Original Article

Randomized Trial to Compare Plasma Glucose Trends in Patients Undergoing Surgery for Supratentorial Gliomas under Maintenance of Sevoflurane, Desflurane, and Propofol

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Abstract

Background: Anesthetic agents influence the glycemic response by affecting the neuroendocrine surgical response or directly modifying pancreatic insulin release. Due to chances of neuronal damage, intraoperative hyperglycemia and hypoglycemia both are detrimental for patients undergoing neurosurgeries. Inhalational (sevoflurane and desflurane) and intravenous (propofol) agents have been found to raise intraoperative glucose levels in nonneurological surgeries. **Aim:** We aimed to compare the intraoperative glucose levels in supratentorial glioma surgeries under the maintenance of three anesthetic agents such as sevoflurane, desflurane, and propofol. **Materials and Methods:** This randomized trial was conducted with 90 nondiabetic adults with supratentorial glioma. Thirty patients were allocated randomly to the three groups receiving sevoflurane, desflurane, and propofol. Baseline and hourly plasma glucose levels were recorded. Postoperatively, the time required to achieve an Aldrete score of 9 and complications were assessed. **Results:** Baseline plasma glucose levels were 111.23 ± 11.67, 109.47 ± 19.75, and 111.7 ± 13.88 mg/dL (P = 0.84) in sevoflurance, desflurane, and propofol group, respectively. All of them showed an elevation of plasma glucose in relation to the time of surgery with variable trends. In the 4th and 5th h, the elevations in the inhalational groups (sevoflurane and desflurane) were significantly higher than the propofol group (P = 0.003 and 0.002, respectively). The time for achieving Aldrete's score of 9 was higher in the propofol group (P < 0.0001). No differences were observed in the duration of hospital stay or complications. **Conclusions:** Maintenance of anesthesia in nondiabetic patients showed clinically modest rise of plasma glucose which is higher in patients under sevoflurane and desflurane than under propofol. However, the immediate recovery was faster with inhalational agents compared to propofol-based anesthesia.

Keywords: *Blood glucose, desflurane, glioma, hyperglycemia, neurosurgical procedures, plasma glucose propofol, propofol*

Introduction

Surgical stimulus provokes an intense stress response that affects the endocrine and metabolic systems causing electrolytic disturbances, lowered insulin levels, and increased plasma glucose levels.[1,2] Inadequately inhibited stress response precipitates hyperglycemia. In neurosurgical patients, hyperglycemia causes neurological damage caused by the anaerobic metabolism of glucose. Hyperglycemia increases postoperative complications (surgical-site infection, bloodstream infections, nosocomial infections, acute renal failure, ventilatory support, etc.) which, in turn, increase hospital costs, length of stay, and the morbidity and mortality. Hypoglycemia is also detrimental as it may aggravate the neuronal damage. Perioperative glycemic status of an individual usually depends on the complex interplay between the preoperative metabolic state of the patient, the evoked stress response, insulin resistance, increase secretion of counterregulatory hormones, and intraoperatively administered medications and fluids. Anesthesia also modulates glycemic response by affecting the neuroendocrine surgical response or directly modifying pancreatic insulin release, even in the absence of surgical stress, and contributes to the development of hyperglycemia. Thus, anesthetic techniques

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during neurosurgical procedures focus on obtunding these metabolic alterations by maintaining an adequate depth of anesthesia, sufficient analgesia, judicious use of intravenous fluids, and insulin for control of high plasma glucose levels.

Intravenous and inhalational agents form the mainstay of anesthetic regimens employed during the conduct of neurosurgical procedures. Sevoflurane and desflurane are two newer inhalational agents widely used in neurosurgery due to the favorable effects of rapid emergence, decreased cerebral metabolism, and preservation of carbon dioxide reactivity. Propofol-based intravenous anesthesia is also a common and well-accepted modality because of its benefits of reducing cerebral blood volume, intracranial pressure, preservation of autoregulation, and vascular reactivity. Several studies have indicated that volatile anesthetics exacerbate hyperglycemia by suppressing glucose-stimulated insulin secretion and impairing glucose utilization and clearance.[3] On the other hand, propofol has been reported to promote insulin resistance but concomitantly increases insulin secretion and preserves glucose utilization in animal models.[4,5]

