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CHARACTERIZATION OF CERTAIN SUPRA AND INFRA TENTORIAL BRAIN ANATOMY -MRI BASED STUDY

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ABSTRACT
Many neuroanatomical studies of normal brain development have been reported. Investigations of aging effects on the supra and infra tentorial anatomical structures are important, not only to understand normal aging process, but also for comparative study of brain disorders. Sex differences in neuroanatomy have been observed in several studies. In this study, our purpose was to assess the sex differences and the age-related areas changes of both supra and infra tentorial anatomical structures on midsagittal MRIs. Midsagittal MRIs of 100 normal individuals were evaluated in this study. The sample included both genders, 43(43% were males) and 57(57% were females), their ages were between <10>61 years old. The infra tentorial anatomical structure including the posterior vermis, declive, folium, and tuber cenerium, anterior vermis and brainstem areas. For the supra tentorium brain anatomy, the cerebrum area ,corpus callosum area (CC)and index have been evaluated in both genders. Calculation of the area of both supra and infra anatomical structures was performed and the collected data were statistically analyzed by using SPSS software. Students't test was applied for gender comparisons. To determine the associations between age, gender and both regions, pearson correlation coefficients were calculated. For infra tentorial anatomy significant sex difference was found in the mean Anterior Cerebellar at $p= 0.006$ favoring males with larger area than females whereas no significant difference was recorded in other structures. For the supra tentoruim brain anatomical structure; significant sex difference was found in the mean Cerebrum Area at p=0.001with no significant difference was recorded in the other variables Significant reduction with increasing age were detected in means of declive, folium, and tuber, anterior vermis , brainstem, of CC area and index at p=0.000, 0.004, 0.000,0.001 and 0.000 respectively. The supra tentorial anatomical structures areas development are significantly correlated with infra anatomical structures. Normative values for supra and infra tentorial anatomical structures were established.

KEYWORDS: brain, supratentoria, infratentoria, MRI.

INTRODUCTION
The tentorium cerebelli is the second largest dural fold after the falx cerebri. It lies in the axial plane attached perpendicularly to the falx cerebri and divides the cranial cavity into supratentorial and infratentorial compartments.[1,2]

The cerebellum is infratentorial structure.[3] Its measurement has been shown to exhibit plasticity based on an individual's experiences and environmental stressors.[4] Cerebellar measurement has been found to decrease with age, driven by loss of white matter.[5] Smaller cerebellum was associated with many diseases.[5,6,7,8] The cerebella of changes may indicate a lower functional efficiency.[9] Interconnectivity between the cerebellum and the cerebrum has been demonstrated in different ways. Constrained spherical deconvolution analysis was used to show a pathway linking the cerebellum and limbic structures.[10] Supratentorial lacunar infarcts and white matter lesions in the cerebrum have been found to be associated with decreased cerebellar measurements.[5]

On the other hand aging of the brain is a differential process in which significant deterioration in some regions coexists with relative preservation in others.[11-13] Although this pattern is apparent in the cerebral cortex, it is unclear whether it can be extended to the structures of the posterior fossa. Moderate shrinkage of the cerebellar hemispheres has been observed.[14,15,16,17] Differential aging of the cerebellar vermis, has also been reported.[17,21] In contrast to the cerebellum, the pons has consistently been shown to maintain its gross size throughout the life span.[19,21,24]

An awareness of normal neuroanatomic variability is important for understanding pathologic changes. In regard to the infratentorial structures, most of the researches record of in vivo studies are few and there is a need for normative data about the cerebellum and brain stem .To the best of our knowledge, no studies were obtained and included measurements of the same individuals for both supra and infra tentorial anatomical structure in the sagittals of MR images as well , in this current study, we examined age and gender related differences the cerebrum and corpus callosum index and area considering them as supratentorial anatomical structures as well the areas in the three segments of cerebellum and brain stem measured in sagital plane for healthy individuals. Our main hypothesis was that in the healthy elderly subjects, the both supra and infra tentorioum anatomical structure would show age-related changes. In addition, we hypothesized that there would be no sex differences.

