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Original Article

Evaluation of the changes in middle cerebral artery flow velocity related to different positions of patients during posterior fossa surgery

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ABSTRACT

Background: This is a prospective observational study to evaluate the changes in middle cerebral artery flow velocities and cerebral perfusion pressure in the various positions used for posterior cranial fossa surgery and to correlate these changes with postoperative recovery characteristics and complications.

Methods: Sixty patients were included in the study – 33 patients with CPA tumors were placed in the supine with head tilt position and the rest 27 with tumors in other locations of posterior fossa were placed in the prone position. The primary aim was to study the changes in middle cerebral artery blood flow velocity related to various positions of the patients used during posterior fossa surgery. The secondary aim was to compare the changes in pulsatility index, resistance index, and effective cerebral perfusion pressure in different position and to correlate these findings with postoperative recovery and the complications associated with these positions.

Results: The systolic and mean flow velocities were higher in the supine with head tilt group than the prone group after positioning and post repositioning, but these values were within normal limits, and the changes with positioning from baseline were comparable between the groups. Furthermore, these changes did not affect the effective cerebral perfusion pressure or the outcomes of the patients.

Conclusion: The current results do not determine whether the supine with head tilt position is better than the prone position during posterior fossa surgery.

Keywords: American society of anesthesiologists, Cerebellopontine angle, Posterior fossa surgery, Prone position, Supine with head tilt position

INTRODUCTION

The posterior fossa can be done in various positions including sitting position, supine with lateral head tilt, prone, lateral, three quarter prone, and park-bench position.[3] The final position for surgery is determined by the location of the pathology considering various risks and benefits. The various complications due to positioning can result in delayed recovery, need for postoperative mechanical ventilation, and poor outcome of the patients. Although the exact mechanism for many of these complications is not understood, the hemodynamic changes associated with the positioning and the resulting inadequate cerebral perfusion could contribute to some of these adverse neurological events.[1,9,10] Transcranial Doppler (TCD) has emerged as a noninvasive means of obtaining information about cerebral hemodynamic. It can be used to measure the cerebral blood flow, the pulsatility index is a measure of distal resistance and the cerebral perfusion pressure.[5,8] This study was conducted to assess the changes in MCA flow velocities and CPP in the various positions used for posterior fossa surgery and correlate these changes with postoperative recovery characteristics and complications.

MATERIALS AND METHODS

After approval from the Institutional Ethics Committee (NK/3831/MD/439 dated October 28, 2017) and prospective registration with the Clinical Trials Registry of India (CTRI/2018/01/011206), this prospective and observational study was conducted in 60 ASA I-III (ASA I- A normal healthy patient, ASA II- A patient with mild systemic disease, and ASA III- A patient with severe systemic disease) patients aged between 18 and 65 years undergoing posterior fossa surgery for various pathologies between July 2017 and December 2018 at a tertiary care center in North India. Patients with preoperative GCS < 13, history of carotid artery disease, ischemic stroke, unstable cardiorespiratory disorders, and renal or hepatic insufficiency were excluded from the study. After taking the patient inside the operation theatre, standard ASA monitors were attached. A baseline heart rate (HR), oxygen saturation, and blood pressure were noted. Intravenous access was taken and anesthesia was induced with propofol (1.5–2.5 mg/kg) and morphine (0.1 mg/kg). Neuromuscular paralysis was achieved with vecuronium (0.1 mg/kg) and an appropriately sized endotracheal tube was placed. Anesthesia was maintained with isoflurane with O_2 and N_2O. Ventilator settings were adjusted to maintain end tidal carbon-di-oxide ($EtCO_2$) between 30 and 35 mm Hg. All the patients received intravenous acetaminophen 15 mg/kg over 10 min at the end of surgery for postoperative analgesia. After skin closure, isoflurane was discontinued. The operating surgeon was requested to choose the quality of the surgical field during the procedure from Boezaart's scale [Annexure 1] of 1–5. After making the patient supine, the neuromuscular paralysis was reversed with neostigmine and glycopyrrolate and the patient was extubated if obeying verbal commands, taking regular, and spontaneous breaths of adequate tidal volume and was hemodynamically stable. Else the patient was mechanically ventilated. Postoperatively, patients were shifted to post anesthesia care unit if extubated and if not extubated to the neurosurgical ward for mechanical ventilation and followed up till discharge.

