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Original Article

Does Endotracheal Suctioning Affect Bispectral Index and Ramsay Sedation Scores in Pediatric Intensive Care Patients?

Çocuk Yoğun Bakım Hastalarında Endotrakeal Aspirasyon Bispektral İndeks ve Ramsey Sedasyon Skorlarını Etkiler mi?

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ABSTRACT

Objective: A particular electroencephalography parameter known as the bispectral index (BIS) is one of the objective methods used to assess sedative and hypnotic effects. The aim of this study is to monitor the level of consciousness of patients who underwent sedation-analgesia in pediatric intensive care unit (PICU) and to evaluate how their sedation levels were affected by painful procedures by examining BIS and Ramsey Sedation Scale (RSS).

Method: This prospective observational study was held 43 pediatric patients who were hospitalized in the 24-bed university-affiliated tertiary PICU. BIS, RSS and vital signs were recorded both before and after the endotracheal suctioning procedure. Patients were divided into two groups according to the chosen analgesic which was fentanyl or morphine. Percentage change (BIS, electromyography activity, signal quality index, RSS score, heart rate, oxygen saturation) of before/after endotracheal suctioning was calculated.

Results: The increase in BIS value, increase heart rates and decrease RSS of patients with endotracheal suctioning were found to be significant ($p<0.01$, $p=0.01$, $p<0.001$ respectively). Percentage changes were compared between two groups and there was no significant difference between morphine and fentanyl group.

Conclusion: Even in patients receiving strong analgesic agents like opioids, any painful procedures such as endotracheal suctioning increase the BIS values of the patients and disrupt their comfort. Continuous BIS value tracing may be more beneficial than clinical scoring systems on sedation monitoring and patient comfort. We also suggest further studies with different groups of analgesic agents should be conducted.

Keywords: Analgesia, pain, pediatrics, critical care, conscious sedation, bispectral index

ÖZ

Amaç: Bispektral indeks (BİS) olarak bilinen belirli bir elektroensefalografi parametresi, sedatif ve hipnotik etkileri değerlendirmek için kullanılan objektif yöntemlerden biridir. Bu çalışmanın amacı, çocuk yoğun bakım ünitesinde sedasyon-analjezi uygulanan hastaların bilinç düzeylerinin izlenmesi ve ağrılı işlemlerden sedasyon düzeylerinin nasıl etkilendiğinin, BİS ve Ramsey Sedasyon Skalası (RSS) ile değerlendirilmesidir.

Yöntem: Bu prospektif gözlemsel çalışma, 24 yataklı üniversiteye bağlı üçüncü basamak pediatrik yoğun bakım ünitesinde yatan 43 çocuk hasta üzerinde yapıldı. Endotrakeal aspirasyon prosedüründen önce ve sonra BİS, RSS ve vital bulgular kaydedildi. Hastalar seçilen analjeziklere göre fentanil veya morfin olmak üzere iki gruba ayrıldı. Endotrakeal aspirasyon öncesi/sonrası yüzde değişimi (BİS, elektromiyografi aktivitesi, sinyal kalite indeksi, RSS skoru, kalp hızı, oksijen satürasyonu) hesaplandı.

Bulgular: Endotrakeal aspirasyon yapılan hastaların BİS değerindeki artış, kalp atım hızındaki artış ve RSS'deki düşüş anlamlı bulundu (sırasıyla $p<0,01$, $p=0,01$, $p<0,001$). BİS ve RSS'deki yüzde değişimler ise iki grup (morfin ve fentanil grupları) arasında karşılaştırıldığında anlamlı fark bulunmadı.

Sonuç: Opioidler gibi güçlü analjezik ajanlar alan hastalarda bile endotrakeal aspirasyon gibi ağrılı işlemler hastaların BİS değerlerini yükseltmekte ve konforlarını bozmaktadır. Sürekli BİS değer takibi, sedasyon izleme ve hasta konforu konusunda klinik puanlama sistemlerinden daha faydalı olabilir. Ayrıca farklı analjezik ajan gruplarıyla daha ileri çalışmaların yapılmasını öneriyoruz.

