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## Original Research Paper

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### Normal Position of the Cerebellar Tonsils in Relation to the Anteroposterior Diameter of the Foramen Magnum in Individuals of Different age groups: *The Zambian Experience*

Patience N. Buumba<sup>1</sup>, Moono Silitongo<sup>1,2</sup>, Hilda Zulu<sup>1</sup>, Dailesi Ndhlovu<sup>1</sup>, Boyd Mudenda<sup>3</sup>, Krikor Erzingastian<sup>4</sup>

<sup>1</sup>Department of Anatomy, School of Medicine, University of Zambia, Lusaka, Zambia.

<sup>2</sup>Department of Basic Sciences, School of Medicine, Copperbelt University, Ndola, Zambia

<sup>3</sup>Department of Public Health, School of Medicine, University of Zambia, Lusaka, Zambia.

<sup>4</sup>Departments of Surgery and Anatomy, School of Medicine, University of Zambia, Lusaka, Zambia

Email: [patiantor@yahoo.com](mailto:patiantor@yahoo.com)

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#### Abstract

**Background:** The Cerebellar Tonsils (CT) are part of the Nervous System (NS), though their functional role is not yet known, although they are believed to coordinate skilled and learned movements. They are prone to herniating through the foramen magnum in conditions causing increased intracranial pressure which, in severe cases, may lead to death. There is no standard position of the cerebellar tonsils and no studies have been carried out on the Zambian population or the region. Therefore the need to carry out the current study.

**Objective:** To determine the relationship between the normal position of the CT and the anteroposterior diameter of the foramen magnum in individuals of different age groups at the Cancer Diseases Hospital in Lusaka, Zambia.

**Methods:** A cross sectional study design was used which analysed retrospectively patient records of MRI brain scans of 127 patients. The study was conducted in the Radiology Department of the Cancer Diseases Hospital in Lusaka. Data was collected first by selecting hard copy reports of MRI brain scans that were free from pathology after which digital images of these scans were copied on to Compact Discs (CDs). Measurements of the position of the CT and AP diameter of the foramen magnum were done using software (rulers) on the digital MRIs. The data collected was then recorded on a data collection sheet. Analysis of data was carried out using STATA version 12. The one-way Analysis of Variance (ANOVA) was used to compare mean values in the position of the cerebellar tonsils among the different age groups. Linear regression was used to determine factors associated with the position of the cerebellar tonsils as well as the anteroposterior diameter of the foramen magnum.

**Results:** A total of 67 (52.8%) brain scans captured for the study were of females and 60 (47.2%) were males. The median age was 28 years (IQR 1 - 75). The mean anteroposterior diameter of the foramen magnum and cerebellar tonsillar position were 36.5mm (range; 23.4mm - 47.6mm) and 0.5mm (range; -14.5mm - 13.1mm) respectively. Trends in the means of the position of the CT showed that the tonsils were below the foramen magnum from ages 1-4 years ascending to a position above the foramen magnum by age 5 years and reaching their highest point between 12-17 years then gradually descending again.

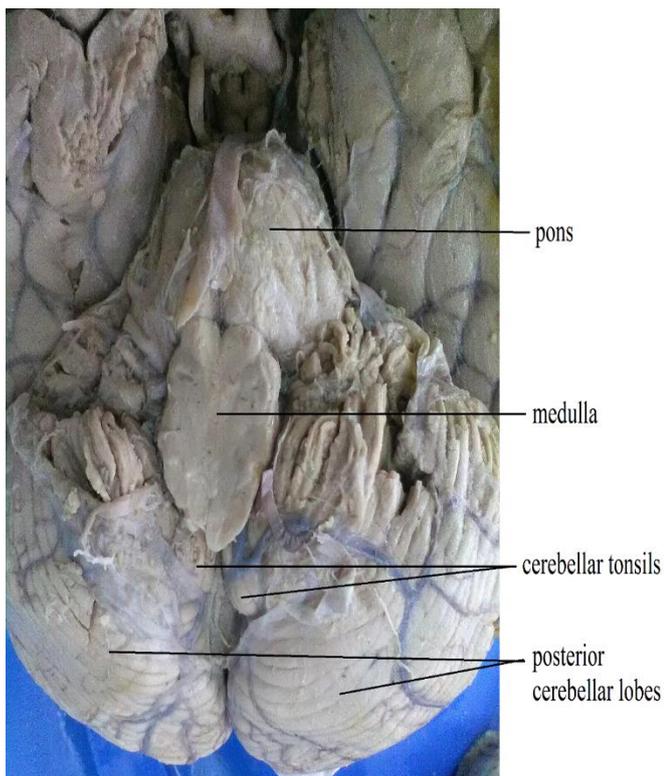
**Conclusion:** There was an association between CT position and AP diameter of the foramen magnum in that AP diameter was seen to be the predictor variable for CT position with 1mm increase in the AP diameter of the foramen magnum causing a descent of 0.13mm of the cerebellar tonsils and CT position was seen to significantly reduce the AP diameter of the foramen magnum.

