

Morphological Study on Age Related Changes in Cortical Thickness Across the Central Sulcus

*K Fatema¹, S Ara², H Afroz³, M Rahman⁴, A A Sultana⁵

*1*Dr. Kanij Fatema, Assistant Professor, Department of Anatomy, Jahurul Islam Medical College Bajitpur, Kishoregonj*

2Prof. Dr. Shamim Ara, Professor & Head of the Department of Anatomy, Dhaka Medical College, Dhaka

3Dr. Halima Afroz, Assistant Professor, Department of Anatomy, Green Life Medical College, Dhaka

4Dr. Mushfika Rahman, Assistant Professor, Department of Anatomy, Dr Sirajul Islam Medical College, Dhaka

5Dr. Anjuman Ara Sultana, Lecturer, Department of Anatomy, Shaheed Suhrawardy Medical College, Dhaka

*Corresponding author

ABSTRACT

The central sulcus, which is located between the primary motor and primary somatic sensory cortexes, is an important structure and landmark of the cerebral hemisphere. Localization of the central sulcus is essential before brain tumor resection. Difference of cortical thickness across the banks of the central sulcus is an important indicator for localizing the central sulcus. Cortical thickness varies with age and in many diseased conditions. This Cross-sectional analytical type of study is carried out to establish a normal standard in different age groups for Bangladeshi people in cortical thickness across the central sulcus. The present study was performed on postmortem cerebral hemispheres of 70 Bangladeshi people in different age groups. Total 140 cerebral hemispheres were taken from these cadavers. Among them lowest age was 22 years in both sexes and highest age was 58 years in male and 48 years in female. The samples were divided into four different age groups i.e. Group A (20-29 years), Group B (30-39 years), Group C (40-49 years) and Group D (50-59 years). All the samples were studied morphologically in the Department of Anatomy, Dhaka Medical College, Dhaka from January 2010 to December 2010. In the present study, thickness of cerebral cortex across the central sulcus decreased with advancing age. The thickness of anterior bank of central sulcus, thickness of posterior bank of central sulcus and cortical thickness ratio across the central sulcus were 2.64 ± 0.15 to 3.41 ± 0.38 mm, 1.67 ± 0.10 to 2.12 ± 0.22 mm and 1.57 ± 0.03 to 1.62 ± 0.04 respectively. The difference in mean thickness between anterior and posterior bank of central sulcus was statistically significant in all age group ($p=0.001$). The difference in mean thickness between left and right central sulci was not statistically significant in any age group. The difference in mean thickness of Anterior bank was statistically significant between group A and C ($p<0.01$), A and D ($p<0.01$), B and C ($p<0.05$), B and D ($p<0.01$) in both left and right central sulci. The difference in mean thickness of posterior bank was significant between group A and C ($p<0.01$), A and D ($p<0.01$), B and D ($p<0.01$) in both left and right central sulci.

Key words: Central sulcus, thickness, age, Bangladeshi people

Introduction

In human highest level of nervous function is localized in cerebral cortex. The cerebral cortex contains the primary sensory and motor areas as well as multiple association areas. These specific areas of the cerebral cortex are concerned with specific parts of the body with

specific types of input and with specific types of activities. The cerebral cortex is an extremely large memory storehouse. Without the cerebral cortex, the functions of the lower brain centers are often imprecise. The vast storehouse of cortical information usually converts these

