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# Dimensions Evaluation of Normal Cerebellum, Cerebrum, Pons and Tentorial Angle: MRI Quantitative Based Study

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**ABSTRACT**

The objectives of this study were to study the normal dimensions of the cerebellum,cerebrum pons and tentorium angle in ages <I year and≤15 years old as well as to evaluate the gender differences and the age-related changes. Axial, and midsagittal of normal brain MRI scans of 200 subjects (104 were males and 96 were females) were evaluated .The study evaluated: (1) The dimensions of the cerebellum for the right and left antroposterior and transverse at axial plane (2) the cerebrum right and left anteroposterior dimension and transverse diameter at axial plane and (3) the Pons antroposterior and craniocaudal dimentions as well as the tentorium angle at sagital plane .The collected data were statistically analyzed by using SPSS program version 16. Student's t -test was applied for gender comparisons. To determine the associations between age and anatomical structures, Pearson correlation coefficients were calculated.The mean of right and left cerebellum anteroposterior and transverse dimension were found to be 4.67±0.87, 4.60±0.92 and 8.68±1.48 cm in respectively. Mean right and left cerebrum anteroposterior and transverse dimension were found to be 13.88±1.91, 13.88±1.91 and 11.61±1.53cm in respectively. The mean of Pons anteroposterior and cranio caudal dimension were found to be 1.47±0.38 and 3.68±18.74 in respectively .The Mean tentorial angle was 40.93°±8.68.

**Introduction:**

There are many researches in the literature where anatomical structures in brain are measured quantitatively in terms of dimensions.( Yucel et al., 2002) Investigations of aging effects on the brain stem and cerebellum are significant, not only to understand normal aging, but also for comparative study of the pathophysiology of degenerative brain disorders. Since the development of magnetic resonance imaging (MRI), many neuroanatomical studies of normal brain growth and atrophy have been reported (Coffey et al., 1992; Pfefferbaum et al., 1994; Blatter et al., 1995; Matsumae et al., 1996).The cerebellum is known to undergo volumetric declines with advanced age. Individual differences in regional cerebellar volume may therefore provide insight into performance variability across the lifespan, as has been shown with other brain structures. (Jessica et al., 2013).The Tentorial Angle has great importance in the clinical setting as it has an implications on surgeries of the pineal region (Hasan and Walter 2018)

There is a growing interest in MRI-based measures and associated standard measurements as imaging methods allowing for the optimal calculation of future clinical changes.( Leow et al., 2009) MRI is widely used as a noninvasive method to evaluate structural measurements, with good results.( Leos et al., 2006)

Many neuroanatomical studies of brain development have been reported as well as investigations of aging and gender impact.(Griffiths et al., 2004)

There is a lack of studies examining together the entire tentorial angle, Pons, cerebellum and cerebellum in young adults and its development between the $6^{th}$ month and 15 years old. Increasing the knowledge of normal brain development strengthen understanding brain abnormalities when it happened. In this study, we analyzed the dimensions of some normal cranial structures. We hypothesized that the dimensions would be proportionally reduced at different ages. We also investigated whether the changes are related to gender.

**Materials and Methods:**

This is analytical cross sectional study. The study population composed of normal brain patients presenting to the Magnetic Resonance unit of International Medical Center (IMC) and Saudi Germen hospitals. Superconducting system Siemens Avanto 1.5 Tesla was used .The sample size consisted of 200 participants. The cases were confirmed to be normal with the presence of the radiologist during the selection of cases for study. The participants ages were between 6 months and 15 years. Abnormal brain patients were excluded. The study took place during the period from July 2015 to July 2017.

**Technique:**

The measurements were performed using spin echo sequences the images are $T_1$ weighted sagittal plane (TR 400) (TE 12). And $T_2$ weighted axial plane TR =4500, TE =117. Slice thicknesses =2mm, gap= 5 mm, field of view =20 cm and display matrix= 314 x 448. Measurement were performed to properly measure the children posterior fossa, important parts were measured: cerebellum, cerebrum,tentorium angle and pones. Using a high-resolution fast spin echo technique providing the area of the posterior fossa and tentorial angle.