METHODOLOGY

Study design and area: Descriptive analytical study, it was conducted at King Faisal Hospital - Taif City, KSA - Radiology Department during period from June 2014 to April 2017.

Inclusion criteria: All MRI brain with normal findings

Study population: The study population of this research was selected from 100 normal MRI brain findings with normal brainstem and cerebellum results.

Material: All the patients were examined in MRI machine GE optima MR450W, 1.5 Tesla and Skyra Siemens AG 2012 , 3 Tesla , version: syngo MRD13, with standard head coil.

Protocol was used:

T1 sagittal image, 5 mm slice thickness with a gap of 1 mm were obtained with the spin- echo (SE) sequence

Method: All data were measured with NIH Image public domain software (Version 1.60, available at the World Wide Web URL http://rsb.info.nih.gov/nih-image). the measurement include brainstem ,cerebrum,corpus callosum and cerebellum. Images were displayed on a 21-inch monitor, and each ROI was traced manually using a digitizing tablet.

Supra tentorial anatomy {Corpus callosum index, corpus callosum area and cerebrum area}

a- The cerebrum was traced carefully around superior sagittal sinuses entering; frontal lobe, parietal lobe and occipital lobe.

b- Corpus callosum index (CCI) was obtained by drawing a straight line at greatest anteroposterior (ab) diameter of CC from splenium part to the genu part and a perpendicular at its midline, owing to points a, b and c in cm. Anterior (aa) line was passed through the genu part, posterior (bb) line was passed through splenium part and medium (cc) line was passed through the middle body of the corpus callosum were measured and normalized to its greatest anteroposterior diameter (ab) according to the equation:

$$\text{Corpus Callosum Index (CCI)} = \frac{aa + bb + cc}{ab}$$

(Fernando Faria, et al 2007)

Corpus callosum area is assessed by tracing the outer contour of corpus callosum**.**

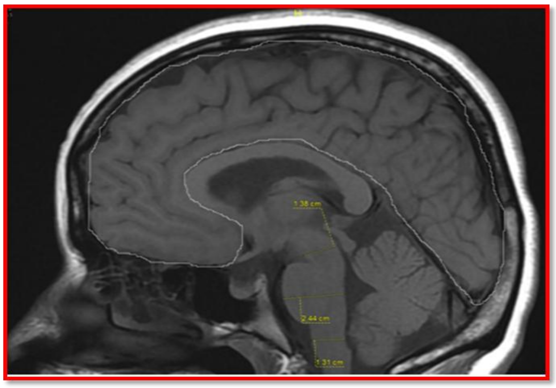
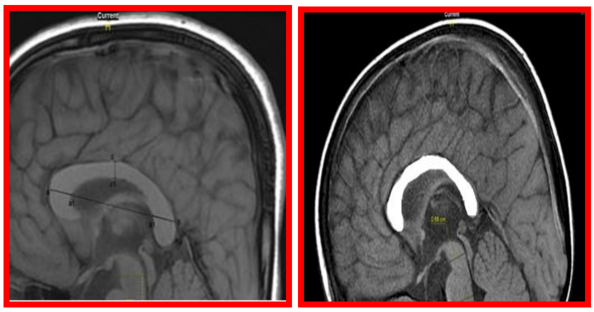


Figure 1: Shows the area measurement of the cerebrum area at mid saggital.



[A] [B]

Figure 2: A and B shows the corpus callosum index and area.