**Key Words:** Cerebellar Tonsils, Anteroposterior Diameter, Foramen Magnum, Zambia.

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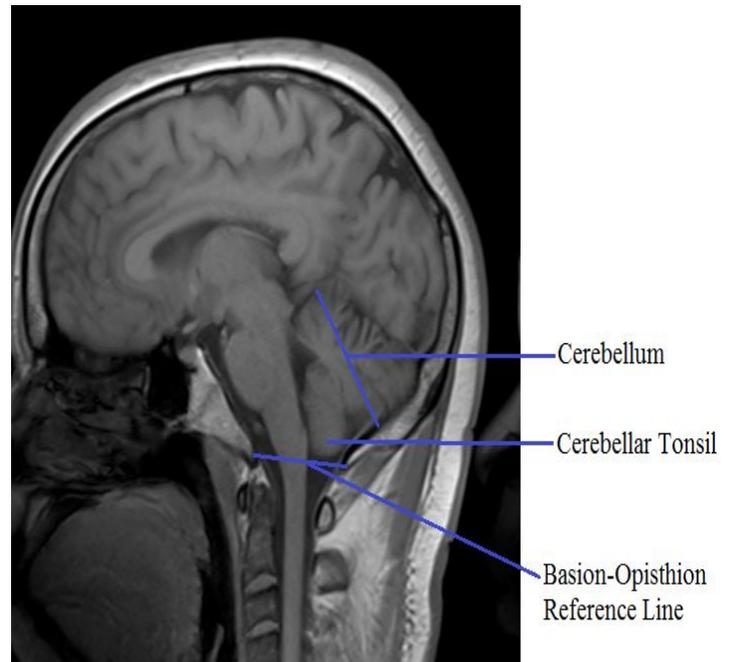
## 1. Introduction

The Cerebellar Tonsils (CT) are part of the Nervous System (NS) which is the chief controlling and coordinating system of the body. The NS adjusts the body to the surroundings and regulates all bodily activities both voluntary and involuntary [1]. The functional role of the CT is not yet known, but they are believed to coordinate skilled and learned movements. They are anatomically located inferomedially on the posterior lobe of the Cerebellum and are the most prominent hemispheric structures of the sub-occipital surface [2] (Figure 1). The position of the CT can be measured with reference to a straight line drawn from the Basion to the Opisthion of the foramen magnum (Basion-Opisthion reference line). This line also represents the Anteroposterior (AP) diameter of the foramen magnum [3].



**Figure 1:** Inferior view of the cerebellum and the position of the tonsils on the inferior aspect of each of the cerebellar hemispheres taken at the dissection laboratory, University of Zambia, School of Medicine.

The CT can easily be seen on sagittal section of the brain (Figure 2). The mean value of the AP diameter of the foramen magnum varies from study to study. Lakshmi in a study in India found the mean value of the AP diameter of the foramen magnum to be 35.57mm with a range from 15-45mm [4]. Osunwoke et al in Nigeria found the average length of the AP Diameter of the foramen magnum to be 36.11 mm [5]. Radhika in India carried out a morphometric study of the foramen magnum and results showed an average anteroposterior diameter of 35.3mm with a range from 27mm to 43mm [6,7].

