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Research Article

Effect of Anesthesia on Intracranial third Ventricular Diameter in Infants and Toddlers- A Case Series

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Abstract

Background and Objective: This case series investigates the effect of anesthetic technique—specifically nitrous oxide use—on the third ventricular diameter (TVD) in infants and toddlers undergoing pediatric surgical procedures under general anesthesia.

Methods: Transcranial sonography was used to assess TVD at multiple intraoperative time points in a cohort of pediatric patients. Comparative analysis was conducted between patients receiving O_2:N_2O and O_2:Air anesthetic mixtures alongwith sevoflurane and caudal / epidural analgesia.

Results: The study cohort of 15 patients was analyzed. A statistically significant change in TVD was observed across time points, particularly between post-skin incision and skin closure. The O_2:Air group demonstrated greater ventricular dilation compared to the O_2:N_2O group. Eleven patients received caudal block, whereas one patient received epidural catheter insertion for perioperative analgesia.

Conclusion: Nitrous oxide usage in 50:50 ratio with oxygen and sevoflurane exerts minimal effect on intraoperative third ventricular dilation. However, confounding factors such as caudal / epidural analgesia efficacy warrant further investigation in form of randomized trials to generate level 1 evidence in this regard.

Keywords: infants; third ventricular diameter; nitrous oxide; intracranial pressure; anesthesia

Introduction

The third ventricle can be visualized using transcranial ultrasound through the trans-temporal bone window—a method primarily described for assessing brain structures and ventricles in patients with hydrocephalus,[1,2] psychiatric disorders3 and neurodegenerative pathologies.[4-6]

In pediatric populations, particularly infants and toddlers, the temporal bone is generally more penetrable, making ultrasound-based measurement of the third ventricle a promising, non-invasive, and radiation-free method for assessing the ventricular system in children with hydrocephalus. However, anesthetic agents such as nitrous oxide (N2O)—commonly used for maintenance during pediatric surgery—can influence craniometrics by altering cerebral blood flow and, subsequently, intracranial pressure.

N2O is a colorless, non-inflammable gas used as a carrier gas for sevoflurane. It has a minimum alveolar concentration of 105% and a blood/gas partition coefficient of 0.46. It acts by partial blockade of acetylcholine, gamma-aminobutyric acid, N-methyl-d-aspartate and histamine receptors. It also partially potentiates GABA and glycine receptors. Because of its poor blood solubility, alveolar and brain concentrations are achieved very rapidly. When administered with sevoflurane it causes increase in cerebral blood flow, however this effect gets decreased when administered with propofol. Increase in intracranial pressure and impairment of cerebral autoregulation have been reported with its use.[7]

Although there is a renaissance in recent studies that are exploring the impact of anesthetic induction on cerebral oxygenation,8 electroencephalography trends[9] and cerebral blood flow.[10] There still remains a gap in published literature regarding effect of N2O on infants and toddlers. Therefore we decided to investigate this potential confounding factor, by conducting an observational study on a cohort of children of this age group. They underwent complex pediatric surgical procedures under general anesthesia. Therefore we assessed the impact of anesthetic maintenance with nitrous oxide on the third ventricle diameter assessed sonographically using the phased array probe of Sonosite TM machine (Figure 1)

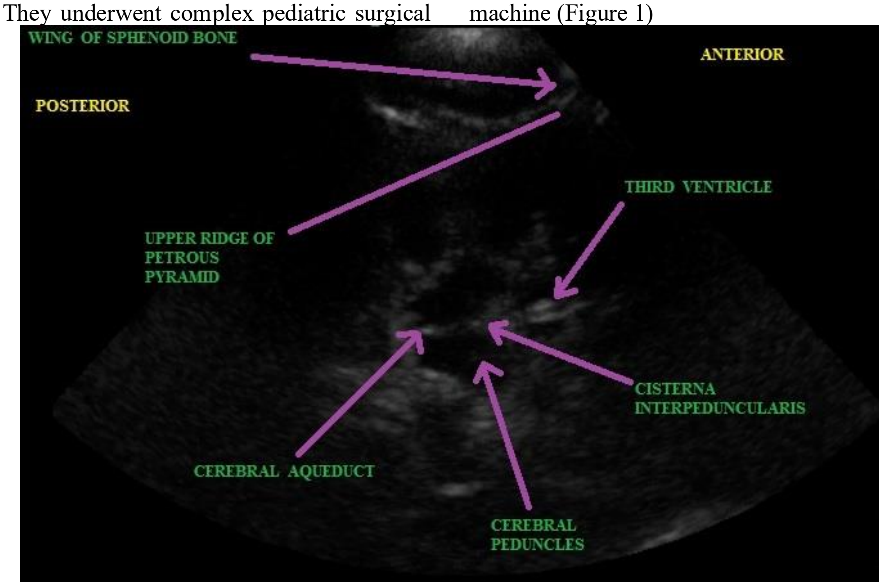

Figure 1: The sonoanatomical landmarks while observing the third ventricle of the brain using phased array transducer of Sonosite ultrasound machine.

