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Effects of Head and Neck Rotation on Internal Carotid Artery Blood Flow Velocity in Infants Undergoing General Anesthesia: assessment by Transfontanelle Ultrasonography

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Abstract

Introduction: Head and neck position can alter cerebral blood flow in infants. While cerebral perfusion is vital, intraoperative monitoring of cerebral blood flow velocity (CBFV) during head tilt has not been previously studied. Understanding this impact is crucial for optimizing infant head positioning during anesthesia. This study is to evaluate the effect of head and neck rotation at 30 and 45 degrees from neutral on internal carotid artery CBFV using transfontanelle doppler ultrasonography, and to assess its association with intraoperative blood pressure in infants undergoing elective surgery.

Methods: This quasi-experimental study included 18 infants aged 1-3 months undergoing elective surgery under general anesthesia. Transfontanelle ultrasonography measured CBFV at head and neck positions of 0, 30, and 45 degrees.

Results: Significant reductions in peak systolic flow velocity (PSFV), end diastolic flow velocity (EDFV), and mean flow velocity (MFV) were observed when tilting the head and neck from 0 to 30 degrees (PSFV $P<0.001$; EDFV $P=0.004$; MFV $P=0.015$) and from 0 to 45 degrees (PSFV $P<0.001$; EDFV $P<0.001$; MFV $P=0.003$). Tilting from 30 to 45 degrees also significantly decreased PSFV ($P<0.001$) and MFV ($P=0.015$), though EDFV did not significantly change ($P=0.092$).

Conclusion: Head and neck tilt at 30 and 45 degrees significantly reduced cerebral blood flow velocity in infants.

Keywords: cerebral blood flow velocity, head and neck rotation, infant, pediatric anesthesia, transfontanelle doppler ultrasonography

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Introduction

The brain is crucial for human survival. Human brain has high metabolism which places it at risk of hypoxia and ischemia when there is a disruption in oxygenation or circulation and could eventually cause neurological problems. The rate of such risk in infants is much higher than in other age groups due to the speed of neural processing that increases dramatically during infancy and takes the longest time to be completely developed.[1] Therefore, anesthesiologists need to understand neurophysiology and factors that can affect neurological function during anesthesia.

Normally, infants receiving anesthesia and surgery in the first month of their life are at higher risk of neurological complications as a result of intraoperative hypotension, hypocapnia, hyperoxia, or hypoxia, and hyperthermia, as well as reduction in blood supply to the brain which could also cause an undesirable neurological outcome.[2] The normal amount of blood flow to the brain in awake infants is around 100 ml/ 100 g of brain tissue/ minute or around 15% of cardiac output which was relatively high when comparing with the brain weight which accounts for 2% of the body weight. During anesthesia, there are several factors affecting cerebral blood flow velocity, i.e., anesthetic induction agents, inhalational anesthetics[3,4], hypotension, vascular resistance, and metabolic derangement. Even positioning can also directly affect brain circulation.[5]

In operating rooms, anesthesiologists usually rotate infant head (left or right) around 30 degrees from the midline to properly secure the endotracheal tube and prevent accidental extubation. However, until the present time, there has been no commonly accepted recommendation or standardized guideline regarding the most suitable pattern to position the infant heads under anesthesia. In some medical procedures, e.g., central venous catheterization requires more head rotation to the opposite of the cannulation site to facilitate the catheter insertion. In the meantime, there has been no continuous cerebral blood flow velocity (CBFV) monitoring during head rotation to demonstrate the amount of blood flow to the brain during anesthesia.

There has been evidence revealed that an extreme rotation by 45 degrees or more causes narrowing of the middle third of ipsilateral vein, presumably by soft tissue related to the sternocleidomastoid muscle.[6,7] And according to forensic radiological examination studied at post mortem, it was found that extreme head flexion or rotation could cause vertebral artery compression adjacent to C1 before the artery enters the transverse foramen.[8] The study on position dependent change of CBFV in infants found that positioning significantly influences CBFV with lower CBFV in prone position with head rotation to the right or left compared to the supine position with head in the midline. These changes were observed in the internal carotid, vertebral, and basilar arteries.[5]

There are 3 basic approaches to the measurement of cerebral blood flow including the Fick principle, the central volume principle, and the doppler effect that applies to ultrasound waves that interrogate the brain tissue at a certain frequency and results in frequency shift that is directly related to the speed of blood flow.[9]

Now, there are no routine devices to monitor blood flow in an infant brain during anesthesia. Furthermore, the anesthetic monitors still lack sensitivity to detect cerebral

hypoperfusion to that account. Transfontanelle doppler ultrasonography is currently used to assess CBFV change in patients undergoing cardiopulmonary bypass for cardiac surgery.[10] This ultrasound scan is considered non-invasive, reproducible, can be done at bedside[11], and has a capability to display precise CBFV.[12] Therefore, we established the use of transfontanelle doppler ultrasound measured CBFV as a surrogate of cerebral blood flow (CBF). This study aimed to evaluate the effects of head and neck rotation at 30 and 45 degrees on changes in the internal carotid CBFV in infants undergoing anesthesia assessed by transfontanelle doppler ultrasonography.