Infra tentorial anatomy {brain stem and cerebellar vermis}

a- The brain stem was traced from midbrain to the medulla oblongata.

b- The cerebellar vermis was traced as faithfully as possible, entering all ‘‘coves’’ created by fissures and sulci, the vermian ROI_1 (the anterior vermis) which consist of consisted of the lobules: lingual, centralis, and culmen, the anterior border of the ROI_1 was the superior medullary velum, and the primary fissure served as its posterior border. The ROI_2 consisted of the lobules (the declive, the folium, and the tuber). ROI_3 (the posterior vermis) included the pyramis, the uvula, and the nodulus. The anterior border was the prepyramidal fissure and the posterior border was the velum. The tonsils were excluded from the vermian *ROIs.*

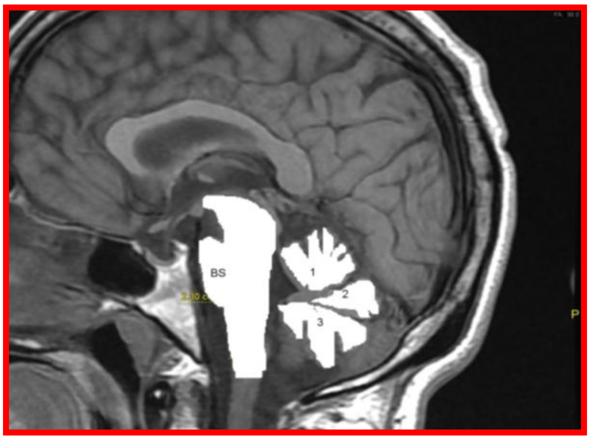


Figure 3: Shows the area measured for the brain stem and cerebellumat the same level.

RESULTS

The sample included both genders 43(43% were males) and 57(57% were females), their ages were between <10>61 years old. Mean age was 39.45±25.45 .maximum age was 91 years old and minimum age was1 years old.

The infra tentorial anatomical structure including the mean posterior vermis, mean declive, folium, and tuber, mean anterior vermis, mean brainstem volume. For the supra tentorium brain anatomy, the corpus callosum area and index have been evaluated in both genders.

Table 1: Shows the area analyses for the supra and infra tentoruim anatomical structures measured in cm^2.

Descriptive Statistics					
	N	Min	Max	Mean	Std. D
Infra tentoruim anatomical structures area measured in cm^2					
Posterior Cerebellar Vermis area	100	124.0	506.0	285.02	0.76
Cerebellum (Declive, Folium, And Tuber) area	100	110.0	365.0	222.06	0.56
Anterior Cerebellar Vermis area	100	169.0	575.0	375.12	0.67
Brainstem area	100	440.0	1219.0	943.29	1.34
Supra tentoruim anatomical structures area measured in cm^2					
Cerebrum area	100	6259.00	10412.00	8388.09	9.13
Callosum area	100	2.27	9.20	562.80	1.11
Callosum Index	100	0.20	0.42	0.31	0.05

Table 2: Shows the Area Analyses for the Infra and Supra Tentoruim anatomical structures, classified according to gender.

Group Statistics					
	Gender	N	Mean	Std. v	P-value
Infra tentoruim anatomical structures area measured in cm^2					
Posterior Cerebellar Vermis area	Male	43	278.16	0.68	0.437
	Female	57	290.20	0.81	
Cerebellum (Declive, Folium, And Tuber) area	Male	43	223.51	0.56	0.825
	Female	57	220.96	0.56	
Anterior Cerebellar Vermis area	Male	43	396.48	0.71	0.006
	Female	57	359.01	0.60	
Brainstem Area	Male	43	952.57	1.52	0.552
	Female	57	936.29	1.20	
Supra tentoruim anatomical structures area measured in cm^2					
Cerebrum Area	Male	43	8722.91	9.06	0.001
	Female	57	8135.50	8.41	
Callosum Area	Male	43	564.61	0.94	0.889
	Female	57	561.43	1.23	
Callosum Index	Male	43	0.31	0.05	0.812
	Female	57	0.31	0.05	

Table 3: shows the area analyses for the infra tentoruim anatomical structure, classified according to age.

