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Original Article

Alternative Placement of Bispectral Index Electrode for Monitoring Depth of Anesthesia during Neurosurgery

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In neurosurgery in particular, the recommended placement of electrodes for monitoring depth of anesthesia during surgery sometimes conflicts with the surgical site or patient positioning. Therefore, we proposed this study to evaluate the agreement and correlation of bispectral index values recorded from the usual frontal area and the alternate, post-auricular areas in neurosurgery patients. Thirty-four patients scheduled for neurosurgery under general anesthesia were included. Bispectral index (BIS) sensors were placed at both the frontal and post-auricular areas. The anesthesia given was clinically adjusted according to the frontal (standard) BIS reading. The BIS values and impedance were recorded; Pearson's correlation and Bland-Altman plots were analyzed. The bias ± 2SD for the electrode placement before, during, and post-anesthesia were 0 ± 23.32, 1.5 ± 10.69, and 2.1 ± 13.52, while the limits of agreement were −23.3 to 23.3, −12.2 to 9.2, and −17.7 to 13.5, respectively. The correlation coefficient between frontal- and post-auricular-area electrodes was 0.74 with a *p*-value < 0.001. The post-auricular placement of a BIS electrode is a practical alternative to frontal lobe placement. Nevertheless, proper electrode location is important to minimize error.

Key words: Bland and Altman analysis, electroencephalogram, instrumentation, equipment

Although the incidence of perioperative awareness in Thailand is only 0.08% [1, 2], the consequences can be very harmful to patients, both physically and mentally. Long-lasting psychological problems may occur [3]. Hence, monitoring the depth of anesthesia has become increasingly necessary. Use of the bispectral index (BIS), a processed electroencephalogram in which depth of anesthesia is evaluated on a scale from 0 to 100, is recommended [3, 4].

Electrodes has been developed as a single simplified ready-to-use strip. It is composed of 4 electrodes applied on the forehead. During a major operation, the patient is placed in a supine position, and the BIS sensor is attached to the forehead and temporal areas (as recommended by the manufacturer) and monitored routinely due to the easy access to the patient's head. However, in prone and lateral positions or when the surgical site lies between the forehead and eyebrows, problems in BIS monitoring may occur. Other areas of BIS electrode placement besides those recommended by the manufacturer should be considered, such as the mastoid and post-auricular region. But the validity and reliability of their BIS values have been questioned.

The bispectral index is the processed electroencephalogram, computed from the frontal area data. But the effects of anesthesia on the brain's electrical activities are not limited to this particular part of the brain. Data on the processing electrical power should be obtained from other areas of the brain when the patient is asleep and awake. Still, BIS has been shown to be topographically dependent [5]. Differences in

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the exact BIS values from various sites on the head including those recommended by the manufacturer should be considered and calculated. Therefore, the authors performed this diagnostic study to evaluate the agreement and correlation of perioperative bispectral index readings in neurosurgical patients from BIS sensors placed in the area of the forehead (the standard position) and in the post-auricular area.

Materials and Methods

Approval for the study (No. 52053/2553) was received from the Prasat Neurological Institutional Ethics Committee (Chairman: Suchart Hanchaipiboonkul) on October 21, 2010, and written informed consent was obtained from all patients. Patients scheduled to have an elective operation under general anesthesia at Prasat Neurological Institute, Bangkok, during December 1, 2010–April 30, 2011 were recruited into the study. The sample size was calculated using equivalence testing and Bland-Altman analysis (Denmark Technical University. Test set validation and biostatistics, 2008. <http://hjem.get2net.dk.> (accessed 25/11/2008)). From the formula by Horiushi *et al.* [6]: $N = \delta^2 (Z_\alpha + Z_\beta)^2 / (\theta_U - \mu_{bias})^2$ where the standard deviation $(\delta) = 7.25$; upper limit of agreement $(\theta_U) = 12.2$; true bias $(\mu_{bias}) = -2.2$; $Z_\alpha = 1.65$; and $Z_\beta = 1.28$ (plus an expected dropout rate of 10%). The sample size was 34. Inclusion criteria were patients over 1 year of age with no contraindications for placing electrodes over the forehead and mastoid region (such as the boundary area being too close to the surgical site, patients having skin infections, *etc.*) [7]. We excluded cases in which surgery was likely to be completed in less than 30 min, *e.g.* tracheostomy, ventriculoperitoneal shunt adjustment, re-suture, *etc.*