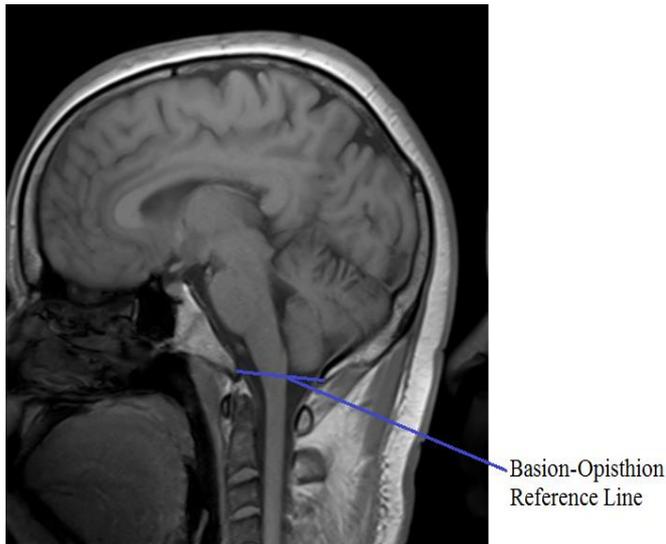


**Figure 2:** MRI sagittal section through the brain showing the cerebellar tonsil taken at Cancer Diseases Hospital, Radiology Department.

Tonsillar herniation can occur in conditions that cause increased Intra-Cranial Pressure (ICP) such as ruptured aneurysms, brain tumors, encephalitis, head injury, stroke, hydrocephalus, as well as in some medical procedures such as lumbar puncture when Cerebrospinal Fluid (CSF) pressure suddenly decreases [8, 9]. Sudden increased ICP is a serious and often life threatening condition. If increased ICP pushes on brain structures and blood vessels, it can lead to serious, permanent problems or even death [10]. The position of the cerebellar tonsils can be measured with reference to a straight line drawn from the Basion to the Opisthion of the foramen magnum (Figure 3). The presence and progression of clinical symptoms can be related to the degree of CT ectopia [11], measuring the position of the CT therefore becomes important to radiologists, neurosurgeons and other health professionals in the diagnosis, prognosis and treatment formulation for patients with CT ectopia. The Basion and Opisthion can easily be identified on the sagittal section of the MRIs of the head.

Appearance of herniation of the CT into the foramen magnum is a frequent normal variation and can be misleading when reading the MRI scans conducted in subjects being evaluated for intracranial medical conditions. Several studies carried out in various places around the world have indicated that there is no one standard normal position of the CT. Mikulis and colleagues (1992) in the USA found in a study they carried out that there was an increase in the position of the tonsils with age, however, they observed no decrease in the position of the tonsils with increasing age [12]. Smith and colleagues in the USA observed a decrease in cerebellar tonsillar position with increasing age into young adulthood and from then on an increase into adulthood [13]. Lakshmi in India found the

largest number of cerebellar tonsillar ectopia was concentrated in the fifth decade of life and thereafter a rise in the position in the seventh decade in both genders [4]. The position of the cerebellar tonsils in infancy and old age was found to be above the foramen magnum [4]. Hence the need to carry out a study in order to have a reference range for diagnosis of our patients. Furthermore, there is no documented data about the normal position of the CT in the Zambian population, or literature relating the size of the foramen magnum to the position of the CT.



**Figure 3:** Sagittal Section through the brain showing a line drawn from the Basion to the Opisthion of the foramen magnum taken at Cancer Diseases Hospital, Radiology Department, Lusaka, Zambia

## 2. Methodology

Data for this study was collected retrospectively using digital MRI scans of the brain from 127 patients over a period of three months from September to December, 2015. Rulers on the MRI software were used to measure lengths for the position of the cerebellar tonsils and the anteroposterior diameter of the foramen magnum. A data collection form formulated for the study was used to record the information collected from the digital MRIs including; the patients' age, sex, anteroposterior diameter of the foramen magnum and position of the CT.