Methods

The study was approved by the Research Ethic Review Committee of Queen Sirikit National Institute of Child Health (REC.021/2565, 64-096). We obtained informed consent from legally authorized representatives or parents for their participation in this research. 18 infants aged 1-3 months, with ASA physical status I-III, undergoing general anesthesia with oral endotracheal intubation for an elective surgery in supine position at Queen Sirikit National Institute of Child Health participated in a quasi-experimental study from March 1, 2022, to March 31, 2023.

The exclusion criteria included: patients with unstable vital signs received inotropes/vasopressors or intubated, being hypotensive prior to anesthesia (SBP<60 mmHg, having physiological disorders which are at higher risk of post-anesthesia hypotension (MAP<20% baseline) including septic shock, severe and persist metabolic acidosis, congenital heart disease, respiratory distress and adrenal insufficiency, patients with abnormal anatomy of the skull, face and neck from physical examination or radiological examination, patients with a history of perinatal asphyxia and patients with cerebral palsy, increased intracranial pressure, hydrocephalus or undergoing brain surgery. (Figure 3)

To reduce measurement bias, the 2 assessors were trained and tested for interrater reliability (IRR) [intraclass correlation coefficient (ICC) 0.89] with the consultant radiologist. The steps of the research process were as follows: 1. The principal investigator/ assessors selected the population that met the inclusion criteria, 2. Parents or legally authorized guardians of the infant were invited and requested for consent to participate in the study on the same day they visited the outpatient clinic to schedule the surgical date. The invitation and the conduction of informed consent occurred under the circumstances that minimize the possibility of coercion or undue influence by the co-researchers and non-primary patient care team. The information sheet was given beforehand. The parents would be explained regarding the assessment process, benefits of the research and possible complications in detail. There would also be a request to use patients' personal medical data, pre-anesthetic assessment, anesthetic records, and further assessment of CBFV using transfontanelle doppler ultrasound, 3. In the operating room, standard anesthetic monitors such as pulse oximeter, electrocardiography, and noninvasive blood pressure device were applied to the patient before anesthesia. The baseline of SpO_2, heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial blood pressure (MAP) was recorded., 4. The anesthesia was proceeded by inhalation

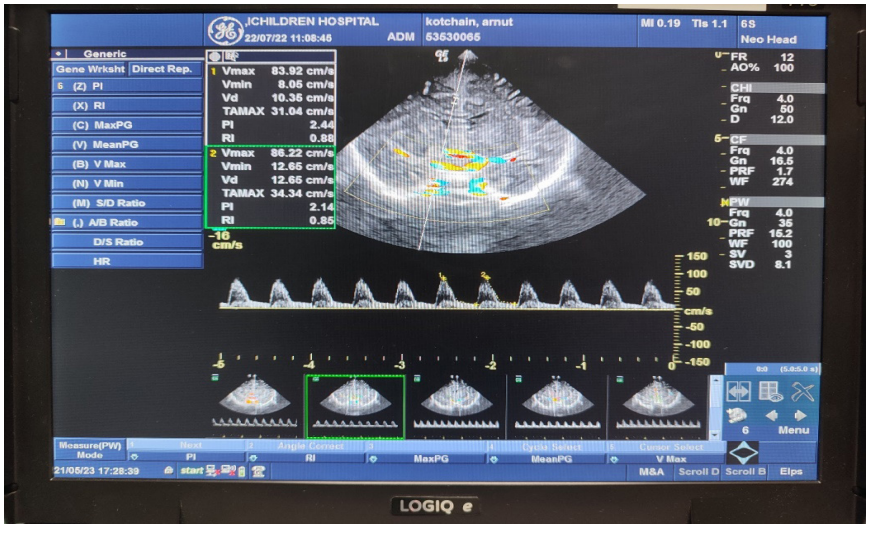


Figure 1 Ultrasonographic view with color doppler in left ICA and doppler recordings of CBFV in a 2-month-old infant

induction with 6-8% sevoflurane in air-oxygen with the flow rate of 4 L/minute. Intubation was done using cisatracurium 0.15 mg/kg., maintained with the combination of cisatracurium, fentanyl, and sevoflurane. The ventilation was controlled to keep end-tidal CO_2 between 35-40 mmHg, end-tidal sevoflurane between 2.5-3.0%, peak inspiratory pressure (PIP) between 10-20 mmHg, and FiO_2 between 0.35-0.4. The HR, SBP, DBP, MAP and oxygen saturation were continuously monitored every 5 min. The nasopharyngeal temperature, blood sugar measured by Accu-Chek® (0.6 microliter sample), and Hct obtained from HemoCue® Hb 201+ System (0.3-1 microliter sample) were recorded once. The intravenous fluid was given in compliance with Holliday-Segar method[13], 5. After anesthesia, the anesthesia team put the patient under supine position with head maintained in the midline. Then, the assessor used the GE LOGIQ e ultrasound machine with 6S-D cardiac sector probe to assess through anterior frontanelle in middle coronal plane with the probe applied and angled about 20-30 degrees to detect the image of internal carotid arteries (supraclinoid portion) on both sides. After that, the image was recorded as set as Figure 1. Next, infant head and neck were rotated either to the right or left with an angle of 30 degrees using goniometer, because dynamic time course of hemodynamic response after passive position change would happen after 30 sec.[14] Therefore, we provided a short 3-min pause after each assessment to have sufficient time for repositioning the infant head and rebalancing the body regulation. Then, assessment was restarted. The next image was recorded as Figure 2. Later, the infant's head

