International Journal of Research in Medical Sciences
Isik B et al. Int J Res Med Sci. 2017 Mar;5(3):1015-1020
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: http://dx.doi.org/10.18203/2320-6012.ijrms20170654

Original Research Article

A comparison of the effects of desflurane and total intravenous anaesthesia on the motor evoked responses in scoliosis surgery

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Received: 26 December 2016
Revised: 05 February 2017
Accepted: 08 February 2017

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ABSTRACT

Background: In the present study, we compared the effects of total intravenous anaesthesia (TIVA) and desflurane anaesthesia on tcMEPs in scoliosis surgery.
Methods: The study included 45 patients between the ages of 18 to 50 years, and classified as ASAI-II; which were planned to undergo posterior fusion/instrumentation operations for elective scoliosis. Anaesthesia was maintained using 50-150 mcg/kg/min propofol in Group T(TIVA), and desflurane (0.5 MAC) in Group D, and with infusions of 0.05-0.3 mcg/kg/min remifentanil at 50 % O2 + air in both groups, by applying drugs at doses so that bispectral index (BIS) would be maintained between 40 and 60 throughout the course of anaesthesia. The tcMEP responses were measured four times during the operation, and BIS, train-of-four (TOF), mean arterial pressure (MAP), heart rate(HR), and end tidal CO2(ETCO2) values were recorded simultaneously. In both group the anaesthesia was ended at the final surgical suture. The recovery parameters were recorded.
Results: The groups were found not to differ regarding the demographic characteristics, duration of the anaesthesia and the surgery, remifentanil dosage, tcMEP, the simultaneously recorded TOF, MAP, HR and ETCO2 values, and the amount of perioperative bleeding. The cooperation time and the orientation time were shorter in group D. The tcMEP responses were recorded in the appropriate times and amplitudes in both groups.
Conclusions: TIVA is primarily used in routine applications in spinal surgery; however our study results revealed that 0.5 MAC desflurane may also be safely used in association with remifentanil, with the resultant correct tcMEP responses.

Keywords: Desflurane, Motor evoked potential, Scoliosis, TIVA

INTRODUCTION

Scoliosis, which is a lateral curve in the spine combined with a rotation of the vertebrae, is a serious malformation that over time causes anatomical disorders in the thorax, which may lead to systemic problems like pulmonary hypertension, right-sided heart failure and respiratory failure. Scoliosis can be repaired using a surgical approach. The frequency of scoliosis surgery has been progressively increasing with developments in technology. This increase is associated with an increase in the rate of complications.[1]

Neurological damage may develop in the medulla spinalis during the course of scoliosis surgery, because of ischemia in the neural structures that specifically results from mechanical compression and/or vascular strain. Primarily, the intraoperative arousal test (wake up test)

was applied, in order to avoid this problem, to make an early diagnosis, and to prevent the causes in an early phase. This was followed by the records of somatosensory evoked potentials (SSEPs) and transcranial motor evoked potentials (tcMEPs).[2]

Evoked potential may be defined as the change in the electrical activity of central nervous system, developing as a response to an external stimulus. tcMEP monitoring for scoliosis surgery made it easy to directly evaluate the motor pathways in medulla spinalis, in order to determine neurological damage that may develop in the intraoperative periods.[3,4] There are various factors affecting tcMEP responses, some of which are as follows: hypothermia, hypoxia, hypo-hypercapnia, isovolemic hemodilution, controlled hypotension, blood loss, and anesthetic methods. There are studies demonstrating that they are mostly depressed by anesthetic agents like neuromuscular blockers, inhalation anesthetics, and nitrogen protoxide, and less affected by total intravenous anaesthesia (TIVA).[5,6]

The purpose of this study was to compare the effects of TIVA and inhalation anaesthesia method applied by desflurane for scoliosis surgery, on transcranial motor evoked potentials (tcMEPs)

METHODS

The study included 45 patients between the ages of 18 to 50 years, and classified as ASA I-II; the patients were planned to undergo posterior fusion and instrumentation surgery for elective scoliosis, in the Haydarpaşa Numune Teaching and Research Hospital. Patients with neurological sensory and/or motor deficit, loss of an extremity, cardiovascular, pulmonary, renal, hepatic, gastrointestinal or neuromuscular disease, and history of chronic alcohol use, and a defined allergy to remifentanil or propofol were excluded from the study. A hemoglobin value above 8, was taken into consideration for being included.

