VIA MEDICA

ORIGINAL AND CLINICAL ARTICLES

Anaesthesiology Intensive Therapy
2014, vol. 46, no 4, 284–288
ISSN 1642–5758
DOI: 10.5603/AIT.2014.046
www.ait.viamedica.pl

The effect of bispectral index monitoring on anaesthetic requirements in target-controlled infusion for lumbar microdiscectomy

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Abstract

Background: Target-controlled infusion (TCI) is used to maintain the desired concentration of a hypnotic drug in the plasma and brain. However, pharmacodynamic variability can cause problems with maintaining the adequate level of anaesthesia. The bispectral index (BIS) is one of only a few parameters that allow an assessment of the depth of anaesthesia. In the present study, we attempted to determine the optimal dosages of drugs used for total intravenous anaesthesia with TCI based on BIS-guided monitoring of depth of anaesthesia.

Methods: The study was conducted in 60 ASA I patients undergoing elective surgery due to lumbar discopathy. The participants were divided into two groups of 30 individuals. The patients were premedicated with 15 mg oral midazolam. Group I was the control group; group II received BIS monitoring. Anaesthesia was induced with TCI propofol (4 $\mu g\ mL^{-1}$), fentanyl (2 $\mu g\ kg^{-1}$) and vecuronium (0.12 $mg\ kg^{-1}$) and maintained with TCI propofol, continuous infusion of vecuronium (0.03 $mg\ kg^{-1}\ h^{-1}$) and fractionated doses of fentanyl. ECG, HR, MAP, SaO_2, $ETCO_2$, and the degree of neuromuscular blockade were monitored, specifically at the following time points: T_1 — before induction, T_2 — after induction, T_3 — after intubation, T_4 — after positioning of the patient, T_5-T_{13} — every 5 min during surgery, T_{14} — on completion of surgery, T_{15} — before extubation, T_{16} — after extubation.

Results: The study groups were comparable in terms of age, body weight, duration of anaesthesia and recovery time. The haemodynamic parameters, such as HR and MAP, did not differ significantly between the groups. In both groups, changes in the mean MAP values were observed between T_1 and T_2, T_2 and T_3, T_3 and T_4 as well as T_{14} and T_{15}. The total dose of fentanyl and the doses of propofol were lower in the group that received BIS monitoring.

Conclusion: BIS monitoring reduces the doses of opioids and hypnotics used during total intravenous anaesthesia by TCI.

Anaesthesiology Intensive Therapy 2014, vol. 46, no 4, 284–288

Key words: general anaesthesia, target controlled infusion; anaesthetics, intravenous, propofol

Propofol is a short-acting intravenous hypnotic used for the induction and maintenance of anaesthesia. Due to its pharmacokinetic properties, this agent should be administered as a continuous infusion [1]. Target-controlled infusion (TCI) enables an anaesthesiologist to achieve the expected clinical effect by pre-programming the desired serum concentration of the drug based on an infusion rate algorithm involving gender, age, body weight and height [2, 3]. TCI propofol ensures the rapid induction of anaesthesia and the maintenance of a stable level [4, 5]. However, the pharmacokinetics of propofol vary between individuals; therefore the dose should be tailored to each patient, for both induction and maintenance of anaesthesia [6, 7].

Individualized dosage requires monitoring of the depth of anaesthesia. The bispectral index (BIS) is one of only a few parameters that can be used for determining the depth of anaesthesia through a simple and non-invasive assessment [8, 9]. BIS values within the range of 40–60 are believed to provide suitable depression of consciousness without short-term episodes of awareness [10, 11].

The aim of this study was to optimise the dosage of agents used for total intravenous anaesthesia with TCI based on BIS monitoring.

METHODS

The present study was approved by the local bioethics committee and recruited ASA I patients undergoing lumbar microdiscectomy due to a herniated nucleus pulposus.