TCD with combined color flow and power Doppler was done at the following time points, through the trans-temporal window – (a) preoperatively before induction with the patient supine, (b) postinduction before positioning the patient, (c) after positioning of the patient in the desired surgical position, and (d) after the patient was made supine (before reversal).

After applying acoustic gel, TCD probe was applied at the temporal area of the patient. A signal was searched for, initially starting at a depth of 50 mm for a FV pulse waveform above and below the zero-line, characteristic of ICA with flow both toward and away from the probe. Signal gain was enhanced by slight adjustments of the insonation angle or by changing the depth (45–70 mm). The depth of insonation was then reduced back to 45–55 mm to identify waveform with only the positive deflection, characteristic of M1 part of the MCA FV waveform. The point of maximum amplitude of deflection was taken for measurements. Procedure was repeated on the other side.

The following parameters were recorded:

- i) Systolic flow velocity (SFV), diastolic flow velocity (DFV), and mean flow velocity (MFV) of the middle cerebral arteries of both sides
- ii) Pulsatility and resistance indices for these arteries
- iii) Transient hyperemic response test (THRT) preoperatively.

Effective CPP (eCPP) was calculated using the formula

$$eCPP = MAP * (DFV/MFV) + 14 \text{ (mmHg)}.$$ [4]

[MAP-Mean arterial pressure; DFV-Diastolic flow velocity, MFV-Mean flow velocity]

THRT was performed keeping the TCD probe in place recording the MCA flow velocity, while manually compressing the ipsilateral common carotid artery, with compression ratio of more than 40% for 10 s. Then, peak MCA flow velocity immediately after releasing the carotid compression was recorded. The ratio of the peak hyperemic flow velocity recorded after carotid release and the precompression baseline flow velocity was calculated. THRR > 1.10 was considered as intact autoregulation, while values < 1.10 were taken as deranged autoregulation. Three readings of THRR were taken at an interval of 2 min between the readings and the average of the 3 readings was taken as the final one. THRR was calculated on both the sides and noted.

Follow-up was done until 1-month postsurgery. Duration of ICU and hospital stay, duration of mechanical ventilation, extended Glasgow outcome score (GOS-E) at discharge and at 1 month, and any postoperative complications (hemorrhage, re-exploration, CSF leak, and meningitis) were recorded.

Statistical analysis

The statistical analysis was carried out using IBM Statistical Package for the Social Sciences statistical version 25. Sample size was calculated using the Minitab software. From the study by Hanouz *et al.*,[6] assuming the change in mean MCA flow velocity as 6 cm/s and a standard deviation of 4 cm/s, the sample size required, with an alpha error of 0.05 and power of 0.09 to demonstrate a change of 6 cm/s was found to be 60. The analysis includes frequency table for demographic variables, and their association based on Chi-square test. All quantitative variables were estimated using measures of central location (mean and/or median) and measures of dispersion (standard deviation and/or interquartile range). Normality of all continuous variables including hemodynamic parameters and all flow velocities were checked by Kolmogorov–Smirnov tests and found to be normally distributed. Hence, their means were compared using Student's paired t-test for comparing variables within groups and normal or modified Independent samples t-test was used for comparing their means for differences between the two groups after checking for equality of variances by Levine's test. The same was done for variables such as intraoperative fluid requirements, volume of blood loss, and urine output. Qualitative variables were compared between the two groups using Fischer exact test or Pearson Chi-square test and for postoperative outcomes between the two groups, Mann–Whitney U-test was done. All statistical tests were done at two-tailed level of significance ($P \leq 0.05$).

