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Original Article

Comparison of propofol and desflurane for postoperative neurocognitive function in patients with aneurysmal subarachnoid hemorrhage: A prospective randomized trial

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ABSTRACT

Background: Following aneurysmal subarachnoid hemorrhage, 40–50% of survivors experience cognitive dysfunction, which affects their quality of life. Anesthetic agents play a pivotal role in aneurysm surgeries. However, substantial evidence regarding their effects on neurocognitive function is lacking. This study evaluated the effects of propofol and desflurane on postoperative neurocognitive function and serum S-100B levels.

Methods: One hundred patients were equally randomized to receive either propofol (Group P) or desflurane (Group D). Cognitive function was assessed using the Montreal Cognitive Assessment scale at three different time points: Preoperatively, at the time of discharge, and one month after surgery. Perioperative serum levels of S-100B were also measured.

Results: The preoperative mean cognitive score in Group P was 21.64 + 4.46 and in Group D was 21.66 + 4.07 ($P = 0.79$). At discharge, a significant decrease in cognitive scores was observed compared to preoperative scores (Group P- 20.91 + 3.94, $P = 0.03$ and Group D-19.28 + 4.22, $P = 0.00$); however, scores were comparable between the two groups ($P = 0.09$). One month following surgery, mean cognitive scores were 22.63 + 3.57 in Group P and 20.74 + 3.89 in Group D, and the difference was significant ($P = 0.04$). Higher memory and orientation scores were observed in Group P than in Group D at one month ($P < 0.05$) in the subgroup analysis. Both groups had similar serum S-100B levels.

Conclusion: The mean cognitive scores one month after surgery improved significantly with propofol compared with desflurane, but without clinical significance. Individual domain analysis demonstrated that orientation and memory scores were better preserved with propofol.

Keywords: Aneurysmal subarachnoid hemorrhage, Desflurane, Montreal cognitive assessment test, Postoperative cognitive function, Propofol, S-100B

INTRODUCTION

Spontaneous rupture of intracranial aneurysm leads to aneurysmal subarachnoid hemorrhage (aSAH). Affected patients develop a neurocognitive deficit in the postoperative period leading to the inability to restitute their daily routine.[12] Apart from aSAH *per se*, other factors leading to cognitive dysfunction are surgical factors (excessive intraoperative brain retraction, parent vessel occlusion, and poor collateral blood flow), anesthetic agents, and postoperative vasospasm.

Anesthetic agents may affect a patient's cognitive function postoperatively due to their inherent action at multiple sites in the brain, which may alter neuronal activity. There is a dearth of literature on the effect of anesthetic agents on neurocognitive functions in such patients. Propofol is a widely preferred agent in neurosurgery because it decreases the cerebral metabolic rate of oxygen consumption ($CMRO_2$) and cerebral blood flow (CBF) and maintains cerebrovascular reactivity to carbon dioxide.[1,26] Desflurane is an inhalational anesthetic agent with a low blood-gas partition coefficient, which facilitates faster recovery and rapid extubation and simultaneously allows early assessment of neurological status after surgery. Furthermore, it decreases $CMRO_2$ and preserves cerebrovascular reactivity.[18] Hence, desflurane is currently used in neurosurgery.

A pilot trial has shown better cognitive functions with propofol compared to desflurane in aSAH patients at discharge.[24] According to another study, desflurane is associated with hyperemia compared to propofol.[5] Nevertheless, the pharmacological effects of anesthetic agents on long-term cognitive function have not been studied in aSAH patients. Therefore, we hypothesized that neuroprotection provided by propofol would result in better preservation of postoperative cognitive functions than desflurane. Thus, the present study was planned to compare the effects of propofol and desflurane on postoperative cognitive function in patients undergoing surgical clipping following aSAH one month following surgery. The primary outcome of the study was an assessment of cognitive function at one month following surgery. Assessment of cognitive function at discharge from the hospital and comparison of a surrogate biomarker of cognitive function (S-100B) were secondary outcomes of the study.

MATERIALS AND METHODS

The prospective randomized comparative study was conducted after obtaining approval from the Institutional Ethical Board over 1½ years (INT/IEC/2015/741 dated 19/11/2015). The trial has been registered with a clinical trial government registry (Clinical Trials.gov with a unique identifier: NCT02987218/2016). The written informed consent was obtained from all enrolled patients. The patients scheduled for surgical clipping of aSAH with clinical and radiological evidence of cerebral aneurysm between 18 and 65 years of either sex or World Federation of Neurosurgeon (World Federation of Neurosurgical Societies) grades 1 and 2 were included in the study. Preoperatively, patients with known psychiatric illness, a history of drug abuse, low level of education (illiterate), or multiple failures in school and multiple surgeries were excluded from the study. Intraoperative complications such as massive blood loss, prolonged clipping time (>20 min), severe intraoperative brain swelling precluding replacement of bone flap, and postoperatively, unconscious, intubated, or tracheostomized patients were also excluded from the study. Figure 1 shows the allocation of the patients in each group.