The study was carried out in 60 patients who were randomLy divided into 2 groups, each containing 13 women and 17 men. Group I was the control group, and group II was assessed by BIS monitoring. The patients were premedicated with oral midazolam at a dose of 15 mg 45 min before anaesthesia. In the operating room, two cannulae were inserted to the antebrachial veins, and 5 mL kg^{-1} Ringer's solution was infused over 15 min. Before induction of anaesthesia, a 5-minute preoxygenation was performed. Anaesthesia was induced with TCI propofol (4 μg mL^{-1}) (Diprifusor Graseby 3500, Great Britain), fentanyl (2 μg kg^{-1}) and vecuronium (0.12 mg kg^{-1}). Tracheal intubation was carried out when the flexor pollicis longus response to TOF stimulation began to decline (TOFWatch SX, Organon, Holland).

Anaesthesia was maintained with TCI propofol, continuous infusion of vecuronium (0.03 mg kg^{-1} h^{-1}), which was discontinued 30 min before the completion of surgery, and fractionated doses of fentanyl. The lungs were mechanically ventilated with a mixture of air and oxygen (FiO_2 = 0.33), maintaining SaO_2 > 95% and E_TCO_2 4.8–5.2 kPa (36–39 mm Hg). The following parameters were continuously monitored during surgery (Dash 3000, GE Medical Systems, USA): ECG; heart rate (HR); mean arterial pressure (MAP), measured non-invasively; and SaO_2. These measurements were performed at the following time points: T_1 — before induction, T_2 — after induction, T_3 — after intubation, T_4 — after positioning of the patient, T_5-T_{13} — every 5 min during surgery, T_{14} — after completion of surgery, T_{15} — before extubation, T_{16} — after extubation.

In group I, the propofol and opioids dosages were selected based on haemodynamic parameters, such as HR and MAP. In group II, BIS monitoring was also performed (BIS AspectMedical Monitoring, USA), and the values were maintained within the range of 40–50 from the time of induction to the completion of surgery. Moreover, the level of neuromuscular blockade and the volume of Ringer's solution infused were monitored.

The criterion for extubation was a return of spontaneous respiration with TV ≥ 4 mL kg^{-1} and TOF-R ≥ 0.9.

The results were statistically analysed using Statistica 9.1 software (Tulsa, USA) and GraphPad InStat version 3.0 (GraphPad Software Inc., USA). The data are presented as the means ± SD. The distribution of the data was evaluated using the Kolmogorov-Smirnov test. The Dunnett`s multiple comparison test was used for intragroup comparisons, and the Mann-Whitney U test was used for intergroup comparisons. Statistical significance was assumed at $P < 0.05$.

RESULTS

The study groups were comparable in terms of age (Fig. 1), body mass (Fig. 2), duration of anaesthesia (Fig. 3) and recovery time (Fig. 4). During anaesthesia, there were no intergroup differences in the mean HR (Fig. 5) and MAP values (Fig. 6). In both groups, the mean MAP values changed between T_1 and T_2, between T_2 and T_3, between T_3 and T_4, and between T_{14} and T_{15}.

The mean total dose of fentanyl was higher in group I (Fig. 7), and the doses of propofol used during the maintenance of anaesthesia were higher in group I (Fig. 8) than in group II (Fig. 9) at the same measurement points. Moreover, the total volume of Ringer's solution was higher in group I (Fig. 9).

DISCUSSION

The pharmacokinetic properties of propofol after a bolus injection or after completion of intravenous infusion are described by the well-known three-compartment open model [12]. After administration, propofol is distributed throughout many tissues and is quickly eliminated by metabolism in the liver [13]. Several other organs are also believed to be involved in the biotransformation of this drug [14, 15]. The studies on propofol metabolism have demonstrated that its uptake by the lungs reduces its serum concentration [16–18]. The use of target-controlled infusion in clinical practice allows for maintenance of the desired depth of anaesthesia by providing appropriate concentrations of the drug in the plasma. According to Van Poucke and colleagues [19], the available systems for determining the concentration of a given drug in the plasma are not ideal, as the serum is not the site of the drug's action. Furthermore, Vuyk and co-workers [20] believe that pharmacodynamic interactions between propofol and sedatives, administered as a premedication, and opioids allow adequate anaesthesia in 50–95% of cases.