Previously, a few studies have investigated the glycemic responses when using isoflurane, sevoflurane, and propofol and reported that propofol-based anesthesia resulted in lower blood glucose levels compared with volatile anesthetic agents during surgery in nondiabetic patients.[6-8] Thus, glycemic responses are different between inhalational and intravenous anesthetic agents, and to the best of our knowledge, no study has compared the intraoperative blood glucose levels in patients undergoing surgery using the three most common contemporary anesthetic agents (namely sevoflurane, desflurane, and propofol) in neurosurgical patients where hyperglycemia can be detrimental to neuronal viability.

With this background, we planned this study to compare the intraoperative blood glucose levels of patients undergoing supratentorial glioma surgery under sevoflurane-, desflurane-, and propofol-based general anesthesia. In addition, we aimed to measure the time required by the patients to achieve a modified Aldrete's score of 9 (required for satisfactory discharge from postanesthesia care unit [PACU]) and compared the perceived satisfaction levels of the patients to their anesthetic management. We also compared the hospital stay and incidences of postoperative complications such as headache, giddiness, nausea, vomiting, or pain at the injection sites.

Materials and Methods

Type and settings

This prospective randomized trial was conducted in a tertiary care teaching hospital in North India from April 2019 to March 2020. The trial was registered at the Clinical Trial Registry of India (CTRI/2019/04/018609 on 15/04/2019).

Ethics

This study was conducted after approval from the Institute Ethics Committee (2019-36-IP-108 dated 25/March 2019). All the participants were adults (age >18 years). The patients were first briefed about the study protocol and its potential harm and benefit. After that, only the willing patients were recruited after obtaining written informed consent in English or Hindi language a day prior to surgery. They were also informed that they can withdraw themselves from the study any moment without stating any reason. The research participants were treated with the highest ethical standard, as per the Declaration of Helsinki.

Minimum sample size calculation

For sample size calculation, we referred to a previously published study[8] to compare the mean blood glucose level (mg/dL) between the two study groups (at 30 min from the induction) where the mean blood glucose levels (mean ± standard deviation) in Group 1 (sevoflurane) and Group 2 (propofol) were 136.56 ± 11.76 and 120.2 ± 12.30, respectively, and the study did not have a third group. At minimum two-sided 99% confidence interval and 95% power of the study, the calculated sample size of each of the two groups (sevoflurane and propofol) came out to be 22 [Effect size = 1.36]. For the Group 3 (desflurane), similar number of patients was enrolled. Keeping in mind the dropout cases, finally, in this study, we have included 30 patients in each of the three groups.

Recruitment

We enrolled 90 patients of supratentorial glioma with intact neurological status (Glasgow Coma Scale 15/15) which were small in size (with one diameter not more than 5 cm) without midline shift (not more than 5 mm) and without significant mass effect who were scheduled to undergo surgery under general anesthesia. Inclusion criteria included adult patients (18–65 years) of either gender belonging to the American Society of Anesthesiologists (ASA) Class I and II. Patients refusing for enrollment; pregnant or lactating patients; patients who could not be extubated immediately after the surgery; patients with psychiatric disorders/behavioral impairment or on antipsychotic drugs; diagnosed diabetic patients; patients with thyroid dysfunction, hepatic, cardiovascular, pulmonary, or renal disorders, morbid obesity, allergy to the study drugs or history of malignant hyperthermia, and chronic drug/alcohol abuse; and patients taking steroids, beta-adrenergic blocking agents, and insulin or oral hypoglycemic agents were excluded from the study.

Randomization

Based on a sequence of computer-generated random numbers, the enrolled patients were randomized and according to sealed envelope methods were allocated to three groups, i.e., sevoflurane (S), desflurane (D), and

propofol (P), and accordingly, the respective agent was used for maintenance of anesthesia.