Methodology

This case series adheres to the EQUATOR network guidelines. As the observational analysis was being done on the existing anesthetic practice of the institute, the ethical clearance was not required. After valid informed consent from the parent of the child, the patient was brought into the operation theatre after premedication.

Anesthetic induction was done as per conventional protocol of balanced anesthesia technique. The muscle relaxant used to facilitate jaw relaxation was recorded in the excel chart. Endotracheal tube was inserted as per the age appropriate formula. Cuffed endotracheal tubes were inserted as per the size predicted by Motoyama formula, whereas the uncuffed endotracheal tubes were inserted as per the size predicted by Cole's formula.

Although the ETT was inserted as per the formula for depth of the tube i.e. (age in years / 2) + 12 cm, we mandatorily auscultated bilateral air entry after insertion of the ETT. The first assessment of third ventricular diameter (TVD) was done at this time using phased array transducer of Sonosite TM machine. Thereafter the child was placed in lateral position for caudal block or epidural catheter insertion as per the requirement cited by the pediatric surgeon (Figure 2). After this procedure, the child was placed in the operative position and TVD was assessed at skin incision, skin closure and prior to extubation.

Figure 2: Child positioned for caudal block in lateral position after endotracheal intubation

Results

The demographic analysis of 13 male and 2 females children revealed an age {mean + standard deviation} of 24.7 + 12.8 months; inter-quartile range (IQR) of 12.5 - 36 months. Uncuffed Oral Endotracheal Tube (UCETT) was used in 7 children, while rest of them were intubated with Cuffed Oral Endotracheal Tube (COETT) (Figure 3).

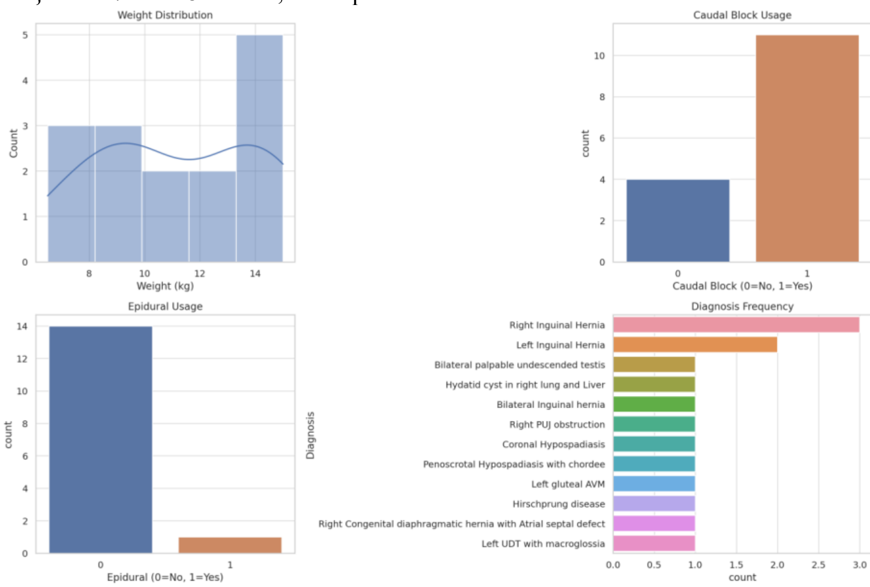

Figure 3: The trend of demographic data

Third ventricle diameter trend across the four intraoperative time points of measurement, depicted a trend toward increase in the TVD after intubation (D1) till skin closure (D3). The largest mean TVD was seen at the skin closure (D3), this suggested transient dilation of the third ventricle during surgery. By the time of extubation (D4), TVD stabilized or decreased slightly but often did not return completely to the initial values observed soon after intubation (D1) (Figure 4).