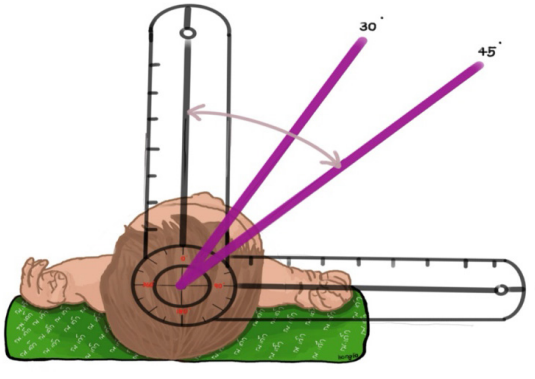


Figure 2 Head rotation during ultrasonographic assessment

and neck were rotated 45 degrees from midline, followed by a short break for 3 min. The final assessment was done, and the image was recorded as Figure 3 (total assessment took less than 10 min). During assessment, the patients still maintained under anesthesia as standard practice, with continuous vital monitoring, 6. After the research process of ultrasonographic assessment was completed, the patient was maintained as routine anesthetic practice, 7. All recorded images in the ultrasound machine were later brought to measure peak systolic flow velocity (PSFV), mean flow velocity (MFV), and end diastolic

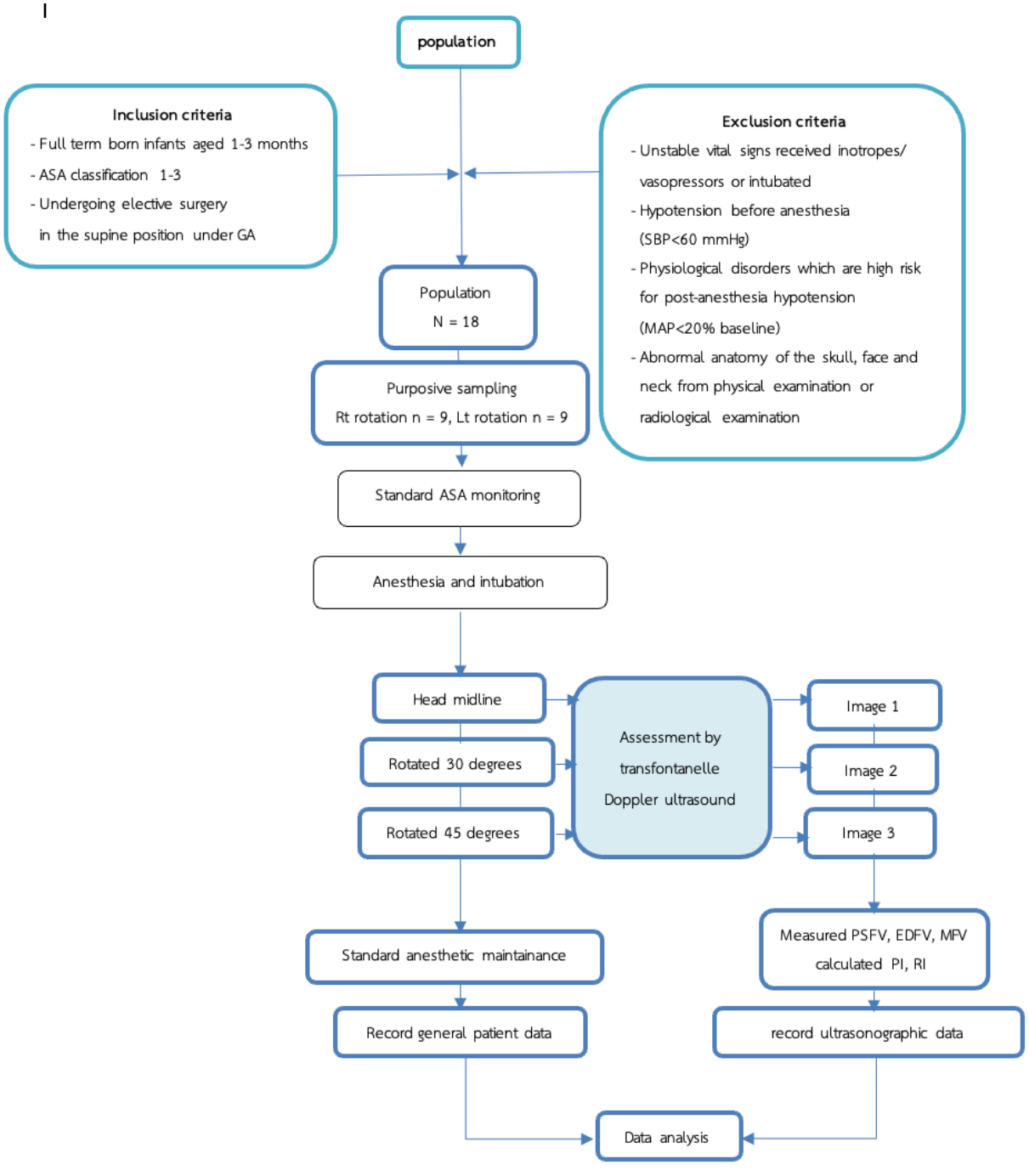


Figure 3 Study process

flow velocity (EDFV) using preset formula; followed by auto-calculation of pulsatility index (PI) and resistive index (RI) by the program in the ultrasound machine to record data in the record form.

Sample size calculation

The sample size to be studied was calculated by testing two dependent means for a pair-matched study. Standard deviation (SD) and different data between 2 groups (ICA head-centered vs ICA head-rotated) were referred to base on the study of Eichler.[5] The number of values in the population (N) = 15, sum of values (Σx) = 92, mean population (μ) = 6.1333333333333, which was brought for substitution in the formula to find SD as follows.[15,16]

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}.$$

$$\sigma^2 = \frac{\Sigma(x_i - \mu)^2}{N}$$

$$= \frac{(7 - 6.1333333333333)^2 + \ldots + (1 - 6.1333333333333)^2}{15}$$

$$= \frac{351.73333333333}{15}$$

$$= 23.448888888889$$

$$\sigma = \sqrt{23.448888888889}$$

$$= 4.8424052792893$$

Standard Deviation, σ: 4.8424052792893

Different data between the 2 groups (d) was brought from the same study.[5] The difference of CBFV between the 2 groups (ICA head-centered vs ICA head-rotated) was 43-38 = 5 cm/s. It was brought to substitute in the formula of testing two dependent means for a pair-matched study as follows.

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2\, \sigma^2}{d^2}$$

When n = sample size per group

σ = standard deviation = 4.84

d = different data between 2 groups = 5

Alpha (α) = 0.05

Beta (β) = 0.20

According to the formula, there were 16 samples obtained. Next, they were divided in groups by purposive sampling into 8 infants with head rotated to the left and the other 8 with head rotated to the right. More samples were also calculated in case of dropout = 10%. The total population obtained for data collection was 18.

Statistics for data analysis