Intervention

On the day of surgery, the patients who were kept fasting for solid foods for 8 h or more as per local protocols prior to surgery were transferred inside the operation theater. The anesthesiologist who conducted the case was not involved in the study. Standard monitors (noninvasive blood pressure, pulse oximetry, electrocardiography, and body temperature) were attached to the patient after his/her transfer. After securing an 18 G intravenous cannula (from which 2 ml blood was collected for the baseline blood sugar estimation), a radial arterial cannula was inserted under local anesthesia for invasive blood pressure estimation and repeated arterial blood gas (ABG) sampling. ABG analysis (baseline) was performed and the results of baseline (T 0) plasma glucose levels and baseline hematocrit values were noted. After preoxygenation with 100% O_2 at 6 l/min for 3 min, induction of anesthesia was achieved with intravenous fentanyl (2 μg/kg) and thiopentone (3–5 mg/kg). Moreover, the patients' tracheas were intubated with appropriate-sized endotracheal tubes after administering injection vecuronium (0.1 mg/kg) when the train-of-four (TOF) count reached 0.

Anesthesia was maintained by oxygen and air mixture (FiO2-0.5) at 2 l/min flow and anesthetic agents depending on the group allocation after opening the sealed envelopes. In Group D, patients were maintained with desflurane 2%–8% (inspired), started immediately after induction; in Group S, maintenance was done with sevoflurane 0.6%–2.4% (inspired), started immediately after induction; and in Group P, anesthesia was maintained with an infusion of propofol (50–200 μg/kg/min), started immediately after the bolus induction dose. In all the patients, BIS monitoring was done and BIS was maintained between 40 and 60 throughout the procedure by titrating the anesthetic agents. All patients received vecuronium infusion (0.8–1.7 mcg/kg/min) for muscle relaxation to keep a TOF count below 2 and infusion of fentanyl at the rate of 1.5 mcg/kg/h for intraoperative analgesia. In case of persistent Persistent Mean Arterial Pressures (MAP) >25% of the preinduction baseline values and/or heart rate >90 bpm suggestive of inadequate analgesia, 0.5 μg/kg of fentanyl was administered and repeated hourly if needed. Normocapnia was maintained by the adjustment of ventilatory parameters (increasing respiratory rate) to maintain end-tidal concentration of 30–35 mmHg, and normothermia (36.5°C–37.5°C) (nasopharyngeal temperature probe) was maintained with warming blankets and warm saline infusions. Intraoperative fluid administration was guided by the hourly maintenance requirements and losses and done with 0.9% normal saline or Plasma-Lyte as per the attending anesthesiologists' discretion, and no glucose-containing fluids were administered.

Vital parameters were continuously recorded at regular intervals, and blood pressure and heart rate were maintained within ± 20% of the baseline value. Glucose levels was measured hourly after induction until the completion of the surgery by collecting 1 mL venous blood in 2 mL syringe using the glucose oxidase peroxidase method from the arm contralateral to the one with the intravenous access. One ml of blood from the arterial line for ABG analysis was also collected which revealed the hematocrit levels. The number-coded syringes (T1, T2, T3, and successive) were labeled and sent directly to the laboratory from where the reports were generated in the hospital electronic information system, retrieved, and entered in the records by the attending anesthesiologists.

As per the protocol, if blood glucose level fell below 80 mg/dl, the study would be discontinued, and prompt treatment with intravenous glucose-containing solution would be instituted. Conversely, if blood glucose level increased to more than 200 mg/dl, then regular insulin (fixed dose) was to be infused to maintain normal blood glucose levels and monitored hourly until the end of the surgery and these patients were to be excluded from the study. During the closing stages of surgery, all the patients were administered intravenous paracetamol (15 mg/kg) and diclofenac sodium (1 mg/kg) for the management of pain and injection ondansetron for (4 mg) for antiemetic prophylaxis. Vecuronium infusion was terminated approximately 30 min prior to skin closure. At the completion of the last skin suture, anesthetic agents were terminated. After sterile dressing, neuromuscular blockade was reversed with neostigmine and glycopyrrolate on the TOF count of 3.

