

The Narcotrend™ – a new EEG monitor designed to measure the depth of anaesthesia

A comparison with bispectral index monitoring during propofol-remifentanil-anaesthesia

Abstract

Introduction. The Narcotrend™ is a new EEG monitor designed to measure the depth of anaesthesia based on a 6-letter classification from A (awake) to F (general anaesthesia with increasing burst suppression) and divided into 14 substages (A, B₀₋₂, C₀₋₂, D₀₋₂, E_{0,1}, F_{0,1}). This study was designed to investigate the assessment of the depth of anaesthesia as measured by the Narcotrend in comparison with bispectral index monitoring (BIS™).

Methods. Both BIS and Narcotrend EEG electrodes were positioned on the patient's forehead as recommended by the manufacturers. All patients were premedicated with diazepam 0.15 mg/kg orally in the evening and on the morning before surgery. Induction of anaesthesia was started with a remifentanil infusion at 0.4 µg/kg/min; 5 min later propofol was given for hypnosis using a target-controlled infusion initially started at 3.5 µg/ml. After loss of consciousness patients received 1.2 mg/kg of suxamethonium. Immediately after intubation, remifentanil was reduced to 0.2 µg/kg/min, and the depth of anaesthesia was adjusted according to clinical needs by regulating the propofol target-controlled-infusion. BIS values and Narcotrend stages were recorded as data pairs in intervals of 1 min during anaesthetic induction and emergence, and in intervals of 5 min during maintenance of anaesthesia. **Results.** Fifty patients undergoing orthopaedic surgery were studied and 2031 data pairs were obtained. An increasing depth of anaesthesia as indicated by the Narcotrend

was associated with significantly lower mean BIS values. With BIS values between 100 and 85 (representing awake patients), 95.5% of all data pairs indicated a Narcotrend stage A or B. In case the BIS was found to be 65–40 (representing general anaesthesia) the corresponding Narcotrend stages were measured as D (52.4%) or E (41.1%). No patient complained of intraoperative recall when interviewed on the 1st and 3rd post-operative day.

Conclusions. We could demonstrate that an increase of the hypnotic component of anaesthesia as indicated by BIS is accompanied by corresponding effects as displayed by the Narcotrend during propofol-remifentanil anaesthesia. The Narcotrend stages D or E are assumed equivalent to BIS values between 64 and 40 indicating general anaesthesia.

Keywords

Electroencephalogram · Narcotrend · Bispectral index scale · Remifentanil · Propofol

Measuring the “depth of anaesthesia” has been of interest since professionals started to deliver anaesthetics. Many investigations [e.g. 11] have focused on the raw electroencephalogram (EEG), however, derived parameters were neither feasible nor available at the bedside until the introduction of modern computer technology. Recently, bispectral index

monitoring (BIS™, Aspect Medical Systems, Natick, MA) was introduced into clinical practice and approved by the U.S. Food and Drug Administration. The bispectral index is an arbitrary scale from 100 (awake patient) to 0 (no cortical activity) [5]. Meanwhile, a huge body of evidence suggests that BIS monitoring may help to assess the hypnotic component of anaesthesia, reduce drug consumption [10] and shorten recovery times [2].

The Narcotrend™ (MonitorTechnik, Bad Bramstedt, Germany), another EEG monitor designed to measure the depth of anaesthesia, has been commercially available in Europe since 2000. The Narcotrend was developed by anaesthesiologists and engineers at the University Medical School of Hannover, Germany and, like the BIS, includes a computerised analysis of the raw EEG. In brief, two commercially available electrodes are placed on the forehead of the patient, a third electrode serves as a reference (see Fig. 1). After artefact analysis a multivariate statistical algorithm transforms the raw EEG data finally resulting in a 6-letter classification of the depth of anaesthesia as follows:

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Der Narcotrend™ – ein neuer EEG-Monitor zur Überwachung des Narkose-EEG. Ein Vergleich mit der Bispektralanalyse bei Allgemeinanästhesie mit Propofol und Remifentanyl