When the patients arrived at the operating theatre, standard monitoring was performed: *i.e.*, blood pressure measurement, electrocardiography, oxygen saturation, end-tidal carbon dioxide tension, end-tidal anesthetic gas tension, and inspired oxygen tension. The invasive arterial blood pressure, central venous pressure, temperature and urine output were considered according to the type of surgery. Monitoring of the depth of anesthesia was performed using an Infinity BISx SmartPod® (Aspect Medical Systems, Newton, MA, USA) and an Infinity® Delta XL monitor (Dräger Medical, Lübeck, Germany). This equipment was in accordance with the standards of the ECRI (Emergency Care Research Institute), JCAHO (Joint Commission on Accreditation of Healthcare Organizations) and AHA (American Hospital Association). Two standard BISx Quatro® Sensors (Aspect Medical Systems) were placed at the forehead and post-auricular area (Fig. 1), as detailed below.

The forehead area. The area was wiped with 70% alcohol and allowed to dry. The first piece of the sensor, consisting of 3 electrodes, was attached to the middle brow, approximately 5 cm above the nose bridge. The other piece (one electrode) was attached 1.5 cm above the eyebrows on the right or left side. The

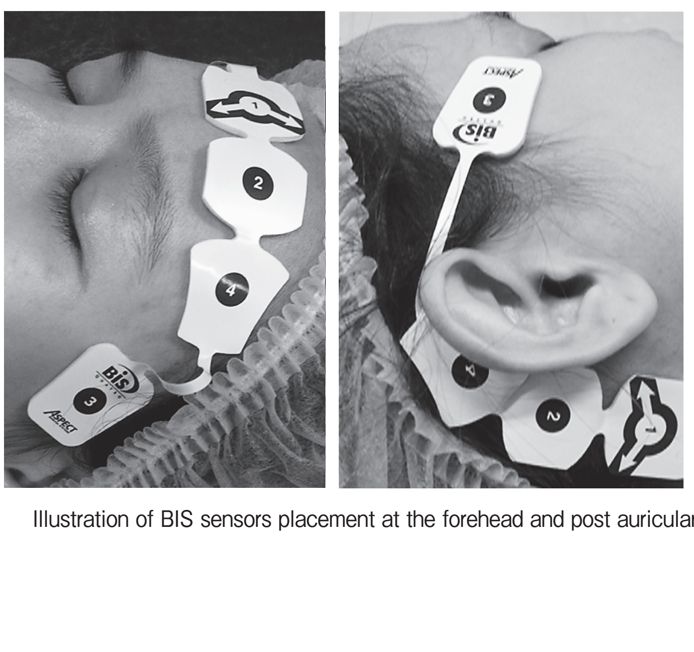

Fig. 1 Illustration of BIS sensors placement at the forehead and post auricular area.

second electrode was attached 2.5 cm immediately next to the first piece, while the third electrode was attached at the temporal area between the lateral canthus and the hairline on the same side.

The post-auricular area. The area was wiped with 70% alcohol and allowed to dry. The first electrode of the sensor was attached approximately 2.5 cm medial to the mastoid area, post-auricularly next to the hairline. The final electrode was attached on the same side between the ear and the hairline at the level of the occipital protuberance. The second electrode was attached at the mastoid area, and the third electrode was attached on the same side at the temporal area between the lateral canthus and the hairline.