Data was analyzed by SPSS for Windows, Version 16.0. Chicago, SPSS Inc; 2007, and R, Version 4.2.3; 2023. Sex, age, birth weight, current weight, length of body, head circumference (HC), patient classification by diseases in compliance with American Society of Anesthesiologists (ASA), general appearance, type of surgery, type of fluid received, and complications. In case of normal distribution, the data was displayed in mean ± SD. In case of non-normal distribution, the data was displayed in median and IQR.

Qualitative data was displayed in number and percentage. The physiological variables of

pre- and post-anesthesia were compared, i.e., systolic blood pressure, diastolic blood pressure, mean arterial pressure, heart rate, and SpO_2. The physiological variables of pre- and post-measurement from head positioning were also compared, i.e., peak systolic flow velocity, end diastolic flow velocity, and mean flow velocity. In case of normal distribution, the results were analyzed by paired Student's t-test. In case of non-normal distribution, the results were analyzed by Wilcoxon signed rank test. A *P*-value < 0.05 was considered statistical significance.

Results

Over a period from March 2022 to March 2023, 18 patients were included in the study. There were 11 male infants (61.1%) and 7 female infants (38.9%). The mean age, birth weight, current body weight, body length, head circumference were 2.7 (0.8) mo, 3.3 (0.4) kg, 5 (0.9) kg, 55.9 (6.4) cm. and 39.7 (3.3) cm, respectively. Most patients were classified as ASA physical status II (77.8%). 44.4% of the patients underwent open abdominal surgery. The average operative time was less than 4 h, and the average withholding period for milk prior to anesthesia was 7.7 (1.1) h (Table 1). Transfontanelle doppler ultrasound scan was completed in 16 patients because the data could not be obtained on the day of anesthesia in one patient in each group. (Figure 4)

Vital parameters prior to anesthesia including SBP, DBP, MAP, HR and pulse oximetry were within the normal range according to age.

Table 1 Demographic data

Variables	n=18
Gender, n (%)	
Male	11 (61.1)
Female	7 (38.9)
Age (mo), mean (SD)	2.7 (0.8)
Birth weight (kg), mean (SD)	3.3 (0.4)
Body weight (kg), mean (SD)	5 (0.9)
Length (cm), mean (SD)	55.9 (6.4)
Head circumference (cm), mean (SD)	39.7 (3.3)
ASA physical status, n (%)	
I	4 (22.2)
II	14 (77.8)
Types of surgery, n (%)	
Laparotomy	8 (44.4)
Urological surgery	1 (5.6)
Ophthalmic surgery	4 (22.2)
Plastic surgery	4 (22.2)
CVC insertion	1 (5.6)
Type of intravenous fluid, n (%)	
5% DN/3	10 (55.6)
5% DN/4	2 (11.1)
10% DN/5	5 (27.8)
5% DN/5	1 (5.6)
Amount of fluid received prior to induction (mL), mean (SD)	78.6 (30.8)
NPO time (h), mean (SD)	7.7 (1.1)