Zusammenfassung

Der Narcotrend® (MonitorTechnik, Bad Bramstedt) ist ein neuer EEG-Monitor, der das Narkose-EEG automatisiert anhand einer Stufen-Klassifikation analysiert und eine Einteilung in Narkosestadien (A, B₀₋₂, C₀₋₂, D₀₋₂, E₀₋₁, F₀₋₁) vornimmt. Im Gegensatz zur Bispektralanalyse (BIS®, Aspect Medical Systems, Natick, USA) ist eine klinische Validierung dieses Systems bisher nicht erfolgt. In der vorliegenden Untersuchung sollte daher das Narkose-EEG von Patienten in Allgemeinanästhesie zeitgleich durch Narcotrend und BIS interpretiert und die Messergebnisse verglichen werden.

Methodik. Bei 50 orthopädischen Patienten wurden die EEG-Messelektroden für BIS und Narcotrend nach Herstellerangaben auf der haarfreien Haut der Stirn platziert. Nach oraler Prämedikation mit 0,15 mg/kg Diazepam abends und morgens vor der Operation wurde Remifentanyl mit 0,4 µg/kg/min über 5 min infundiert; anschließend erfolgte die Anästhesieeinleitung mit Propofol als Target-Controlled-Infusion (TCI) mit einer Startkonzentration von 3,5 µg/ml. Nach Relaxierung mit 1,2 mg/kg Succinylcholin und orotrachealer Intubation wurde die Remifentanyl-Infusion auf 0,2 µg/kg/min reduziert und blieb im weiteren Verlauf unverändert; die Propofol-Dosierung wurde anhand klinischer Kriterien gesteuert. Die Messwerte von BIS und Narcotrend wurden während Anästhesieeinleitung und -ausleitung 1-minütlich, ansonsten in 5-min-Intervallen als Datenpaare registriert und anschließend statistisch ausgewertet.

Ergebnisse. Insgesamt wurden 2031 Datenpaare bei 50 Patienten im Alter von 51 ± 16 Jahren erfasst. Dabei zeigte sich, dass eine vom Narcotrend angezeigte Vertiefung des Narkose-EEG gleichzeitig mit einem signifikanten Abfall des BIS-Werts einherging. Umgekehrt entsprach ein BIS-Wert von 100–85 (wacher Patient) in 95,5% der Narcotrend-Stufe A oder B, ein BIS-Wert von 65–40 (Allgemeinanästhesie) der Narcotrend-Stufe D (52,4%) oder E (41,1%). Intraoperative

Originalien

Wachheit wurde bei Nachbefragung am 1. und 3. postoperativen Tag nicht berichtet. **Schlussfolgerungen.** Veränderungen des Narkose-EEG bei Allgemeinanästhesie mit Propofol und Remifentanyl werden von BIS und Narcotrend gleichsinnig erfasst und interpretiert. Unter diesen Bedingungen entspricht ein BIS-Wert von 64–40 der Narcotrend-Stufe D oder E.

Schlüsselwörter

Elektroenzephalogramm · Narcotrend · Bispektralanalyse · Remifentanyl · Propofol

- A (awake),
- B (sedated),
- C (light anaesthesia),
- D (general anaesthesia),
- E (general anaesthesia with deep hypnosis),
- F (general anaesthesia with increasing burst suppression).

This classification was originally described in 1981 by Kugler [7] and includes 14 substages (A, B₀₋₂, C₀₋₂, D₀₋₂, E_{0,1}, F_{0,1}). The results of the Narcotrend

analysis are displayed on a personal computer monitor including the individual substage of anaesthesia and additional information (e.g. raw EEG, median frequency, spectral edge frequency 90%, trend analysis; see Fig. 2). Markers help to identify and document specific situations, e.g. intubation or start of surgery, a hardcopy and a report function may be used for documentation purposes. This study was designed to investigate the assessment of the depth of anaesthesia as measured by the Narcotrend in comparison with BIS monitoring using a standardised propofol-remifentanyl anaesthetic technique.