Randomization and blinding

A total of 100 patients were randomized into Group P and Group D using a computer-generated random number algorithm. These random numbers were kept sequentially in numbered opaque envelopes, and concealment was done by an anesthesiologist who was not involved in the assessment of cognitive functions. The person assessing cognitive functions (clinical psychologist) was blinded to a study drug.

Anesthesia protocol

The standard general anesthesia technique as per institutional protocol was followed. Standard monitors applied were 5-lead electrocardiography, noninvasive automated blood pressure, pulse oximetry, capnography, and entropy. Induction of anesthesia was carried out with propofol in titrated doses. Vecuronium 0.1 mg/kg was used to achieve muscle relaxation. Intraoperative analgesia was achieved with fentanyl two μg/kg bolus followed by 0.5–2 μg/kg/h infusion. Subsequently, as per the randomization, patients were maintained on either propofol or desflurane along with oxygen/air (50/50) and titrated to keep state entropy in the range of 40–60. Mannitol 0.5 g/kg was administered in both groups. Fentanyl infusion was stopped at the beginning of scalp closure whereas the maintenance agents were stopped at the time of application of staples for skin closure. At the end of anesthesia, residual neuromuscular blockade was reversed using neostigmine 50 mcg/kg and glycopyrrolate 10 mcg/kg. Subsequently, patients were extubated, and those who were not extubated were shifted to a neurosurgical intensive care unit for further management.

Intraoperatively, hemodynamic parameters, end-tidal carbon dioxide, and entropy were measured. Intraoperative aneurysm rupture and temporary clipping time were also noted.

The duration of postoperative mechanical ventilation and hospital stays were recorded. Postoperative complications

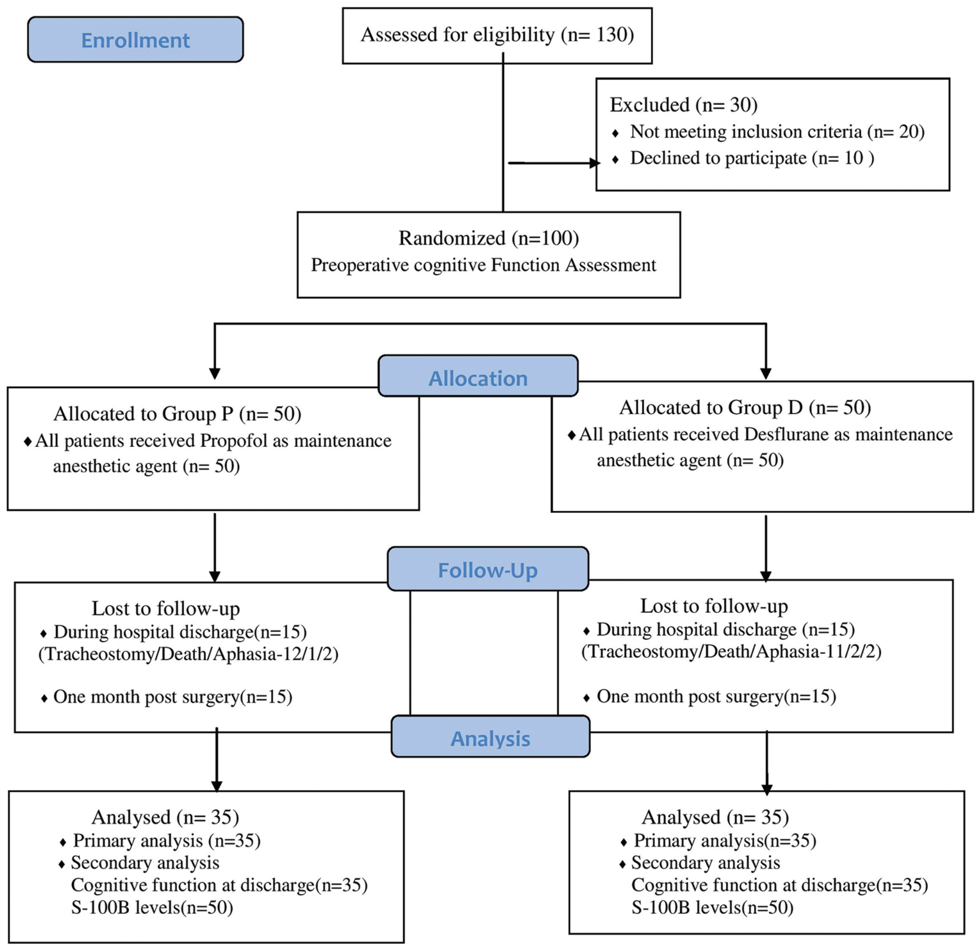

Figure 1: CONSORT flow diagram showing patient recruitment in the study.

such as vasospasm, hydrocephalus, infarction, ventilator-associated pneumonia, and rebleeding were also noted.

