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Beyond Frontal Leads: Unveiling Optimal Electrode Placements for BIS Monitoring in Neurosurgical Cases

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Introduction

Background: At the core of general anesthesia lies the critical objective of ensuring patient comfort while preventing awareness, not only to alleviate psychological distress but also to shield the anesthesiologist from potential legal repercussions(1). The consequence of inadequate sedation is the potential postoperative recollection of pain and sounds, underscoring the indispensable role of the Bispectral Index (BIS) in monitoring sedation depth through EEG signals, translated into an objective numerical value.(2) Maintaining BIS values within the 40 to 60 range is imperative to guarantee optimal anesthesia, mitigate awareness, and diminish the likelihood of patient distress and legal entanglements for the anesthesiologist(3,4). This significance is particularly accentuated in the intricate landscape of extensive neurosurgical brain and spine procedures.

Rationale For Study

Brain surgeries necessitating incisions such as bi-coronal, frontal, fronto-temporal, pterional, parietal, etc., face limitations on electrode placement imposed by the surgical team to prevent interference with the sterile environment or surgical site. This restriction has led to the

formulation of the concept of alternate electrode placement.[5] This concept is grounded in the understanding that EEG activity exhibits non-uniform patterns across the scalp. Research has demonstrated the topographical dependency of BIS, suggesting that electromagnetic waves likely propagate from the frontal region to other facial areas. As a result, EEG, and consequently BIS values, are generated from various locations.[6] The various sites explored are nasal (Infraorbital), supralabial, postauricular (retroauricular) , Mandibular , Occipital [7], [8]

Research Aim & Objectives

This pilot study is designed to evaluate and compare the reliability of Bispectral Index (BIS) readings obtained from alternative electrode placements in neurosurgical patients. With a specific emphasis on nasal (infraorbital) and postauricular (retro auricular) lead positions, we aimed to discern their efficacy compared to the well-established gold standard of frontal lead placement. Through thorough scrutiny of the reliability of BIS measurements across these alternative placements, the study aspires to provide nuanced insights, guiding the optimization of electrode positioning strategies during neurosurgical procedures. The overarching objective is to enhance the precision of BIS monitoring, contributing to elevated standards of patient care, mitigated awareness under anesthesia, and improved outcomes within the realm of neurosurgery.

Literature Review

History

In 1996, the FDA approved BIS to aid in monitoring anesthetic effects. In 2003, the FDA further approved its use to reduce awareness and recall during General anesthesia.

BIS, though not a standard ASA mandatory monitor, a closed claim project by ASA, revealed that 2% of all claims on anaesthesiologists were for awareness during operation.[9]

By definition, the Bispectral index or BIS is a processed electroencephalogram (EEG) computed from the brain's frontal lobe to monitor the sedative effects of anesthetics and, thus, the depth of anesthesia. It is derived using EEG composite measures from EEG signal processing techniques. It is a proprietary algorithm, a number from 0 to 100 calculated from the EEG. 100 is the regular cortical activity, and 0 is cortical electrical silence. With the range of 40 to 60 being the surgical plane, it suffices to say that if BIS is less than 60, the postoperative recall and awareness are very low. This algorithm is used to optimize the correlation between EEG and the clinical effects of anesthesia and is quantified using the BIS index range. The Signal Quality Index (SQI) is the percentage quality of the EEG signal, with 100% representing perfect signal quality and 0% poor signal quality. It should be 90 to 100 for maximum reliability of BIS value.[10], [11]

These were studies from gold standard frontotemporal cortex placement of BIS electrodes (BIS TM Quantro Sensor, Aspect Medical Systems Newton, MA, USA) [12], [13]

Table 1: The co-relation of EEG from the frontal cortex, the BIS scores, and the clinical depth was demonstrated well by Lawrence Litt. [10]

EEG waves & frequency	BIS	Depth of Anaesthesia
β (Beta) waves 15 to 30 Hz/high frequency, low amplitude	90	Awake state
α (Alpha) waves 9 to 12 Hz/medium frequency, higher amplitude EEG seen in occipital lobes	70	Awake, but eyes closed
θ (Theta) waves 4 to 8 hz/low frequency	40 to 60	General anesthesia, surgical plane
δ (Delta) waves 0 to 4 hz/Very low frequency or isoelectric waves	< 30	Depressed functions of the brain, deep plane of anesthesia, coma, hypoxia, ischemia, infarction, poor metabolism.