functions to determinative and precise operations¹. The cerebral cortex and its connection responsible for conscious perception, voluntary action, personality, emotion, memory and thought. The cerebral cortex is able to influence or control all aspects of central nervous system function, both conscious and unconscious². Surfaces of cerebral hemisphere are moulded into a number of gyri separated by sulci. Sulci and gyri provide a natural topographic partition of the cortical anatomy. The junctional zones between adjacent functional fields frequently run along the bed of major or minor cortical sulci³. The central sulcus is an important structure and landmark of the cerebral hemisphere. Precentral gyrus forms the anterior bank of the central sulcus, corresponds to the primary motor cortex and the postcentral gyrus forms the posterior bank of the central sulcus, corresponds to the primary somatosensory area⁴. Central sulcus is the only sulcus in the brain in which the difference of thickness between the two banks is large. The difference of cortical thickness across the banks of the central sulcus is so pronounced that it can be readily identified by direct visual inspection⁵. Sulci and gyri are the natural routes to deep brain structures in certain neurosurgical procedures. Precise knowledge about difference in cortical thickness across the central sulcus is essential for surgical planning of deep brain structures. Before surgical intervention for localizing the central sulcus via cortical thickness measurement is done by CT Scan or MRI. But there is no existing study on cerebral cortex of Bangladeshi population for comparing. We need our own standard baseline from which we can compare cortical thickness across the central sulcus in our own population.

Changes in cerebral cortex are found in large number of clinical conditions. Thickness of cortex decreases with age and also in many diseases such as in Alzheimer's disease⁶, chronic schizophrenia⁷, multiple sclerosis^{8,9}, Huntington's disease¹⁰, motor neuron disease^{11,12}, cerebral small vessel disease¹³. Some degenerative diseases have prominent involvement of cerebral cortex such as

Alzheimer disease which is the most common cause of dementia in the elderly¹⁴. and 7th leading cause of death in USA¹⁵.

The findings of the present study are expected to help neurologists, neurosurgeons, sonologists for diagnosis and to adopt appropriate plans for management of brain tumor and other pathology of cerebral cortex.

Materials and methods

The present study was performed on postmortem cerebral hemispheres of 70 Bangladeshi people in different age groups. Total 140 cerebral hemispheres were taken from these cadavers. Among them lowest age was 22 years in both sexes and highest age was 58 years in male and 48 years in female.

The samples were collected from the unclaimed dead bodies that were under examination in the Department of Forensic Medicine, Dhaka Medical College, Dhaka from February 2010 to December 2010. After completion of all legal formalities and requisite permission from the department of Forensic Medicine, the whole brains were collected within 24 hours of death. During collection of the samples, appropriate age, sex and the cause of death were noted from the morgue's record book. The samples were brought to the Department of Anatomy, Dhaka Medical College, Dhaka. The samples were tagged immediately bearing code numbers for subsequent identification. Soon after collection, each sample was gently washed with tap water on a dissection tray for removing blood. After collection of whole brain, 100 ml of 40% formaldehyde solution was injected by using a 50 cc syringe into the brain through the surfaces (superolateral and inferior surfaces). Then it was preserved in 40% formaldehyde solution (Origin - Germany) for 15 days. After fixation of the whole of the human brain, cerebral hemispheres were collected by the following steps. The brainstem was sectioned at the level of the cerebral peduncle and cerebral hemispheres were separated by a midline sagittal section. Then meninges and blood vessels of cerebral hemisphere were carefully removed.

The study was carried out in the Department of Anatomy, Dhaka Medical College, Dhaka, Bangladesh, from January 2010 to December 2010. The study was approved by the Ethical Review Committee (ERC) of Dhaka Medical College.

For convenience of description, in relation to age, the collected samples were divided into four groups (according to Magnotta et al¹⁶) i.e. Group A (20-29 years), Group B (30-39 years), Group C (40-49 years) and Group D (50-59 years).

Measurement of Thickness of central sulcus and cortical thickness ratio across central sulcus (according to Meyer et al⁵):

Thickness of central sulcus was obtained by measuring the cortical thickness along the anterior bank of central sulcus and along the posterior bank of the central sulcus (Fig-1). This cortical thickness was estimated as the distance between the gray /white boundary and the outer cortical surface. Each cerebral hemisphere was sectioned vertically parallel to mid sagittal line into three pieces and three readings were taken from each piece of cerebral hemisphere for both anterior and posterior bank of central sulcus and average result was calculated. These measurements were taken by using a digital slide calipers in mm (Fig-2). Cortical thickness ratio across the central sulcus was calculated by dividing the cortical thickness along the anterior bank of central sulcus by the cortical thickness along the posterior bank of the central sulcus.