The mean body temperature, Hct level and blood sugar were 36.7 (0.3) °C, 34.7 (4.3) % and 99.5 (6.4) mg/dL, respectively. The median time taken from the initiation of anesthesia to transfontanelle ultrasonographic scanning was 8 (7.4, 9.2) min with one patient having to spend 40 (8.3) min during this period because of an endotracheal leakage requiring

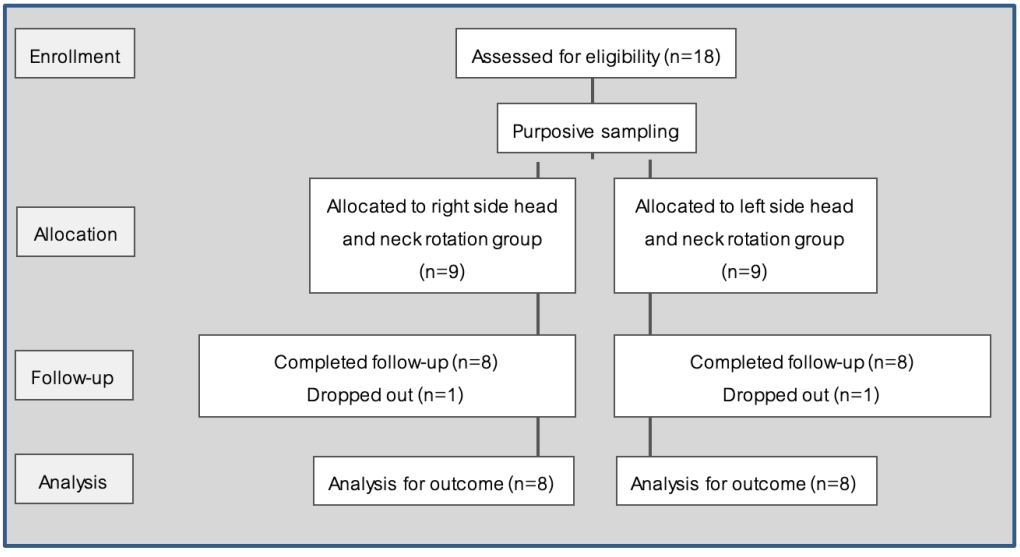


Figure 4 Consort flow

a replacement and unavailability of the ultrasound machine (Table 2).

After anesthesia, there was a significant decrease in systolic, diastolic and MAP when rotating the head to an angle of 30 and 45 degrees from midline (P<0.05) (Figure 5). There were no clinical or statistically significant changes in end tidal CO_2 (35-40 cmH_2O), end tidal sevoflurane (2.5-3%), Peak inspiratory pressure (12-18 mmHg), oxygen pulse oximetry throughout the study. The average evaluation time per person was 8 min.

Table 2 Physiologic and preoperative parameters collected in awake patients

Variables	Total (n=18)
Systolic blood pressure (mmHg), mean (SD)	86.6 (12.4)
Diastolic blood pressure (mmHg), mean (SD)	47.9 (11.1)
Mean arterial pressure (mmHg), mean (SD)	60.6 (12)
Heart rate (bpm), mean (SD)	141.4 (23.3)
SpO_2 (%), median (IQR)	100.0 (100.0, 100.0)
Head and neck rotation side, n (%)	
Left	9 (50.0)
Right	9 (50.0)
Time from induction to 1st assessment (min), median (IQR)	8.0 (7.4, 9.2)
Body temperature (°C), mean (SD)	36.7 (0.3)
Hct (%), mean (SD)	34.7 (4.3)
Blood sugar level (mg/dL), mean (SD)	99.5 (6.4)