Hard copies of patients' MRI reports were used to select scans of the brain which were certified by a radiologist as having no pathology. These copies were then used to find digital MRI brain scan records on the computer. Individual patients' digital MRI brain scans were then transferred on to compact discs (CDs). Measurements were taken using computer software tools and data collected was then recorded on the data collection form. Data analysis was performed using the Stata version 12 statistical software package. The One-Way Analysis of Variance (ANOVA) was used to compare mean values in the position of the cerebellar tonsils among the different age groups. Linear regression was used to determine factors associated with the position of the cerebellar tonsils as well as the anteroposterior diameter of the foramen magnum

and results were summarised on tables and graphs. All statistical tests were performed at 5% significance level or 95% confidence interval with p-value of <0.05 to determine statistical significance.

## 3. Results

The study investigated retrospectively the relationship between the normal position of the cerebellar tonsils and the Anteroposterior diameter of the foramen magnum in individuals of different age groups. A sample of 127 was collected, the median age was 28 years (IQR 1 - 75). The average anteroposterior diameter of the foramen magnum and cerebellar tonsillar position in the participants were 36.5mm (range; 23.4mm - 47.6mm) and 0.5mm (range; -14.5mm - 13.1mm) respectively.

### Position of the Cerebellar Tonsils and anteroposterior diameter of the foramen magnum in different age groups

Table 1, illustrates the means and interquartile ranges of Cerebellar tonsillar position and anteroposterior diameter of the foramen magnum in different age groups measured in millimetres (mm).

### Comparing the different means of CT position and AP diameter with respect to age groups

The results of the differences in means of the cerebellar tonsillar (CT) position and AP diameter for different age groups are shown in Table 2. Overall, there was no evidence of a statistical difference in the means of CT position ( $p = 0.8196$ ) and AP diameter ( $p = 0.0608$ ) for the different age groups. However, comparing each age group for the AP diameter using linear regression was able to show that the means for those aged 1-4yrs and 40-59yrs were statistically different ( $p = 0.033$ ).

### Factors associated with cerebellar tonsillar (CT) position

Table 3 below shows factors that are related to the position of the cerebellar tonsils. Univariate analysis showed that, one year increase in age reduced the CT position by 0.01mm (95% CI -0.4, 0.02), although the findings were statistically insignificant ( $p = 0.648$ ). One unit increase in AP diameter of the foramen magnum significantly reduced the CT position by 0.13mm (95% CI -0.26, -0.01;  $p = 0.041$ ). Hence, AP diameter is the predictor variable for CT position because it was the only variable that was still significant during multivariate analysis (Table 3).

### Factors associated with anteroposterior (AP) diameter

Univariate analysis (Table 4) showed that, as the age of a person increases by one year, anteroposterior diameter is increased by 0.04mm (95% CI 0.00, 0.08), however the findings were not statistically significant ( $p = 0.069$ ). Cerebellar tonsil (CT) position was seen to significantly reduce the anteroposterior diameter by 0.24 (95% CI -0.48, -0.01,  $p = 0.041$ ). Hence, CT position was a significant predictor of AP diameter.

**Table 1:** CT position and AP diameter of the foramen magnum for different age groups

Age group (years)	Mean CT position (IQR)	Mean AP diameter (IQR)
1 - 4yrs	-0.6 (-4.5 to 4)	31.6 (23.4 to 39.1)
5 - 11yrs	0.3 (-12.7 to 4.9)	36.6 (27.8 to 47.0)
12 - 17yrs	1.0 (-3.1 to 6.4)	36.0 (26.3 to 39.8)
18 - 39yrs	0.7 (-14.5 to 13.1)	36.9 (26.3 to 47.6)
40 - 59yrs	0.4 (-2.7 to 5.7)	37.4 (32.0 to 44.2)
60 - 75yrs	-0.5 (-3.6 to 1.3)	37.2 (34.2 to 43.2)

Abbreviations: CT; Cerebellar tonsils, IQR; interquartile range, AP; anteroposterior