Methods

With institutional review board approval and written informed consent, 50 adult patients undergoing orthopaedic surgery were studied. Exclusion criteria were a history of central nervous or cerebrovascular diseases. All patients were premedicated with diazepam 0.15 mg/kg orally in the evening and on the morning before surgery. In the operating room an intravenous catheter was inserted into a larger forearm vein and



Fig. 1 ▲ BIS sensor™ and Narcotrend™ electrodes as positioned for our investigation according to the manufacturers' recommendations. Please note that all electrodes were positioned to predominantly monitor the left (dominant) hemisphere in right-handed patients. The Narcotrend™ electrodes #1 and #2 are placed on the forehead with a minimum distance of 8 cm, #3 indicates the reference electrode which is positioned laterally of electrode #1

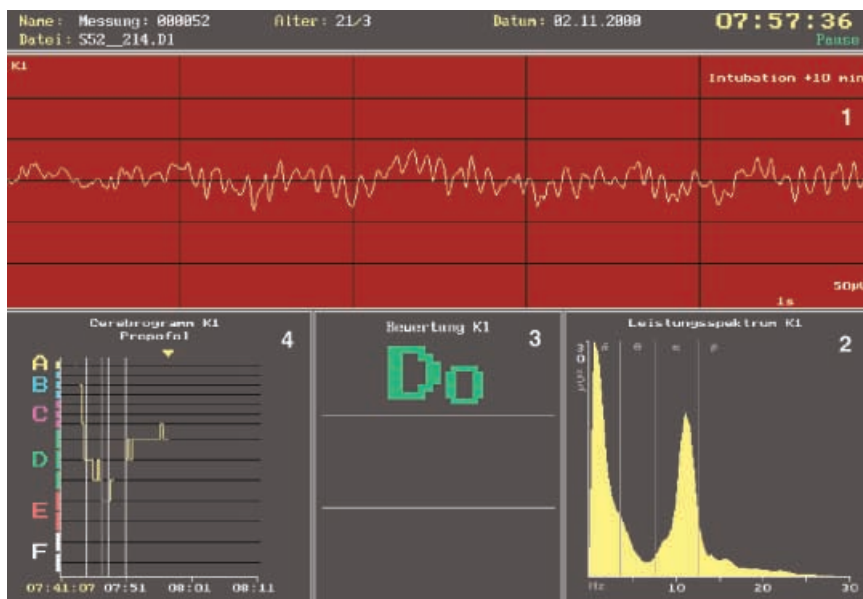


Fig. 2 ▲ Hardcopy of the Narcotrend monitor display (version 2.0 AF, MT MonitorTechnik, Bad Bramstedt, Germany), (1) raw EEG, (2) spectral parameters, (3) Narcotrend stage, (4) trend display of Narcotrend stages

standard monitors were applied. The EEG was recorded continuously using an Aspect A-2000 BIS monitor (software version 3.0) and a Narcotrend (software version 2.0 AF). After the skin of the forehead had been degreased with 70% isopropanol, both the BIS (BIS sensor™) and the Narcotrend (Blue sensor™, Medicotest, Olstykke, Denmark) electrodes were positioned as recommended by the manufacturers. For the Narcotrend two commercially available electrodes were placed on the forehead with a minimum distance of 8 cm, a third was positioned laterally serving as a reference electrode (Fig. 1). Finally, impedances were measured for each set of electrodes to ensure optimal electrode contact defined as $\leq 6 \text{ k}\Omega$ [9] for the Narcotrend and $< 7.5 \text{ k}\Omega$ for the BIS [8].

