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# 10

# Patient state index

David Drover* MD

Assistant Professor of Anaesthesia

*Department of Anesthesia, H3580, Stanford University School of Medicine, 300 Pasteur Drive, Stanford, CA 94305-5640, USA*

H.R. (Rick) Ortega[1] BA

Manager

*Technology and Clinical Development Physiometrix Inc., Five Billerica Park, 101 Billerica Ave., N. Billerica, MA 01862, USA*

The patient state index (PSI) is a clinically validated measure of the effect of anaesthesia and sedation. The PSI is calculated via a proprietary algorithm by a high-resolution 4-channel electroencephalograph (EEG) monitor after advanced artifact rejection. The PSI has been designed specifically for intra-operative and intensive care use to monitor patient sedation and drug effect. The algorithm relies on EEG power, frequency and phase information from anterior–posterior relationships of the brain as well as coherence between bilateral brain regions. The EEG monitor, initially called the PSA4000®, is also the SEDLine® monitor, the newest generation of the device. The SEDLine® system provides the clinician the option of storing and downloading patient data for future use as well as monitoring bilateral brain function and symmetry with a density spectral array (DSA) display.

**Key words:** Patient state index; PSI; EEG; electroencephalography.

## INTRODUCTION

The patient state index (PSI) (Physiometrix Inc., North Billerica, MA, USA) is a processed parameter of a 4-channel electroencephalograph (EEG). The EEG effect of various medications including those used for anaesthesia has been well documented. Predictable changes in brain electrical activity displayed by the raw EEG has been shown for loss of consciousness from anaesthesia medications as well as for the onset of any sleep states.

* Corresponding author. Tel.: +1–650–725–0364; fax: +1–650–725–8544.
*E-mail addresses:* ddrover@stanford.edu (D. Drover), rortega@physiometrix.com (H.R. Ortega).
[1] Tel.: +1 800 474 9746x298; fax: +1 978 670 2817.

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Historically, the indicators of depth of anaesthesia have encompassed both autonomic and somatic responses. Autonomic signs commonly used by the clinician to guide anaesthetic dosing include heart rate and blood pressure changes, diaphoresis and lacrimation. Somatic signs are movement, whether purposeful or reflex in nature. It has been shown that many of the autonomic and somatic events are poor indicators of anaesthetic depth. The unreliability of these items commonly comes from their blockage by many medications used by the patient pre-operatively or by the anaesthesiologist intra-operatively. Many anti-hypertensive medications prevent heart rate and blood pressure responses to inadequate anaesthesia and many anaesthetic drugs impair diaphoresis and lacrimation. The use of muscle relaxant drugs can totally impair any somatic movement responses of the patient.

The goal of general anaesthesia is to produce amnesia, sedation, analgesia and frequently immobility. The majority of anaesthetic medications (with the exclusion of muscle relaxants) affect the electrical activity of the brain. Considering the inherent limitations of autonomic signs and the influence of most anaesthetic drugs on the EEG, a monitor that measures anaesthetic effect would have clear utility in clinical practice.

## THEORY BEHIND PSI DEVELOPMENT

The electrical activity of the brain can be measured with simple surface electrodes placed on the scalp. The EEG activity recorded from any point on the surface relates to the complex EEG signals generated by millions of pyramidal cells of the cerebral cortex. The electrical signal in the simplest form can be broken down into amplitude, frequency and phase of the waveform. The brain's electrical activity, as characterized by the EEG, is precisely regulated by a complex neuroanatomical/neurochemical system. Computer-based quantitative analysis (QEEG) has established that the electroencephalogram's power spectrum has a stable (over the age span), state dependent frequency composition and that this EEG frequency information can be characterized on a regional basis.[1,2]

An alert patient's quantitative descriptors of the power spectrum, as the power in a particular frequency band over a specific region of the scalp, will correspond closely to normative data. An individual's state dependent QEEG is extremely stable and reproducible if there has been no change in the state of the subject. However, the administration of any substance that acts upon the brain will produce a disturbance in the chemical equilibrium of the brain, causing characteristic changes in the QEEG both within and between regions. Certain invariable changes in the QEEG are highly correlated with administration of particular anaesthetic agents.

Loss of consciousness is associated with an increase in beta (12.5–25 Hz) frequencies in the frontal areas of the brain. A similar parallel anteriorization of power occurs in delta, theta, and alpha bands. A loss of consciousness is associated with a global decrease in gamma frequencies ($>25$ Hz) that is distinct from loss of electromyographic (EMG) activity, which can produce interference in the same gamma frequency band.

Coherence of the EEG signal describes the order and relation between particular areas of the brain, which may thereby establish an association between these brain regions. The anteriorization of power at loss of consciousness is accompanied by a loss of coherence of cerebral hemispheres, more so in the posterior areas of the brain. This lack of coherence is consistent during various stages of anaesthesia. The largest

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