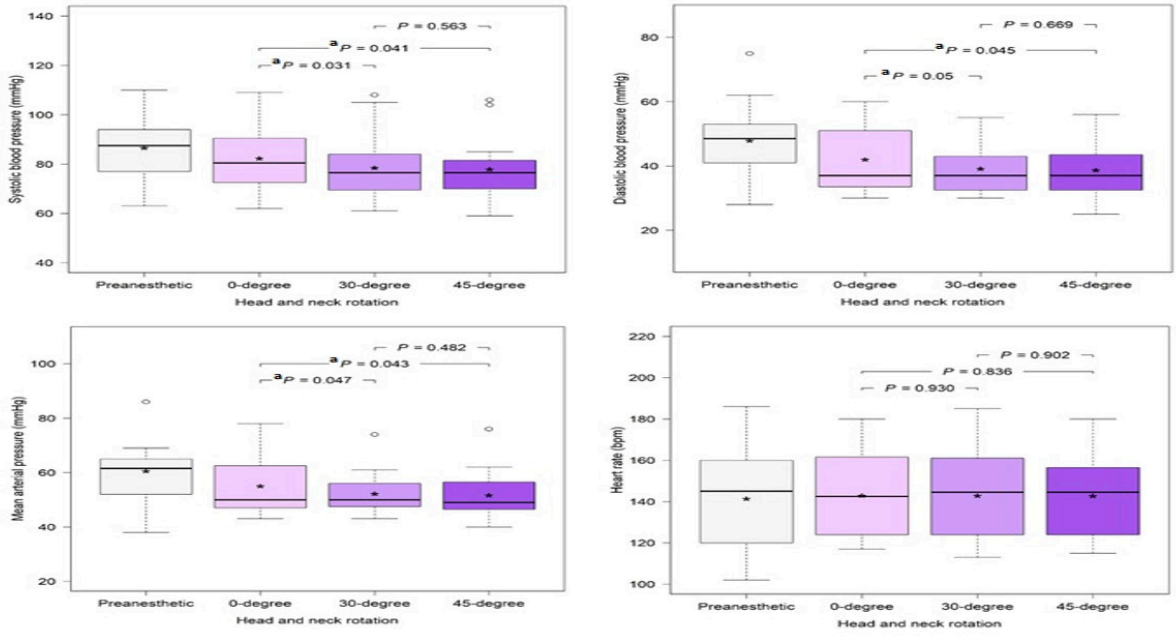


Figure 5 Comparison of physiologic parameters at baseline and after head and neck rotation under anesthesia

[a] *P*-value < 0.05; * mean; - median

Following electronically storing perioperative ultrasonographic images, PSFV, MFV and EDFV were measured with a built-in formula. A significant reduction in PSFV, EDFV and MFV values were observed when infants heads were tilted from an angle of 0 to 30 degrees; PSFV 106 (29.4) vs. 98.7 (29.1) cm/s (*P*<0.001), EDFV 28.7 (12.8) vs. 23.8 (10.8) cm/s (*P*=0.004), MFV 55.2 (19.8) vs. 49.5 (17.4) cm/s (*P*=0.015) and from an angle of 0 to 45 degrees; PSFV 106 (29.4) vs. 91.6 (26.8) cm/s (*P*<0.001), EDFV 28.7 (12.8) vs. 22 (11.4) cm/s (*P*<0.001), MFV 55.2 (19.8) vs. 45.1 (16.7) cm/s (*P*=0.003), and it was found that when tilting the patient's head and neck from an angle of 30 to 45 degrees, the PSFV and MFV decreased significantly with PSFV 98.7 (29.1) vs. 91.6 (26.8) cm/s (*P*<0.001), MFV 49.5 (17.4) vs. 45.1 (16.7) cm/s (*P*=0.015) respectively, but the EDFV did not change. The EDFV was 23.8 (10.8) vs. 22 (11.4) cm/s (*P*=0.092) (Table 3).

We analyzed flow parameters in the internal carotid arteries during the head and neck rotation to each side at different degrees after anesthesia. By comparing the flow on each side, we found difference of data between the left and the right sides as demonstrated in Table 4 and 5, and Figure 6.

There was no correlation between blood pressure and CBFV (Pearson correlation coefficient 0.05-0.28). In addition, our study found no significant relationship between CBFV and variables such as Hct level, blood sugar, body temperature, and the amount of intravenous fluid administered prior to anesthesia. There were no anesthetic or

Table 3 CBFVs in the ICA at different degrees of head rotation

Variables	0	30	45	mean difference (0 vs 30)	*P*-value (0 vs 30)	mean difference (0 vs 45)	*P*-value (0 vs 45)	mean difference (30 vs 45)	*P*-value (30 vs 45)
PSFV (cm/s) % change	106.0 (29.4)	98.7 (29.1) [6.89]	91.6 (26.8) [13.58]	7.264	<0.001*	14.372	<0.001*	7.108	<0.001*
EDFV (cm/s) % change	28.7 (12.8)	23.8 (10.8) [17.07]	22.0 (11.4) [23.34]	4.946	0.004*	6.793	<0.001*	1.847	0.092
MFV (cm/s) % change	55.2 (19.8)	49.5 (17.4) [10.33]	45.1 (16.7) [18.3]	5.734	0.003*	10.124	0.001*	4.391	0.015*

PSFV, EDFV, MFV, PI and RI are expressed as mean (SD)
% change indicated percentage of CBFV reduction from 0 degree (neutral position)
* *P*-value < 0.05

Table 4 CBFVs in the right ICA at different degrees of head rotation

Variables	0	30	45	mean difference (0 vs 30)	*P*-value (0 vs 30)	mean difference (0 vs 45)	*P*-value (0 vs 45)	mean difference (30 vs 45)	*P*-value (30 vs 45)
PSFV (cm/s) % change	106.9 (28.8)	99.0 (29.1) [7.39]	92.8 (26) [13.19]	7.86 (4.45, 11.27)	<0.001*	14.05 (8.93, 19.17)	<0.001*	6.19 (1.79, 10.59)	0.009*
EDFV (cm/s) % change	29.6 (13.1)	24.2 (10.4) [18.24]	21.9 (11.4) [26.01]	5.32 (1.78, 8.86)	0.006*	7.61 (3.58, 11.65)	0.001*	2.29 (-0.59, 5.18)	0.1103
MFV (cm/s) % change	55.6 (20.7)	50.1 (17.7) [9.89]	45.3 (17.1) [18.53]	5.48 (1.83, 9.13)	0.006*	10.30 (3.30, 17.29)	0.007*	4.81 (0.35, 9.28)	0.036*