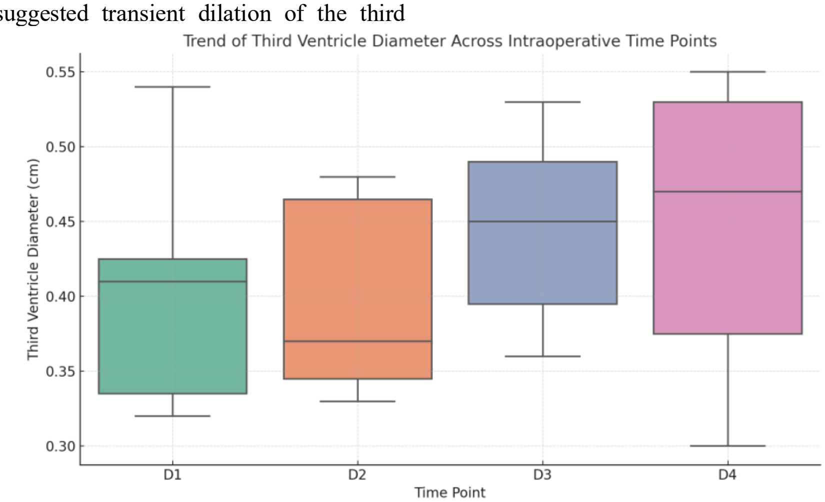

Figure 4: Boxplot illustrating the trend of third ventricular diameter across the observed time points

Non-parametric test for repeated measures (Friedman test) revealed a statistically significant difference in third ventricle diameters across the four intraoperative time points, (p-value= 0.0062). Post-Hoc pair-wise comparisons using the Wilcoxon Signed-Rank Test showed a statistically significant change in the third ventricle diameter over the course of surgery i.e. between skin incision (D2) and skin closure (D3) ($p < 0.01$) (Table 1). This indicated that intraoperative factors- like usage of nitrous oxide, surgical manipulation, anesthetic depth, were associated with measurable changes in ventricular dimensions.

Comparison of TVD between observed time points	p-value	Interpretation
D1 vs D2	1.000	Not significant
D1 vs D3	0.382	Not significant
D1 vs D4	0.723	Not significant
D2 vs D3	0.004	Significant
D2 vs D4	0.108	Not significant

D3 vs D4	1.000	Not significant

Table 1: Comparison of TVD between the observed time points using Wilcoxon Signed-Rank Test

Analysis between patients who received O2:N2O and O2: Air: was done by using the numerical encoding of 0 for O_2: N_2O group and 1 for O_2: Air group. The O_2: N_2O group exhibited a increase in diameter till the culmination of anesthesia protocol (D1 to D4). However, the overall trend appeared to be more stable in comparison to the O_2: Air group. This group showed a steeper rise, between the time points from D1 to D3, and thereafter it exhibited a modest decrease in TVD at the time of culmination of anesthesia, just prior to extubation (D4) (Figure 5). Interestingly the O_2: Air: group demonstrated greater fluctuation in ventricular size, with a notably larger increase at the time of skin closure (D3).

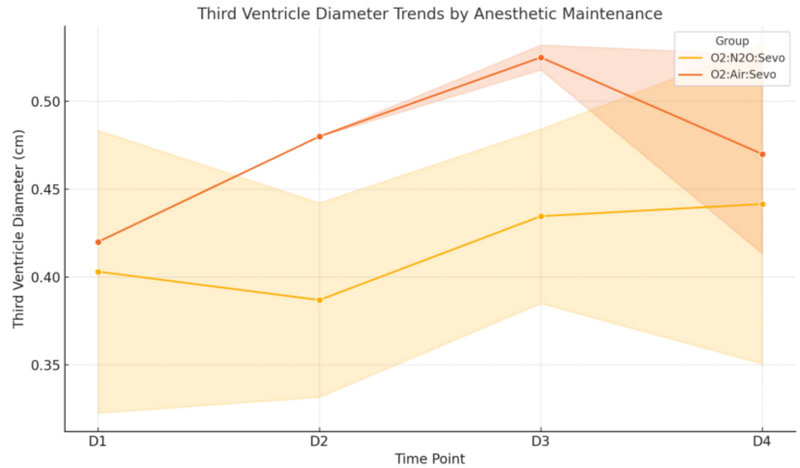

Figure 5: Comparison of third ventricular diameter between the O2:N2O group and O_2:Air group

The comparison between the observed time points of TVD assessment was done using Mann-Whitney U test. It revealed significant differences at D2 (post skin incision) and D3 (skin closure). At these time points, the O_2: Air group had significantly larger third ventricle diameters compared to the O_2: N_2O group. There was no significant differences at baseline (D1) or pre-extubation (D4). (Table 2)