Cognitive function assessment

The cognitive functions were assessed using a Hindi version of the Montreal Cognitive Assessment (MoCA) test, a 30-point scale that includes executive functions, orientation, naming, attention, abstraction, and delayed recall.[21,30] A score of ≥26 is considered as normal. The cognitive impairment is considered if the score is either 25 or <25. An assessment of cognitive functions was done at three intervals: preoperatively, postoperatively (at the time of discharge), and one month following surgery. Following changes to MoCA were incorporated considering the convenience and familiarity of our patient population. The picture of the rhinoceros was replaced with an elephant in the naming section; the Hindi word K was used instead of the English word A in the reading column, and to name maximum words started with alphabet F in the fluency segment, alphabet M was used. For assessment of delayed recall and language, words and sentences in the Hindi language were used.

Biomarker S-100B

S-100B levels were measured in serum. Arterial blood samples were collected in plain BD (Becton Dickson) vacutainer. Blood was left undisturbed at room temperature for 30 min. After that, centrifugation of the sample was carried out at 2500 rotation/min for 10 min, and the supernatant was collected. Serum samples were stored at −80° C. Sandwich enzyme-linked immunosorbent assay (ELISA) was performed using precoated ELISA KIT YH Bio search (Cat No-YHB3336Hu) for S-100B (Human). Serum S100B levels were measured preoperatively, intraoperatively after clipping of the neck of the aneurysm, and one h postoperatively.

Sample size calculation

The sample size was estimated based on the mean difference of 3.7 in POCD scores between the propofol group when compared to the desflurane group with a standard deviation (SD) of 5.[24] The sample size came out to be 35 subjects per group at a power of 80% and a confidence interval of 95%.

Adjusting for possible dropouts and mortality in aneurysmal patients, we included 50 patients per group.

Statistical analysis

Normality of quantitative data was checked using measures of Kolmogorov–Smirnov test. The variance analysis of repeated measurement data was applied for statistical treatment. All measured data were expressed as mean ± SD. The means have been compared using unpaired *t*-tests between groups. Paired *t*-test was used in comparison in each group. Categorical variables were analyzed using the Chi-square test and presented as numbers and percentages. All calculations were two-sided and were performed using the Statistical Package for the Social Sciences Inc., version 22.0 for Windows, Armonk, NY, USA. The "*P*" value <0.05 indicates that the difference has been statistically significant.

RESULTS

In this study, 100 patients were enrolled and randomized equally into two groups – Group P and Group D. However, data were analyzed for 70 patients (Group P [n = 35], Group D [n = 35]) at 1-month follow-up for the primary outcome of the study [Figure 1]. The demographic characteristics, intraoperative data, and postoperative parameters were comparable in both groups [Table 1]. Intraoperative hemodynamic parameters such as mean heart rate and mean arterial blood pressure were comparable in both groups [Figure 2].

Cognitive functions

The preoperative cognitive function and that at the discharge from the hospital were similar between Group P and Group D. However, one month following surgery, cognitive functions were significantly better with the use of propofol compared to desflurane [Table 2].

During preoperative assessment, the mean cognition score in Group P and Group D was not different (P = 0.79). At the time of hospital discharge, the mean cognition score decreased in both groups and was comparable (P = 0.09). One month following surgery, mean scores were higher in Group P (22.63 ± 3.56) compared to Group D (20.74 ± 3.89) (P = 0.04) [Table 2].

Subgroup analysis of individual domains of cognitive functions within the group (intragroup) revealed no difference in domains such as executive functions, naming, language, and abstraction in both groups [Figure 3]. However, mean orientation scores in both groups were reduced at the time of hospital discharge when compared to preoperative scores but gradually improved and reached baseline values at 1-month postsurgery assessment (P = 0.00). In Group P, mean memory scores decreased at the time of discharge (2.54 ± 0.24) and gradually increased to 3.09 ± 0.21 at one month postsurgery (P = 0.03).

Table 1: Demographic, intraoperative, and postoperative characteristics.