Anahtar kelimeler: Analjezi, ağrı, pediatri, yoğun bakım, bilinçli sedasyon, bispektral indeks

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INTRODUCTION

In intensive care, sedation and analgesia are very important for the effectiveness and success of treatment. Even just being in the intensive care unit (ICU) can cause anxiety and stress in patients. In patients receiving invasive and non-invasive respiratory support, this anxiety and stress lead to an increase in the oxygen consumption of the myocardium as well as patient-ventilator asynchrony, and the barotrauma in the lungs. Effective sedation and analgesia may shorten and facilitate the treatment of critically ill patients. A comfortable ICU stay with easy awakening should be defined as a goal in intensive care patients[1].

Since subjective scoring systems used to monitor patients' sedation levels may vary depending on the individual, objective evaluations provide us with a more realistic level of sedation. One of the objective methods, bispectral index (BIS), is a special electroencephalography (EEG) parameter used to quantify sedative and hypnotic effects. The BIS is an analysis method that examines the correlations between sinus wave components and it specifically shows the quantitative level of synchronization in the bispectral EEG[1]. BIS monitor detects EEG signals with the electrodes applied to the forehead and temporal region and it provides information on the signal quality index (SQI), suppression ratio, electromyography activity (EMG) and the raw EEG waveform. BIS values are updated to reflect the correct value from 0 (deep sedation) to 100 (awake)[2]. The SQI gives information about the adequacy of the EEG signal. A higher value of SQI indicates better signal. When the SQI is above 50%, this indicates sufficient EEG transmission, however, in most studies, it is aimed to have an SQI which is over 80%. Electromyographic power shows the EMG effect on BIS elevations. For example, being above 50 decibels may cause serious interactions with BIS[3]. Ramsay sedation scale is the most widely used sedation scale in critically ill children. It allows us to visually assess the state of consciousness of patients in 6 categories, from full sleep to agitated awake (Table 1)[4]. The aim of this study is to demonstrate how painful procedures altered the BIS values and Ramsey Sedation Scale (RSS) scores of pediatric ICU patients.

Table 1. Ramsay sedation scale

Clinical score	Level of activity
1	Awake; agitated or restless, or both
2	Awake; cooperative, oriented and tranquil
3	Awake; only responds to verbal commands
4	Asleep; brisk response to a light glabellar tap or loud auditory stimulus
5	Asleep; sluggish response to a light glabellar tap or loud auditory stimulus
6	Asleep; no response to a light glabellar tap or loud auditory stimulus

MATERIALS and METHODS

This was a prospective observational study conducted in the pediatric patient population, ages 1 month to 18 years, who were hospitalized in the pediatric ICU of University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital from August 2017 to August 2018. The study was approved by the University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital Ethics Committee (protocol no: 2017/157, date: 06.07.2017) and written informed consent was obtained from the parents of all participating subjects. The sample size was calculated to be 43 patients with a 0.76 effect size, 95% power, and 5% type-1 error using the G*Power program (version 3.0). The study included 43 patients who required mechanical ventilation and were under sedation-analgesia. Patients with epilepsy, neurodegenerative diseases with acute or chronic seizure activity, muscular diseases, postoperative patients, patients who received neuromuscular blockage, patients who required more than two additional sedative bolus doses after suctioning during a 6-hour period, and patients who had more than one suctioning per hour due to excessive secretions were excluded from the study.

Sedation level was evaluated by both RSS score, and BIS monitoring. Pediatric 4-sensor probe (Covidien IIC, Mansfield, USA) compatible monitor (Philips Medizin Systeme, Boeblingen, Germany) was used. The probes were placed one by one after the patient's skin was cleaned with 70% alcohol. The

first probe was placed 1 cm above the nasal root, the second probe right next to the first probe, the fourth probe was placed parallel to the eyebrow and the third probe was placed between the lateral part of the eye and the hairline.