**Measurements:**

**In sagittal section:** the structure under study is best visualized in this plane was the pons

**The Pons:**

Two lines were drawn to define the major axes, corresponding to oblique superior-inferior axes .The maximal measurement perpendicular to the major axis was taken. In all cases, the posterior border of the Pons was clearly identifiable and did not include the pontine tegmentum .AP diameter was measured in the Pons midline at the level of the opening of the sella turcica. The transverse diameter of the Pons was measured as the distance between two points perpendicular to the midline along the tangent lateral to the Pons; this was similar to the methods done by (Massey et al., 2013).

**The Cerebellum:**

Axial transverse cerebellar diameter (TCD) measurements were taken at the point of maximal length. Allows examination of mid brain at cisterna magna and cerebellar vermis the routine examination includes a transverse scan at the level of the cavum septum demonstrates the lateral borders of the anterior portion.TCD was defined as the maximum distance from the right to left hemispheres in the transverse plane. Right and left hemispheric the medial aspect of each cerebral hemisphere was taken as a convenient' horizontal' and all vertical sections were cut normal to this reference plane. Anteroposterior (AP) diameter is defined as the maximum distance between the most anterior portion and the most posterior portion of the cerebellum**.**

**The cerebrum:** transverse diameter which is the longest measurement of the long axis of the cerebral hemispheres as done by (Bruno et al., 2017) the level of the cavum septi pellucidi, which demonstrates the lateral borders of the anterior, medial and posterior horns of the lateral ventricles measures were done on the axial image in T2-weighted including deep nuclei gray matter and Monro's foramens. The right and left sides were measured.

**Data analysis**

Data were analyzed by using SPSS program and the results were presented in form of tables.

**Ethical consideration**

No identification or individual details were published.

No information or patient details were disclosed or used for reasons other than the study.

**Results**

**The following tables represented the study results. The participants were 200, their ages were as the following** < One years were 38(19%),1-5 years were74(37%),6-10 years were 63(31.5%),11-15 years were 25(12.5%) with their mean 5.39±3.98 min=0.11- max=15.00

Table (1) Descriptive Statistics of the variables:

| cerebellum measurements/cm (axial) | | | | | |
|---|---|---|---|---|---|
| *Cerebellum* | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
| Anteroposterior (RT) in axial plane | 200 | 1.83 | 6.50 | 4.67 | 0.87 |
| Anteroposterior (LT)in axial plane | 200 | 1.96 | 9.90 | 4.60 | 0.92 |
| Transverse Diameter | 200 | 4.01 | 11.80 | 8.68 | 1.48 |
| Tentorial angle/° measurement | | | | | |
| | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
| Tentorium Angle | 200 | 21.70° | 64.26° | 40.93° | 8.68 |
| cerebrum/cm measurements | | | | | |
| *Cerebrum* | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
| Anteroposterior (RT) | 200 | 5.60 | 18.79 | 13.88 | 1.91 |
| Anteroposterior (LT) | 200 | 5.40 | 18.85 | 13.83 | 1.91 |
| Transverse Diameter | 200 | 4.40 | 14.44 | 11.61 | 1.53 |
| Pons/cm measurements | | | | | |
| *Pons* | *N* | *Minimum* | *Maximum* | *Mean* | *Std. Deviation* |
| Anteroposterior dimension in sagital plane | 200 | 0.72 | 2.97 | 1.47 | 0.38 |
| Craniocaudal Diameter | 200 | 0.54 | 2.18 | 3.68 | 18.74 |

Table (2) Group Statistics of The variables classified according to gender:

cerebellum measurements classified according to gender

| *Cerebellum* | *Gender* | *N* | *Mean* | *STDV* | *P-value* |
|---|---|---|---|---|---|
| Anteroposterior (RT)/cm | Male | 104 | 4.68 | 0.86 | 0.785 |
| | Female | 96 | 4.65 | 0.88 | |
| Anteroposterior (LT)/cm | Male | 104 | 4.56 | 0.81 | 0.521 |
| | Female | 96 | 4.64 | 1.03 | |
| Transverse Diameter/cm | Male | 104 | 8.75 | 1.53 | 0.447 |
| | Female | 96 | 8.59 | 1.42 | |

Tentorial angle measurements

| | *Gender* | *N* | *Mean* | *Std. Deviation* | *P-Value* |
|---|---|---|---|---|---|
| Tentorium Angle | Male | 104 | 39.81º | 8.21 | .059 |
| | Female | 96 | 42.13º | 9.04 | |