Indications of BIS:

- To facilitate intraoperative neuromonitoring using TIVA while avoiding the use of neuromuscular blockers and inhalational agents.
- Monitoring depth of anesthesia to maintain Guedel's Stage 3, Plane 3 of anesthesia intraoperatively.
- Avoid awareness or recall during anesthesia.
- Aid early emergence from General anesthesia.
- To see the effect of 'burst suppression' produced by anesthetic drugs for brain protection during aneurysm clipping surgeries.
- Epilepsy surgeries - A sudden increase in BIS values may suggest the generation of a seizure.

Lee et al. (14) reported a strong correlation between frontal and mandibular sensor placements; however, they advised further study for the same as no EEG is generated under the mandible and thus detected EEG or BIS is likely conducted from other parts of the cerebral cortex to the mandibular region thereby generating a BIS score.

Dahaba et al.[15] Compared standard frontal with occipital placement and reported significant differences in BIS values of Frontal and Occipital placement before induction and at the maintenance of anesthesia.

Sinha PK et al.[16] reported a case study of good depth of anesthesia for aneurysm clipping with spectral entropy with sensors placed at the occipital area.

Shiraishi et al.[19] compared frontal and occipital placements, though their results had weak correlations, especially during emergence.

Konul Hajiyeva et al.[7] In their study pointed out that there is a significant correlation in BIS values between nasal and frontal placements at all time points, concluding that nasal dorsum is a good and safe alternative when sensor position might

interfere with the surgical site in neurosurgical operations.

Nelson et al.[8] revealed in their study, which compared nasal and frontal BIS monitoring in frontal craniotomies, that nasal dorsum sensor placement shows comparable efficiency to standard frontal measurements.

Akavipal et al.[5] compared frontal placement with postauricular placement. This study in Thailand found that the correlation coefficient between frontal and post-auricular electrodes was 0.74 with a p-value of <0.001. and thus highly recommend this as a practical alternative in NS patients based on acceptable co-relation coefficient and limit of agreement.

Jitendra K. Dubey et al.[18] conducted a study on BIS monitoring, focusing on the supralabial site. Their findings indicate that the agreement limits of BIS, SQI, and EMG between the frontal and supralabial sites were comparable at different time points, aligning with the frontal gold standard. They agreed with Lee et al.'s assertion that, despite the absence of EEG sources in the supralabial region, the conduction of electromagnetic wave potential from the frontal region to adjacent parts explains the generation of BIS values in non-frontal sites. The study also highlighted the occurrence of electromagnetic interference during the use of electrocautery and drills, leading to a reduction in the Signal Quality Index (SQI) and subsequently impacting the accuracy of BIS scores.

Maintaining BIS scores between 40 and 60 is safe with adequate depth of anesthesia and avoids awareness in all subjects.[19]

Methodology

Study Design

This study was a prospective, observational, single-institute pilot study done to compare BIS alternative lead placements of Nasal and Postauricular against the gold standard Frontal placement. The subjects selected for nasal or postauricular study were not case-specific.

Sample Selection

Inclusion Criteria

- ASA I-III
- Age 20 to 75 years
- Elective craniotomy for SOL removal lasting for a duration of 3 to 4 hours
- Bicoronal incision, frontal, temporal, frontotemporal, parietal, and pteryonal craniotomy
- Intramedullary SOL of the cervical or dorsal spine in prone position involving intraoperative neuromonitoring.

Exclusion Criteria

- Neurointerventional cases
- Skin infection on site, especially on the forehead
- Patients on antipsychotic medications

Description of Electrode Placement Protocols

Two standard BIS TM Quatro Sensors from Aspect Medical System in Newton, MA, USA, were used.

Figure 1 BIS TM Quatro Sensors

Follow these placement positions for the Standard Frontal Placement, per the clear instructions on the Sensor electrode strip. Wipe and dry the skin, apply the electrodes diagonally on the forehead, press firmly for five seconds, secure with a waterproof dressing, and connect to the patient interface cable.