Patient characteristics	Group P (*n*=50)	Group D (*n*=50)	*P*-value
Age (years)	46.64+11.42	44.36±11.81	0.47
Weight (kg)	63.65±9.33	63.26+10.11	0.89
Sex (M/F)	25/25	22/28	0.34
Education status (>12 years/6–12 years)	20/30	25/25	0.21
Coexisting illness (hypertension/diabetes mellitus/hypothyroidism)	20	19	0.97
Site of aneurysm (ACom/MCA/DACA/ICA/PCom)	24/13/6/7/0	14/19/4/11/2	0.13
Fischer grades (I/II/III/IV)	3/8/28/11	5/9/23/13	0.75
WFNS grade (I/II)	39/11	40/10	0.80
Anesthesia time (minutes)	228.50±34.42	220.19±30.17	0.42
Surgery time (minutes)	185.10±35.32	181.12±34.24	0.51
Brain swelling at dura opening (Grade-I/II/III/IV)	20/15/11/4	17/13/12/8	0.62
Brain swelling at dura closure (Grade-I/II/III/IV)	38/12/0/0	34/13/03/0	0.12
Temporary clipping time (sec)	281.55±41.76	363.3±46.53	0.44
Intraoperative hemodynamics Hypotension/hypertension/bradycardia/tachycardia	4/15/8/3	5/7/3/3	0.73/0.06/0.11/1.0/0.82
Intraoperative aneurysm rupture	12 (24%)	13 (26.0%)	0.71
Postoperative complications (Vasospasm/hydrocephalus/infarction/ventilator-associated pneumonia/rebleeding)	19/1/4/5/2	13/2/6//7/2	0.2/0.2/0.3/0.8/0.5
Postoperative mechanical ventilation days	2.38+2.72	2.28+3.53	0.58
Postoperative hospital stay	10.92+3.65	10.56+3.97	0.20

Data were expressed as mean±standard deviation or in number (percentage) of patients, results were analyzed using an unpaired *t*-test. *P<0.05 is statistically significant. None of the demographic, intraoperative and postoperative characteristics are significant. ACom: Anterior communicating artery, MCA: Middle cerebral artery, DACA: Distal anterior cerebral artery, ICA: Interior cerebral artery, PCom: Posterior communicating artery, WFNS: World Federation of Neurosurgical Societies

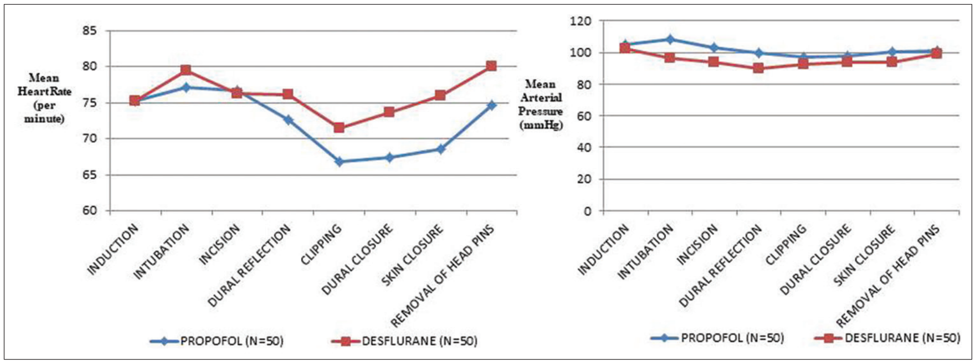

Figure 2: Intraoperative hemodynamics between two groups.

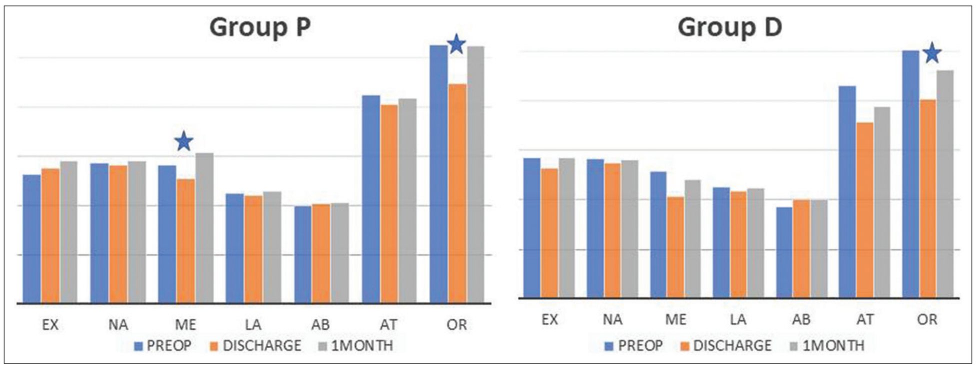

Figure 3: Intragroup individual domain analysis Ex: Executive, NA: Naming, ME: Memory, LA: Language, AB: Abstraction, AT: Attention, OR: Orientation, PREOP: Preoperative. *Indicates statistically significant difference(P<0.05) in the scores at three time points.

