Neurological Case Reports

Case Report
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Neuromonitoring by qEEG and HRV during a Patient's Cardio-Respiratory Arrest

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Abstract

The EEG monitoring system (cEEG), Neuronic, S.A., we assessed patient JJO for three hours and four minutes following a heart infarct. Monitoring commenced with the onset of the first clinical signs of the infarct. At 2 h and 21 min, and again at 44 min, the record displayed ECG complexes alternating with isoelectric periods. Ventricular Fibrillation (VF) ensued at 2 h and 22 min, leading to Cardiac Arrest (CA) at 2 h and 59 min. The cEEG revealed persistent Gamma activity throughout the recording. With the onset of VF, there was a marked increase in Gamma Absolute Power, peaking post-CA.

It is important to note that while these observations are compelling, they do not yet provide a definitive explanation for NDEs. The exact reasons why near-death experiences occur and the role of gamma wave surges in these experiences are still subjects of ongoing scientific investigation. However, these studies are significant steps toward understanding the complex relationship between brain activity and consciousness at the end of life.

Keywords: Cardio-respiratory arrest; EEG monitoring system; Neurosurgery; Gamma activity

Case Presentation

Using our continuous EEG monitoring system (cEEG), Neuronic, S.A., we assessed patient JJO for three hours and four minutes following a heart infarct. Monitoring commenced with the onset of the first clinical signs of the infarct. At 2 h and 21 min, and again at 44 min, the record displayed ECG complexes alternating with isoelectric periods. Ventricular Fibrillation (VF) ensued at 2 h and 22 min, leading to Cardiac Arrest (CA) at 2 h and 59 min.

The cEEG revealed persistent Gamma activity throughout the recording. With the onset of VF, there was a marked increase in Gamma Absolute Power, peaking post-CA (Figure 1).

Our cEEG system also facilitates continuous HRV assessment. A substantial rise in the Very-Low-Frequency band (VLF) was observed at the start of VF, which intensified further post-CA (Figure 2).

Discussion

The surge of brain activity at the time of death

Cerebral blood flow halts during complete global ischemia, such as that occurring after cardiac arrest, leading to the cessation of the cerebral cortex's functional (electrical) activity [1-3]. Initially, there is a decline in the high-frequency component of the EEG, accompanied by a rise in the low-frequency component, before the EEG becomes isoelectric. CPR may revive heartbeat and circulation, potentially restoring Cerebral Blood Flow (CBF) [4,5].

We observed a patient who experienced a heart infarct and was under continuous monitoring. Notably, Gamma activity was dominant throughout the recording and persisted beyond Ventricular Fibrillation (VF) and Cardiac Arrest (CA). Monitoring from the initial clinical symptoms indicated that ECG activity was insufficient for adequate cerebral blood flow prior to VF and CA. Additionally, we noted increased values across all HRV bands, potentially indicative of emotional responses in this critical state [6,7].

Regarding the autonomic system, we found that HRV in brain-dead patients significantly diminishes across all time and frequency domain variables. Furthermore, we identified an unreported HRV surge associated with supratentorial brain damage leading to diencephalic dysfunction, marked by a progressive autonomic burst as coma deepens to Glasgow Coma Scale