After meeting the clinical criteria for safe extubation, the patients' trachea was extubated and they were shifted to the PACU. Modified Aldrete's score of extubated patients was recorded every 5 min till they achieved a score of 9 and could be shifted out of the PACU by an observer blinded to the anesthesia strategy. Twenty-four hours after they were extubated, the patients were asked to report any complications they had experienced (nausea, vomiting, headache, giddiness, or pain at the injection site). Moreover, they were asked to rate their satisfaction regarding the quality of anesthesia on a 3-point scale in their vernacular language (dissatisfied, neither dissatisfied nor satisfied, and satisfied) by an anesthesiologist who was not part of the study during the postanesthesia rounds.

Associated data collection

Age, sex, anesthetic and surgical duration, intraoperative fluid consumption, and intraoperative vitals including temperature were obtained from the anesthetic records of the patients. Intraoperative hourly heart rate, blood pressure, temperature, and hematocrit were also recorded.

Statistical analysis

Continuous variables were expressed in mean and standard deviation. Categorical variables were expressed in number and percentage. Continuous variables were statistically compared among groups by one-way analysis of variance (ANOVA) (ordinary). Categorical variables were arranged in contingency tables and tested by Chi-square test. Hourly change in blood glucose was compared by ANOVA (repeated measures). Baseline glucose reading was subtracted from the hourly glucose reading to get the difference. The difference in three groups in terms of blood glucose levels, intraoperative vitals, hematocrit, and temperature across the groups was compared by Kruskal–Wallis one-way ANOVA. All the statistical analyses were carried out in GraphPad Prism 6.01 (GraphPad Software, La Jolla, CA, USA). $P < 0.05$ was considered statistically significant in all the tests.

Results

Among the total of 90 eligible patients, all the patients completed the study. The CONSORT flowchart is shown in Figure 1.

Group-wise age, sex, ASA status, fasting duration, types and volume of intraoperative fluids, duration of surgery, and anesthesia are presented in Table 1. Age-wise distribution ($P = 0.93$) and sex-wise distribution ($P = 0.7$) of subjects in three groups were similar. There were no differences in fasting hours, duration of surgery, and duration of anesthesia.

Baseline blood sugar values were similar among the three groups (111.23 ± 11.67, 109.47 ± 19.75, and 111.73 ± 13.88 mg/dL ($P = 0.84$) in sevoflurane, desflurane, and propofol group, respectively) [Table 2]. In the succeeding hours, it was seen that the patients in the sevoflurane group showed a gradual rise in the blood sugar during the intraoperative period. Similar changes were observed in the patients of the desflurane group who exhibited a rise of blood glucose values achieving significant levels. However, the trends were different for the propofol group [Figure 2].

Intergroup comparison showed that at 4th and 5th h, the elevations in the inhalational groups (sevoflurane and desflurane) were significantly higher than the propofol group [Table 2]. Intergroup comparison of the change in blood glucose showed statistically significant variations at the 3rd, 4th, and 5th h of the surgeries [Table 3].

Intraoperative parameters such as core temperature and hourly hematocrit levels were similar in the three groups [Table 4].

Postoperatively, patients in the propofol group required more time as compared to patients maintained on sevoflurane or desflurane to achieve an Aldrete score of 9, allowing them to be shifted from the PACU [Table 1]. An