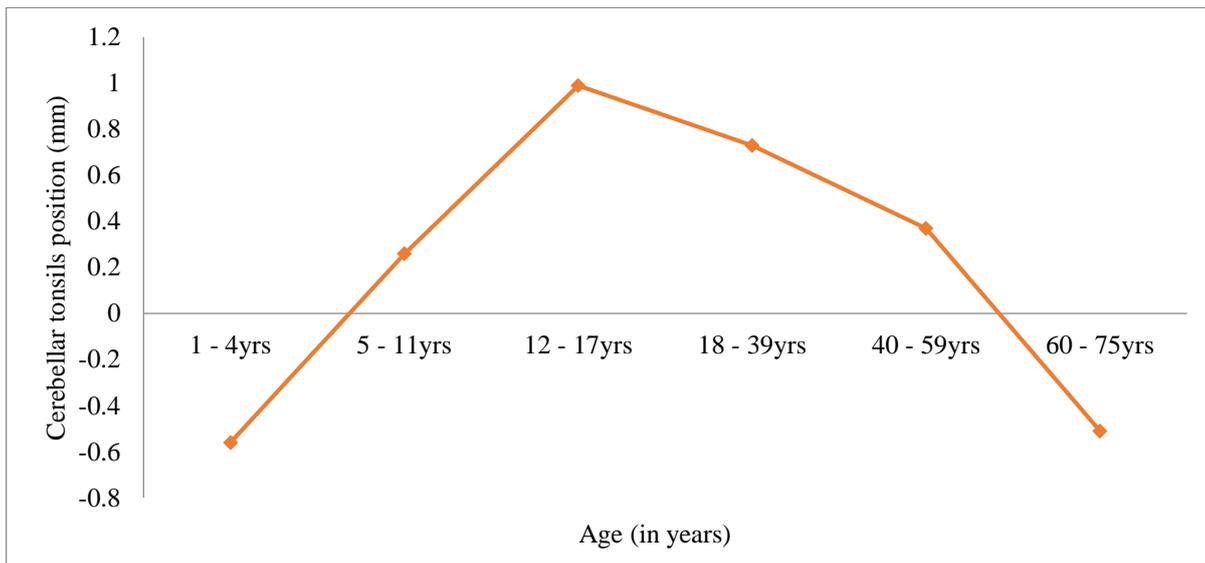


Figure 1: Mean position of the cerebellar tonsils in different age groups

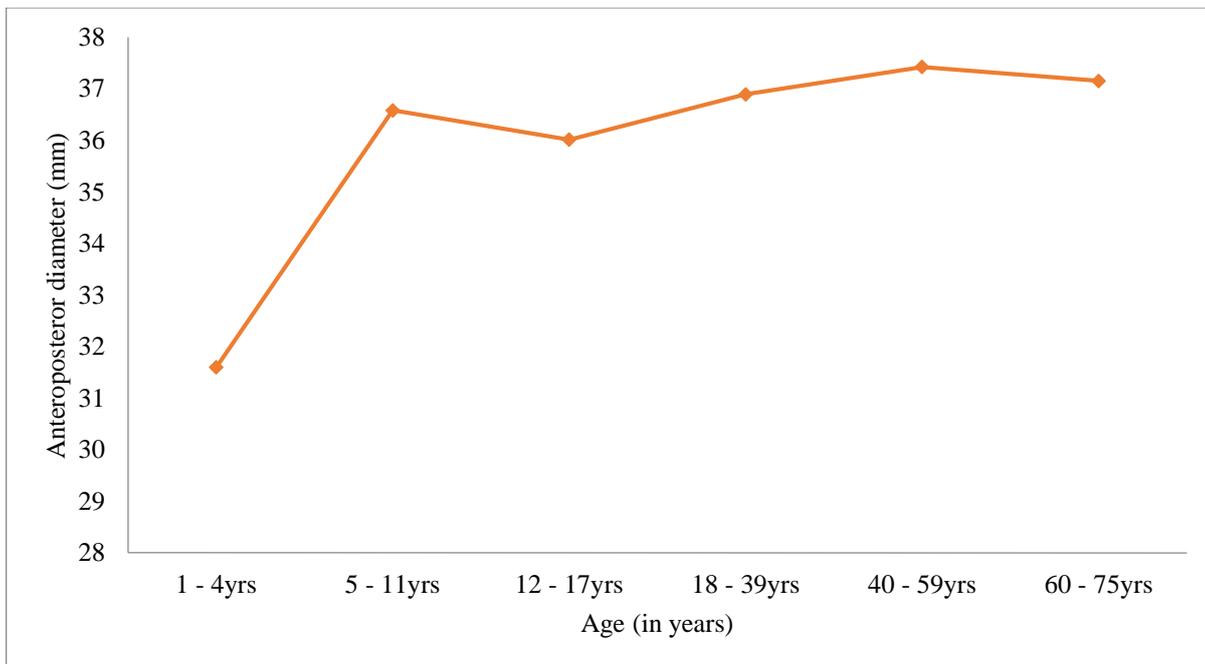


Figure 2: Mean Anteroposterior diameter of the foramen magnum in different age groups

**Table 2:** Difference in means of CT position and AP diameter for age groups

Age category (in years)	Frequency	Mean CT position	P-value	Mean AP diameter	P-value
1 - 4yrs	7	-0.6	0.8196 <sup>aCT</sup>	31.60	0.0608 <sup>aAP</sup>
5 - 11yrs	20	0.3		36.58	
12 - 17yrs	15	1.0		36.01	
18 - 39yrs	54	0.7		36.89	
40 - 59yrs	23	0.4		37.42	0.033 <sup>bAP</sup>
60 - 75yrs	8	-0.5		37.15	

Abbreviations: CT- cerebellar tonsils; AP- anteroposterior; aCT- overall p-value for CT position means; aAP- overall p-value for AP diameter means; bAP- p-value for the difference in means between age group 1 – 4yrs and 40 – 59yrs.

**Table 3:** Predictors of cerebellar tonsils (univariate and adjusted analysis)

Characteristics	Univariate		Adjusted	
	Coef (95%CI)	P-value	Coef (95%CI)	P-value
Age	-0.01 (-0.4, 0.02)	0.648	-0.00 (-0.03, 0.03)	0.882
AP diameter	-0.13 (-0.26, -0.01)	0.041**	-0.14 (-0.27, -0.01)	0.032**

Abbreviations: CI- confidence interval; AP- anteroposterior; \*\*p-value <0.05

**Table 4:** Predictors of anteroposterior diameter (univariate and adjusted analysis)

Characteristics	Univariate		Adjusted	
	Coef (95% CI)	P-Value	Coef (95% CI)	p-value
Age	0.04 (0.00, 0.08)	0.069	0.04 (- 0.01, 0 .08)	0.085
CT position	-0.24 (-0.48, -0.01)	0.041**	-0.25 (-0.49, -0.02)	0.032**

Abbreviations: CI- confidence interval; CT- cerebellar tonsils; \*\*p-value <0.05