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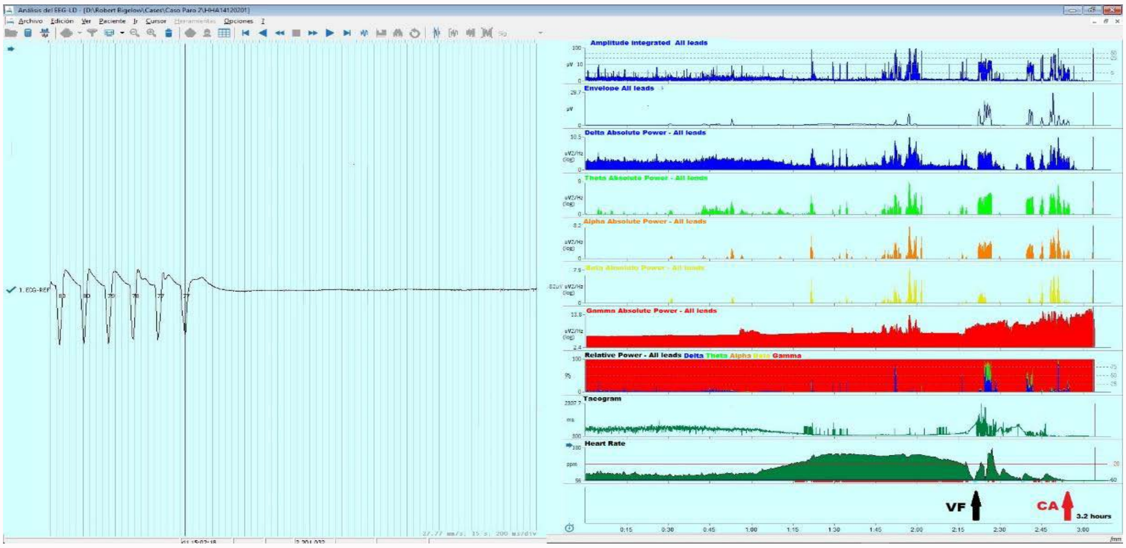

Figure 1: Continuous EEG monitoring (cEEG) confirmed the presence of Gamma activity for the duration of the recording. A significant rise in Gamma Absolute Power was noted with the initiation of Ventricular Fibrillation (VF), culminating in a maximum value following Cardiac Arrest (CA).

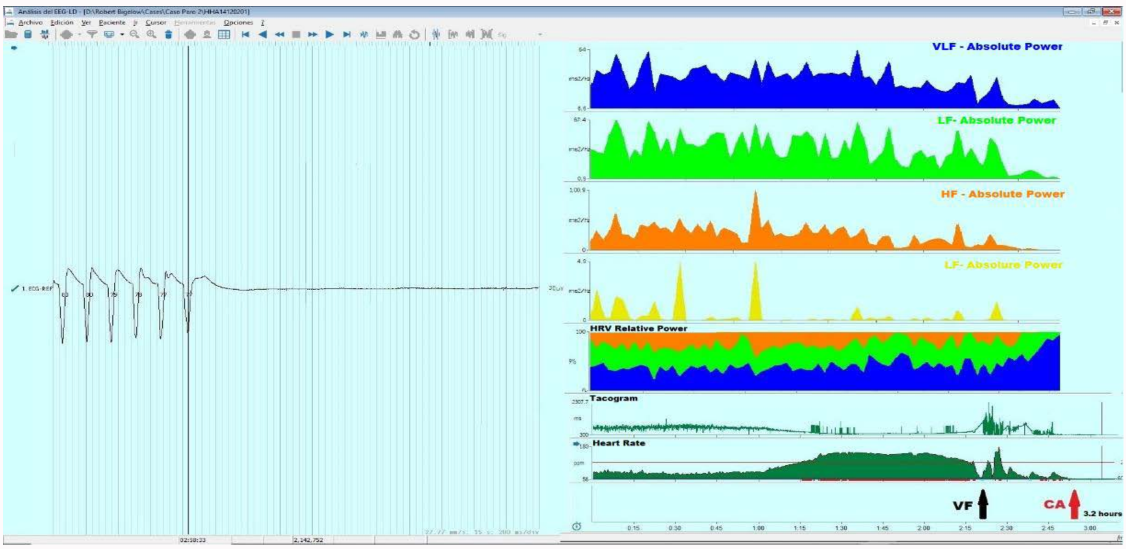

Figure 2: Continuous HRV assessment using the cEEG system. The onset of Ventricular Fibrillation (VF) was marked by a significant increase in HRV - VLF, which escalated further following Cardiac Arrest (CA).

(GCS) values below eight [8-12].

We also documented a patient, assessed *via* HRV methodology immediately after a brain death diagnosis, exhibiting residual very low-frequency waves for approximately ten minutes [9]. Jahi McMath, despite clinical findings of Brain Death/Determination of Non-Candidacy (BD/DNC), maintained EEG activity and autonomic responsiveness to the "Mother Talks" stimulus [13].