Figure 2 Frontal Lead Placement

Frontal lead placement

1. Sensor 1: Center of the forehead, approximately 2 inches above the bridge of the nose.
2. Sensor 2: Follows Sensor 1 placement.
3. Sensor 3: On the temple, between the corner of the eye and the hairline.
4. Sensor 4: Directly above the eyebrow.

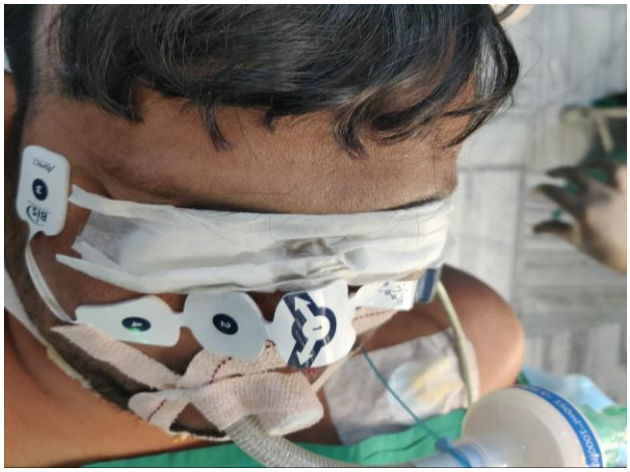


Figure 3 Alternative lead placement: Nasal/Infraorbital

Nasal/Infraorbital lead placement:

- Lead 1: Nasal dorsum
- Lead 2: Naso-facial angle
- Lead 3: Ipsilateral temporal area
- Lead 4: Zygomatic bone

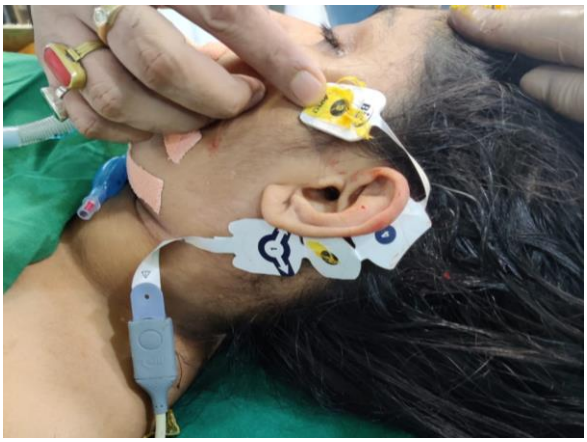


Figure 4 Alternative lead placement: Postauricular

Post-Auricular

- Lead 1: 2.5 cm medial to the mastoid area behind the ear, near the hairline.
- Lead 2: Mastoid area
- Lead 3: Ipsilateral temporal area between lateral canthus and hairline
- Lead 4: Occipital protuberance between ear and hairline

Data Collection Procedures

After the surgeon completed positioning, clamping, and navigation, two BIS Quatro Sensors were affixed to the patient. Two separate monitors were used for two sites:

1. Standard Frontal sensor with Nasal (infraorbital)
2. Standard Frontal sensor with Postauricular site.

In eight patients, BIS Quatro sensors were placed simultaneously on the forehead(frontal) and across the nasal bridge (Nasal/Infraorbital), each connected to separate monitor screens. Waterproof dressing was applied over the electrodes to minimize signal loss.

Frontal and post-auricular electrodes were simultaneously secured for comparison for another eight patients. BIS values from both sites were compared only during the maintenance phase, recorded every 15 minutes after intubation until just before extubation.

BIS readings were documented when the Signal Quality Index (SQI) was 90 or higher. Extubation

was performed at a Frontal BIS value of 90 or higher.

The adopted general anesthesia technique was consistent across all cases, allowing flexibility in the choice of drugs. However, maintenance was carefully adjusted for safety, targeting gold standard Frontal BIS scores ranging from 40 to 60.

Premedication:

- Fentanyl: 1 mcg/kg
- Midazolam: 0.05 mg/kg
- Glycopyrrolate: 0.2 mg

Induction:

- Propofol: 1 mg/kg
- Atracurium: 0.08 mg/kg
- IPPV (Intermittent Positive Pressure Ventilation)

Standard Endotracheal Intubation:

A flexometallic tube was preferred.