Results

Results are shown in the Table I, Table II, Table III, Table IV, Fig- 3 and Fig- 4.

The difference in mean thickness between anterior and posterior bank of central sulcus was statistically significant in all age group ($p=0.001$). The difference in mean thickness between left and right central sulci was not statistically significant in any age group. (Table I, Fig- 4).

The difference in mean thickness of Anterior bank was statistically significant between group A and C ($p<0.01$), A and D ($p<0.01$), B and C ($p<0.05$), B and D ($p<0.01$) in both left and right central sulci. The difference in mean thickness of posterior bank was significant between group A and C ($p<0.01$), A and D ($p<0.01$), B and D ($p<0.01$) in both left and right central sulci. The highest mean was found in group A and the lowest one in group D (Table II and III). The highest mean was found in group A and the lowest one in group B. The difference in mean ratio between left and right central sulcus was not statistically significant in any group. The difference in mean ratio across both central sulcus was statistically significant in group A and C ($p<0.01$) in left hemisphere and in group A and C ($p<0.05$) in right hemisphere (Table IV, Fig- 5).

Table I: Thickness of anterior and posterior bank of central sulcus of left and right hemispheres in different age groups

Groups(n)	Thickness of anterior and posterior bank of central sulcus in mm			
	Left	p value	Right	p value
Group A (18)				
Anterior bank	3.40 ± 0.38 (2.98 -4.16)	0.001***	3.41 ± 0.38 (3.01-4.18)	0.001***
Posterior bank	2.10 ± 0.23 (1.83 -2.63)		2.12 ± 0.22 (1.85 -2.57)	
Group B (28)				
Anterior bank	3.20 ± 0.22 (2.97 -3.90)	0.001***	3.24 ± 0.27 (2.98-3.92)	0.001***
Posterior bank	2.01 ± 0.12 (1.82 -2.32)		2.02 ± 0.12 (1.84-2.34)	
Group C (18)				
Anterior bank	2.99 ± 0.23 (2.58 -3.40)	0.001***	2.99 ± 0.21 (2.61-3.37)	0.001***
Posterior bank	1.89 ± 0.13 (1.67 -2.11)		1.89 ± 0.13 (1.68 -2.09)	
Group D (6)				
Anterior bank	2.64 ± 0.15 (2.49 -2.91)	0.001***	2.66 ± 0.16 (2.51-2.95)	0.001***
Posterior bank	1.67 ± 0.10 (1.56 -1.85)		1.68 ± 0.08 (1.58 -1.82)	

Data was expressed as Mean±SD. Figures in parentheses indicate range. Comparison between anterior and posterior bank done by unpaired Student's t test. *** = significant at ≤ 0.001 .

Table II: Thickness of anterior bank of central sulcus of left and right hemispheres in different age groups

Data was expressed as Mean \pm SD. Figures in parentheses indicate range. Comparison between left and right hemispheres done by unpaired Student's t test and between different age group by One-way ANOVA (Post Hoc) test. ns = not significant, * = significant at ≤ 0.05 , ** = significant at ≤ 0.01 .

Groups(n)	Thickness of anterior bank of central sulcus in mm		
	Left	Right	p value
A (18)	3.40 \pm 0.38 (2.98-4.16)	3.41 \pm 0.38 (3.01-4.18)	>0.50 ^{ns}
B (28)	3.20 \pm 0.22 (2.97-3.90)	3.24 \pm 0.27 (2.98-3.92)	>0.50 ^{ns}
C (18)	2.99 \pm 0.23 (2.58-3.40)	2.99 \pm 0.21 (2.61-3.37)	>0.50 ^{ns}
D (6)	2.64 \pm 0.15 (2.49-2.91)	2.66 \pm 0.16 (2.51-2.95)	>0.50 ^{ns}
A vs B	>0.10 ^{ns}	>0.10 ^{ns}	
A vs C	<0.01**	<0.01**	
A vs D	<0.01**	<0.01**	
B vs C	<0.05*	<0.05*	
B vs D	<0.01**	<0.01**	
C vs D	>0.05 ^{ns}	>0.10 ^{ns}	