Table 2: Mean cognitive scores at different time points using the MoCA test.

Mean cognitive scores	Preoperative (1)	At discharge (2)	One-month postsurgery (3)	*P*-value
Group P	21.64±4.46	20.91±3.941	22.63±3.572	0.00* (1 vs. 2=0.03, 2 vs. 3=0.01, 1 vs. 3=0.97)
Group D	21.66±4.07	19.28±4.22	20.74±3.89	0.00* (1 vs. 2=0.00, 2 vs. 3=0.00, 1 vs. 3=0.41)
P-value	0.79	0.09	0.04*	

Values were expressed as mean±standard deviation. Mean scores between the two groups were analyzed using an independent *t*-test. Mean scores within the group were analyzed using repeated measure analysis of variance with Bonferroni correction. *$P<0.05$ was considered statistically significant.
MoCA: Montreal cognitive assessment

In intergroup analysis of individual domains of cognitive function, we found no difference in mean cognitive scores during the preoperative period and at the time of discharge. However, one month following surgery, we found significantly higher mean scores in memory and orientation domains of cognition in Group P compared to Group D ($P < 0.05$) [Figure 4], while the remaining cognitive function domains were similar between groups at one month following surgery.

Serum S-100B levels (a biomarker of cognitive dysfunction)

In both groups, intraoperative S-100B levels (measured after clipping of the neck of the aneurysm) were significantly reduced compared to the preoperative value ($P = 0.00$). However, postoperative values were not significant compared to the preoperative and intraoperative values ($P = 0.05$) [Table 3].

DISCUSSION

Both intravenous and inhalational agents have been used for the maintenance of anesthesia during neurosurgery. However, the data comparing various anesthetic agents specifically for cognitive function outcomes following surgery for aneurysmal neck clipping after aSAH is limited. Hence, this prospective randomized control trial analyzed cognitive function with inhalational and intravenous anesthetic agents at one month after craniotomy and clipping in aSAH patients. The study observed that both groups' preoperative and postoperative discharge scores were comparable. At

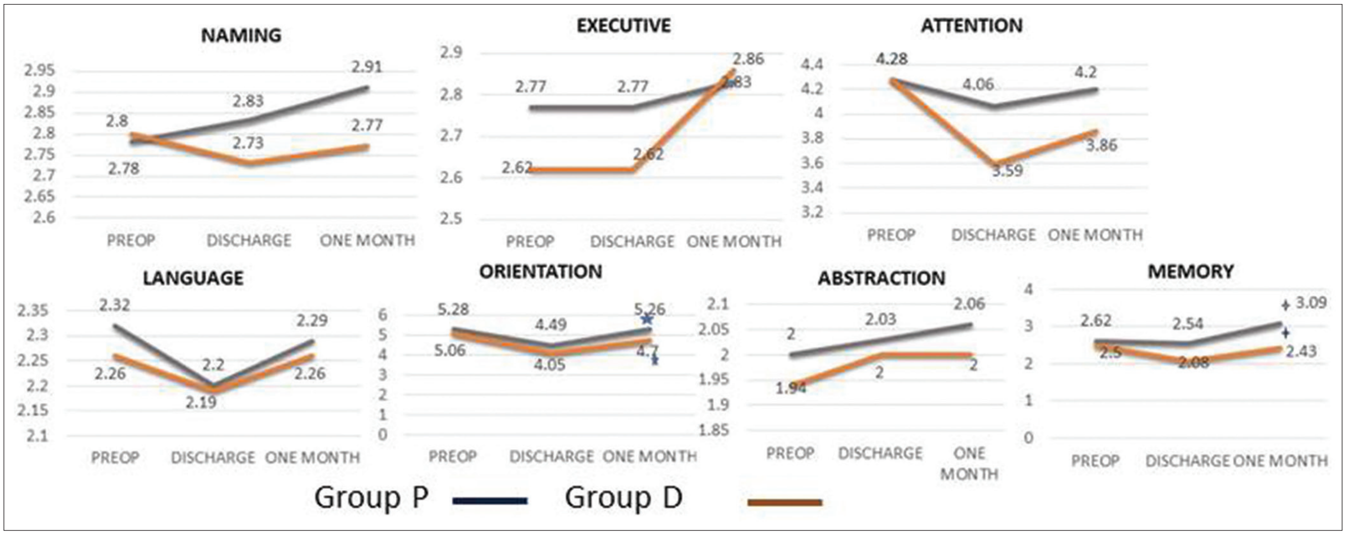

Figure 4: Intergroup individual domain analysis. PREOP: Preoperative.

Table 3: Serum S-1OOB levels (measured as µg/L) at different time points.