Maintenance:

- Air: Oxygen: Desflurane (MAC 0.5 to 0.6)
- Infusion 1: Propofol at 0.3 to 0.6 mg/kg/hour
- Infusion 2: Atracurium at 0.3 to 0.6 mg/kg/hour

In cases with intraoperative Neuromonitoring, muscle relaxants were omitted, and an infusion protocol was followed:

- Propofol at standard doses
- Fentanyl at 0.5 to 1 mcg/kg
- Midazolam at 0.05 to 0.4 mg/kg
- Dexmedetomidine infusion at 0.05 to 1 mcg/kg/hour.

Reversal:

- Atropine: 0.05 mg/kg
- Neostigmine: 0.05 mg/kg

Reversal drugs were administered when the Frontal BIS reached 90 or higher.

Patients were queried for awareness, assessing recall of the procedure in the Post-Anesthesia Care Unit (PACU).

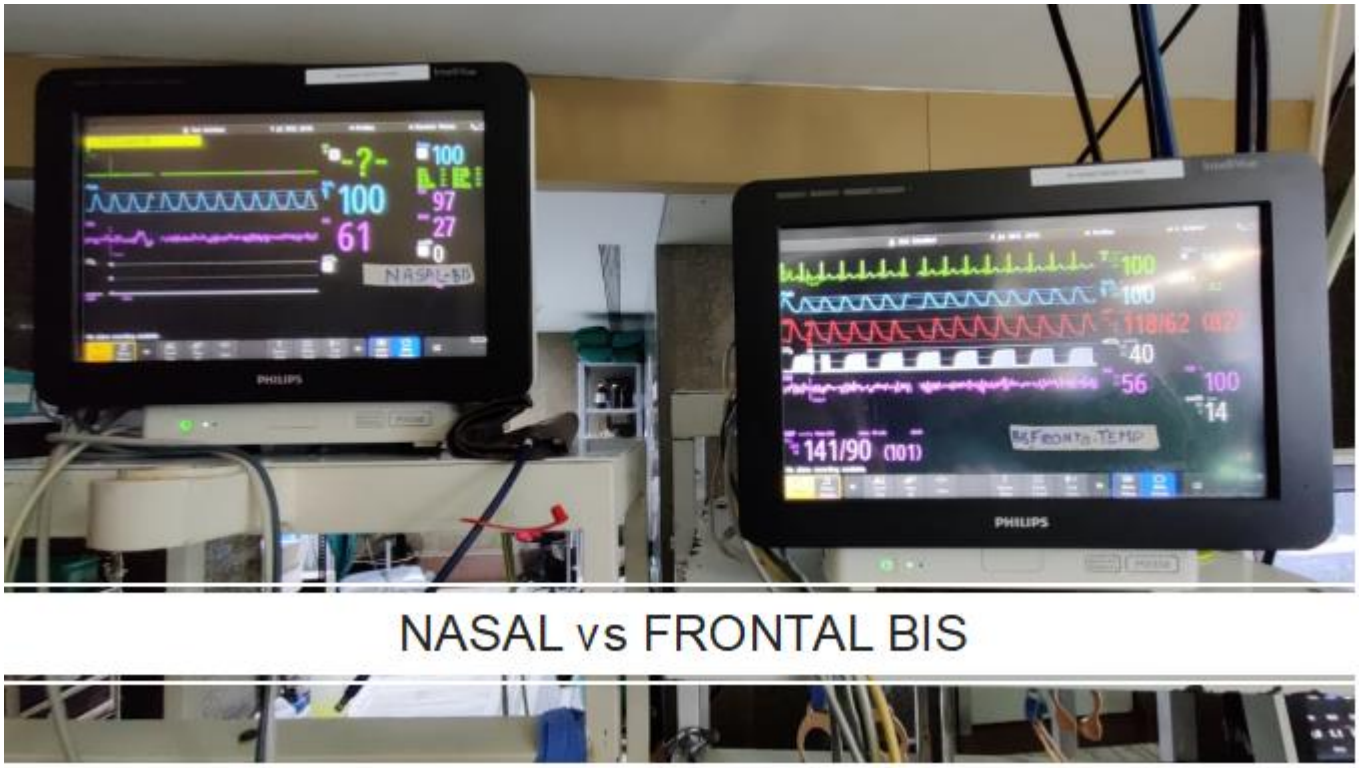


Figure 5: Monitor readings of Nasal vs Frontal BIS, taken simultaneously from the same patient at the same time.