PSFV, EDFV, MFV are expressed as mean (SD); Mean differences are expressed as median (IQR)
% change indicated percentage of CBFV reduction from 0 degree (neutral position)
* *P*-value < 0.05

Table 5 CBFVs in the left ICA at different degrees of head rotation

Variables	0	30	45	mean difference (0 vs 30)	*P*-value (0 vs 30)	mean difference (0 vs 45)	*P*-value (0 vs 45)	mean difference (30 vs 45)	*P*-value (30 vs 45)
PSFV (cm/s) % change	105.1 (30.6)	98.4 (29.3) [6.37]	90.4 (27.9) [13.99]	6.67 (3.63, 9.71)	<0.001*	14.69 (9.51, 19.87)	<0.001*	8.02 (5.16, 10.88)	<0.001*
EDFV (cm/s) % change	27.9 (12.6)	23.4 (11.3) [16.13]	22.0 (11.7) [21.15]	4.58 (1.69, 7.46)	0.004*	5.98 (3.11, 8.85)	<0.001*	1.40 (-0.72, 3.52)	0.180
MFV (cm/s) % change	54.8 (20.1)	48.8 (17.5) [10.95][d]	44.9 (17) [18.07][d]	5.99 (1.33, 10.64)	0.015*	9.95 (4.37, 15.53)	0.002*	3.96 (0.97, 6.96)	0.013*

PSFV, EDFV, MFV are expressed as mean (SD); Mean differences are expressed as median (IQR)
% change indicated percentage of CBFV reduction from 0 degree (neutral position)
* *P*-value < 0.05

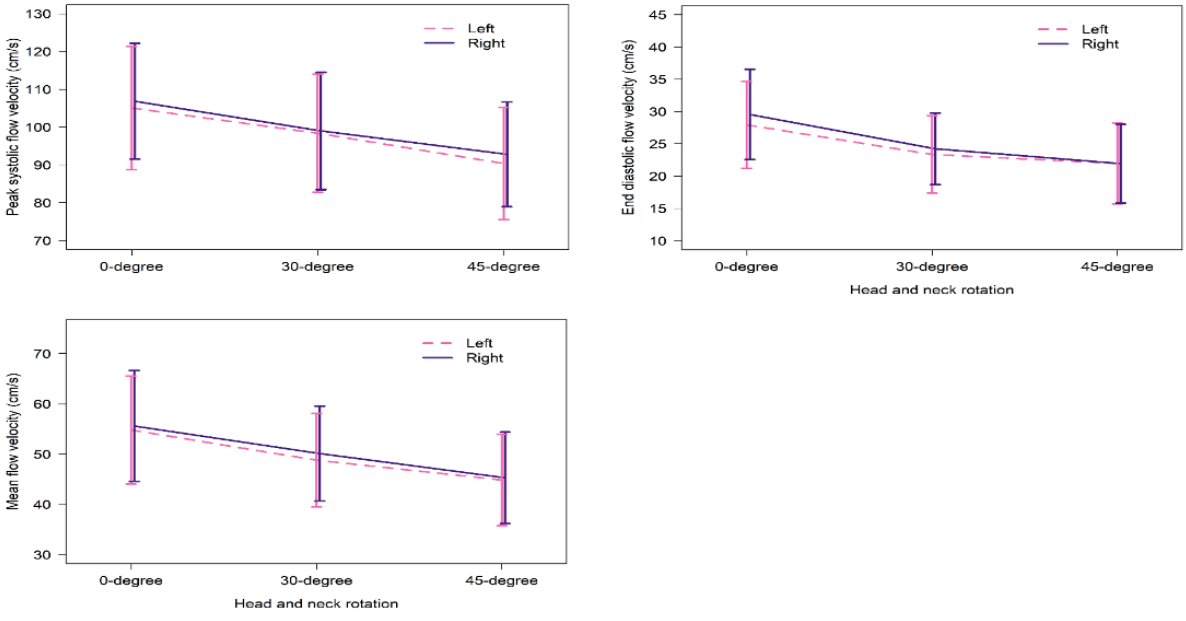


Figure 6 Comparison of internal carotid flow velocity between the left and right sides during head and neck rotation

ultrasonographic device complications found during the study process. Moreover, all patients being analyzed in this study did not have any neurological abnormalities when assessed during the post-operative hospital stay.

Discussion

This study is the first study to demonstrate that head and neck rotation cause statistically significant decrease in CBFV assessed non-invasively using transfontanelle ultrasound in infants aged 1-3 months undergoing general anesthesia, as the heads were tilted from an angle of 0 to 30 or 45 degrees.

