</sup>

*Discontinuous pattern (D)*: It appears as a "wide belt" or "girdle." It is normal in preterm NBIs less than 31 weeks of gestation (WG) (*Figure 3-b*).<sup>8</sup>

Burst suppression (BS): It resembles a "comb" with a basal line between 0  $\mu$ V and 2  $\mu$ V and bursts reaching 25  $\mu$ V. In the case of more than 100 bursts/h, activity is classified as BS+ and, with less than 100 bursts/h, BS-. This is the most common abnormal pattern (*Figure 3-c*).<sup>8</sup>

Low voltage (LV): The mnemonic corresponds to a "very thin belt" with a maximum amplitude of 10  $\mu$ V (*Figure 3-d*).<sup>8</sup>

Continuous pattern after 39 WG: After 39 WG, there is a reversal in the minimum and maximum amplitude of QS and AS/W. QS has a

Pattern	Minimum amplitude	Maximum amplitude	Interpretation
Discontinuous	< 5 µV	> 10 µV	Normal until
31 WG			
Continuous	> 5 µV	> 10 µV	Normal
Burst suppression	0–2 μV	> 25 μV	Abnormal
Low voltage	< 5 µV	< 10 µV	Abnormal
Flat	0 μV	< 5 µV	Abnormal

TABLE 1. Classification of aEEG background patterns (adapted from Magalhães LVDS)<sup>6</sup>

aEEG: amplitude-integrated electroencephalography; WG: weeks of gestation.





a) C = snake, broader bandwidth QS and narrower bandwidth AS/W. b) D = wide belt or girdle.
c) BS = comb. d) LV = very thin belt. e) Continuous pattern after 39 WG. f) Se = mountain. g) SE = mountain range.
aEEG: amplitude-integrated electroencephalography; C: continuous; QS: quiet sleep; AS/W: active sleep/wakefulness;
D: discontinuous; BS: burst suppression; LV: low voltage; WG: weeks of gestation; Se: seizure; SE: status epilepticus.
Source: Personal files of César G. Sánchez-Acosta.

higher amplitude than AS/W, and no difference is observed between the bandwidth of these 2 *stages* (*Figure 3-e*).<sup>9</sup>

Seizures (Se): The increase of the minimum and maximum amplitude during the hypersynchronous electrical discharge of a group of neurons produces an image resembling a "mountain." Status epilepticus (SE) mimics a "mountain range," with epileptic activity duration of  $\geq$  30 minutes (*Figures 3-f* and *3-g*). Epileptic activity should be confirmed in the raw EEG.<sup>8,10</sup>

# **aEEG WHILE USING ANTIEPILEPTIC DRUGS, SEDATIVES, AND ANESTHETIC AGENTS**

The use of sedatives is common in critically ill NBIs and antiepileptic drugs are critical for the management of most causes of neonatal encephalopathy (NE); for this reason, the

FIGURE 4. Stairs of patterns and effect of multiple drugs

Brown line: Effect of antiepileptic drugs, e.g., phenytoin or levetiracetam. Yellow line: Effect of routine doses of phenobarbital, opioids, midazolam. Blue line: Effect of anesthetic agents, opioids in critically ill NBIs or NBIs with NE and receiving high doses of midazolam. NBI: newborn infant; NE: neonatal encephalopathy.

Source: Personal files of César G. Sánchez-Acosta.

interpretation of an aEEG during the use of these drugs is paramount. In these cases, the interpretation of the aEEG may be compared to a "stair" because some drugs modify the baseline background pattern and may "step down" (C->D, D->BS, BS->LV, LV->Flat).<sup>11</sup>

#### **Antiepileptic drugs**

Phenobarbital is the most widely used antiepileptic drug to control seizures. Their use modifies the background pattern and a "1 step" decrease is usually observed in the "stair of patterns." Other antiepileptic drugs (phenytoin or levetiracetam) do not usually affect the background pattern.<sup>12</sup>

#### **Sedatives**

When opioids are used as sedatives, they discreetly modify the background pattern and show a 1 step decrease, except in NBIs with severe conditions or NE; in this scenario, the decrease may account for 2 steps (even at conventional doses). Premedication with morphine for intubation in preterm NBIs resulted in decreased cyclicity and a discontinuous pattern in the first 24 hours post-dose.<sup>13</sup> Continuous infusion with midazolam alters the background pattern. In NBIs with NE due to perinatal asphyxia, 1-step decreases may be

observed (dose: 0.15 mg/k/h).<sup>14</sup> We have observed that step-downs depend on the dose used: a higher dose produce a greater modification in the background pattern.

# **Anesthetic agents**

These drugs (sevoflurane, isoflurane) usually cause a 2-step decrease in the stair of patterns.<sup>15</sup>

Potential scenarios are summarized in *Figure 4.* 

#### CONCLUSION

An aEEG is an affordable and simple neuromonitoring technique that has made EEG friendly and accessible to healthcare staff involved in the care of the NBIs; it has become a "bridge" between neurologists and neonatologists. The use of mnemonics facilitates the interpretation and correct use of this brain monitoring technique.

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