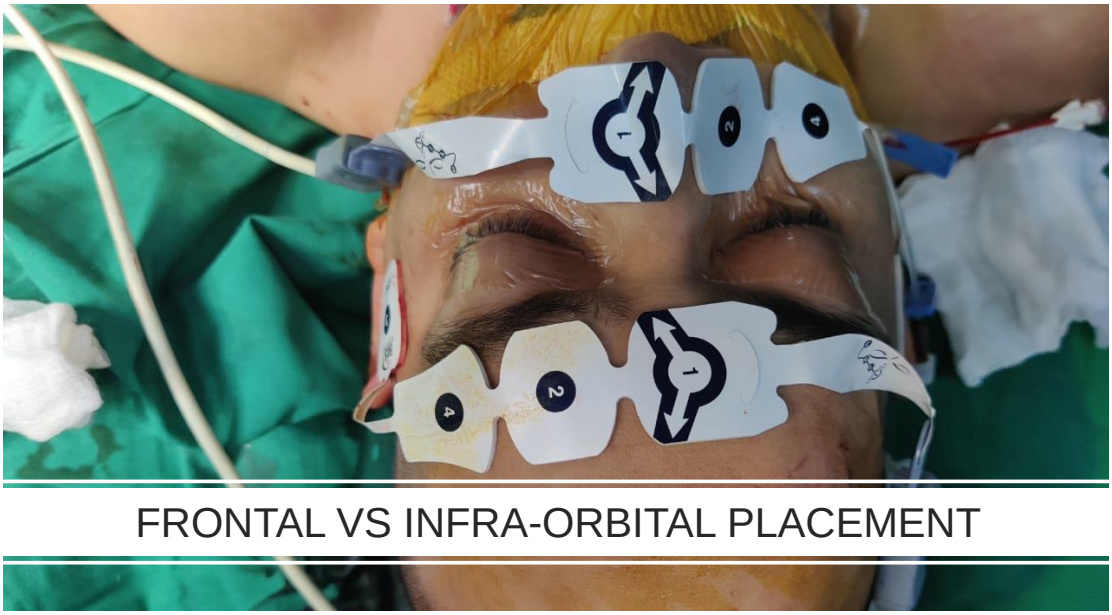


Figure 6 Depicts the placement of frontal and infraorbital/nasal leads simultaneously in one patient.

Observation & Results

Demographic Data

Total number of cases n=16

Age: 23 years to 76 years

Table 2 Demographic data

SECTION	Total cases n=16	Percentage
1. GENDER:		
Male	n=8	50%
Female	n=8	50%
2. ASA Grade:		
I II III	n=1 n=10 n= 5	6.25 % 62.5 % 31.25 %
3. OPERATIONS:		
Spinal Intramedullary SOL	n = 5	31.25%
Craniotomy for SOL excision	n = 11	68.75 %
4. Location of the lesion/incision	BIS F – N BIS F - PA	F – N F – PA 56.25 % 43.75 %
a. Bicoronal flap	n = 3 n =3	37.5 %
b. Temporal	n =1 n =1	12.5 %
c. Pteryonal	n=1 n = 0	6.25%
d. Fronto-Temporal-Parietal (F-T-P)	n =1 n =1	12.5 %
e. Spinal	n = 3 n = 2	
5. AWARENESS	n = 0 n = 0	0%
6. POSITION		
a. Supine	n = 6	37.5 %
b. Prone	n = 5	31.25%
c. Lateral/Head turn	n = 5	31.25%

Key:

BIS F-N: comparison of frontal vs nasal Bispectral index

BIS F-PA: comparison of frontal vs postauricular bisectoral index

SOL: Space occupying lesion

Statistical Analysis

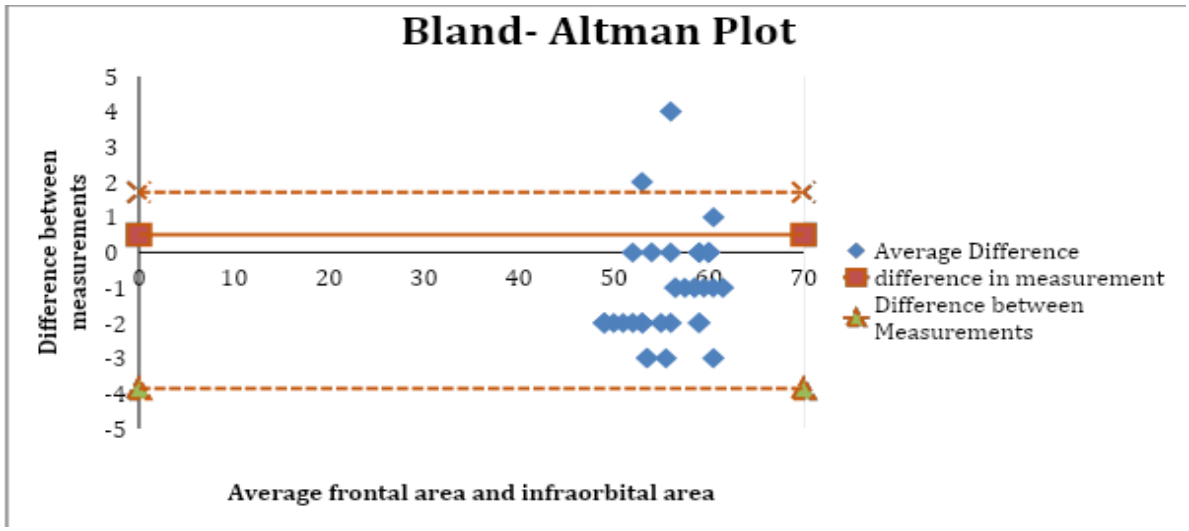
- **Frontal vs. Infraorbital/Nasal**

Table 3 Statistical Analysis Frontal vs. Infraorbital; S = SIGNIFICANT; NS -= NOT SIGNIFICANT. T-test was used to compare the mean values of the two groups.

	FRONTAL	INFRAORBITAL	SIGNIFICANCE
T1	60.2 ± 0.84	61 ± 1	P=0.29 NS
T2	58.2 ± 1.48	59.2 ± 1.30	P=0.034 S
T3	54.4 ± 2.88	56.6 ± 1.67	P=0.019554 S
T4	54.6 ± 3.97	54 ± 3.16	P=0.61 NS
T5	51.2 ± 3.35	53 ± 3	P=0.00084 S
T6	51 ± 2.83	52.6 ± 2.41	P=0.016 S
T7	53.2 ± 3.27	54.4 ± 2.7	P=0.071 NS
T8	59 ± 1	59.6 ± 0.55	P=0.21 NS

Table 3 provides a detailed comparison of BIS values between the Frontal and Infraorbital sites, employing T-tests for statistical analysis denoted as “S” for significance and “NS” for no significance. The mean BIS values are reported at 15-minute intervals from T1 to T8, representing the period from intubation to extubation. Notably, at T1, there was no significant difference (p=0.29) between Frontal (60.2 ± 0.84) and Infraorbital (61 ± 1) BIS values. However, at T2 and T3, Frontal BIS values were significantly lower than Infraorbital (p=0.034 and p=0.019554, respectively). Conversely, T4, T7, and T8 showed no significant differences between the sites, while T5 and T6 revealed statistically significant differences.

These results illuminate the temporal dynamics of BIS readings at different anatomical locations during the monitoring period.



Mean = -1.075

The limit of agreement: ±1.96SD = (1.71 to -3.86)

The correlation coefficient between the frontal and infraorbital area was 0.94.

- **Frontal vs. Postauricular**

Table 4: S = SIGNIFICANT; NS -= NOT SIGNIFICANT. T-test was used to compare the mean values of the two groups.