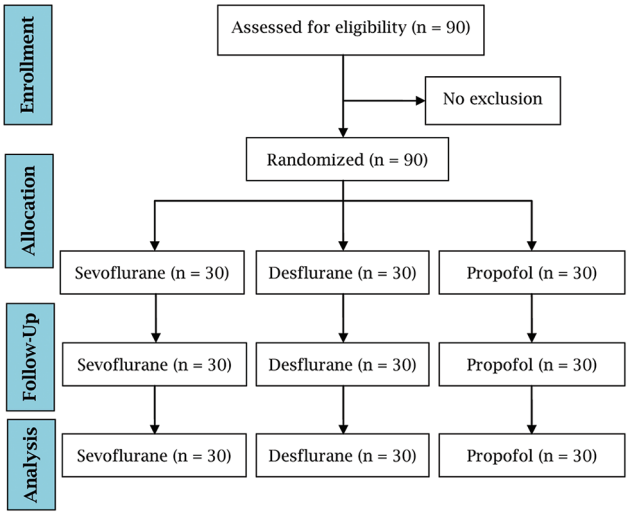

Figure 1: CONSORT flowchart of the randomized trial

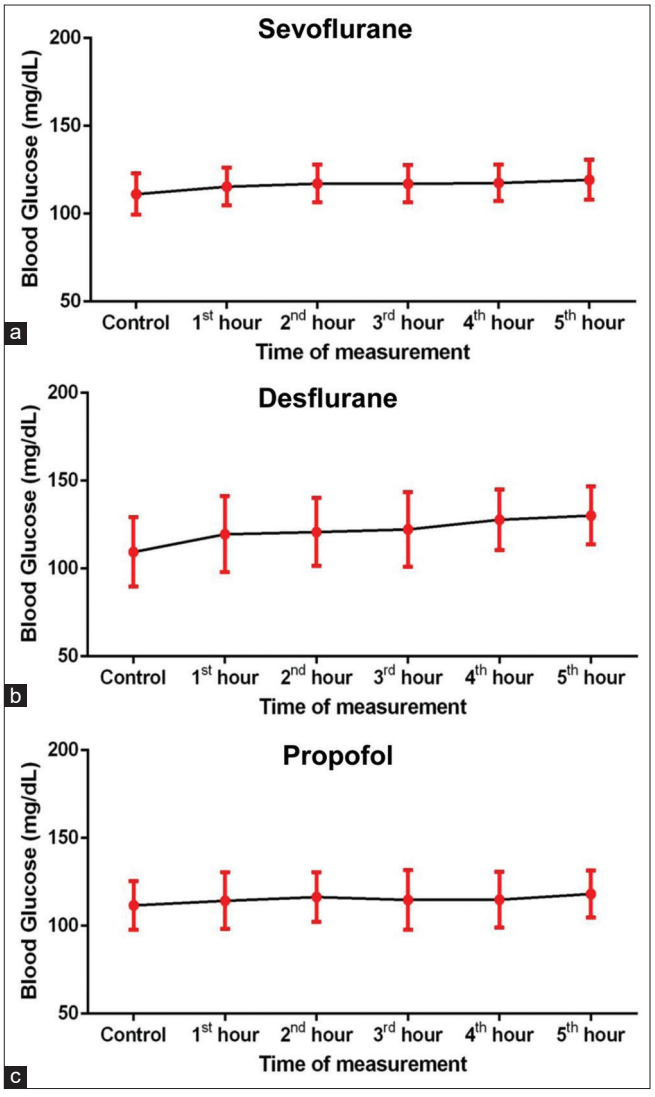

Figure 2: Plasma glucose trends during the course of surgery using sevoflurane (a), desflurane (b), and propofol (c) based anesthesia

Table 1: Characteristics of participants and surgery

Parameters	Anesthetic used			*P**
	Desflurane	Propofol	Sevoflurane	
Sex (%)				
Female	10 (33.33)	8 (26.67)	11 (36.67)	0.7
Male	20 (66.67)	22 (73.33)	19 (63.33)	
Age (years), mean±SD	42.47±13.64	41.87±17.38	43.47±16.94	0.93
Duration of surgery (min), mean±SD	359.83±36.23	382.73±57.12	361.67±28.25	0.07
Duration of anesthesia (min), mean±SD	425.67±43.07	428.33±53.19	424.77±44.64	0.95
ASA physical status (%)				
I	21 (70)	20 (66.67)	16 (53.33)	0.36
II	9 (30)	10 (33.33)	14 (46.67)	
Fasting (h), mean±SD	11.27±1.48	11.7±2.29	11.67±2.26	0.66
Amount of fluid (mL), mean±SD	3773.33±1068.01	3838.33±1168.83	3841.67±1126.95	0.96
Type of fluid (%)				
NS	12 (40)	17 (56.67)	9 (30)	0.11
NS + Plasma-Lyte	18 (60)	13 (43.33)	21 (70)	
Time to achieve Aldrete's score 9, mean±SD	22.2±2.99	27.57±4.49	23.13±3.21	<0.0001†
Hospital stay (days), mean±SD	5.53±1.53	5.93±1.44	5.23±1.1	0.14
Complications (%)				
Yes	1 (3.33)	0	2 (6.67)	0.36
No	29 (96.67)	30 (100)	28 (93.33)	
Satisfaction (%)				
Dissatisfied	3 (10)	0	4 (13.33)	0.14
Neither dissatisfied nor dissatisfied	7 (23.33)	6 (20)	2 (6.67)	
Satisfied	20 (66.67)	24 (80)	24 (80)	