Patients existing with hemodynamic instability during surgery (those who require infusions of inotropic vasopressor and peripheral vasodilator), were excluded from the study. The informed consents of the patients were obtained prior to the operation. Premedication was administered with 0.5 mg IM atropine, and 10 mg IM diazepam, 30 minutes before the operation.

Electrocardiography (ECG), systemic blood pressure and peripheral oxygen saturation (SpO2), bispectral index (BIS Vista Monitoring 2013-USA) were monitorized in the operation room. Basal values of the heart rate (HR), systolic and diastolic blood pressures, and the systolic, diastolic, mean blood pressure (SBP, DBP, and MBP) were recorded. Intravenous cannulation was applied in two veins in all patients, to provide venous access, using 18-20 G cannulas. Cases were randomized, and grouped in two in the operation room, using the computerized simple random sampling method.

Anaesthesia was induced in both groups by the intravenous administration of 2 mcg/kg fentanyl + 2-2.5 mg/kg propofol + 0.5 mg/kg rocuronium. Anaesthesia was maintained using 50-150 mcg/kg/min propofol in group T (TIVA, n=22), and 0.5 MAC desflurane in group D (Desflurane, n=23), and with infusions of 0.05-0.3 mcg/kg/min remifentanil at 50 % O2+air in both groups, by applying drugs at doses so that BIS values would be maintained between 40 and 60 throughout the course of anaesthesia. TOF was monitored on the ulnar nerve trace. The peripheral temperature was followed-up via temperature probe of the TOF device. End-tidal carbon dioxide (ETCO2) values were monitorized. The tcMEPs were recorded by the same technician in each case, using the Nim Spine Model (USA, 2003) device. For this procedure, specific electrodes (stimulating electrodes) were placed bilaterally on the tibialis anterior, heads of the gastrocnemius medialis and lateralis, rectus femoris and quadriceps muscles of the patients.

Control electrodes were appropriately placed on the biceps muscle and scalp, considering the application principles of the device. The tcMEPs were recorded four times in each patient (before surgical insicion, two times when the operation team required, the end of the surgery) and more than that in some cases if required; the initial recording was performed just before the surgical incision, to observe the basal level. Motor evoked potential measurement time and the graphical values of tcMEP were recorded. The TOF responses were investigated in correlation with the tcMEP measurements, before the related technician observed the tcMEP responses. The measurements were allowed to be applied after the patient was determined not to be curarized. (TOF ratio > 3) TOF values were recorded.

When the systolic arterial pressure was found to have increase by 30 % of the basal level, the BIS value of the patient was checked; bolus IV nitroglycerin at a dose of 100 mcg/ml was administered following exclusion of the anaesthesia level and arousal signs. When the heart rate was determined to be 50/min, other hemodynamic parameters of the patient were also controlled. When bradycardia was found to affect the patient's hemodynamics, and the mean arterial pressure was lower than 30 % of the basal level, the patient was administered 0.5 mg of IV atropine.

The HR, SBP, DBP, MBP, SpO_2, $ETCO_2$ and BIS values were recorded in both groups at five-minute intervals within the first 20 minutes with the start of anaesthesia induction, and at 15-minute intervals thereafter; BIS, TOF, HR, MAP, and end-tidal CO2 values were recorded also simultaneously with each of the four recordings of the tcMEP responses.

All operations were performed by the same surgical team. The tcMEP measurements were repeated by the relevant technician when the operation team required, and the team was informed about the analysis of these tcMEP recordings. Additional doses of rocuronium were administered, depending on the clinical signs and TOF measurement values (TOF > 3), when it was not required for the tcMEP responses to be investigated.

Anaesthesia applications were concluded in both groups with the final skin suture. When the TOF 2 response was observed; 0.01 mg/kg atropine and 0.03 mg/kg neostigmine were administered for decurarization. Times of extubation, response to verbal stimulus, cooperation, orientation, and an Aldrete score of above nine, were recorded in the patients. After the patients were oriented, they were evaluated in the post-operative recovery room, by simple questions related to their perioperative arousal and consciousness (Did you wake up during the operation? Did you hear any noise? Did you understand what you heard?).