Either midazolam-fentanyl or midazolam-morphine standardized infusions were given to 43 mechanically ventilated patients who needed sedation. Initially, both groups of patients received an intravenous infusion of midazolam at a dose of 0.1 mg/kg/hour after an intravenous bolus of 0.1 mg/kg midazolam. In some of the patients, IV Fentanyl infusion (1 mcg/kg/hour) was added to continuous IV midazolam infusion whereas in some of the patient's IV Morphine infusion (0.025 mg/kg/hour) was added. Preference for fentanyl or morphine was based on the clinical decision of the physician. Ramsay score, and infusion rates were adjusted to obtain a Ramsay score above 4 and a BIS level at 70 before the beginning of the protocol. We chose this value because BIS values of 40-70 have been suggested for adequate sedation[5].

Pediatric BIS probes were attached to the patients according to the previously described technique. One hour after the onset of infusion; EMG, BIS, SQI values, RSS score and vital measurements of the patient were recorded as the baseline value. The same values were recorded during the follow-up of the patients, immediately before and after the suctioning. Endotracheal suctioning was performed by the same physician after 30 seconds of preoxygenation with a suction catheter of appropriate caliber in the accompaniment of another healthcare provider. While the BIS values were noted by the physician, the RSS was noted for all patients by the other physician who was censored for the BIS values in order to avoid bias. In addition, the nurse who applied the scale together with the service senior nurse was also present for each patient as an observer.

Patients were divided into two groups according to the chosen analgesic which was fentanyl and morphine. Percentage change of BIS, EMG, SQI, RSSs, HR, oxygen saturation (SpO_2) values between before and after endotracheal suctioning was calculated [(after suctioning-before suctioning/before suctioning)*100].

The Statistical Package for Social Sciences (SPSS) software for Windows 21.0 was used to analyze the data. The results are presented as either the mean and standard deviation or median and interquartile range, depending on the distribution of the data. Paired samples t-test was used for normally distributed data, and the Wilcoxon signed-rank test was used for data that was not normally distributed. Descriptive analytics were also performed using the median and quartile intervals for non-normally distributed variables. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic data and baseline measurements after sedoanalgesia at the first hour of BIS, SQI, EMG, pulse, SpO_2, body temperature and RSS scores are given in Table 2. Simultaneous EMG, BIS values of patients with SQI values of 85 and above were recorded and included in the study.

There was a moderately significant negative correlation between the BIS value measured at the first hour and the RSS evaluated simultaneously (r=-0.782, p<0.001). Patients with high BIS scores had lower RSS scores, vice versa the patients with lower BIS scores had higher RSS scores. When compared, there was a significant increase in the BIS data obtained before

Table 2. Demographic characteristics and baseline measurements of patients

Demographics	**n=43**
Gender	**n (%)**
Male/female	19 (44.2)/24 (55.8)
Age	**Median; (IQR)**
Months	12; (28)
PICU admission diagnoses	**n (%)**
Respiratory failure	18 (41.9)
Cardiac failure	8 (18.6)
Septic shock	11 (25.6)
Metabolic crisis	4 (9.3)
Hematological disease	2 (4.7)
Analgesia	**n**
Fentanyl/morphine	25/18
Baseline measurements	**Median; (IQR)**
BIS	59 (13)
EMG	32 (8)
SQI	95 (6)
RSSs	5 (1)
HR	108 (35)
SpO_2	95 (2)

HR: Heart rate (per minute), SpO_2: Oxygen saturation (%), BIS: Bispectral index, EMG: Electromyographic activity, SQI: Signal quality index, RSSs: Ramsey Sedation Scale score, IQR: Interquartile range

and after the endotracheal suctioning procedure (p<0.001). There was no significant difference between EMG and SQI values before and after suctioning (p=0.206, p=0.214). There was a significant decrease in RSS scores (p=0.001). No significant difference was found in the SpO_2 values of the patients related to suctioning (p=0.75). Heart rate values showed an increase with endotracheal suctioning. This increase was statistically significant (p<0.001) (Table 3).