**P* value is of ANOVA in case of data expressed in mean and standard deviation or it is of Chi-square test if data is presented in number and percentage, †Statistically significant *P* value. SD – Standard deviation; ASA – American Society of Anesthesiologists; NS – Normal saline

Table 2: Baseline and hourly blood glucose level in three groups of participants

Anesthetic used	Baseline blood glucose (mg/dL)	Hourly blood glucose (mg/dL), mean±SD					*P*
		1st	2nd	3rd	4th	5th	
Sevoflurane	111.23±11.67	115.47±10.68	117.13±10.75	117.07±10.63	117.53±10.38	119.27±11.37	0.0002*
Desflurane	109.47±19.75	119.6±21.55	120.87±19.28	122.33±21.22	127.77±17.27	130.17±16.5	<0.001*
Propofol	111.73±13.88	114.3±16.09	116.4±14.07	114.77±16.93	114.97±16.86	118.2±13.37	0.04*
P	0.84	0.44	0.47	0.21	0.003†	0.002†	-

*Statistically significant *P* value of ANOVA (one-way with repeated measures), †Statistically significant *P* value of ANOVA (one-way ordinary). ANOVA – Analysis of variance; SD – Standard deviation; - – Data not available

equal number of patients (80%) were satisfied with the quality of anesthesia they had received in sevoflurane and desflurane groups, whereas 66.7% of the patients reported satisfaction with the quality of anesthesia delivered with propofol [Table 1]. The total hospital stay of the patients of the three groups was similar. One patient in the desflurane group complained of headache and one patient each in the sevoflurane group complained of nausea and vomiting, respectively.

Discussion

Dysregulation of glucose metabolism is an expected result of surgical stress, and this is dependent on the type of anesthetic regimen which is being employed. It occurs due to the neurohumoral and metabolic alterations and release of stress hormones. In patients undergoing neurosurgical procedures, hyperglycemia accentuates cerebral cellular injuries due to lactic acidosis produced during the operative period which is often associated with ischemia. Volatile anesthesia is known to cause insulin resistance, which results in elevated blood glucose and adverse postoperative outcomes in critically ill patients and impaired glycemic control in surgical patients with diabetes, although the mechanism has not been elucidated yet. On the other hand, propofol has been reported to promote insulin resistance, but concomitantly increases insulin secretion and preserves glucose utilization in animal models.[4,5]

In our study, we compared the trends of plasma glucose levels in nondiabetic patients anesthetized with sevoflurane, desflurane, and propofol. Preoperative fasting durations, depth of anesthesia, fluid administered, intraoperative blood loss (evidenced by hematocrit levels), and temperature were

observed to be within similar ranges. Our findings revealed that patients under sevoflurane anesthesia demonstrated a steady rise in plasma glucose levels over the course of the surgery. A parallel trend was observed in patients administered desflurane for anesthesia maintenance, although the changes compared to the baseline levels achieved significant levels at all points of surgery. These changes, even though statistically being significant, were clinically insignificant. Patients in the propofol group also showed an uneven elevation of blood glucose levels. Resistance to insulin is induced by sevoflurane and propofol,[5] and similar trends of elevated glucose along with cortisol levels intraoperatively irrespective of the depth of desflurane anesthesia have been reported previously.[9]