RESULTS

Of the total 60 patients enrolled in the study, 33 patients who had cerebellopontine angle tumors were placed in the supine position with head tilt to the side opposite of the side of tumor, whereas the other 27 patients were placed in the prone position. The distribution of demographic characters was similar in both the groups [Table 1]. All patients had adequate hemoglobin values and had a GCS of 15 preoperatively. The neurological deficits present preoperatively were due to different locations of tumors in the two groups.

The hemodynamic parameters were maintained within the normal limits during the surgery. Although the HR deviated from the baseline on many occasions, there were only two episodes of bradycardia due to brainstem handling in both groups that needed intervention and these numbers were comparable. The mean arterial pressure also deviated from the baseline at many timepoints of observation. There was a significant fall postinduction in both groups. The HR and MAP readings were comparable between both the groups at all points. $EtCO_2$ concentrations were within normal limits, though there was a decrease postpositioning and it was close to baseline values at the end of the surgery. The two groups did not differ significantly between themselves in terms of the $EtCO_2$ concentrations.

Table 1: Demographic data.

Parameter	Prone (*n*=27)	Supine with head tilt (*n*=33)	*P*-value
Age (in years)	35.85±13.43	34.58±13.12	0.393
Gender			
Male: Female	15:12	16:17	0.586
Comorbidities			
Diabetes mellitus	1	2	
Systemic hypertension	2	2	
Diagnosis			
Astrocytoma	7		
Ependymoma	3	–	
Hemangioblastoma	5	–	
Meningioma	5	4	
Medulloblastoma	4	–	
Epidermoid cysts	2	2	
Schwannomas	–	27	
Metastasis	1	–	

All patients had normal transient hyperemic response ratios in both the groups and had intact autoregulatory mechanisms that would maintain their cerebral blood flow despite changes in MAP. The values were also comparable on both the sides indicating no side to side discrepancy. The flow velocity parameters were within normal limits and when compared between the right and left sides within each group, they were comparable at all-time points of observation. Hence, there was no side to side discrepancy due to anesthesia and positioning. Pulsatility index and resistivity index measurements revealed normal values on both sides indicating a normal cerebrovascular resistance on both sides in both groups.

The SFV values and the mean flow velocities were significantly higher in supine with head tilt group than the prone group, after positioning and post repositioning. The diastolic flow velocities were comparable at all-time points. The SFVs as compared to baseline fell significantly postinduction and postpositioning in both the groups ($P < 0.05$) [Table 2]. However, post repositioning values were significantly lower than the baseline values in the prone group only. As compared to postinduction values, the SFV did not change significantly after positioning and after repositioning in both the groups. However, all changes from the baseline and from the postinduction values at later time points were comparable between the groups. The diastolic flow velocities did not change significantly when compared to the baseline and postinduction values in the prone group as well as the supine with the head tilt group [Table 3]. All changes were comparable between the groups. There was a fall in the MFV

Table 2: Systolic flow velocity trends and changes (in cm/s).

Timepoint/Compared between	Prone			Supine with head tilt			*P*-value between groups
	Mean (cm/s)	SD (cm/s)	*P*-value	Mean (cm/s)	SD (cm/s)	*P*-value	
Baseline	59.25	12.95		64.84	13.24		0.106
Postinduction	53.46	13.90		59.82	13.30		0.076
Postposition	49.79	11.19		58.48	12.64		0.007**
Post reposition	51.18	9.28		59.99	11.72		0.002**
Baseline-postinduction	5.79	12.07	0.019**	5.02	14.60	0.047*	0.825
Baseline-postposition	9.46	12.97	0.001**	6.35	13.66	0.012*	0.375
Baseline–post reposition	8.07	12.95	0.003**	4.85	14.41	0.062	0.371
Postinduction-postposition	3.67	9.82	0.063	1.34	12.39	0.537	0.432
Postinduction-post reposition	2.28	12.24	0.342	−0.16	10.85	0.932	0.416

SD: Standard deviation, * p-value less than 0.05 is statistically significant, ** highly significant

Table 3: Diastolic flow velocity trends and changes.