Propofol given as a single agent causes loss of consciousness in 50% of patients when the serum concentration reaches 3.4 μg mL^{-1} [3, 21] and in 90% of patients when the serum concentration of 4 μg mL^{-1} [22]. The doses of propofol required to achieve suppression of the response to stimulation induced by laryngoscopy, endotracheal intubation or surgery, are substantially higher when administered as a monotherapy [3, 21].

The combination of TCI propofol with opioids allows a decrease in the dose required of to produce the loss of consciousness [21, 22]. According to our observations, a se-

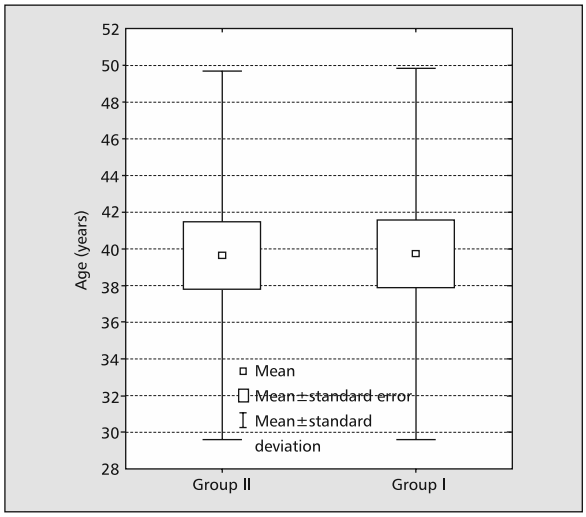

Figure 1. Comparison of mean ages in the study groups

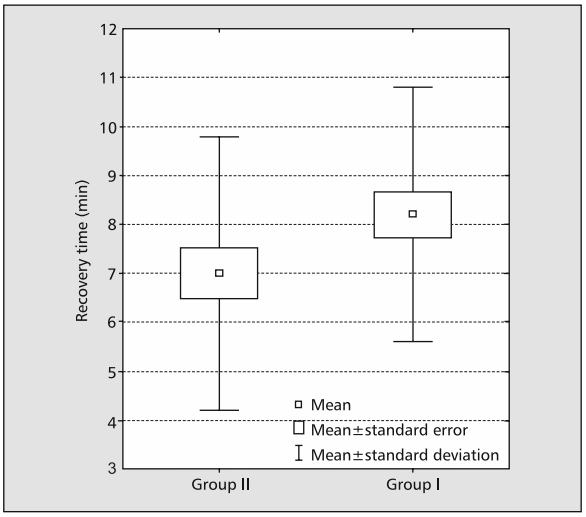