Thereafter, the impedance was checked; a number less than 5 kilo-ohms was expected in order to ensure adequate signal quality. When the signal quality index was 100%, the records were collected at various times: after the electrode was initially attached (T_0); before induction of anesthesia (T_1); at loss of eyelash reflex (T_2); before intubation (T_3); during intubation (T_4),; immediately after intubation (T_5); during positioning (T_6); before incision (T_7); at the start of the operation (T_8); every 15 min after incision throughout the surgery (T_9, T_{10}, T_{11}, ...); at the end of surgery (T_{EO}); and at the end of anesthesia (T_{EA}). There was no restriction on the type of anesthetic drug used, which was dependent on individual considerations. However, the titration of anesthetic depth was maintained at BIS values between 40–60.

For demographic data, descriptive statistics were analyzed and reported as means, standard deviations (SDs), numbers and percentages. BIS values were analyzed to compare means with a match-paired *t*-test across each individual time point; results were considered statistically significant when *p*-values < 0.05. Pearson's correlation and Bland-Altman analysis was conducted using MedCalc software for Windows 8.1.0.0 (June 13, 2005) and displayed in a Bland-Altman plot, together with the bias and 95% limit of agreement. The acceptable bias was considered to be in a range of −5 to 5 clinically.

Results

The 34 patients in the study had a mean age of 59.41 ± 10.13 years; most of them were female. The demographic data are shown in Table 1. The patients were put under general anesthesia during the operations; the average anesthetic time was 209.17 ± 49.38 min. The distributions of sensor placement were: 19 (55.9%) on the right forehead, 15 (44. 1%) on the left forehead, 15 (44.1%) on the right post-auricular area, and 19 (55.9%) on the left post-auricular area. Following determination of acceptable signal quality indexes, all 118 BIS values before anesthesia, 374 BIS values during anesthesia, and 68 BIS values after anesthesia were subjected to final analysis. Average BIS values at the different times are shown in Table 2.

In the period before and after anesthesia, the biases, *i.e.*, the mean systematic difference between the measurement ± 2SD of placing BIS sensors at the post-auricular area and frontal areas, were 0 ± 23.32 (before) and 2.1 ± 13.52 (after) while the range including plausible outliers were −23.3 to 23.3 (before) and −17.7 to 13.5 (after), respectively. During the period of anesthesia, the bias ± 2SD between BIS sensor placement at the frontal and post-auricular areas was -1.5 ± 10.69 and the limit of agreement was −12.2 and 9.2, as shown in Fig. 2. The correlation coefficient between frontal and post-auricular areas electrodes was 0.74 at a *p*-value < 0.001.

Discussion

The bispectral index is determined by the weighted parameters of measurements of the brain's electrical activity, *i.e.* the frequency, amplitude, and the sequence of fast Fourier analysis. The model was developed by recording and studying this type of data from more than 1,000 electroencephalograms from normal volunteers (both when awake and when under sedation by hypnotic drugs); the data are then transformed into a linear dimensionless scale known as the BIS value [8].

In the present study, the difference in BIS values obtained from the forehead and post-auricular area was considered acceptable. The average BIS value from the post-auricular area was only 1.5 higher than that of the frontal area, and the limit of agreement for the 2 locations was −12.2 to 9.2. However, the bias ± 2SD and the limit of agreement would be improved if the analysis excluded the BIS values before and after anesthesia (-1.2 ± 8.5 and −9.7 to 7.4, respectively).

Previously, BIS values obtained from different

Table 1 Demographic data

Category	Number	Percent
Sex:		
Male	12	35.3
Female	22	64.7
Diagnosis:		
Cerebral meningioma	10	29.4
Cerebral aneurysm	4	11.8
Pituitary adenoma	4	11.8
Lumbar spondylolithesis	4	11.8
Subdural hematoma	3	8.8
Hydrocephalus	2	5.9
Others, *e.g.*, carotid stenosis, trigeminal neuralgia, skull defect, subdural empyema, *etc.*	7	20.6
Operations:		
Craniotomy with lesion removal (41.2%) while	14	41.2
Trans-endoscopic lesion removal (14.7%) and	5	14.7
Craniotomy with aneurysmal clipping	4	11.8
Others, *e.g.* transpedicular screws, ventriculo-atrial shunt, microvascular decompression, *etc.*	11	32.4
Location of the lesions:		
Frontal area	9	26.5
Temporal area	9	26.5
Pituitary area	4	11.8
Parietal area	3	8.8
Spinal area	6	17.6
Others	3	8.8
Position:		
Supine	18	52.9
Prone	7	20.6
Left lateral decubitus	5	14.7
Right lateral decubitus	4	11.8