Cerebrum measurements

| *Cerebrum* | *Gender* | *N* | *Mean* | *Std. Deviation* | *P-value* |
|---|---|---|---|---|---|
| Anteroposterior (RT)/cm | Male | 104 | 13.83 | 2.06 | 0.668 |
| | Female | 96 | 13.94 | 1.76 | |
| Anteroposterior (LT)/cm | Male | 104 | 13.78 | 2.07 | 0.724 |
| | Female | 96 | 13.88 | 1.74 | |
| Transverse Diameter/cm | Male | 104 | 11.61 | 1.67 | 0.983 |
| | Female | 96 | 11.62 | 1.36 | |

Pons measurements

| *Pons* | *Gender* | *N* | *Mean* | *Std. Deviation* | *P-value* |
|---|---|---|---|---|---|
| Anteroposterior dimension/ cm | Male | 104 | 1.43 | 0.36 | 0.112 |
| | Female | 96 | 1.52 | 0.40 | |
| Craniocaudal Diameter/cm | Male | 104 | 1.80 | 0.45 | 0.138 |
| | Female | 96 | 5.75 | 27.04 | |

Table (3) Cerebellum measurements classified according to age and p- value:

| *Cerebellum* | | *N* | *Mean* | *STDV* | *Minimum* | *Maximum* | *P-value* |
|---|---|---|---|---|---|---|---|
| | Descriptive Statistics | | | | | | |
| Anteroposterior (RT)/cm | < One years | 38 | 4.59 | 0.86 | 2.20 | 6.15 | 0.027 |
| | 1-5 years | 74 | 4.59 | 0.91 | 2.70 | 6.50 | |
| | 6-10 years | 63 | 4.60 | 0.87 | 1.83 | 6.10 | |
| | 11-15 years | 25 | 5.16 | 0.59 | 4.04 | 6.25 | |
| | Total | 200 | 4.67 | 0.87 | 1.83 | 6.50 | |
| Anteroposterior (LT)/cm | < One years | 38 | 4.48 | 0.81 | 2.20 | 6.38 | 0.021 |
| | 1-5 years | 74 | 4.48 | 0.84 | 3.00 | 6.40 | |
| | 6-10 years | 63 | 4.67 | 1.11 | 1.96 | 9.90 | |
| | 11-15 years | 25 | 4.95 | 0.66 | 3.80 | 6.39 | |
| | Total | 200 | 4.60 | 0.92 | 1.96 | 9.90 | |
| Transverse Diameter/cm | < One years | 38 | 8.04 | 0.00 | 4.20 | 10.01 | 0.000 |
| | 1-5 years | 74 | 8.60 | 1.47 | 4.20 | 11.20 | |
| | 6-10 years | 63 | 8.62 | 1.55 | 4.01 | 10.70 | |
| | 11-15 years | 25 | 9.98 | 0.59 | 9.09 | 11.80 | |
| | Total | 200 | 8.68 | 1.48 | 4.01 | 11.80 | |

Cerebellum transverse diameter = 8.013 + 0.123 * Age [$R^2$=0.108].

Cerebellum Anteroposterior (RT) = 4.491 + 0.033 * Age [$R^2$=0.023]

Table (4) Tentorium angle measurements classified according to age and p- value:

| | | *N* | *Mean* | *STDV* | *Minimum* | *Maximum* | *P-value* |
|---|---|---|---|---|---|---|---|
| | Descriptive Statistics | | | | | | |
| Tentorium Angle | < One years | 38 | 41.17° | 7.95 | 23.98° | 54.00° | 0.603 |
| | 1-5 years | 74 | 41.11° | 9.64 | 26.00° | 64.26° | |
| | 6-10 years | 63 | 41.43° | 9.05 | 21.70° | 64.24° | |
| | 11-15 years | 25 | 38.74° | 5.17 | 29.10° | 49.10° | |
| | Total | 200 | 40.93° | 8.68 | 21.70° | 64.26° | |