While oxygen was given via a face mask at 10 l/min for preoxygenation, induction of anaesthesia was started with a remifentanyl infusion at $0.4 \mu\text{g}/\text{kg}/\text{min}$. After 5 min propofol was given for hypnosis using a target-controlled infusion (Diprifusor, AstraZeneca, Wedel, Germany) initially started at $3.5 \mu\text{g}/\text{ml}$. After loss of consciousness face mask ventilation was initiated with pure oxygen, patients received $1.2 \text{ mg}/\text{kg}$ of suxamethonium, the trachea was intubated 60 s later and the lungs were ventilated to an end-tidal carbon dioxide concentration

of 35 mmHg. Immediately after intubation, remifentanyl was reduced to $0.2 \mu\text{g}/\text{kg}/\text{min}$ and remained unchanged throughout the further course of surgery. The depth of anaesthesia was adjusted according to clinical needs by regulating the propofol target-controlled infusion.

BIS values and Narcotrend levels were continuously recorded as data pairs at intervals of 1 min during induction of anaesthesia, at intervals of 5 min during maintenance of anaesthesia and at intervals of 1 min during emergence from anaesthesia until the patient's trachea was extubated.

Finally, all patients were visited in the postanaesthesia care unit and on the 1st and 3rd post-operative day and interviewed about intraoperative recall.

Statistics

Statistical analysis was performed by one-way analysis of variance on ranks (ANOVA on ranks) and Student-Newman-Keuls test for pairwise comparisons. Statistical significance was defined as $P < 0.05$ and data are presented as mean and standard deviation (SD). Statistical analysis was planned and performed in collaboration with a statistician from the Institute of Medical Biometrics, Epidemiology and Informatics, University of Saarland, using SigmaStat

2.03 and SigmaPlot 6.00 computer software (SPSS GmbH, Erkrath).

Results

Fifty patients were studied and demographic data are displayed in Table 1. Problems with skin adherence of the electrodes were not observed and none of the electrodes became detached.

During the study period a total of 2031 data pairs was obtained consisting of a Narcotrend substage and the corresponding BIS value. In general, an increasing depth of anaesthesia as indicated by the Narcotrend substage was associated with lower mean BIS values (Fig. 3). In particular, corresponding BIS values of each Narcotrend substage were significantly lower when compared to the BIS values of the preceding Narcotrend substage with the exception of a comparison of B₂ to C₀.

In addition, data pairs were grouped according to the bispectral index scale (Table 2). When BIS values were measured between 100 and 85 (representing an awake patient [5]), 95.5% of all data pairs indicated a Narcotrend stage A or B. In cases where the BIS was found to be 64–40 (representing general anaesthesia [5]) the corresponding Narcotrend stages were predominantly measured as D (52.4%) or E (41.1%).

With both monitors data pairs were identified that indicated sufficient anaesthesia in one but insufficient/light anaesthesia in the other monitor: In 71 data pairs a BIS value below 65 was accompanied with Narcotrend stages B and C, whereas in 60 data pairs a Narcotrend stage of D or E was paralleled by BIS values of 65 or above. However, no patient complained of intraoperative recall.

Table 1
Demographic data

No. of patients	50
Age (years)	51±16
Weight [kg]	80±14
Sex (male/female)	27/23
ASA physical status I, II, III	10, 31, 9

Values are number of patients or mean ±SD.