Timepoint/Compared between	Prone			Supine with head tilt			*P*-value between groups
	Mean (cm/s)	SD (cm/s)	*P* value	Mean (cm/s)	SD (cm/s)	*P* value	
Baseline	29.84	9.07		30.56	7.54		0.737
Postinduction	26.83	6.95		27.48	5.65		0.881
Postposition	27.26	7.18		29.50	6.68		0.215
Post reposition	26.84	6.83		29.42	6.39		0.100
Baseline-postinduction	3.00	9.95	0.129	3.07	6.74	0.054	0.827
Baseline-postposition	2.58	9.42	0.166	1.06	7.19	0.405	0.480
Baseline-post reposition	3.28	9.06	0.071	1.14	7.76	0.407	0.328
Postinduction-postposition	−0.42	4.86	0.656	−2.02	6.62	0.059	0.366
Postinduction-post reposition	0.27	7.40	0.849	−1.96	6.87	0.059	0.679

SD: Standard deviation

postinduction in both the groups as compared to baseline [Table 4]. There was a significant fall from the baseline values postpositioning and after repositioning in the prone group but not in the supine with head tilt group. There was no change in MFV from postinduction values after positioning in both groups. All these changes themselves whether from the baseline or from the postinduction values to the later observation time points within the groups were comparable between the two groups.

In both groups, the effective CPP was normal and was comparable at baseline, postinduction, and postpositioning [Table 5]. It was normal but significantly lower in supine with head tilt group than the prone group after repositioning ($P < 0.05$). In the prone group as compared to baseline, there was a significant fall in effective CPP postinduction ($P < 0.01$). The postpositioning and post repositioning values were similar to baseline values. When compared to postinduction values, there was a significant increase in the eCPP values both at postpositioning and post repositioning ($P < 0.01$). In the supine with head tilt group, as compared to baseline, there was a significant fall in the effective CPP postinduction ($P < 0.01$) and also at post repositioning ($P < 0.05$). When compared with postinduction values, there was an increase in effective CPP postpositioning and post repositioning.

Both the groups, in our study, had comparable blood losses and satisfactory surgical field gradings. The duration of surgery and also the intravenous fluid requirement was higher in the supine with head tilt group as compared to prone group. A significantly greater proportion of the posterior fossa patients with lesser duration of surgery were extubated on table as compared to the supine with head tilt group who were mechanically ventilated electively due to greater surgical manipulation or presence of preoperative neurological deficits. Patients of supine with head tilt group had similar hospital stay and GOS-E score at discharge and at 1 month as compared to the prone group. In patients not extubated on table, two patients of the supine with head tilt group were tracheostomized. Otherwise, both groups had similar durations of ICU stay and hospital stay [Table 6].

At discharge, the patients in the prone group had a lower GOS-E due to persistence of ataxia than the supine with head tilt group. However, at 1 month, they had similar GOS-E scores as CPA tumor patients as ataxia improved. No positioning related complications were recorded in this study.

DISCUSSION

The position during surgeries of intracranial tumors of the posterior fossa is mainly dictated by the location of the tumor

Table 4: Mean flow velocity trends and changes.

Timepoint/Compared between	Prone			Supine with head tilt			*P*-value between groups
	Mean (cm/s)	SD (cm/s)	*P*-value	Mean (cm/s)	SD (cm/s)	*P*-value	
Baseline	39.64	9.95		41.99	9.14		0.346
Postinduction	35.71	8.46		37.99	7.65		0.275
Postposition	34.77	7.95		39.16	8.06		0.039*
Post reposition	34.77	6.98		39.61	7.55		0.013*
Baseline-postinduction	3.93	9.88	0.049*	3.98	8.99	0.015**	0.981
Baseline-postposition	4.87	9.90	0.017*	2.82	8.60	0.069	0.395
Baseline-post reposition	4.88	9.88	0.016*	2.37	9.06	0.142	0.311
Postinduction-postposition	0.94	5.44	0.377	−1.16	7.43	0.370	0.222
Postinduction-post reposition	0.94	7.85	0.538	−1.61	6.88	0.184	0.182

SD: Standard deviation, * p-value less than 0.05 is statistically significant, ** highly significant

Table 5: Effective cerebral perfusion pressure trends and changes.