Descriptive							
		N	Mean	Std. v	Min	Max	P-value
Posterior cerebellar vermis area	<10	12	309.82	0.82	219.0	506.0	.109
	11-20	19	298.16	0.83	124.0	421.0	
	21-30	13	313.14	0.79	233.0	504.0	
	31-40	9	262.73	0.42	196.0	321.0	

	41-50	11	249.58	0.72	132.0	376.0	
	51-60	11	309.55	0.72	182.0	419.0	
	61+	25	261.34	0.71	138.0	409.0	
	Total	100	285.02	0.76	124.0	506.	
Cerebellum (declive, folium, and tuber) area	<10	12	229.72	0.49	132.0	288.0	.000
	11-20	19	259.45	0.63	175.0	363.0	
	21-30	13	227.10	0.34	166.0	280.0	
	31-40	9	230.84	0.61	123.0	337.0	
	41-50	11	195.09	0.37	125.0	251.0	
	51-60	11	248.94	0.59	192.0	365.0	
	61+	25	184.21	0.41	110.0	289.0	
	Total	100	222.06	0.56	110.0	365.0	
Anterior cerebellar vermis area	<10	12	375.72	0.66	252.0	480.0	.004
	11-20	19	419.56	0.86	254.0	575.0	
	21-30	13	390.32	0.49	323.0	485.0	
	31-40	9	389.67	0.59	309.0	529.0	
	41-50	11	327.44	0.61	169.0	382.0	
	51-60	11	374.23	0.65	215.0	449.0	
	61+	25	349.30	0.46	236.0	424.0	
	Total	100	375.12	0.67	169.0	575.0	
Brainstem Area	<10	12	793.88	1.28	570.0	1040.0	.000
	11-20	19	993.35	1.03	824.0	1135.0	
	21-30	13	988.27	2.09	440.0	1219.0	
	31-40	9	1007.48	1.08	764.0	1166.0	
	41-50	11	951.22	1.13	696.0	1100.0	
	51-60	11	986.79	0.71	867.0	1107.0	
	61+	25	907.84	0.89	719.0	1101.0	
	Total	100	943.29	1.34	440.0	1219.0	

Table 4: shows the area analyses for the supra tentoruim anatomical structure, classified according to age.

Descriptive							
		N	Mean	Std. v	Min	Max	P-value
Cerebrum Area	<10	12	8119.19	10.03	6961.0	9817.0	
	11-20	19	8621.25	8.80	6785.0	10201.0	0.219
	21-30	13	8824.95	9.00	7361.0	10412.0	
	31-40	9	8485.30	5.88	7693.0	9470.0	
	41-50	11	8090.93	8.80	6259.0	9384.0	
	51-60	11	8500.05	8.10	7043.0	96.88.0	
	61+	25	8159.27	9.97	6393.0	10216.0	
	Total	100	8388.09	9.13	6259.0	10412.0	
Corpus Callosum Area	<10	12	441.20	1.07	227.0	640.0	0.001
	11-20	19	604.64	1.01	442.0	794.0	
	21-30	13	615.90	.77	491.0	740.0	
	31-40	9	566.98	.99	376.0	702.0	
	41-50	11	587.56	1.34	402.0	920.0	
	51-60	11	579.90	1.15	408.0	781.0	
	61+	25	541.83	.87	391.0	766.0	
	Total	100	562.80	1.11	227.0	920.0	
Corpus Callosum (Index)	<10	12	0.32	0.04	0.24	0.42.0	0.000
	11-20	19	0.34	0.03	0.29	0.42.0	
	21-30	13	0.33	0.05	0.22	0.41.0	
	31-40	9	0.32	0.05	0.25	0.42.0	
	41-50	11	0.31	0.05	0.22	0.39.0	
	51-60	11	0.32	0.04	0.20	0.38.0	
	61+	25	0.26	0.04	0.20	0.36.0	
	Total	100	0.31	0.05	0.20	0.42.0	

Table 5: shows the Paired Samples Test correlation analyses between the supra and infra tentoruim brain anatomical structures.