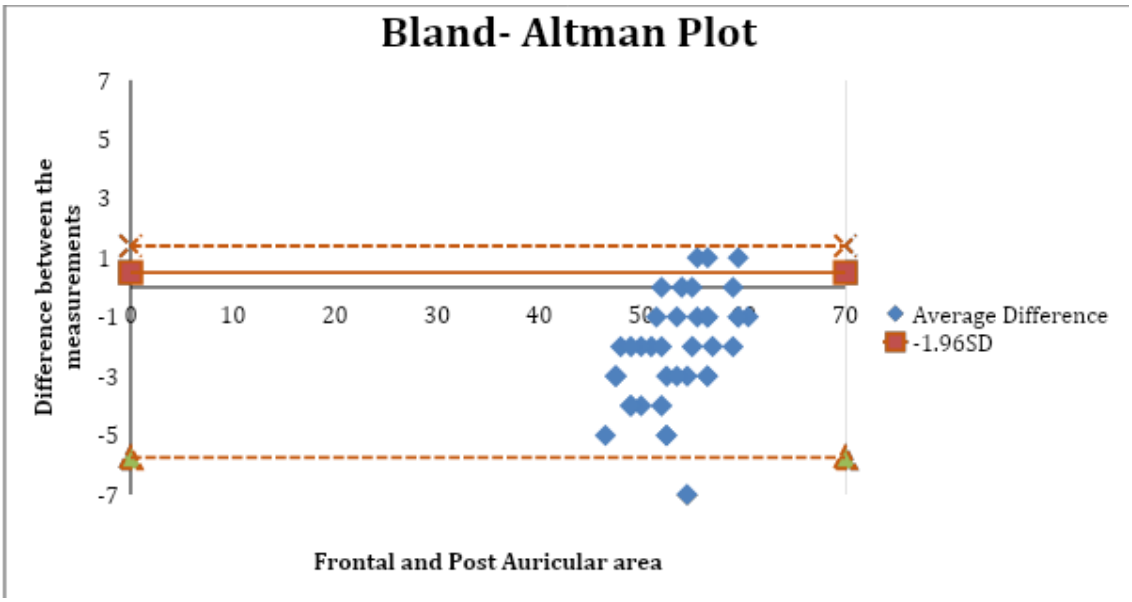
	FRONTAL	POSTAURICULAR	SIGNIFICANCE
T1	55.6 ± 2.96	56.8 ± 1.64	P=0.467 NS
T2	55.6 ± 3.64	56.6 ± 3.84	P=0.14 NS
T3	55 ± 2.55	56.8 ± 2.387	P= 0.037 S
T4	50.6 ± 3.91	53.4 ± 3.51	P=0.018 S
T5	47.2 ± 2.68	50.6 ± 2.3	P=0.002629 S
T6	48.2 ± 1.92	51 ± 1.22	P=0.0086 S
T7	49.6 ± 2.07	52.8 ± 2.28	P=0.0054 S
T8	56.8 ± 2.58	58 ± 1.58	P=0.14 NS

Table 4 presents a comparative analysis of BIS values between the Frontal and Postauricular sites, indicating statistical significance as "S" and no significance as "NS." The mean BIS values at different time intervals (T1 to T8) are recorded, representing the time from intubation to extubation.

At T1, no significant difference (p=0.467) was observed between Frontal (55.6 ± 2.96) and Postauricular (56.8 ± 1.64) BIS values. T2 and T8 similarly showed no significant differences

(p=0.14). However, at T3, T4, T5, T6, and T7, Frontal BIS values were significantly different from Postauricular values (p=0.037, p=0.018, p=0.002629, p=0.0086, and p=0.0054, respectively). These results illuminate variations in BIS readings over time, underscoring specific time points where Frontal and Postauricular sites exhibit significant differences and others where they do not. Our pilot study found BIS values from frontal leads correlating strongly with Infraorbital and Post-auricular BIS readings, meaning they are possible

alternatives to the standard placement, especially when the forehead is not available for us to place the sensors.



Mean = -2.175

The limit of agreement: ±1.96SD =(1.4 to -5.75)

The correlation coefficient between frontal and postauricular area was 0.92.

However, further studies with larger sample sizes are essential to establish a statistically significant correlation between the two test groups, Frontal –Nasal and Frontal –Postauricular. BIS scores of 40-60 are the acceptable range to ensure adequate anesthesia depth.