Aberrant CBF may serve as a prognostic indicator of neurological outcomes in children. Abnormal CBF may also be a target for reducing brain injury. However, clinical significance of CBF reduction and lower limit of CBFV in the studied population have not yet been established. Additionally, Hansen NB[17] found that the mean CBFV is the best predictor of changes in CBF. We found 10.3-18.3% reduction of mean CBFV with a turn of the head by 30°-45° which may assumingly reflect a decrease in the CBF and PP.

Normal CBF values in infants have not been established. We compared our initial arterial blood flow velocity data with data from Bode and colleagues.[18] assessing mean flow velocities in basal cerebral arteries in children aged 11-90 days and found an overall consistency: ICA PSFV 77 (19) cm/s (our data: 106 (29.4) cm/s). ICA EDFV 24 (8) cm/s (our data: 28.7 (12.8) cm/s) and ICA MFV 43 (12) cm/s (our data: 55.2 (19.8) cm/s). The higher CBFV observed in infants in our study can be attributed to the fact that most of our patients were older compared to the participants in the

previous study. This aligns with the findings of another study, which indicated that cerebral vascular peak velocities increase significantly during infancy and continue to decline gradually until the age of 18 and remained relatively stable thereafter.[19]

Although Pamphlett et al. found that a 45° head tilt from midline initially compressed internal jugular vein, and complete vascular occlusion occurred at 60° head tilt.[20] They did not reveal whether compression alters CBF. While Eichler et al., found that the mean flow velocity in the internal carotid, vertebral and basilar arteries was reduced in prone positions with the head turning left or right compared to the supine position with the head at neutral (P=0.004). It was also found that CBFV did not differ when measured at the internal carotid artery or the vertebral artery and whether evaluated from the left or right.[5] This is consistent with our study which found that the PSV, EDV, and MV in the internal carotid arteries were significantly decreased when the patient's head and neck were tilted from 0 to 30 degrees and from 0 to 45 degrees (P<0.05) and found that when tilting the patient's head and neck from an angle of 30 to 45 degrees, the PSV and MV also decreased significantly (P<0.05). These values obtained from tranfontanelle ultrasonography were not different whether assessed from the right or left. Therefore, it is possible that head and neck rotation influence both cerebral artery and vein.

Rhondali study in children younger than 6 months showed that when MAP value is 38 +/- 9 mmHg, CBFV significantly decreases under sevoflurane anesthesia about 1 MAC. Therefore, they stated that this value may be the lower limit of autoregulation in children younger than 6 mo with sevoflurane anesthesia about 1 MAC. In addition, the effect was more important in the brain of infants younger than 6 mo, who specifically have a higher MAC of sevoflurane.[4] In our study, MAP when maintaining end tidal sevoflurane between 2.5-3 was 60.6 (12) mmHg. Despite a decrease in BP following anesthetic induction in all infants, it is noteworthy that our MAP was consistently maintained within the autoregulation range referring to Rhondali's. This indicates that CBFV remained relatively unaffected by the decrease in BP induced by anesthesia. We further investigated the lack of correlation between these variables (PSV, EDV, MV and SBP, DBP, MAP) by utilizing the Pearson correlation coefficient, which yielded values ranging from 0.05 to 0.28.

Most of the patients in this study underwent abdominal surgery, unlike previous studies that were conducted at intensive care units[5,21,22], carried out as a radiological study[6,20] or evaluated in pediatric patients undergoing coronary artery catheterization[7]. Although ultrasound assessment is quite safe, it does carry some risks of pressure and thermal injuries resulted from the probe pressure and temperature generated within the process. The assessors stayed within the British Medical Ultrasound Society[23] recommended scan times throughout the study. From post operative hospital stay to hospital discharge, no complications were observed in any of the participants. The results of our study provide information that the rotation of the head and neck during

anesthesia can disrupt CBF. However, the clinical significance of this finding could not be demonstrated. A retrospective cohort study of critical incidence in pediatric anesthesia at Queen Sirikit National Institute of Child Health[24] in 44,263 patients, 1,105 complications were found (in 1,070 patients) out of 44,263 patients during anesthesia. Nevertheless, there has been no data of neurological complications related to head positioning. However, the disruption of CBF might have the potential to compromise the perfusion and neurological function of the brain. Therefore, anesthesiologists caring for infants should be careful when position the infant's head and neck during anesthesia.

There were several limitations. The CBFV was used as a surrogate for cerebral blood flow in this study. Its association with cerebral outcomes has not been established. We have not assessed cerebral oximetry and neurological outcome as an end point. Further studies are needed to confirm the results, including assessment the cerebral oximetry and finding the association between CBFV and regional cerebral oxygenation. The future long-term neurological follow-up study should be performed.

Conclusion

Head and neck tilted at the angles of 30 and 45 degrees reduced the CBFV in infants. It appears more advisable to be more vigilant and attentive during anesthesia, by optimizing head positioning and appears increasingly evident that a continuous monitoring of cerebral perfusion is necessary to help us in accurately taking care of specific infants that are at risk of neurological problems. Further research is required to assess the clinical significance of the percentage reduction in CBFV to gain a better understanding of the potential impact and relevance of changes in CBFV and how it may influence patient outcomes.

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