Observed time point for TVD assessment	U statistic	p-value	Interpretation
D1	9.0	0.55	Not significant
D2	0.0	0.033	significant
D3	0.0	0.033	significant
D4	12.0	0.93	Not significant

Table 2: Comparison of observed time points for TVD assessment using Mann-Whitney U test

Discussion

Mechanical ventilation and ETT positioning can directly influence intracranial pressure. While formulas such as Motoyama's and Cole's provide population-based ETT size estimation, optimal depth of insertion of endotracheal tube is required for avoiding mainstem bronchus intubation. That is why we inserted the ETT as per the PALS estimation formula for this purpose {[Age (in years) / 2] + 12}

Nevertheless, there are other formulas also but their performance is variable for each individual patient, because age-based or height-based formulas are based on population statistics and the current patient may be outside the mean of that population.12 Internal diameter estimation of ETT can be done by simply following the equation: 3 x ID of ETT. However, it can only be used for ETT 3.0 or greater, and it has ~ 59% accuracy in prediction of placement.

The Penlington formula is used to estimate the appropriate internal diameter (ID) of an uncuffed endotracheal tube (ETT) for children. It's a simple, age-based formula, and the formula varies depending on the child's age: ID (mm) = (age in years) / 4 + 4.5 if the child is less than 6.5 years old and ID (mm) = (age in years) / 3 + 3.5 if the child is 6.5 years or older.

ETT placement confirmation has typically begun with auscultation of breath sounds. Equal bilateral breath sounds would seem to suggest aeration from above the carina. The problem is that ETT's with a Murphy eye can generate bilateral breath sounds even in the setting of a main stem bronchial intubation. Bilateral breath sounds do not exclude main stem intubation.13

Third ventricle ultrasound is usually a simple technique, although a large insonation angle could lead to an overestimation of third ventricular diameter. de Cassai et al.14 conducted a study using a mathematical model to evaluate the impact of probe inclination on the false positive rate while evaluating the TVD. They used R software to simulate a pool of 100,000 fictitious patients for assessing TVD sonographically for 30 consecutive days. The insonation angle of > 35 degrees contributed to false positive rate of 3.71%, whereas the insonation angle of ≤ 15 degrees had a false positive rate of mere 0.06%. We too kept our insonation angle as parallel as possible to the temporal bone in order to achieve similar accuracy in our data.

Hernández et al.15 studied TVD using computed tomography (CT), ultrasound and magnetic resonance imaging (MRI) in a study cohort of 30 patients with mean age 48.5 years. 66.6% of the patients were females in this study cohort. In the CT scans they observed the mean TVD to be 2.98 mm in males and 2.56 mm in females. On sonographic assessment, the mean third ventricle diameter was 3.97 + 2.58 mm. Whereas on MRI assessment it came out to be 3.70 +/- 2.27 mm. There was a high correlation between the values (r =0.85). Nevertheless, they did not study impact of anesthesia on TVD, unlike our case series.

Nitrous oxide has cerebral vasodilatory effect therefore it increases the cerebral blood flow. This leads to an increase in cerebral blood volume, which, shall increase the intracranial pressure in non-compliant patients.16 However, in our analysis between O_2: Air (50:50) group and O_2: N_2O group (50:50), we observe a statistical paradox situation, where nitrous oxide appeared to attenuate intraoperative ventricular dilation as per the analyzed data. This can be explained by the rationale that we used nitrous in 50:50 ratio with oxygen in our series. Therefore, the effects as described by previous authors were not evident, because they had used nitrous in 66:33 ratio with oxygen.

Another issue is, that in the presence of sevoflurane in the anesthetic gas mixture for maintenance, the role of nitrous became secondary - i.e. it became a carrier gas. Therefore, the primary effect of sevoflurane dominated the clinical picture on TVD assessment.

Also, it will be worth speculating that there could have been a delayed effect of caudal block / epidural analgesia in the O2: Air group could have influenced the pain pathway and thereby affected the systemic and cerebral hemodynamics to cause this effect in our analyzed data.

Nevertheless, the sample size of the study cohort is small, and an adequately powered randomized trial should be done in future to validate the findings observed in results of our case series.

Conclusion

As per the data obtained from this study cohort, the usage of nitrous oxide in 50-50 % with oxygen does not result in increase in ICP in comparison to using oxygen Air mixture in same ratio. However, adequately powered level 1 evidence is mandated for further research in this regard.

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