Timepoint/Compared between	Prone			Supine with head tilt			*P*-value between groups
	Mean mmHg	SD mmHg	*P*-value	Mean mmHg	SD mmHg	*P*-value	
Baseline	84.76	12.08		84.83	7.64		0.979
Postinduction	73.07	7.65		74.61	8.24		0.462
Postposition	83.08	8.66		82.28	10.42		0.751
Post reposition	84.87	9.46		79.82	9.02		0.039*
Baseline-postinduction	11.69	9.83	0.000*	10.22	6.97	0.000*	0.735
Baseline-postposition	1.67	11.71	0.464	2.54	12.55	0.253	0.784
Baseline-post reposition	−0.11	12.90	0.965	5.01	11.36	0.016*	0.108
Postinduction-postposition	−10.02	9.46	0.000*	−7.67	10.36	0.000*	0.113
Postinduction-post reposition	−11.80	11.39	0.000**	−5.21	11.58	0.002**	0.063

SD: Standard Deviation, * p-value less than 0.05 is statistically significant, ** highly significant

Table 6: Postoperative outcomes.

On table extubated patients			
Parameter	**Prone (*n*=20)**	**Supine with head tilt (*n*=4)**	***P*-value**
Hospital Stay in no of days median (interquartile range)	4 (3–5)	4 (3–4)	0.477
Gos-E at discharge median (interquartile range)	6.5 (6–7)	7 (7–7)	0.135
Gos-E at 1 month median (interquartile range)	7 (6–7)	7 (7–7)	0.388
Patients not extubated on table			
Parameter	**Prone (*n*=7)**	**Supine with head tilt (*n*=29)**	***P*-value**
Mechanical ventilation duration in hours median (interquartile range)	17 (14–20)	16 (15–18)	0.050
Duration of ICU stay in days median (interquartile range)	3 (2–3)	3 (2–4)	0.480
Hospital stay in days median (interquartile range)	5 (4–5)	5 (4–6)	0.230
Gos-E at discharge median (interquartile range)	6 (6–7)	7 (6–7)	0.002*
Gos-E at 1 month median (interquartile range)	7 (6–7)	7 (6–7)	0.505

and the position providing best access to the surgeon. Each of these positions is inherent with specific complications and can be due to the alterations in cerebral perfusion pressure in the various positions. Our aim, in this study, was to measure and compare the changes in the middle cerebral artery flow velocities that occur with positioning, among the various positions, in which the patients are placed for surgery of the posterior fossa. Our patients were placed in the supine with head tilt position for cerebellopontine angle tumors and in the prone position for other posterior fossa tumors.

In our study, the significant fall in systolic and mean flow velocities in both the groups postinduction paralleled the fall in mean arterial pressure in both the groups during induction. While there was a fall in systolic and mean flow velocities in the prone group postpositioning, in the supine with head tilt group, there was a significant fall in the SFV alone which did not reflect in a significant fall in the MFV. This could be due to the lesser changes in diastolic flow velocities in the supine with head tilt group than in the prone group. From the postinduction values, neither the SFV nor the MFV changed significantly after positioning and after repositioning in both the groups and the changes themselves were comparable between the groups. Hence, the changes in the systolic and MFV were due to the changes in mean arterial pressure and not due to positioning. The difference between the groups can be explained by the greater fall in mean arterial pressure in the prone group than the supine with head tilt group. Hanouz *et al*.,[6] in their study of changes in MCA flow velocity with placing the patient in beach-chair position from baseline supine position in shoulder surgery, found a small statistically significant decrease in the middle cerebral artery MFV (33 ± 10 cm/s vs. 39 ± 14 cm/s) after beach chair positioning. In our study, the change in MFV from the postinduction values after positioning in the prone and the supine with head tilt group was 0.94 ± 5.44 cm/s and −1.16 ± 7.43 cm/s, respectively, but these were not significant. These changes were lower than the fall due to beach chair positioning of 5 cm/s in the above study.