Supra and infra anatomical structures areas correlations	T	Sig. (2tailed)
Cerebrum Area - Posterior cerebeller vermis area	89.90	0.000
Cerebrum Area - cerebellum (declive, folium, and tuber)	3.70	0.000
Cerebrum Area- Anterior cerebeller vermis	89.25	0.000
Cerebrum Area - Brainstem Area	84.17	0.000
Cerebrum Area - callosum Area	88.49	0.000
Cerebrum Area - callosum (Index)	91.57	0.000

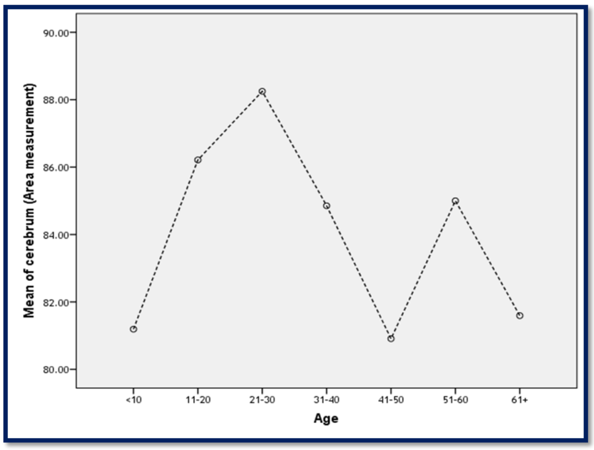


Figure 4: Shows the Development of Cerebrum Area With Age.

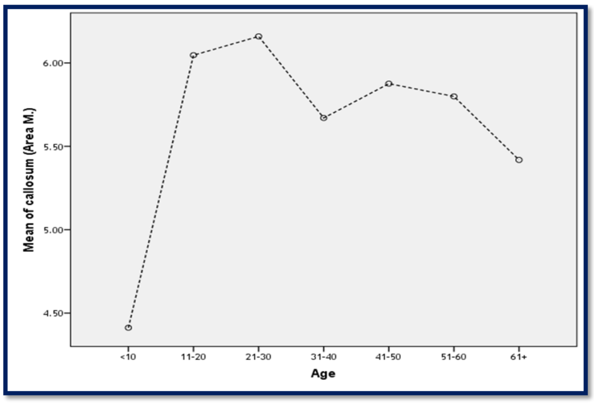


Figure 5: Shows the Development of CC Area with Age.

DISCUSSION

Understanding the developmental route of normal brain and differences between the genders is important for the interpretation of clinical imaging studies. There are many studies in the literature where anatomical structures in brain are measured quantitatively in terms of volume, area, width and length.[25] Therefore certain areas in the supra and infra anatomical structures have been measured and evaluated table (1) and table (2).

The current results showed that males have larger areas of supra and infra anatomical structure with significant differences in both gender for anterior cerebellar vermis and cerebrum area at p=0.006 and 0.001 respectively. Similar investigators have observed gender differences in gross cerebellar neuroanatomy. Males were shown to have larger cerebella than females, although in these reports the possibility that these differences could have reflected sexual dimorphism of body size, and their measurements showed that men evidenced significantly larger pons areas[21] this reflects and justify the difference in the whole brain stem measured area .

The results showed larger brain stem in males, this may explain the correlation between supratentorial larger brain measured in males and the brain stem structures, or might denote that there is a correlation in the common physiological process between supratentorial brain and brain stem structures either in their growth or in their atrophy. But the area showed that the differences were not significant between two genders regarding the brain stem, posterior cerebellar vermis, cerebellum (declive, folium, and tuber), corpus callosum area and index. Some researchers speculated that sexual dimorphism in cerebellar measurements can be attributed to the effects of sex hormones.[26,27] Escalona et al.[16] observed that women have significantly smaller cerebellar measurements than men