Changes of BIS and RSS values were compared between fentanyl and morphine groups, too. There was no significant difference between morphine and fentanyl group (Table 4).

Table 3. Comparison of measurements before/after endotracheal aspiration

Measures/ scores	Before suctioning Median (IQR)	After suctioning Median (IQR)	p-value
BIS*	56 (16)	66 (15)	<0.001
EMG*	35 (9)	34 (10)	0.206
SQI*	95 (6)	93 (6)	0.214
RSSs*	5 (1)	5 (2)	0.001
HR*	110 (42)	130 (40)	<0.001
SpO_2*	96 (2)	95 (4)	0.75

*Wilcoxon t-test, HR: Heart rate (per minute), SpO_2: Oxygen Saturation (%), BIS: Bispectral index, EMG: Electromyographic activity, SQI: Signal quality index, RSSs: Ramsey Sedation Scale score, IQR: Interquartile range

Table 4. Comparison of changes in BIS, EMG, SQI, RSS, HR, BIS percentages before and after endotracheal aspiration between Fentanyl and Morphine groups

Measures/ scores PC**	Fentanyl group Median (IQR)	Morphine group Median (IQR)	p-value*
BIS	10.52 (16.11)	10.52 (11.85)	0.721
EMG	0 (15.71)	-2 (21.92)	0.117
SQI	0 (7.7)	0 (4.75)	0.489
RSSs	0 (22.50)	0 (5)	0.341
HR	11.45 (8.44)	9.57 (8.51)	0.571
SpO_2	0 (1.58)	-0.53 (3.16)	0.084

*Mann Whitney-U Test, **PC: Percentage change before/after endotracheal suctioning, HR: Heart rate (per minute), SpO_2: Oxygen saturation (%), BIS: Bispectral index, EMG: Electromyographic activity, SQI: Signal quality index, RSSs: Ramsey Sedation Scale score, IQR: Interquartile range

DISCUSSION

The aim of sedation in critically ill patients is to ensure that the patient remains calm, does not feel pain, and continues to breathe spontaneously; thus helps to reduce the length of stay in ICU and duration of mechanical ventilation. However, the clinician should avoid the undesired side effects of excessive sedation. Amnesia is probably another useful goal of sedation therapy so that the patient has no recall of unpleasant events or surroundings[6-9]. Prospective studies reported that BIS index values between 40-60 indicate sufficient hypnotic effect during general anesthesia[10].

In the follow-up of sedation levels of critically ill patients in ICU; different objective and subjective measurements such as clinical scales, hemodynamic changes, BIS, EEG and auditory evoked potentials are used[11,12].

In our study, we observed that BIS, HR and RSSs were changed by endotracheal suctioning. We found that sedation levels decreased. In a study, Brocas et al.[13] reported additional dose of analgesia was required during endotracheal suctioning. We suppose that giving an additional dose of analgesic before painful procedures will prevent deterioration of sedation level and patient comfort. Benzodiazepines and opioids are the most commonly used agent for sedation and analgesia in pediatric ICU (PICU). It is known that the BIS is not correlated with the level of analgesia but with the level of sedation[14]. In ICU patients, there is an increase in BIS index in nociceptive stimuli such as tracheal suctioning. This increase is related to a central noradrenergic stimulation causing cortical alertness. The effect of different sedative drugs (benzodiazepine or opioid) on BIS may be different. The addition of opioids to sedation in the presence of painful stimuli may suppress the increase in the BIS index[15].

In our study, we examined all patients who received fentanyl or morphine for analgesia in addition to midazolam which is the first line sedative agent that routinely used in our PICU. Moreover, we assessed the subgroups according to the analgesic agent (morphine group/fentanyl group). We found that the percentage changes before and after suctioning were not different between the groups. The midazolam infusion doses we started for sedation were different between patients, but opioid doses were started as standard, so we compared percentage changes. Considering that opioid-derived analgesics have similar effects, differences may occur between analgesics of different effects. Chun et al.[16]

evaluated the effects of dexmedetomidine-ketamine (DK) against dexmedetomidine-midazolam-fentanyl (DMF) combinations on sedation/analgesia quality and recovery profiles for monitored anesthesia. Patients during a port catheter insertion were given DK in one group and DMF in the other. BIS was used to monitor anesthesia activity, as well as extra sedation demands, waking time, and cardiorespiratory variables. According to the authors, superior data were obtained in the second group[16].