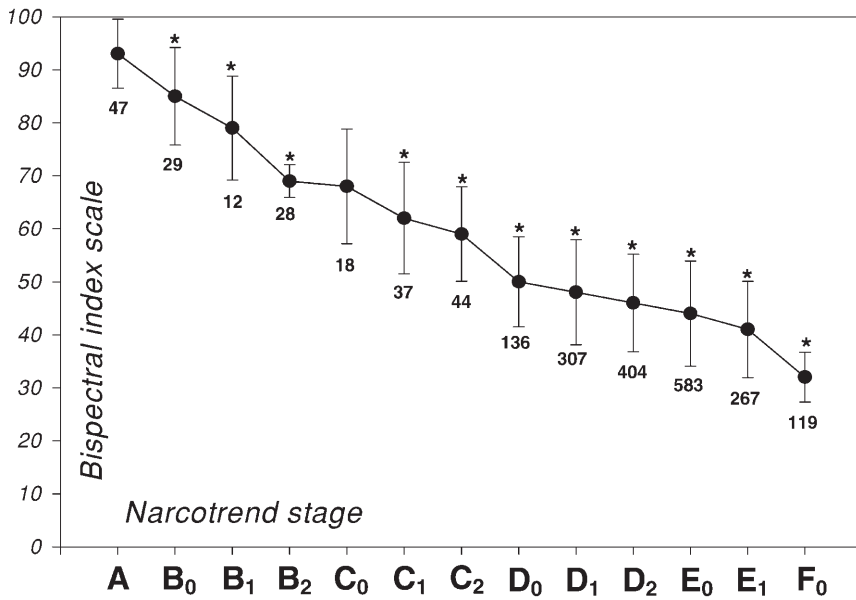


Fig. 3 ▲ Narcotrend™ stages and corresponding BIS values as measured during a propofol-remifentanyl-anaesthetic in 50 patients undergoing orthopaedic surgery. A total of 2031 data pairs were obtained. Data are presented as mean ±SD; the number of data pairs to describe the individual Narcotrend substage is indicated below the error bars. BIS values obtained during the different Narcotrend substages were compared by one-way ANOVA on ranks and Student-Newman-Keuls test for pairwise comparisons. The asterisk (*) indicates that BIS values of an individual Narcotrend substage are significantly different with $P < 0.05$ when compared to the BIS values of the preceding Narcotrend substage

Discussion

Currently, an increasing number of monitors built to determine anaesthetic depth is introduced into clinical practice. Evaluation of these monitors implies many difficulties and is associated with the need to measure surrogate parameters, e.g. clinical endpoints such as loss of consciousness [2], reduction of recovery times [2] or drug consumption [10]. Meanwhile, the bispectral index scale has been studied in a large number of investigations [3, 6] and must now be considered as the main competitor for all new devices developed in this field.

The Narcotrend is a new EEG monitor, commercially available in Europe since 2000 and based upon a 6-letter classification of the depth of anaesthesia from A (awake) to F (general anaesthesia with increasing burst suppression) [7]. The results of the present study indicate that increasing depth of anaesthesia as measured by the BIS is accompanied by a corresponding effect as displayed by the Narcotrend stages. In detail, during general anaesthesia with BIS values between 64 and 40, the corresponding Narcotrend stages will be D or E in 93.5% of the cases. In addition, we

were able to demonstrate that even changes of one Narcotrend substage (e.g. from C₂ to D₀) were associated with a significant reduction of the corresponding mean BIS value.

Some concern may arise with the finding that with both monitors data pairs were identified that indicated sufficient anaesthesia in one but insufficient/light anaesthesia in the other monitor. This is another important secondary result of the present study and warrants further investigations on sensitivity and specificity of the displayed monitor results. None of our patients complained of intraoperative recall. However, missing recall must be discussed

cautiously as it may not rule out intraoperative awareness, especially in patients with benzodiazepine premedication.

Furthermore, it must be highlighted that the above comparison of Narcotrend and BIS values only applies to patients receiving a propofol-remifentanyl-anaesthetic after premedication with diazepam and may not be transferred to inhalational agents. In addition, the relative contribution of propofol, remifentanyl or diazepam to the observed changes cannot be determined with this investigation. For bispectral index monitoring, contradictory results were reported in the literature: Finianos and colleagues [1] demonstrated that remifentanyl does not affect the bispectral index or the relationship between propofol and BIS at induction of anaesthesia, whereas Guignard and co-workers [4] concluded that the addition of remifentanyl to propofol may affect BIS values if a painful stimulus is applied. Whether or not remifentanyl will influence the monitoring of the depth of anaesthesia, it was infused at a constant rate of 0.2 µg/kg/min intraoperatively in the present investigation and one may at least conclude that no alterations in remifentanyl infusion rate have influenced the relationship of BIS and corresponding Narcotrend results.