## 4. Discussion

### Position of the Cerebellar Tonsils in different Age Groups

According to the results that were obtained from the sample collected in this study, the trends in the means of the cerebellar tonsils in different age groups showed that the tonsils were generally below the foramen magnum from ages 1-4 years ascending to a position above the foramen magnum by age 5 and reaching their highest point between 12-17 years and then gradually descending again. Therefore, there was increase in the position of the tonsils with increasing age until adolescence after which there was a gradual decrease. There were some similarities in trends with results from other studies. Mikulis and colleagues (1992) in the USA found in a study they carried out that there was an increase in the position of the tonsils with age, however, they observed no decrease in the position of the tonsils with increasing age [12]. Smith and colleagues in the USA observed a decrease in cerebellar tonsillar position with increasing age into young adulthood and from then on an increase into adulthood [13]. Lakshmi in India found the largest number of cerebellar tonsillar ectopia was concentrated in the fifth decade of life and thereafter a rise in the position in the seventh decade in both genders [4]. The position of the cerebellar tonsils in infancy and old age was found to be above the foramen magnum [4]. This was contrary to what was observed in this study where tonsillar ectopia was seen in children from 1-4 years and adults over 60 years. This

result could mean two things for the Zambian population, that they have smaller skulls or larger a brain volume. This theory however remains to be tested.

