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Editorial

Monitoring brain activity: Where are we now and in which direction should we move in the future?☆,☆☆

Monitorización de la actividad cerebral: ¿Dónde estamos y hacia dónde debemos dirigirnos?

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Anesthesiology is a medical specialty in which quantification—the capacity to measure—is of major importance. The basic principle of our interventions as anesthesiologists is based on the administration of drugs, the observation of the effect that these drugs have on the patient, and the adjustment of drug delivery depending on the response that is observed. The magnitude of this response depends on: 1. Factors directly related to the patient such as their age, physical state, and the medication he/she is taking and, 2. Contextual factors such as the type of surgical procedure, its urgency, the point of time within the procedure, and the complications that can appear (bleeding, hypothermia, state of shock) to cite just a few of the most relevant aspects. Observing, adjusting, and magnitude—they are concepts that imply the possibility of measuring to precisely evaluate how the patient reacts in each and every moment of anesthetic drug delivery process.

Technological developments over the last 30 or 40 years and digitalization at all levels have favored the creation of more exact and portable measuring systems. These systems are applicable to the dynamic study of the function of practically all the organs that make up the human body. In the operating room we have access to non-invasive systems that are capable of continually assessing the degree of blockage of the neuromuscular junction, cardiac function, breathing and the efficiency of mechanical ventilation, hemoglobin levels in the blood... We can also assess the effect that the drugs used in anesthesia have on the brain by studying the electroencephalogram.

The electroencephalogram (EEG) is a register of the changes in voltage of the pyramidal neurons in the cerebral cortex. It is a non-invasive, continuous process and sensitive to the effect of anesthetics. Nevertheless, its signal is also susceptible to interference from other, more powerful, electrical currents, it is difficult to understand when one observes the wave trains exclusively, it can change if there is a pathological situation in the brain and, depending on where and how the electrodes are placed, the wave changes can vary.[1] Intravenous hypnotic drugs, benzodiazepines, opiates, and inhalation agents can all induce consistent changes in the

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form of the electroencephalogram (EEG). Although the signal has small amplitude—approximately 100 times smaller than the amplitude of an electrocardiogram—it can be detected and stored. Despite its chaotic appearance, it can be analyzed by applying mathematical and statistical methods.

EEGs have been used to analyze the effect of drugs that act on the nervous system since the early 20th century. In the last quarter of the last century analysis methods began to be applied to study and quantify the changes brought about by the anesthetics. In this way, pharmacokinetic and pharmacodynamic models capable of defining the relationships between dosage, plasma concentration, and effect could be constructed. The way that we administer propofol,[2,3] remifentanil,[4] benzodiazepines,[5] and other drugs today has its origins in the pioneering work of researchers like Stanski and Shafer, who used this methodology. Their vision of the EEG as a source of information exclusively about the pharmacological effect functioned as a starting point for defining a method for measuring the depth of the anesthetic state.

Since then, multiple indicators of the effect of anesthetics have been used to individualize the delivery in response to each patient. With a basis in the concept of the individualization or personalization based on quantification of response, the consequences of hypnotic underdosing—such as intraoperative waking—have been studied[6] along with the consequences of overdosing, which is manifested not only as a tendency toward hemodynamic depression or a delay in waking but, as some authors have proposed, as an increase in the long-term perioperative death rate.[7]

However, the cortex is only one part of the brain and probably what we observe from the changes in the EEG is a reflection of the pharmacological effects that appear at a subcortical level, in areas like the locus ceruleus, the thalamus or other nuclei.[8] The great development in neuroscience based above all on in-laboratory studies in animals has allowed for significant advances in our knowledge of brain function. Diverse research groups have been able to study the phenomenon of the transition between consciousness and unconsciousness by using imaging techniques in volunteers under anesthesia.[9,10]

Other research groups have tried to join—using a vision of systems analysis—the findings at the experimental level with what has been observed in volunteers and patients, using changes in the EEG as a link. The work of Dr. E. Brown in this field area has established how the effect of propofol, dexmedetomidine, and other anesthetic agents is produced. This explains changes in the EEG in light of what is observed in the clinic and what is known based on basic research. The anteriorization and appearance of activity in the frontal alpha waves can be considered a sufficiently sensitive and specific indicator of unconsciousness induced by propofol.[11]

Currently, we are at a highly interesting point of convergence for our specialty. The resources, both from Europe and the USA, dedicated to neuroscience research to unravel the workings of the brain as a key for understanding so many diseases is increasing significantly. Furthermore, anesthesiologists have integrated the EEG as part of their monitoring arsenal. At our disposal we have the tools that allow us to contribute, via our every day work, to widening our knowledge about the brain: patients, continuous measuring systems and pharmaceuticals that induce unconsciousness quickly and quantifiably.

Moreover, we have a vast experience of more than twenty years in the personalization of anesthetics delivery according to the response of each patient by considering the changes in indicators extracted from the EEG as an information source. We can find out what the state of the patient's brain is by assessing the changes that the induction dose of hypnotic drugs has caused in the EEG form in a specific patient. We can predict when he/she will regain consciousness by observing the indicator value.

In which direction, then, should we move in the future? The choice is clear. It is not a question of adopting any single one of the trends that we have commented here. The rewarding solution is to adopt both. As anesthesiologists, we are experts in quantification. We are familiar with the use of the EEG and we know best how to induce the anesthetic state in our patients by using systems based in EEG analysis. Additionally, we have the necessary tools—the EEG, as well as a basis in physiology, pharmacology, and clinical analysis—to contribute, through our work and our ideas, to the knowledge of the workings of the brain. This—improving our knowledge of the brain—is one of the great challenges of neuroscience research, and we could not be in a better clinical and research position to rise to it.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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