Proper placement of electrodes is essential for a good signal quality of 100%

None of our patients had perioperative Recall /Awareness.

Discussion

A. Interpretation of Results:

Our pilot study provides valuable insights into the reliability of Bispectral Index (BIS) readings from alternative electrode placements in neurosurgical patients. The high correlation coefficients (0.94 for frontal vs. infraorbital/nasal and 0.92 for frontal vs. postauricular) and narrow limits of agreement affirm the viability of these alternative sites, showcasing their potential as reliable alternatives to the gold standard frontal placement. These results align with previous studies

emphasizing the topographical dependency of BIS values and the need for alternate electrode placements to optimize clinical application (6,7).

The mean differences, such as -1.075 for frontal vs. infraorbital/nasal and -2.175 for frontal vs. postauricular, along with the correlation coefficients, indicate comparable efficacy among these placements. The limits of agreement further underscore the clinical feasibility of these alternative sites, reinforcing their potential applicability in neurosurgical settings.

B. Implications for Neurosurgical Practices

BIS monitoring is essential in neurosurgical brain or spine cases, especially those involving odd patient positions and skull clamps. Our study suggests that relying on nasal (infraorbital) and postauricular electrode placements offers reliable alternatives, enabling accurate detection of the light plane of anesthesia crucial for preventing jerky movements that could have catastrophic consequences for neurological outcomes. Applying BIS as an additional monitor, mainly when intraoperative neuromonitoring is employed, is advisable to avoid awareness and recall events in lighter anesthesia planes (5).

Additionally, the study highlights the importance of proper electrode placement, position, and grounding to ensure accurate BIS interpretation. The dependence of BIS accuracy on the distance between electrodes and the potential interference of electrical cautery or drills with the Signal Quality Index emphasizes the need for meticulous attention to these factors in neurosurgical practices (20).

C. Limitations of the Study:

While our pilot study provides valuable insights, it is essential to acknowledge its limitations. First, the exclusion of BIS scores during induction, opting to apply electrodes after clamp and navigation, may introduce variations in the results. This decision was made to avoid interference with navigation points; however, it does narrow the scope of our analysis. Second, the study does not explicitly address the potential impact of electrocautery on the Signal Quality Index, representing a notable gap in understanding potential sources of interference. Additionally, the absence of a dedicated exploration of awareness scoring is a limitation, as it could have offered a more comprehensive understanding of the patients' experience. Lastly, the sample size in our pilot study is relatively modest, necessitating cautious interpretation and emphasizing the need for larger-scale studies to establish statistical significance and generalizability.

D. Recommendations for Future Research:

Building upon the insights gained from our pilot study, future research in neurosurgical practices should consider expanding sample sizes to enhance statistical robustness. Investigating BIS scores during induction and the impact of electrocautery on Signal Quality Index would offer a more comprehensive understanding of the factors influencing BIS accuracy. Separately

studying awareness scoring would provide additional valuable information for clinical practice. Additionally, exploring alternative electrode placements in a broader range of neurosurgical procedures and patient positions would contribute to refining BIS monitoring strategies and improving patient outcomes.

Conclusion

A. Summary of Findings

The study establishes the reliability of alternative BIS electrode placements, notably nasal (infraorbital) and postauricular, in neurosurgical patients. High correlation coefficients (0.94 and 0.92) and narrow limits of agreement indicate their comparable efficacy, offering practical alternatives to the gold standard frontal placement.

B. Clinical Implications

In neurosurgical practices, the study highlights the crucial role of accurate BIS monitoring in preventing adverse events. Nasal (infraorbital) and postauricular placements emerge as viable alternatives, ensuring precise detection of the light plane of anesthesia, crucial for averting catastrophic consequences in complex surgical scenarios. Additionally, the study underscores the importance of meticulous electrode placement, addressing challenges posed by electrical cautery and drills.

C. Overall Contribution to the Field:

The study significantly contributes to refining neurosurgical practices by expanding electrode positioning strategies. The evidence supporting alternative placements enhances BIS monitoring methodologies, addressing challenges in restricted electrode placement. While acknowledging limitations, the study sets the stage for future research, urging continual exploration and larger-scale studies to strengthen evidence in neurosurgical BIS monitoring.

Acknowledgement

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