	Preoperative (1)	After clipping (2)	One-hour surgery (3)	*P*-value
Group P (*n*=50)	0.56±0.32	0.38±0.24	0.44±0.29	0.00* (1 vs. 2=0.00*, 2 vs. 3=0.67, 1 vs. 3=0.07)
Group D (*n*=50)	0.51±0.34	0.39±0.31	0.38±0.29	0.00* (1 vs. 2=0.00*, 2 vs. 3=1.00, 1 vs. 3=0.06)
P-value	0.46	0.82	0.25	

Values were expressed as mean±standard deviation. Mean scores between the two groups were analyzed using an independent *t*-test. Mean scores within the group were analyzed using repeated measure analysis of variance with Bonferroni correction. *$P<0.05$ was considered statistically significant.

one month following surgery, propofol was associated with statistically improved cognitive scores compared to desflurane, but clinically there is no improvement with either of the anesthetic agents. When we compared individual domains of cognitive function, most domains were comparable except for memory and orientation, which were better with propofol. The markers of neuroinflammation S-100B were also comparable between the two drug groups.

During aSAH, elevated intracranial pressure (ICP) compromises CBF. When these patients are subjected to anesthesia, exposure to propofol decreases cerebral metabolic rate (CMR) by 48–58%, while desflurane decreases CMR by 35%.[18,19,23,27] Hence, the cerebral demand-supply ratio is better maintained with propofol than with desflurane. Consequently, propofol may have a better neuroprotective effect than desflurane, which could have reflected in better statistical cognitive scores with propofol in our study.

Using digital subtraction angiography, the effects of propofol and sevoflurane on the cerebral vasculature of patients undergoing endovascular coiling after aSAH were studied.[13] The authors concluded that the inhalational agents have cerebral vasodilating properties. As compared to propofol, desflurane was associated with cerebral hyperemia in another study.[30] Hence, we propose that an increase in CBF with the inhalational agent (desflurane) in a patient with raised ICP may further jeopardize brain physiology and can have long-lasting adverse effects on cognitive functions.

It has been shown in a previous study that pharmacological neuroprotection with propofol during temporary clipping did not improve cognitive function in this subset of the population at 24 h postoperatively or during discharge compared with a control group.[16] In neuroradiological suites for aneurysm or arteriovenous malformation embolization, another group of authors reported similar findings regarding neurocognitive functions (at 24 h) with the use of propofol and isoflurane.[4]

Aneurysmal SAH patients show the most frequent impairment in memory, executive function, and language components.[2] In the present study, individual domains were comparable in both groups during the preoperative period and at discharge. One month after surgery, memory and orientation scores were higher in the propofol group as compared to the desflurane group. Both short-term and long-term memory loss are associated with anesthetic agents. Modulation of excitatory neurotransmitters (NMDA receptors), inhibitory neurotransmitters (GABA receptors), and nicotinic acetylcholine receptors (nACHs) are some of the mechanisms implicated in memory loss.[17] Furthermore, nACH dysfunction has a strong association with Alzheimer's and Parkinsonism.[28] Beta-amyloid accumulation occurs with inhalational agents (isoflurane/sevoflurane).[31] In animal studies, desflurane exposure altered protein expression on the neuronal membrane, resulting in altered synaptic neurotransmission.[11]

Our study observed a decrease in the memory scores with propofol at the time of discharge. However, scores recovered one month after surgery. In the desflurane group, no similar findings were observed. Children exposed to propofol anesthesia have impaired short-term memory at seven days compared to baseline values. However, their memory scores recovered after three months.[32] Disruption of functional interactions between sensory, higher order auditory verbal memory and cognitive function, long-term depression of GABA receptors, and impairment of long-term inhibition of NMDA receptors could be a reason for improved memory scores in the propofol group in our study.[10,15,20]

Orientation, a fundamental cognitive function, is mediated by cortical activation in the precuneus, inferior parietal, and medial frontal cortex of the brain. The orientation scores were also found to be decreased at discharge in both the groups, which improved to baseline values at one month following surgery. A stressful perioperative period (stress of surgery, postoperative complications, and lack of home environment) may contribute to low orientation scores at discharge, which may slowly improve over some time.[6,7,9,14,22,25]

In a preliminary trial, we found that propofol preserved executive function, attention, and orientation better than desflurane. In addition, the present study showed that orientation and memory were better maintained with propofol than with desflurane. This could be because a preliminary study with a small sample population was not powered to study endpoints. However, the present study with a larger sample was adequately powered.

A preoperative assessment of cognitive functions is paramount for establishing the patient's baseline function. However, it is challenging to evaluate them in the preoperative period due to higher reported baseline cognitive dysfunction (70%) in aSAH patients.[8] The presence of headache, meningismus, sleep deprivation, anxiety, and fatigue secondary to aSAH may impair the patient's ability to perform the cognitive function testing accurately.