Table (3) and (4) shows the area analyses for the infra and supra tentorium anatomical structure, classified according to age .The results showed that there are significant reduction in the mean Anterior cerebellar vermis, declive, folium, and tuber and brain stem area, however the mean posterior cerebellar vermis and Cerebrum area did not affected significantly with age. Investigations of aging effects on the brain stem and cerebellum are important, not only to understand normal aging, but also for comparative study of the pathophysiology of degenerative brain disorders. Since the development of MRI, many neuroanatomical studies of normal brain growth and atrophy have been reported.[28-31] Cerebral and brain stem shrinkage with aging might result from intrinsic or extrinsic factors such as hormones[32] and hypertension.[33] Interactions with environmental factors.[34]

The sexual dimorphism of the CC started with the original report de Lacoste-Utamsing and Holloway.[35] The measurements of the adult CC may show variety according to gender and age.[36] Several studies have indicated that CC development continues to progress throughout adolescence.[37,38] Despite decades of research, there is still no agreement over the presence of gender-based morphologic differences in the human CC.[39] However our study showed that there is no significant difference in the corpous callosum area and index between gender [p=0.889 and 0.812] and showed significant changes occur as the age increased at *p*=0.000,0.000 respectively

Studies provide important information about key aspects of developmental neuroanatomy.[40] Clearly, our results showed that there are considerable brain maturational changes in years less than 10years old that may reflect or predict normal behavioral development as mentioned by Giedd et aL1996.[40] Large data sets of well-defined normal subjects are still needed to obtain accurate quantification of the highly variable developmental changes of children and adolescents.

This need is particularly relevant for ongoing MRI studies addressing assuming slight variation in brain development in certain disorders[40] Several gross anatomic structures have already been concerned *as well* midsagittal corpus callosum area differences in Dyslexia[41] and cerebral volume,[41,42] Interpretation of these studies has been limited by the small sample sizes and lack of normative data.

To deal with this needs, and to assess normal brain maturational changes, a group of 100 healthy subjects including children and adolescents were recruited from the local community for participation in a quantitative MRI study. The common practice of using as normal participants referred clinically for MRI and whose scans were subsequently read as normal was included Those areas measurements were the base for evaluating and characterizing the relationship between age, gender and brain morphometry. Normative data were enhanced and presented in the study tables (1-5).

Figure (4) showed the Age-related changes in the cerebrum. Studies with similar findings have mentioned that the increases in the rate of decline are consistent with the notion of nonlinear regional brain aging. Such increases confirm the cross-sectional findings that suggested an inverted-U trajectory of lifespan change, with measurements increase in young adulthood, plateau in middle age and precipitous decline in the old age[43,44] The mid-fifties appear as a likely point of inflection of age trend, with sizeable variation across individuals. Nonlinear shrinkage is consistent with age-related augmentation of age differences in other indices of white matter integrity which was found also in the corpous callosum Figure (5).

The Paired Samples Test correlation analyses between the supra and infra tentoruim brain anatomical structures was obtained. The cerebrum and CC area, index, cerebellum correlations and mean difference were presented in table (5). All the measured areas were correlated significantly with cereberum area at p= 0.000, 0.000, 0.000and 0.000 for cerebellum, brain stem, corpous callosum area and index respectively. The functions of the CC can generally be thought of as integrating the activities of the cerebral hemispheres.5 this may justify the correlation between the two compartments. Studies found that cerebellar measurements were larger for larger brain volume.[45]

It is important to study the brain anatomic measures because the measured values difference/ correlations between supra and infra tentoria structures and age/gender related difference may reflect the interpretation of metabolic data[46] declining in cerebral blood flow.[47-49] and could explain the structural effects.[50]

CONCLUSION

In conclusion, we reveal significant changes of brain areas in the human brain from ages expanded from less than 10 years up to more than 60 years old. Our observed results are consistent with previous theoretical hypotheses, providing clues for the age/gender underlying changes in cerebrum, CC area, CC index, brain stem, cerebellum areas in the human brain. This paper also considers the normalization in brain development through life span as well the correlation between the supra and infra tentoria structures and suggests that gender effects has partially an impact on certain measured anatomical areas at MRIs sagital images.

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