Table (5) Cerebrum measurements classified according to age and p- value:

| *Cerebrum* | | *N* | *Mean* | *STDV* | *Minimum* | *Maximum* | *P-value* |
|---|---|---|---|---|---|---|---|
| | Descriptive Statistics | | | | | | |
| Anteroposterior (RT)/cm | < One years | 38 | 12.74 | 0.00 | 5.60 | 16.88 | 0.000 |
| | 1-5 years | 74 | 13.79 | 1.76 | 9.43 | 18.79 | |
| | 6-10 years | 63 | 13.99 | 1.84 | 7.76 | 16.81 | |
| | 11-15 years | 25 | 15.63 | .79 | 14.41 | 17.39 | |
| | Total | 200 | 13.88 | 1.91 | 5.60 | 18.79 | |
| Anteroposterior (LT)/cm | < One years | 38 | 12.69 | 2.04 | 5.40 | 16.86 | 0.000 |
| | 1-5 years | 74 | 13.73 | 1.78 | 9.29 | 18.85 | |
| | 6-10 years | 63 | 13.94 | 1.83 | 7.71 | 16.92 | |
| | 11-15 years | 25 | 15.56 | .73 | 14.36 | 17.04 | |
| | Total | 200 | 13.83 | 1.91 | 5.40 | 18.85 | |
| Transverse Diameter/cm | < One years | 38 | 10.88 | 0.00 | 7.23 | 13.44 | 0.000 |
| | 1-5 years | 74 | 11.64 | 1.65 | 4.40 | 14.44 | |
| | 6-10 years | 63 | 11.56 | 1.43 | 6.27 | 13.64 | |
| | 11-15 years | 25 | 12.79 | .56 | 11.97 | 14.22 | |
| | Total | 200 | 11.61 | 1.53 | 4.40 | 14.44 | |

Cerebrum transverse diameter = 10.961 + 0.122*Age[$R^2$=0.101]
Cerebrum anteroposterior (RT) = 12.818 + 0.198 * Age[$R^2$=0.169]

Table (6) Pons measurements classified according to age and p- value:

| Descriptive Statistics | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Pons* | | *N* | *Mean* | *Std. Deviation* | *Minimum* | *Maximum* | *P-value* |
| Anteroposterior dimensions/cm | < One years | 38 | 1.61 | 0.31 | 1.11 | 2.20 | .033 |
| | 1-5 years | 74 | 1.49 | 0.39 | 0.79 | 2.60 | |
| | 6-10 years | 63 | 1.39 | 0.43 | 0.72 | 2.97 | |
| | 11-15 years | 25 | 1.42 | 0.21 | 0.97 | 1.80 | |
| | Total | 200 | 1.47 | 0.38 | 0.72 | 2.97 | |
| Craniocaudal Diameter | < One years | 38 | 1.63 | 0.36 | 0.54 | 2.45 | 0.815 |
| | 1-5 years | 74 | 4.68 | 2.51 | 0.87 | 2.18 | |
| | 6-10 years | 63 | 4.41 | 1.94 | 1.00 | 1.55 | |
| | 11-15 years | 25 | 2.04 | 0.31 | 1.40 | 2.54 | |
| | Total | 200 | 3.68 | 1.87 | 0.54 | 2.18 | |

***Pons Anteroposterior Diameter = 1.555-0.015*Age[$R^2$=0.023]***

Table (7) Correlation between the RT and LT Cerebrum and Cerebellum Antroposterior measurements:

| *Cerebellum* | | *Anteroposterior dimension (RT)/cm* |
|---|---|---|
| Anteroposterior dimensions (LT)/cm | Pearson Correlation | .821(**) |
| | Sig. (2-tailed) | .000 |
| | N | 200 |
| *Cerebrum* | | *Anteroposterior dimension(RT)/cm* |
| Anteroposterior dimension(LT)/cm | Pearson Correlation | .992(**) |
| | Sig. (2-tailed) | .000 |
| | N | 200 |

** *Correlation is significant at the 0.01 level (2-tailed).*

**Discussion:**

Knowledge of normal brain development is a gate for understanding brain malformations, while the introduction of magnetic resonance imaging (MRI) into clinical practice has improved the detection and classification of brain anatomy and pathology.

We determined the dimensions of cerebellum, cerebrum, Pons and tentorium angle on normal MRI brain scans. Our study evaluated the following (1) The dimensions of the cerebellum for the right and left antroposterior and transverse at axial plane (2) the cerebrum right and left anteroposterior dimension and transverse diameter at axial plane and (3) the Pons antroposterior and craniocaudal dimentions as well as the Tentorial angle at sagital plane.

A sample of 200 participant was involved in the current study with mean age of 5.39±3.98 years old .The higher frequency was found in the ages between 1-5 years old (74) constituting (37.0%). Descriptive statistics of cerebellum (RT) and (LT) anteroposterior dimensions and transverse diameter , tentorium angle , cerebrum (RT) and (LT) anteroposterior dimensions and transverse diameter and Pons anteroposterior and craniocaudal were presented as mean and standard deviation ,maximum and minimum values in table(1) .