Table 2 Mean (SD) bispectral index values from frontal and post-auricular area sensors

	Frontal area	Post-auricular area	*p*-value
Before anesthesia ($T_{0\text{-}1}$)	88.56 (10.57)	88.56 (8.59)	1.00
During anesthesia ($T_{2\text{-}EO}$)	51.05 (12.73)	52.52 (12.94)	$<$0.001
After anesthesia (T_{EA})	87.90 (8.28)	89.97 (6.46)	0.17

T_0, time of initial monitoring in the operating theater; T_1, time before induction of anesthesia; T_2, time at loss of eyelash reflex; T_{EO}, time at end of operation; T_{EA}, time at end of anesthesia.

sensor placement areas were studied and found comparable. For example, the study of Horiuchi *et al.* demonstrated that the bias ± 2SD for BIS sensor placement at the right lateral canthus rather than the standard forehead placement was -2.2 ± 14.5, while the limit of agreement was -16.7 to 22.2 [7]. Nelson *et al.* showed a statistically significant difference for BIS scores of 2 greater between the standard BIS placement and the nasal dorsum [9]. One case study of a burn patient who was scheduled for a skin graft reported that the bias of the BIS value between the frontal and occipital areas was 1, with a limit of agreement range of -7 to 9, without any difference in impedance [10]. Another diagnostic study reported a correlation between frontal and occipital placements of $r^2 = 0.96$ at a *p*-value of 0.03, but it did not use a Bland-Altman plot [11]. Apart from this, another case report showed good depth-of-anesthesia monitoring resulting from spectral entropy during a craniotomy with aneurysm clipping when the sensors were

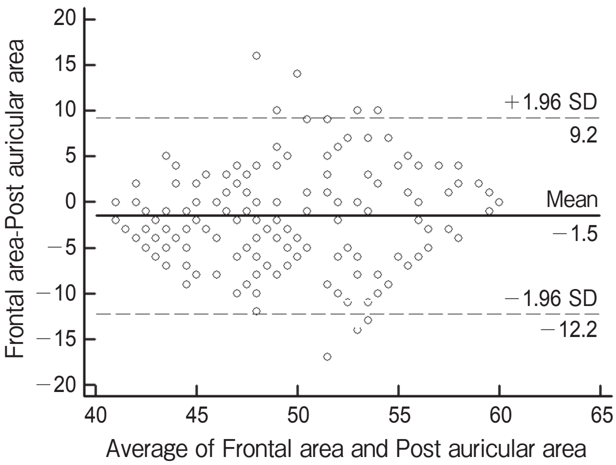

Fig. 2 Bland-Altman plot for bispectral index values from frontal and post-auricular area sensors during anesthesia.

placed at the occipital area [12].

On the other hand, one study demonstrated significant differences between BIS values from the frontal and occipital placements of BIS-Vista™ sensors before induction and at anesthesia maintenance. The specific types of sensor electrode and the independent oscillators in the occipital regions which generated the spontaneous alpha rhythms are explained in that study [13].

BIS readings may differ from case to case, depending on the distance between each electrode from which the electroencephalogram amplitude is determined [14]. Moreover, surgical cautery and other electrical monitoring may interfere with the signal quality index. The placement, positioning, grounding and interpretation of the electrode should be performed clearly and carefully.

In conclusion, the placement of the BIS sensor at the post-auricular area is an alternative method of monitoring depth of anesthesia. This finding will eliminate the previous limitation for anesthetic depth monitoring during specific procedures, such as frontal craniotomy. Placement in accordance with either the manufacturer's instructions or the descriptions of this study is of primary concern as readings will depend on specific clinical circumstances.

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