BIS monitoring is being used in the operating rooms and adult ICUs in order to monitor the level of anesthesia applied. In a study conducted in the PICU, it was found that there was a significant correlation between sedation scoring and BIS in order to determine the sedation levels of the patients in the PICU so that authors concluded that BIS monitoring could be useful in PICUs[17]. A survey conducted in England revealed that only 2% of ICUs were using BIS while 88% of them used sedation scales. Regarding the scales, 66% of them were RSS and 5% of them were Richmond agitation sedation scale[18]. We follow the sedation levels of patients with RSS in our PICU. In addition, we use BIS as an objective measurement method in some critical patients who receive neuromuscular blocking agents and whom RSS is inapplicable.

One of the major challenges in BIS follow-up is keeping the probes stable on the patient's skin. The signal quality deteriorates during sweating and routine interventions. In our study, SQI values were monitored carefully in order to obtain accurate results during BIS follow-up. The BIS values were obtained when SQI levels are higher than 85[19]. Moreover, in our study population, we did not have any RSS scores below 4 which is an unavoidable reason for adequate sedation in mechanically ventilated pediatric patients. It may be more appropriate to include mildly sedated patients in future studies to determine the correlation of lower scores with BIS values. Furthermore, we expect that monitoring a continuously updated value on the monitor will allow clinicians and health personnel to intervene at the appropriate moment. Both high dose and inadequate sedation will adversely affect our treatment outcomes. During our study, the nurses who took care of the patients reported that sedation monitoring with a numerical scale is more comfortable than RSS. The use of BIS may facilitate nurse-led sedation in PICU.

Study Limitations

One limitation of our study is its single centered design. Another limitation is that only RSS is used for clinical sedation scoring. In terms of patient comfort, the effects of endotracheal suctioning can be evaluated by using comfort scale. As far as we can determine our study was the first study to evaluate the effect of sedation with pain stimulus and BIS monitoring and clinical scores in the PICU.

CONCLUSION

Our recent study investigated the effects of painful procedures, such as endotracheal suctioning, on patients receiving sedation and strong pain medications like opioids in an intensive care setting. To our surprise, we found that these procedures significantly increased the BIS values of the patients and disrupted their comfort, despite the use of sedation and strong pain medications. While our study focused solely on the impact of endotracheal suctioning, it is important to consider that similar results may not be seen with other painful interventions.

The use of BIS monitoring in intensive care patients is a topic of ongoing debate, with some arguing that it can effectively reduce the need for sedative medications, prevent self-extubations, and ultimately decrease the cost and length of stay in intensive care. However, there is a lack of data specifically on the use of BIS monitoring in pediatrics, and there are still several questions that need to be addressed regarding its impact on patient comfort, long-term neurophysiological function, and overall patient outcomes. Further research is necessary to fully understand the benefits and limitations of using BIS monitoring in this patient population.

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Ethics

Ethics Committee Approval: The study was approved by the University of Health Sciences Turkey, Dr. Behçet Uz Pediatric Diseases and Surgery Training and Research Hospital Ethics Committee (protocol no: 2017/157, date: 06.07.2017).

Informed Consent: Written informed consent was obtained from the parents of all participating subjects.

Peer-review: Externally peer reviewed.

Author Contributions

Surgical and Medical Practices: G.A., S.T., E.S., Concept: G.A., G.C., M.Ç., Design: G.A., M.Ç., R.İ., Data Collection or Processing: Ö.S.S., F.S., E.S., Analysis or Interpretation: G.C., E.S., R.İ., H.A., Literature Search: G.A., Ö.S.S., F.S., U.K., R.İ., H.A., Writing: G.A., S.T., U.K., H.A.

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