ELECTROENCEPHALOGRAM SPECTRAL EDGE FREQUENCY, LOWER ESOPHAGEAL CONTRACTILITY, AND AUTONOMIC RESPONSIVENESS DURING GENERAL ANESTHESIA

Ahmed F. Ghouri, MD,* Terri G. Monk, MD,* and Paul F. White, PhD, MD, FFARACS†

ABSTRACT. Both the electroencephalogram (EEG) spectral edge frequency (SEF) and lower esophageal contractility (LEC) indices have been reported to be useful indicators of anesthetic depth. We designed a prospective study to evaluate the relationship between changes in these two variables and objective measurements of physiologic responsiveness to surgical stress (i.e., changes in hemodynamic variables and plasma levels of norepinephrine, epinephrine, total catecholamines, and vasopressin). Eighty-nine consenting adult males undergoing radical prostatectomy procedures under a standardized general anesthetic technique were studied according to a randomized, single-blinded protocol. General anesthesia was induced with 30 μg/kg intravenous (IV) alfentanil, 2.5 mg/kg IV thiopental, and 0.1 mg/kg IV vecuronium, and subsequently maintained with 0.5 μg/kg/min alfentanil, nitrous oxide (N2O) 67% in oxygen, and 0.8 μg/kg/min vecuronium. Following retropubic dissection, 81 patients (92%) manifested acute hypertensive responses, with mean arterial pressure increasing from 90 ± 14 to 122 ± 14 mm Hg (mean ± SD). This acute hypertensive response was treated with one of three different treatment modalities (20 to 60 μg/kg IV alfentanil, 0.5 to 2.0% inspired isoflurane, or 0.05 to 0.15 mg/kg IV trimethaphan) to return the mean arterial pressure to within 10% of the preincisional (baseline) value within 5 to 10 minutes. Although the mean arterial pressure, heart rate, and plasma levels of catecholamines and vasopressin significantly increased following the surgical stimulus, and decreased after adjunctive therapy, the EEG-SEF and LEC index (LECI) values did not significantly change during these study intervals. Furthermore, using a logistic regression analysis, we observed that preincision EEG-SEF and LECI values could not predict whether patients would manifest a hypertensive response. Therefore, the EEG-SEF and LECI were unreliable indicators of anesthetic depth.


Determinination of "depth of anesthesia" during an operation involves evaluation of hemodynamic, somatic, and autonomic responses to surgical stimuli. Since these variables are altered by a wide variety of physiologic and pharmacologic factors, a noninvasive monitor of anesthetic depth would be extremely valuable. An ideal monitor would reliably predict the patient's global responses to surgical stimuli, independent of the anesthetic drug being used [1]. The electroencephalogram (EEG) measures cortical electrical activity, and it has been suggested that this monitor is a clinically useful indicator of central nervous system depression produced by intravenous (IV) anesthetic and analgesic drugs [2,3]. There are many algo-
rithms that allow the EEG waveform to be processed into a numerical value to quantify central nervous system activity. For example, the EEG spectral edge frequency (SEF) is defined as the frequency below which 95% of the power of the EEG waveform exists, and is calculated by integrating the area under the frequency versus power histogram. Unfortunately, use of the EEG-SEF has limitations that inevitably result from compressing a complex waveform into a single number. In addition, EEG patterns differ markedly depending on the anesthetic technique [4].

It has been proposed that lower esophageal contractility (LEC) also may provide useful information regarding the degree of central nervous system depression produced during anesthesia [5]. Since the smooth muscle of the lower esophagus is innervated by the vagus nerve, it exhibits both peristaltic provoked lower esophageal contractions and nonperistaltic spontaneous lower esophageal contractions [6]. Both types of activity are said to decline with increasing end-tidal concentrations of inhaled anesthetics [1]. To enhance sensitivity, the rate of spontaneous contractions and the amplitude of provoked contractions have been combined into a single parameter, the LEC index (LEC1). Previous studies have suggested a dose-dependent relationship between the LECI and end-tidal anesthetic agent concentrations [1,7]. The LECI also has been reported to increase significantly during periods of intense surgical stimulation [7]. Since smooth muscle does not contain nicotinic (type II) receptors, esophageal activity can be measured during surgery in the presence of neuromuscular blocking agents [8]. It has been suggested, therefore, that the LECI, like the EEG-SEF, could be a useful measure of depth of anesthesia [4].

We designed a prospective study to evaluate the relationship between changes in EEG-SEF and LECI values and changes in objective measures of physiologic responsiveness to surgical stress (i.e., changes in hemodynamic variables and stress hormone levels) in patients undergoing a standardized procedure using an identical anesthetic technique. We sought to determine whether EEG-SEF and/or LECI values could predict hemodynamic responses to a specific surgical stimulus during "light" (inadequate) anesthesia. Finally, we compared the changes in EEG-SEF and LECI values when three different classes of drugs (an opioid analgesic, an inhalation agent, and a vasodilator) were used to treat the clinical signs of inadequate anesthesia.

**MATERIALS AND METHODS**

Eighty-nine consenting adult males, ASA physical status I-III, scheduled for elective radical prostatectomy under general anesthesia were studied according to a randomized, single-blinded protocol. The study was approved by the Washington University Human Studies Committee. All patients were premedicated with 0.1 mg/kg intramuscular midazolam 30 to 45 minutes prior to arriving in the preoperative holding area, where peripheral venous and arterial catheters were inserted.

After obtaining preinduction (baseline) hemodynamic values, anesthesia was induced with 30 μg/kg IValfentanil, 2.5 mg/kg IV thiopental, and 0.1 mg/kg IV vecuronium. Immediately following tracheal intubation, anesthesia was maintained with 0.5 μg/kg/min alfentanil, nitrous oxide (N₂O) 67% in oxygen, and 0.8 μg/kg/min vecuronium. Ventilation was controlled with a volume-cycled ventilator to maintain end-tidal CO₂ values at 34 ± 3 mm Hg (mean ± SD). Mean arterial pressure (MAP) and heart rate (HR) were continuously monitored using an integrated monitor (Cardiocap II, Datex Medical Instrumentation, Tewksbury, MA). A venous catheter was placed in the internal jugular vein and the central venous pressure was maintained between 3 and 8 mm Hg throughout the study period by administering crystalloid and/or blood products. Depth of anesthesia was maintained to provide adequate surgical anesthesia (i.e., no clinical response to skin incision), yet ensure a high probability of a hypertensive response to retropubic dissection (RD).

Esophageal contractility was measured using a Lectron 302 electronic monitor (American Antec, Valencia, CA). The probe consisted of an esophageal stethoscope that had been fitted with 2 balloon cuffs. The proximal balloon was used to provoke contractions from the lower esophagus and the distal balloon measured the frequency and amplitude of all contractions. The transducer was zeroed to atmospheric pressure (with adjustments to compensate for intrathoracic pressure variations). Following induction of anesthesia, the probe was placed in the distal esophagus (approximately 35 cm from the patient's incisor teeth). The esophagus was provoked every 90 seconds for 5 seconds by inflating the proximal balloon of the LEC probe to a pressure of 100 to 200 mm Hg. Esophageal responses were continuously recorded.

A Neurotrac EEG monitor (Interspec Medical, Conshohocken, PA) with compressed spectral array (CSA) capability was used to assess the EEG-SEF. This monitor displays the raw EEG of the left and right hemispheres as well as CSA values. Five subdermal platinum needle electrodes were placed in a symmetric frontal-mastoid montage. The ground electrode was placed in the middle of the forehead near the hairline. Channels 1 and 2 were connected by their positive (G₂) terminals to the left and right electrodes, respectively, and placed...