Table 3: Difference of blood glucose in three groups of research participants

Time of reading	Anesthetic agent	Difference	*P*
1st h - baseline	Sevoflurane	4.23±7.86	0.12
	Desflurane	10.13±23.06	
	Propofol	2.57±8.23	
2nd h - baseline	Sevoflurane	5.9±8.39	0.17
	Desflurane	11.4±21.99	
	Propofol	4.67±9.96	
3rd h - baseline	Sevoflurane	5.83±8.67	0.03*
	Desflurane	12.87±21.03	
	Propofol	3.03±10.04	
4th h - baseline	Sevoflurane	6.3±9.44	0.0002*
	Desflurane	18.3±20.24	
	Propofol	3.23±9.39	
5th h - baseline	Sevoflurane	8.03±11.49	0.0004*
	Desflurane	20.7±19.74	
	Propofol	6.47±11.09	

*Statistically significant P value of Kruskal-Wallis one-way ANOVA. ANOVA – Analysis of variance

Certain investigations have concluded that hyperglycemia during surgery may occur due to surgical pain and metabolic responses to surgical stress which cannot be blocked with even deep anesthesia.[10-14] Adequate analgesia can however maintain blood glucose in normal limits and prevent hyperglycemia and its complications during perioperative period.[15,16] Animal studies have emphasized the utility of propofol-based anesthesia in neurosurgical anesthesia. Propofol can prevent lactic acidosis, decrease cerebral edema, ischemia-induced cellular injury and hyperglycaemia-induced vasoconstriction, and improves cerebral microvasculature by decreasing levels of superoxides in the brain.[17,18] Under surgical stress, blood glucose levels have been found to be markedly increased with sevoflurane anesthesia but are relatively stable with propofol anesthesia.[4] In another trial comparing effects of sevoflurane and propofol anesthesia, the results indicated that blood glucose levels were higher in the sevoflurane group.[7] In spite of several prospective trials reporting lower blood glucose levels during propofol anesthesia in comparison to volatile anesthesia, a blanket recommendation of propofol anesthesia over inhalational anesthetic agents based on ours and previous studies on different surgeries to maintain perioperative glycemic control remains controversial because of factors such as varying nature of surgical stimulation during different stages of surgery,[19] maintenance of euglycemia irrespective of anesthetic, or lack of glucose data in the postoperative period (<72 h),[12,20] which is an important contributor to hyperglycemia-induced complications in surgical patients.

A previous investigation had found that even though mean blood glucose was lesser in propofol group than the sevoflurane group, it did not translate into improved postoperative outcomes and reduced short-term mortality

Table 4: Baseline and hourly vital parameters in three groups of participants

Parameters	Anesthetic used	Baseline reading	Hourly reading					ANOVA
			1st	2nd	3rd	4th	5th	*P*
Heart rate (bpm)	Sevoflurane	84.9±15.34	80.77±16.29	83.47±17.94	83.63±13.02	85.37±13.14	85.23±12.49	0.29
	Desflurane	84±18.61	83.53±12.97	84.93±11.06	81.6±24.46	89.07±15.13	87.67±14.53	0.25
	Propofol	75.07±10.91	75.27±9.72	76.63±10.66	77.13±13.94	78.23±12.94	78.6±13.93	0.25
Temperature (°C)	Sevoflurane	36.25±0.48	36.17±0.63	36.23±0.61	36.17±0.49	36.16±0.53	36.01±1.08	0.47
	Desflurane	35.39±0.78	35.96±0.78	35.96±0.77	35.99±0.77	35.99±0.76	35.98±0.72	0.38
	Propofol	35.84±0.63	35.6±0.59	35.55±0.74	35.65±0.85	35.73±0.85	35.66±1.03	0.16
Systolic blood pressure (mm of Hg)	Sevoflurane	130.27±19.09	123±15.16	116.8±17.43	121.23±19.06	124±16.46	120.77±12.81	0.005*
	Desflurane	132.2±15.14	121.3±19.05	114.9±11.29	117.1±16.27	118.63±10.62	119.23±9.91	<0.0001*
	Propofol	128.83±20.11	121.23±19.17	122.87±17.73	121.93±12.58	121.57±10.61	119.9±11.05	0.17
Diastolic blood pressure (mm of Hg)	Sevoflurane	81.6±13.72	76.57±14.77	73.33±15.23	75.13±14.07	73.9±11.51	73.93±10.82	0.01*
	Desflurane	84.07±14.83	76.67±12	70.4±11.33	73.77±13.57	74.8±12.69	73.77±9.24	<0.0001*
	Propofol	78.2±11.47	71.23±14.03	69.57±12.12	70.17±9.02	70.57±9.17	68.46±9.31	0.01*
Hematocrit (%)	Sevoflurane	33.96±4.94	33.97±4.98	33.63±5.1	33.03±6.54	33.23±6.12	33.26±5.8	0.08
	Desflurane	35.04±3.72	35.42±4.07	35.32±3.82	34.91±3.96	34.63±4.56	34.56±4.46	0.08
	Propofol	34.2±5.75	34.41±5.79	34.38±5.75	33.43±5.64	34.18±5.61	34.04±5.75	0.43