Power analysis

Power analysis performed by using power and sample size program, sample size was determined to be minimum n:14 for each group detected for Power:0.80 and α:0.05.

Statistical analysis

Statistical analyses were performed using the SPSS 21.0 statistical software.

The categorical data were compared using the Pearson Chi-square and Fisher's exact tests. Parameters were compared between the groups by Mann Whitney U test.

The results were evaluated within a 95% confidence interval; p <0.05 was accepted to be significant, and p <0.01 or <0.001 were accepted to be highly significant.

RESULTS

The groups did not differ with regard to the age, weight, BMI, ASA, and the quantity of perioperative bleeding. The duration of anaesthesia did not differ between the groups. The total remifentanil dosing did not differ between the groups (Table 1). The groups did not differ regarding TOF value (Table 2). Beginning from the onset of anaesthesia, the duration of the tcMEP measurements did not differ between the groups. All the tcMEP measurements were associated with positive responses (Table 3). The post-operative evaluation of the cases did not reveal any sign related with consciousness throughout the course. The cases did not differ with regard to side-effects. None of the patients were determined to have a neurological deficit. The extubation time, time for response to a verbal stimulus, and an Aldrete score of >9, did not differ between the groups.

Table 1: Demographic properties.

	Group T (Mean±SS)	Group D (Mean±SS)	P
Age (year)	25.9±7.8	22.7±6,4	0,064
Weight(kg)	58±10,4	64±12.9	0,102
Body Mass Index (BMI)	21.7±2.7	22.5±4.4	0,594
ASA I	18.2 %(4)	30.4 % (7)	X^2=0.914
ASA II	81.8 % (18)	69.6 % (16)	p=0.339
Duration of Anesthesia (min)	219.4±27.1	216.7±32.4	0.716
Total doses of remifentanyl (mgr)	2.76±1	3.3±1	0.121
Bleeding Value(ml)	403.6 ±151.8	394.7±123.1	0.689

Table 2: TOF ratio at the same time of tcMEP.

	Group T (Mean±SS)	Group D (Mean±SS)	P
TOF1	3.7±1.7	4±0	0.114
TOF2	3.5±1	4±0	0.301
TOF3	3.6±1.1	4±0	0.662
TOF4	4±0	4±0	-

The mean time for cooperation, beginning from the end of anaesthesia in group T was significantly longer than that of the patients in group D (p=0.03).

Table 3: Time of the tcMEP (minute).

Time of the	Group T (Mean±SS)	Group D (Mean±SS)	P
tcMEP 1	24.6±5.8	23.6±8.1	0.900
tcMEP 2	122.8±22.3	123.9±24	0.407
tcMEP 3	139.4±20.6	146.9±22.7	0.247
tcMEP 4	189.2±40.2	195±43.2	0.509

Table 4: Properities of the recovery.

Time of the	Group T (Mean±SS)	Group D (Mean±SS)	P
Extubation (min)	11.9±6.4	9.4±5.9	0.111
Verbal (min)	15.9±8.1	14.2±10.3	0.133
Cooperation (min)	18.5±9	14.9±10.8	0.030*
Orientation(min)	21±10.8	15.3±10.8	0.012*
Reach Aldrete> 9	17.6±8.8	15.3±10.7	0.133

The mean time for orientation beginning from the end of anaesthesia in group T was found to be significantly longer than that of group D (Table 4). The questioning in recovery room performed for the perioperative arousal, did not reveal any sign related to the perioperative consciousness, in either group.

DISCUSSION

In spinal surgery, it is very important to decrease the neurological complications like spinal cord damage to minimal levels, with regard to the surgical and anaesthesiological approaches. Neuromonitarization exists as an important procedure in this respect.[7] Considering the results of a retrospective analysis including 60,366 cases, the Scoliosis Research Society and the European Spinal Deformity Society recommended to their members in 1991, to use SSEPs during intraoperative monitorization for spinal surgery.[8]