Figure 4. Comparison of mean recovery times in the study groups

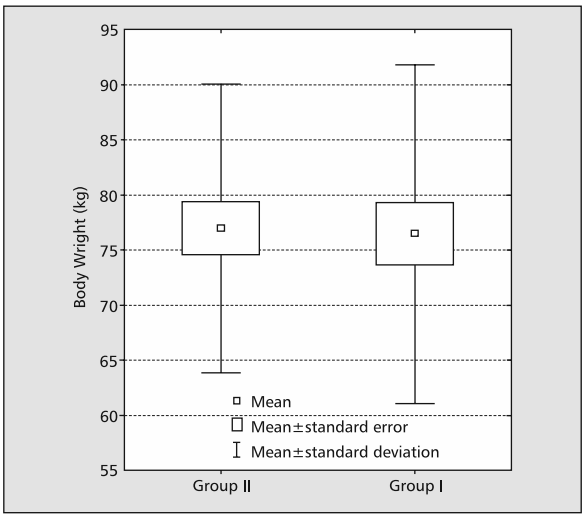

Figure 2. Comparison of mean body weights in the study groups

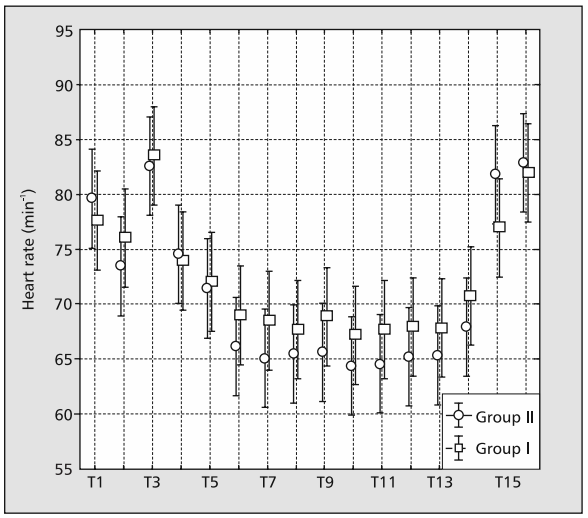

Figure 5. Comparison of mean HR values during anaesthesia in the study groups

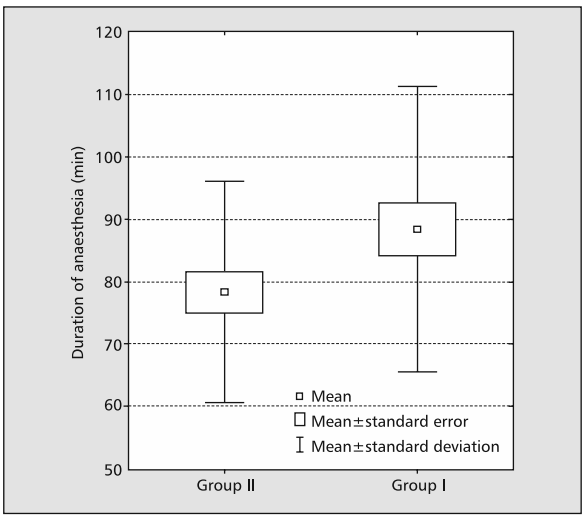

Figure 3. Comparison of mean durations of anaesthesia

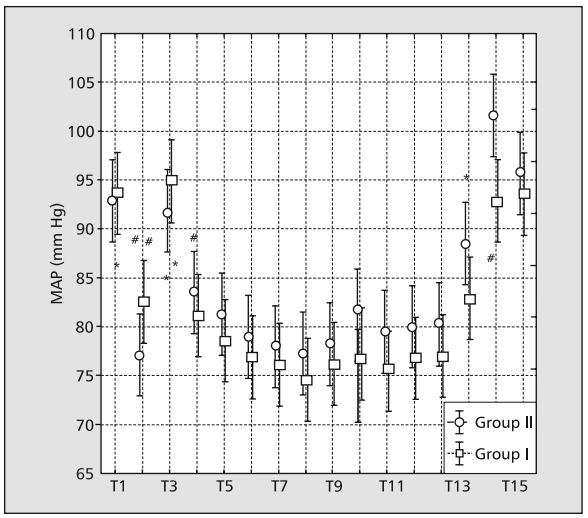

Figure 6. Comparison of mean MAP values during anaesthesia in the study groups; *P <0.05, #P < 0.05 T1-T2, T2-T3, T3-T4 and T14-T15 respectively, for the groups I i II

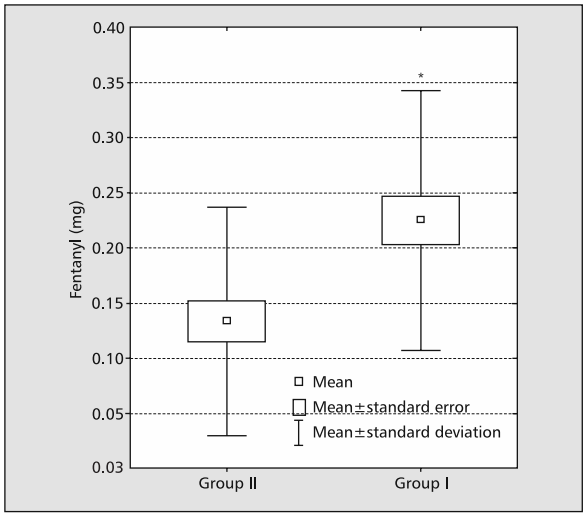

Figure 7. Comparison of mean total fentanyl doses in the study groups. *$P < 0.05$