*Statistically significant *P* value. Bpm – Beats per minute; °C – Degree Celsius; Hg – Mercury; ANOVA – Analysis of variance (one-way with repeated measures)

in the propofol group.[21] Although in the present study the measurement of long-term outcomes was not set up to be the primary outcome, we recorded the time required for the patients to achieve an Aldrete score of 9 which signified the readiness of shifting the patient from PACU. Significant differences were observed in patients of the propofol group to achieve the same Aldrete score compared to the sevoflurane and desflurane groups, although these differences might not be clinically significant. Among the desflurane and sevoflurane groups, patients of the desflurane group achieved a score of 9–10 in a shorter time period than the sevoflurane group. This was supported by the previous investigations.[22,23] This discrepancy of time reported in the previous studies[22,23] might be attributed to a longer anesthesia times compared to that reported in our study. Moreover, in the previous study, remifentanil was used for intraoperative analgesia whose metabolism is instantaneous as compared to fentanyl which was used in our study. This could partly explain the longer duration of time needed to achieve a similar Aldrete score. Although the mean glucose levels in the propofol group were lower than the sevoflurane and desflurane groups, immediate postoperative recovery was delayed in the propofol group. Song *et al*. also reported similar findings where significant differences were found in patients to achieve similar Aldrete scores when administered similar agents that were used in our study.[24]

When the side effect profiles were compared, two patients of sevoflurane complained of nausea and vomiting each and one patient of desflurane group had headache. No side effects were observed in the propofol group. The most common side effect of propofol is injection pain, with the incidence ranging between 30% and 70%.[25] Co-administration of opioids along with propofol might have prevented the injection pain commonly associated with propofol.[26,27] Patients not experiencing nausea and vomiting may have been due to the antiemetic properties of propofol.

We interviewed the patients 24 h after the extubation to rate the degree of their satisfaction levels with their anesthetic regimens on a 3-point Likert Scale of highly satisfied, neither satisfied nor dissatisfied, and dissatisfied. Patients rating a high degree of satisfaction were higher in the propofol group along with the desflurane group than sevoflurane which was previously substantiated by the study of Tang *et al*.[28]

The study has certain limitations that need to be mentioned. The study estimated blood glucose levels within the intraoperative period only. All the surgeries finished within 6–7 h duration; thus, a limited number (five) of readings were obtained intraoperatively. The measurement of blood glucose was not continued in the postoperative period which might have been influenced by the longer duration of measurement. The study involved nondiabetic patients having normal glycemic status. These findings cannot be extrapolated to patients with altered glucose regulation, and the effects of these agents on these patients need to be investigated. Blood glucose levels in patients with dysregulated glucose metabolism might have demonstrated different patterns. Levels of plasma hormones and catecholamines were not assessed, and it was assumed that the plasma glucose levels reflected the neurohumoral stress response to anesthesia. Finally, long-term follow-up was not done in our study. Therefore, any correlation with the delayed outcomes with anesthetic regimens used could not be assessed.

Conclusions

In normoglycemic patients, maintenance of anesthesia either with inhalational (sevoflurane and desflurane) as well as intravenous (propofol) agents causes a rise in blood sugar levels even though normal blood glucose levels are maintained. The steady rise of plasma glucose levels observed with using inhalational agents is significantly higher than the rise exhibited in patients under propofol anesthesia although immediate recovery appears quicker with inhalational agents.

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Conflicts of interest

There are no conflicts of interest.

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