SSEPs alone are inefficient for the detection of deficits in the motor pathway and it is for this reason transcranial motor evoked potentials (tcMEPs) have been widely used in recent years. In monitoring the ventral spinal cord, tcMEP can be used. It can be used in the early diagnosis of patients who may develop postoperative motor deficits, if its sensitivity and specificity are adequate; this issue is one of the advantages of using tcMEPs instead of SSEPs, for the monitorization of the spinal cord.[3,9] tcMEP monitorization, applied for decreasing intraoperative and post-operative neurological deficits in the course of high-risk and long-lasting scoliosis surgery, requires an appropriately developed method of anaesthesia, to achieve good consequences.[10] tcMEP responses are affected and inhibited by anaesthetic agents like neuromuscular blockers, inhalation anaesthetics, and nitrous oxide; however, these responses are known not to be affected by the TIVA method.[11,12] When inhalation anaesthetics were investigated, studies demonstrated that sevoflurane and isoflurane in particular depress the amplitudes of tcMEPs in a dose-dependent manner.[13,14]

In a prospective study of Lo et al. conducted with desflurane, one study group was administered desflurane anaesthesia, the other was applied TIVA (propofol), and both groups were also given morphine when required; in this study, the proper tcMEP responses were recorded in both groups.[15] In this method of tcMEP measurement, being different from the routine applications, they used 60% nitrous oxide in the desflurane group, and maintained the end-tidal concentration of desflurane between 3.4% and 4.3% . tcMEPs were followed-up in a retrospective study of Sloan et al and they formed two groups of cases, as the TIVA (propofol-opioid) and desflurane (3%) (with 50% air) groups; additionally, opioid or propofol was administered in these groups.[10] When the groups were compared regarding the tcMEP and SSEP responses, no statistically significant differences were detected. The retrospective nature of the study, and non-randomized sampling of the patients may be considered as limitations to this study. In light of the results, the authors have concluded that desflurane at 3% concentration had similar effects on tcMEPs with those of the TIVA application, and it might be used safely, with the suggestion of confirming these results by prospective and randomized studies performed on this subject. In one study group, we also applied desflurane at a concentration so that 0.5 MAC would be maintained, and with 50% O_2 and air. Propofol acts only on the GABA-A receptors; however, desflurane has various ways of acting: on the pre-post synaptic NMDA receptors, on the nAch sodium and potassium channels, increasing the inhibition of glycine, activating the serotonin type 3 receptors, and interacting with the hydrophobic region of the cell membrane Na-K-ATPase channels. For these reasons, desflurane is an anaesthetic agent that can maintain sufficient amnesia and anaesthesia levels at a low MAC (0.5 MAC).[16-18]

The tcMEP responses in our study were sufficient in the estimated time and amplitudes, in both of the TIVA and desflurane groups. We did not determine neurological deficit in our patients in their intraoperative, and postoperative, controls. Specifically, TIVA applied with propofol is preferred, since it does not affect the tcMEP measurements; however, there are also studies demonstrating that tcMEP responses are affected by propofol. In the study of Nathan et al. in the patients with scoliosis, whom they followed-up, propofol administered by target-controlled infusion decreased the amplitudes of tcMEPs, in a dose-dependent manner.[19] The authors also claimed that it is important to know well about these effects of propofol before surgery, with regard to the accurate evaluation of tcMEP responses. In a study performed on anaesthesia in scoliosis surgery, lidocaine was added to the propofol infusion in order to decrease the concentration levels of propofol, and cortical SSEPs and tcMEPs were found not to differ significantly.[20] In another two studies, similarly conducted, propofol and dexmedetomidine infusions were administered together, and dexmedetomidine was recommended to be used as a TIVA component associated with propofol, in spinal cases who undergo neurological monitorization.[21] Suvadeep et al have reported that dexmedetomidine-added TIVA leads to a radical lowering of propofol concentrations, with the subsequent occurrence of the required depth of anaesthesia without any complication, and with the correct tcMEP and SSEP data.[22] In recent studies it has been determined that tcMEP responses decreased in a dose-dependent manner when only remifentanil was administered as a single agent. During an infusion of 0.35 mcg/kg/min in half of the patients, tcMEP values were found to decrease by 50% below the basal level.[23] In Present study, 0.05-0.3 microg/kg/min remifentanil was administered by infusion in both groups, and responses occurred in the appropriate time and quantities in both groups. We used a combination of propofol and remifentanil in the TIVA group. We maintained the control of the depth of anaesthesia by BIS monitarization, with the resultant optimization of drug doses; thus, we avoided the use of drugs in high concentrations. The 1st, 2nd, 3rd, and the 4th measurements of tcMEP, and the simultaneously measured corresponding values of BIS (1, 2, 3, and 4), were found to be lower in the TIVA group; however, BIS values in all the patients were within the limits of the anesthetic interval (BIS:40-60) for which we