The current study showed no significant gender related differences for all the measured variables: table (2) except the tentorium angle, there is significant difference between the two genders at $p$=0.059 .This was not consigned with what was mentioned in other previous studies who mentioned that there are sex differences in gross cerebellar neuroanatomy (Escalona et al., 1991, Shah et al., 1991, Raz et al., 1998, Luft et al., 1999).The justification may be due to the small sample size.

The cerebellum and cerebrum selected dimensions were significantly increased by increasing age from 6 months up to 15 years old table (3,5) however the increasing of age have no impact neither on the tentorial angle measurements table( 4) nor the Pons craniocaudal diameter table(6 )at $p$= 0.603 and $p$=0.815 in respectively.

The study showed that the ages where the most changes/development happened in the cerebellum right and left anteroposterior dimensions and transverse diameter were found between 11-15 years .For the Cerebrum the right and left anteroposterior dimensions and transverse diameter maximum, development were happened at the ages between 11-15years tables (3,5) it developed by nearly about 1 cm every five classes of ages (6-10 years and 11-15 years old)

Early MR morphometry studies comparing the cerebrum morphology in children and adults showed that changes were considerably larger in school-aged children than in young adults (Jernigan and Tallal 1990; Jernigan et al., 1991; Pfefferbaum et al., 1994), another studies showed that the changes in gross brain structure that continue past the ages over the first 2-3 years of life are subtle (Joan and Terry 2010) , this was similar to our results. As well our results showed the progress of growth was found to be increased at the age of 6-10 years old and increasing more at the young adults at 11-15 years for the right and left anteroposterior dimensions and transverse diameter of cerebrum, cerebellum however the Pons was found to be at maximum measurements at the ages less than one year for the antroposterior measurements, and reduced at the age from 6-10 years and then increased again at the age of 11-15 years significantly at $p$=0.033 with no significant changes were found in all age groups for the cranio caudal diameter (3,5,6). This might be justified as suggested by (Joan and Terry 2010 )that tissue alterations related to brain maturation might be much more extended during childhood than was generally supposed, and that some of these alterations might be regressive; that is, they might involve tissue loss. These findings were also confirmed and extended by the study done by (Toga et al., 2006) but the changes remain a matter of assumption as mention by (Joan and Terry. 2010). Other studies have provided more anatomical details for studying age-related change (Giedd, et al., 1996; Sowell et al., 1999a; Sowell et al., 1999b; Sowell et al.,2002).

The tentorial angle measurement does not affected by increasing age as presented in table (4).No significant difference between the right and left side of cerebrum and cerebellum antroposterior measurements at $\boldsymbol{p}$= 0.000 and 0.000 respectively table (7).

Understanding the normal development of the cerebellum and cerebrum might help to distinguish pathological changes from healthy growth during development in the age's <than 1 and ≤15 years old, which can help in the early diagnosis of any presence of abnormalities. There is a lack of studies examining the cerebellum, cerebrum, pons and tentorium angle. Therefore in this study, we analyzed the dimensions of the selected variable in normal brain scans in order to establish values to be as reference at this period of ages. As well we study the development progression at different age groups in order to ease the diagnosis if any pathology might occur.

Our results could supply reference material for the identification of abnormalities in the anteroposterior dimensions of pons ,cerebrum and cerebellum as well as the transverse diameter of cerebrum and cerebellum and thus could be used in the detection of any abnormalities that may took place. These new equations might predict the normal dimensions for the known subjects' age.

**Conclusion:**

The study concluded that the cerebellum and cerebrum right and left anteroposterior dimensions and transverse diameter were significantly increased as the age increased during the developing period from ages less than 1 year to 15 years old, as well the Pons anteroposterior diameter was significantly affected with age. On the other hand; no significant relationship was found between the Pons craniocaudal diameter/age and the tentorium angle/age. No significant gender related differences were detected in all the selected variables except the tentorium angle. New predictive equation for the variables were establishes as reference values.

Cerebellum transverse diameter = 8.013 + 0.123 * Age

Cerebrum transverse diameter = 10.961 + 0.122*Age

Cerebellum Anteroposterior (RT) = 4.491 + 0.033 * Age

Cerebrum anteroposterior (RT) = 12.818 + 0.198 * Age

Pons Anteroposterior Diameter = 1.555-0.015*Age

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