In a study in neurocritical care unit caring for postoperative patients by Kose and Hatipoglu,[7] in which the cerebral blood flow velocities were compared both preoperatively and postoperatively when changing the patients' position from the supine position with neck kept neutral to supine position with head elevation of 30°, right and left lateral positions with either flexion or extension of 30˚, they found that the MFV was in the higher side of the range in all positions in the postoperative period. There was no significant change postpositioning in the preoperative period as well as in the postoperative period, but the increase in MFV was higher in all other positions than the supine position with 30° elevation. They concluded that the increase in postoperative values as compared to preoperative values was not due to changes in position but due to surgical interventions. They recommended supine with head elevation of 30° as the best for nursing care. In our study, the MFV was measured with the patient still under the effect of anesthesia but not extubated after repositioning. These postsurgery values were lower than the baseline preoperative values in our study, but were similar to the postinduction values. This could be due to the effect of anesthetic agents.

Bombardieri *et al*.[2] studied in 22 patients undergoing lumbar spinal surgeries in prone position, the changes in cerebral blood flow velocities postpositioning, and every 15 min until 75 min from positioning on a single side from the post anesthetized values. The flow velocities were similar at all-time points until 75 min. Our study compared changes in cerebral blood flow velocities with prone positioning for surgical excision of tumors of the posterior fossa tumors in 27 patients. We chose the preinduction awake state values as the baseline. We measured on both sides the CBFV's after induction, and immediately after fixation of head postpositioning and immediately post repositioning. The postinduction MFV in our study was similar to their study (38 ± 13 in spine surgery study vs. 35.71 ± 8.46 and 37.99 ± 7.65 in theprone and supine with head tilt group, respectively). The MFV values after positioning remained similar to postinduction values in our study too. However, our study demonstrated a decrease in MFV postinduction and postpositioning as compared to baseline preoperative values in the prone group. The previous study did not mention preoperative flow velocity values.

The effective cerebral perfusion pressure was within normal limits in both the groups at all-time points. The effective cerebral perfusion pressure was lower in the supine with head tilt group than the prone group after repositioning. This change could be due to surgical manipulation. The effective cerebral perfusion pressure decreased in both the groups postinduction and returned close to baseline after positioning and after repositioning, demonstrating an increase. These changes paralleled the changes in the mean arterial pressure. All changes in eCPP in both the groups whether from baseline or from postinduction values to the later time points were comparable.

However, some of the limitations of our study were (a) we could not measure the flow velocities continuously during intraoperative period which requires a fixation device (helmet), as it would have interfered with the surgical positioning and pin application. (b) No patients were subjected to surgery in the sitting, beach chair or lateral positions; hence, the effect of positioning could not be compared with respect to these positions. (c) Our study was a single center study. A multicenter study with a larger sample size would better demonstrate changes with different surgical positions.

CONCLUSION

We found that the systolic and mean flow velocities were higher in the supine with head tilt group than the prone group after positioning and post repositioning, but these values were within normal limits, and the changes with positioning from baseline were comparable between the groups. Furthermore, these changes did not affect the effective cerebral perfusion pressure or the outcomes of the patients. Therefore, the current results do not allow us to determine whether the supine with head tilt position is better than the prone position.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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ANNEXURE- I

SURGICAL FIELD GRADING (BOEZAART'S SCALE)

0 No bleeding.
1 Slight bleeding - no suctioning of blood required.
2 Slight bleeding- occasional suctioning required. Surgical field not threatened.
3 Slight bleeding- frequent suctioning required. Bleeding threatens surgical field a few seconds after suction is removed
4 Moderate bleeding- frequent suctioning required. Bleeding threatens surgical field directly after suction is removed
5 Severe bleeding- constant suctioning required. Bleeding appears faster than can be removed by suction. Surgical field severely threatened and surgery not possible

A Boezaart's score of less than 4 will be considered as surgeon's satisfaction.