had aimed. In addition to the anesthetic methods, hypothermia, hypoxia, hyper/hypocapnia, hypotension, structural damage of the medulla spinalis, acute spinal stretching, pressing on nerves, medulla spinalis ischemia, isovolemic hemodilution, controlled hypotension, blood loss, and anemia are other factors that affect tcMEP responses.[24,25]

Changes in temperature can lead to changes in the latency of MEP responses. In various animal studies, the latencies of tcMEP responses during hypothermia were found to be increased linearly with the increase in temperature. However, despite these temperature effects on tcMEPs, the duration in which to perceive the spinal cord ischemia in hypothermia was found not to differ, compared with the normothermic group.[26] We did not determine hypothermia in our cases during their temperature follow-ups performed with TOF. We have limited knowledge about the effects of hypoxia on the tcMEP responses in humans. However, in experimental studies conducted with animals, amplitudes of tcMEPs did not change until the saturation of inhaled O2 decreased to a level of 10%, and amplitudes began to decrease at saturations lower than this value.[27] SPO_2 levels in our study did not show any decline. Hyper-hypocapnia are known to have a depressive effect on cortical activity, and the anterior horn. However, changes in the tcMEP waves do not cause any significant sign, except when CO_2 levels reach extreme values. In animal studies, this level of $PaCO_2$ was determined to be higher than 70 mmHg. When the effects of hypocapnia were investigated in studies conducted with animals and humans, values of $ETCO_2$ occurring between 13 mmHg and 30 mmHg, did not cause any change in the tcMEPs.[28] In our study, $ETCO_2$ values, determined simultaneously with the tcMEP recordings, were found to be slightly hypocapnic throughout the course. As mentioned above, this value interval does not have any significant effect on the tcMEP.

Changes in tcMEPs occur when the mean arterial pressure declines below the level of 50 mmHg.[29] We have not applied standard controlled hypotension in our patients, that was coordinated with the surgical team; moreover, the mean arterial pressure values were simultaneously measured with the tcMEP responses, and the MAP levels were maintained between 80 mmHg and 90 mmHg in both groups. Nevertheless, the amount of bleeding was at an optimal level, and no difference was determined between the groups. The hemodynamic course (SBP, DBP, MBP, HR) during surgery was stable in both groups. Considering the anaesthesia protocol, and when BIS responses occurred in anaesthesia levels, bolus dose IV nitroglycerin 100 mcg/ml was administered when the SBP increased by 30% above the basal level. In both groups, the mean doses of nitroglycerin applied were within clinically acceptable levels (group T:358.3±220, and group D: 300±244.9). Similarly, 0.5 mg IV atropine was administered when the HR was <50/min. Bradycardia, and repetitive atropine administrations in the same patient, occurred more frequently in group D. Atropine applications occurred in a significantly higher frequency in group D, and this value also included the repetitive atropine doses applied to the same patient; in group D, 0.5 mg atropine was administered twice in three cases, at different times. The bradycardic effect of remifentanil, which was added to maintain the concentration of desflurane at 0.5 MAC, was more effective in group D. Remifentanil doses used in group D were found to be slightly higher; however statistically significant difference was not determined between groups regarding the remifentanil dose.

During cases of spinal surgery associated with neuromonitarization, TIVA is primarily preferred in routine applications, due to its safety; however, the results of our study revealed that the desflurane application at 0.5 MAC value, associated with remifentanil, may also be used safely with the occurence of the correct tcMEP responses. Both procedures are appropriate for the measurement of tcMEPs; however, signs of early recovery concommitant with desflurane anaesthesia, may be considered as advantageous. This fact results in our use of desflurane anaesthesia in our daily practice in the doses that we have recommended, as an alternative to TIVA.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Isik B, Turan G, Abitagaoglu, Ekinci O, Özgültekin A. A comparison of the effects of desflurane and total intravenous anaesthesia on the motor evoked responses in scoliosis surgery. Int J Res Med Sci 2017;5:1015-20.