In conclusion, this is the first investigation evaluating the Narcotrend system, a new EEG device designed to measure the depth of anaesthesia, in comparison to bispectral index monitoring. We could demonstrate that with propofol-remifentanyl, an increasing depth of anaesthesia as indicated by BIS is accompanied by corresponding effects as displayed by the Narcotrend. Furthermore, within the Narcotrend classification of A–F, the stages D or E are as

Table 2
Groups of BIS values

n	BIS	Narcotrend™ [n (%)]					
		A	B	C	D	E	F
66	100–85	43 (65.2)	20 (30.3)	2 (3.0)	1 (1.5)	0	0
138	84–65	4 (2.9)	42 (30.4)	33 (23.9)	47 (34.1)	12 (8.7)	0
1160	64–40	0	7 (0.6)	63 (5.4)	608 (52.4)	477 (41.1)	5 (0.4)
668	<40	0	0	1 (0.1)	191 (28.6)	361 (54.0)	115 (17.2)

sumed to be equivalent to BIS values between 64 and 40 indicating general anaesthesia. Further studies are warranted to investigate whether Narcotrend monitoring will affect clinical endpoints and may be applicable to inhalational anaesthetics as demonstrated for the BIS.

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Tracheotomie

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Das vorliegende Fachbuch beschreibt ausführlich illustriert und gut gegliedert alle zur Zeit gängigen Techniken der Tracheotomie. Die einzelnen Kapitel umfassen Themenbereiche wie historische Entwicklung, Anatomie, Indikation und Zeitpunkt der Tracheotomie, Techniken und Komplikationen der perkutanen Tracheotomie auch bei typischen intensivmedizinischen Problemen wie respiratorischer Insuffizienz und Gerinnungsstörungen. In dem Fachbuch sind ebenso die Sicht der Hals-, Nasen- Ohrenheilkunde, des Chirurgen, des Pädiaters, des Kiefer- und Gesichtschirurgen sowie des pneumologisch-internistischen Intensivmediziners aufgenommen worden. Außerdem werden in einem gesonderten Kapitel die Nottracheotomie, Notkoniotomie und Notfälle bei Tracheostomieträgern beschrieben.

Der Schwerpunkt des Buches liegt sicherlich in der schnellen und übersichtlichen Orientierung in der sich der Assistenzarzt und Facharzt einen



Überblick über das jeweilige operative Vorgehen machen können. Dabei wird grosser Wert auf die einzelnen operativen Schritte gelegt, die nicht nur detailliert beschrieben, sondern auch durch eine großzügige Illustration eindringlich veranschaulicht werden. Komplikationsmöglichkeiten bei

den jeweiligen Verfahren werden durch übersichtliche Tabellen vermittelt. Ebenso geben die Autoren im Text Tipps und Tricks gewisse Komplikationen zu verringern oder gar zu vermeiden. Die beschriebenen Verfahren können prinzipiell bettseitig auf der Intensivtherapiestation vom Intensivmediziner durchgeführt werden. Dadurch entfallen lange und personalaufwendige Transporte der meist kritisch kranken Patienten.

Die Gliederung der einzelnen Kapitel und das gut aufgebaute alphabetische Register ermöglichen dem Leser ein rasches Nachschlagen.

Dieses Buch stellt nicht nur für den sich in Ausbildung befindlichen Arzt, sondern auch für den Intensivmediziner ein wertvolles Nachschlagewerk dar. Den Herausgebern ist es gelungen Theorie und Praxis so zu verknüpfen, dass sich der Leser in diese faszinierende und aktuelle Thematik nach neuestem Kenntnisstand einarbeiten kann.

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