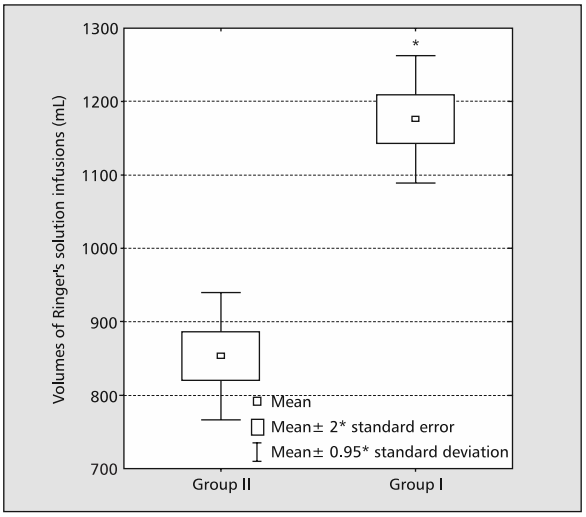

Figure 9. Comparison of mean volumes of Ringer's solution infused in the study groups. *$P < 0.05$

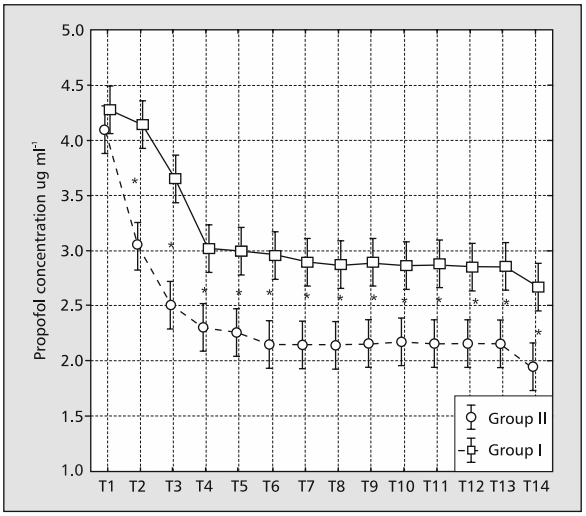

Figure 8. Comparison of mean programmed serum concentrations of propofol at individual measurement points in the study groups *$P < 0.05$

rum concentration of propofol of 3-4 μg mL^{-1} supplemented with 2 μg kg^{-1} of fentanyl ensures cardiovascular stability. Using a continuous infusion of propofol to ensure a serum concentration of 3.4 μg mL^{-1}, Albertin and colleagues [23] maintained the BIS within the range of 40–50, which is consistent with our findings.

Many authors report that it is necessary to monitor the depth of anaesthesia using the BIS to avoid episodes of awareness during critical moments of surgery [24, 25]. Our findings demonstrate that BIS monitoring reduces the dose of opioids and intravenous hypnotics used in anaesthesia, which is consistent with the results reported by other authors [26]. By performing BIS monitoring during general anaesthesia, the doses of drugs can be rationally adjusted to meet the needs of individual patients; hence, the side effects can be limited.

The higher volumes of infused fluids observed in the BIS monitoring group in this study may be associated with a higher rate of propofol infusion. In addition to the economic aspects, BIS-guided anaesthesia increases the comfort and safety of patients undergoing surgery [27, 28].

It is important to note that the BIS has a lower diagnostic value with inhalational hypnotics, particularly in children [28, 29]. Moreover, diseases of the CNS modify the value of BIS in response to intravenous hypnotics [30].

CONCLUSION

BIS monitoring reduces the levels of opioids and hypnotics administered during total intravenous anaesthesia using TCI.

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Received: 10.04.2014
Accepted: 11.06.2014