The means of the position of the cerebellar tonsils of different age groups were compared using a one way analysis of variance (ANOVA). This was done in order to find out whether there were any significant differences in the cerebellar tonsillar positions of the different age groups. Results showed that even though there were differences from group to group in the position of the tonsils, these differences were not statistically significant with p-value of 0.8196.

### Anteroposterior Diameter of the Foramen Magnum in Individuals of Different Age Groups

The average anteroposterior diameter of the foramen magnum was found to be 36.5mm with a range from 23.4-47.6mm. These results were similar to those of other studies, for example, Lakshmi in a study in India found the mean value of the AP diameter of the foramen magnum to be 35.57 with a range from 15-45mm [4]. Osunwoke et al in Nigeria found the average length of the AP Diameter of the foramen magnum to be 36.11mm [5]. Radhika in India carried out a morphometric study of the foramen magnum and results showed an average anteroposterior diameter of 35.3mm with a range from 27mm to 43mm [6]. The results of the current study and those of Osunwoke and colleagues could suggest an African trend in

the AP diameter of the foramen magnum. This could mean that Africans have larger foramen magna compared to those of other ethnic groups.

The means of the anteroposterior diameter of the foramen magnum were also compared using the one way ANOVA. When all measurements were compared against each other, the differences were seen to be statistically insignificant with P-value of 0.0608. However, when the means of age groups 1-4 years and 40-59 years were compared, there was a significant difference seen with P-value of 0.033.

Trends in the means of the AP diameter of the foramen magnum in the different age groups seen in this research showed an increase in the size of the foramen magnum up to the beginning of adolescence (defined in this research as 12 years) at which point it remains almost constant. In a study by Lakshmi, results showed an increase in the size of the foramen magnum up to the age of 14 after which the size remains constant [14].

#### **Association of the Cerebellar Tonsillar Position and Anteroposterior Diameter of the Foramen Magnum**

A univariate analysis of the position of the cerebellar tonsils against the anteroposterior diameter of the foramen magnum showed that one unit (1mm) increase in the diameter of the foramen magnum resulted into a significant reduction of 0.13mm in the position of the cerebellar tonsils. Therefore, of all the variables that were analysed against the position of the cerebellar tonsils, the anteroposterior diameter of the foramen magnum is the one that was statistically seen to be a predictor of cerebellar tonsillar position because it was the only one that was statistically significant with P-value of 0.041.

#### **Factors Associated with Cerebellar Tonsillar Position**

Linear regression was done to determine factors that affect the position of the cerebellar tonsils. Position of the cerebellar tonsils was analysed against two (2) other factors that could affect cerebellar tonsillar position including the age of the patient and their gender.

With respect to age, univariate analysis showed that an increase in the age of the patient by one year caused a reduction in the position of the cerebellar tonsils by 0.01mm. This was done at 95% confidence interval. In a study by Bartholomeusz et al in the USA, they observed that in early childhood, there is an increase in both head circumference and brain volume, and from adolescence onwards, brain volume decreases while head circumference does not. However, there was no indication of the rate of increase of the circumference of the skull in relation to that of the volume of the brain [11]. Finding out the rate of increase of both head circumference and brain volume could give reasons as to why there is ectopia in the early years of life observed in this study.

#### **5. Conclusions**

A statistically significant relationship was observed between the size of the foramen magnum and the position of the cerebellar tonsils. It was observed that the larger the anteroposterior diameter of the foramen magnum, the lower the position of the cerebellar tonsils.

The position of the cerebellar tonsils changes with increasing age, with the tonsils situated below the foramen magnum between ages 1-4 years and gradually ascending to a position above the foramen magnum reaching their maximum position at about 17 years then gradually descending. The study showed an increase in the anteroposterior diameter of the foramen magnum with age until about 12 years after which it became somewhat constant.

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