Although the brain is presumed to be hypoactive during cardiac arrest, the possibility and mechanism of conscious brain activity during such an event remain contentious. Various studies employing EEG or Bispectral Index (BIS) monitoring have reported surges of brain activity during cardiac arrest [14,15].

Recent studies have indicated that there is an increment in EEG gamma activity following cardiac arrest. This phenomenon has been observed in both animal studies and human cases. For instance, one study noted an increase in gamma-band activity after cardiac arrest, which was attributed to hypercapnia before and the cessation of cerebral blood flow after the event [16,17]. Another significant finding from a different study was the surge in 'gamma oscillations' during the transition period to death, even after neuronal activity ceased, which ultimately declined after cardiac arrest.

These Gamma oscillations are the fastest brain activities and are associated with consciousness, perception, memory, and emotion. The increase in Gamma wave activity has been linked to the brain's heightened state of connectivity among different regions during the moments preceding death. Borjigin et al. evaluated rats subjected to experimental cardiac arrest using continuous EEG. They analyzed changes in power density, coherence, directed connectivity, and cross-frequency coupling. The researchers observed a transient increase in synchronous Gamma oscillations within the first 30 sec post-cardiac arrest, occurring before the EEG became isoelectric. These gamma oscillations were widespread and exhibited remarkable coherence during cardiac arrest. Additionally, this frequency band demonstrated a notable rise in anterior-posterior directed connectivity and tightly matched phase-coupling with theta and alpha oscillations. The authors reported that the high-frequency neurophysiological activity observed in the near-death state exceeded the levels typically seen during the conscious waking state. They posited that the mammalian brain can produce neural correlates of enhanced conscious processing at the brink of death, presenting a paradoxical phenomenon [17].

The surge of EEG Gamma activity after CA has been associated with Near-Death Experiences (NDEs). These experiences often include sensations of leaving the body, seeing a bright light, or reliving memories [18-20]. Recent research has provided intriguing insights into this phenomenon. This surge in Gamma waves, which are associated with attention, working memory, and long-term memory, suggests a heightened state of brain connectivity and could potentially be linked to the vivid experiences reported by some individuals during NDEs [20,21].

The presence of a gamma burst after cardiac arrest is a fascinating and complex phenomenon. During cardiac arrest, when the heart stops and blood flow to the brain ceases, the brain experiences a state of complete global ischemia. This lack of blood flow and oxygenation leads to the cessation of the cerebral cortex's functional activity, typically observed as an isoelectric EEG, indicating no measurable electrical activity in the brain [6,22].

However, some studies have reported a transient surge of synchronous gamma oscillations during this period. Gamma oscillations are high-frequency brain waves associated with higher cognitive functions, such as perception and consciousness. The surge in Gamma activity, often referred to as a "Gamma burst," has been observed within the first 30 sec after cardiac arrest and before the EEG becomes isoelectric [16,17,23].

This gamma burst is particularly intriguing because it suggests that even in the face of severe hypoxia and potential brain injury, the brain can generate a high level of neurophysiological activity. This activity surpasses what is typically observed during the conscious waking state and may be related to the brain's last efforts to sustain consciousness or a heightened state of processing at near-death, and might be the neural explanation of NDEs. The exact mechanisms behind this phenomenon are not fully understood, but it is hypothesized that in response to the sudden and severe lack of oxygen and glucose, the neurons may release a flood of neurotransmitters, leading to a final burst of activity. This could be the brain's last attempt to maintain ion homeostasis and prevent cell death, or it could be related to the brain's intrinsic mechanisms to cope with severe stress [21,24].

It is important to note that while these observations are compelling, they do not yet provide a definitive explanation for NDEs. The exact reasons why near-death experiences occur and the role of gamma wave surges in these experiences are still subjects of ongoing scientific investigation. However, these studies are significant steps toward understanding the complex relationship between brain activity and consciousness at the end of life.

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