In aSAH, initial mean daily values S-100B levels above 0.4 mcg/L predict a poor outcome in terms of Glasgow outcome score at six months.[29] In the present study, higher preoperative S-100B levels and higher incidence of cognitive dysfunction were seen. Furthermore, S-100B levels below 0.4 mcg/L intraoperatively and 1-h postsurgery may indicate some degree of neuro resuscitation provided by anesthetic agents despite brain tissue handling. A pilot investigation in aSAH indicated a reduction in intraoperative CSF caspase-3 levels and one-hour postsurgery serum caspase-3 levels, implying that general anesthesia may provide neuro resuscitation by delaying neuronal apoptotic activity.[3]

The main strength of our study was that the trial was done prospectively in aSAH patients undergoing craniotomy and clipping. So far, this was the first study in this subset population where cognitive function assessment was done in the preoperative period. Furthermore, biomarker levels were assessed as surrogate markers for cognitive function assessment.

There are a few limitations of this study. First, we assessed cognitive functions using the MoCA test. This test covers six different domains of cognition but does not evaluate individual domains in detail. Hence, a more comprehensive scale might predict the affected domain in a better way and aid in planning the rehabilitation of the patient. Second, the study was done in only a modest number of patients in a single center. Larger multicenter studies are required to substantiate the results before a definitive conclusion is made. Third, we included only good grade patients. However, poor-grade patients are more likely to suffer cognitive function decline, and the effect of hypnotic agents may vary.

CONCLUSION

This study concluded that the mean cognitive scores at one month following surgery were better maintained with propofol as compared to desflurane. In individual domain analysis, orientation and memory scores were better preserved with propofol compared to desflurane. Future large multicenter studies are needed to substantiate the findings of the present study.

Ethical approval

The study conformed to the standards of the Declaration of Helsinki and was approved by the Institute Ethics Committee (Reference no. NK/6671/DM/471).

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI.

REFERENCES

1. Adembri C, Venturi L, Pellegrini Giampietro DE. Neuroprotective effects of propofol in acute cerebral injury. CNS Drug Rev 2007;13:333-5.
2. Al-Khindi T, Loch Macdonald R, Schweizer TA. Cognitive and functional outcome after aneurysmal subarachnoid hemorrhage. Stroke 2010;41:e519-36.
3. Balasubramanian M, Kuberan A, Rawat A, Dhandapani S, Panda N, Kumar A, *et al*. Effect of general anesthetics on caspase-3 levels in patients with aneurysmal subarachnoid hemorrhage: A preliminary study. J Neurosurg Anesthesiol 2021;33:172-6.
4. Bharati SJ, Mahajan C, Prabhakar H, Goyal K, Chowdhury T, Chandra H. Early cognitive functions in patients after embolization in neuroradiological suite - a comparison of two anesthetic techniques. J Anesth Clinic Res 2011;2:3.
5. Bhardwaj A, Bhagat H, Grover VK, Panda NB, Jangra K, Sahu S, *et al*. Comparison of propofol and desflurane for postanaesthetic morbidity in patients undergoing surgery for aneurysmal SAH: A randomized clinical trial. J Anesth 2018;32:250-8.
6. Borsook D, George E, Kussman B, Becerra L. Anesthesia and perioperative stress: Consequences on neural network and postoperative behaviours. Prog Neurobiol 2010;92:601-12.
7. Canet J, Raeder J, Rasmussen LS, Enlund M, Kuipers HM, Hanning CD. Cognitive dysfunction after minor surgery in the elderly. Acta Anaesthesiol Scand 2003;47:120410.
8. Cheng H, Shi J, Zhou M. Cognitive assessment in Chinese patients with aneurysmal subarachnoid hemorrhage. Behav Neurol 2006;17:117-20.
9. De Santis A, Laiacona M, Barbarotto R, De Divitiis O, Migliore M, Capitani E. Neuropsychological outcome of operated cerebral aneurysms: Prognostic factors in 148 patients. Acta Neurol Scand 1998;97:393-7.
10. Feng HJ, Macdonald RL. Multiple actions of propofol on alpha beta gamma and alpha beta delta GABAA receptors. Mol Pharmacol 2004;66:1517-24.
11. Flutterer CD, Maurer MH, Schmitt A, Feldmann RE, Kuschinsky W, Washke KF. Alterations in the rat brain proteins after desflurane anesthesia. Anesthesiology 2004;100:302-8.
12. Hutter BO, Kreitschmann-Andermahr I, Mayfrank L, Rohde V, Spetzger U, Gilsbach JM. Functional outcome after aneurysmal subarachnoid hemorrhage. Acta Neurochir Suppl (Wien) 1999;72:157-74.
13. Joys S, Panda NB, Ahuja CK, Luthra A, Tripathi M, Mahajan S, *et al*. Comparison of effects of propofol and sevoflurane on the cerebral vasculature assessed by digital subtraction angiographic parameters in patients treated for ruptured cerebral aneurysm: A preliminary study. J Neurosurg Anesthesiol 2023;1;35(3):327-332.33.
14. Kreiter KT, Copeland D, Bernardini GL, Bates JE, Peery S, Claassen J, *et al*. Predictors of cognitive dysfunction after subarachnoid hemorrhage. Stroke 2002;33:200-8.
15. Lui X, Lauer KK, Ward BD, Rao SM, Li SJ, Hudetz AG. Propofol disrupts functional interaction between sensory and high-order processing of auditory verbal memory. Hum Brain Mapp 2012;33:2487-98.
16. Mahajan C, Chouhan RS, Rath GP, Dash HH, Suri A, Chandra SP, *et al*. Effect of intraoperative brain protection with propofol on postoperative cognition in patients undergoing temporary clipping during intracranial aneurysm surgery. Neurol India 2014;62:262-8.
17. Mandal PK, Schifillliti D, Mafrica F, Fadale V. Inhaled anesthesia and cognitive performance. Drugs Today (Barc) 2009;45:47-54.
18. Mielck F, Stephan H, Buhre W, Weyland A, Sonntag H. Effects of 1 MAC desflurane on cerebral metabolism, blood flow and carbon dioxide reactivity in humans. Br J Anaesth 1998;81:155-60.
19. Muzzi DA, Lossaso TJ, Dietz NM. The effect of desflurane & isoflurane on CSF pressure in humans with supratentorial mass lesions. Anaesthesiology 1992;76:720-4.
20. Nagashima K, Zorumski CF, Izumi Y. Propofol inhibits long-term potentiation but not long-term depression in rat hippocampal slices. Anesthesiology 2005;103:318-26.
21. Nasreddine ZS, Phillips NA, Bedirian V, Charbonneau S, Whitehead V, Collins I. The Montreal cognitive assessment, MoCA: A brief screening tool for mild cognitive impairment. J Am Geriatr Soc 2005;53:695-9.
22. Ogden JA, Mee EW, Henning M. Prospective study of impairment of cognition and memory and recovery after subarachnoid hemorrhage. Neurosurgery 1993;33:572-86.
23. Patel PM, Drummond JC. Cerebral physiology and the effects of anesthetic drugs. In: Miller RD, editor. Miller's anesthesia. 7th ed., Vol. 1. Philadelphia, PA: Churchill Livingstone; 2009. p. 305-40.
24. Sharma N, Wig J, Mahajan S, Chauhan R, Mohanty M, Bhagat H. Comparison of postoperative cognitive dysfunction with the use of propofol versus desflurane in patients undergoing surgery for clipping of aneurysm after subarachnoid hemorrhage. Surg Neurol Int 2020;11:174.
25. Stenhouse LM, Knight RG, Longmore BE, Bishara SN. Long-term cognitive deficits in patients after surgery on aneurysms of the anterior communicating artery. J Neurol Neurosurg Psychiatry 1991;54:909-14.
26. Strebel S, Kaufman M, Guardiola PM, Schaefer HG. Cerebral vasomotor responsiveness is preserved during propofol and midazolam anaesthesia in humans. Anaesth Analg 1994;78:884-8.
27. Vandesteene A, Trempont V, Engelman E. Effect of propofol on cerebral blood flow and metabolism in man. Anaesthesia 1988;43:42-3.
28. Wei H, Xie Z. Anesthesia, calcium homeostatsis and Alzheimers disease. Curr Alzheimer Res 2009;6:30-5.
29. Weiss N, Sanchez P, Roche S, Beaudeux JL, Colonne C. S-100B as an additional prognostic marker in subarachnoid aneurysmal hemorrhage. Crit Care Med 2006;36:2267-73.

30. Wong GK, Lam S, Ngai K, Wong A, Mok V, Poon WS, *et al*. Evaluation of cognitive impairment by the montreal cognitive assessment in patients with aneurysmal subarachnoid Hemorrhage: Prevalence, risk factors and correlations with 3-month outcomes. J Neurol Neurosurg Psychiatry 2012;83:1112-7.
31. Xie Z, Culley DJ, Dong Y, Zhang B, Moir RD. The common inhalational anesthetic isoflurane induces caspase activation and increases amyloid beta protein *in vivo*. Ann Neurol 2008;64:618-27.
32. Yin J, Wang SL, Lui XB. The effects of general anesthesia on memory in children: A comparison between propofol and sevoflurane. Anaesthesia 2014;69:118-23.

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