Table III: Thickness of posterior bank of central sulcus of left and right hemispheres in different age groups

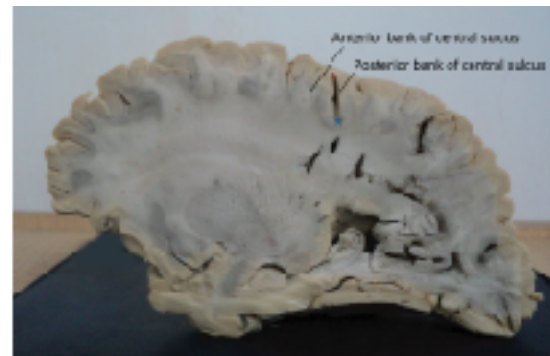
Groups(n)	Thickness of posterior bank of central sulcus in mm		
	Left	Right	p value
A (18)	2.10 \pm 0.23 (1.83-2.63)	2.12 \pm 0.22 (1.85-2.57)	>0.50 ^{ns}
B (28)	2.01 \pm 0.12 (1.82-2.32)	2.02 \pm 0.12 (1.84-2.34)	>0.50 ^{ns}
C (18)	1.89 \pm 0.13 (1.67-2.11)	1.89 \pm 0.13 (1.68-2.09)	>0.50 ^{ns}
D (6)	1.67 \pm 0.10 (1.56-1.85)	1.68 \pm 0.08 (1.58-1.82)	>0.50 ^{ns}
	p value	p value	
A vs B	>0.10 ^{ns}	>0.10 ^{ns}	
A vs C	<0.01**	<0.01**	
A vs D	<0.01**	<0.01**	
B vs C	>0.10 ^{ns}	>0.05 ^{ns}	
B vs D	<0.01**	<0.01**	
C vs D	>0.10 ^{ns}	>0.10 ^{ns}	

Data was expressed as Mean \pm SD. Figures in parentheses indicate range. Comparison between left and right hemispheres done by unpaired Student's t test and between different age group by One-way ANOVA (Post Hoc) test. ns = not significant, * = significant at ≤ 0.05 , ** = significant at ≤ 0.01 .

Table IV: Cortical thickness ratio across the central sulcus of left and right hemispheres in different age

Groups (n)	Cortical thickness ratio across the central sulcus		
	Left	Right	P value
A (18)	\pm 0.04 (-1.68)	1.61 \pm 0.03 (1.54-1.66)	>0.50 ^{ns}
B (28)	\pm 0.04 (-1.67)	1.59 \pm 0.04 (1.52-1.67)	>0.50 ^{ns}
C (18)	\pm 0.03 (-1.65)	1.58 \pm 0.03 (1.53-1.65)	>0.50 ^{ns}
D (6)	\pm 0.04 (-1.64)	1.58 \pm 0.05 (1.53-1.65)	>0.50 ^{ns}
	p value	p value	
A vs C	<0.01**	<0.05*	
A vs D	>0.05 ^{ns}	>0.10 ^{ns}	
B vs C	>0.50 ^{ns}	>0.50 ^{ns}	
B vs D	>0.50 ^{ns}	>0.50 ^{ns}	
C vs D	>0.50 ^{ns}	>0.50 ^{ns}	

Data was expressed as Mean \pm SD. Figures in parentheses indicate range. Comparison between left and right hemispheres done by unpaired Student's t test and between different age group by One-way ANOVA (Post Hoc) test. ns = not significant, * = significant at ≤ 0.05 , ** = significant at ≤ 0.01 .

**Fig-1:** Photograph showing banks of the central sulcus (red star - superficial end and green star - deep end of the central sulcus).

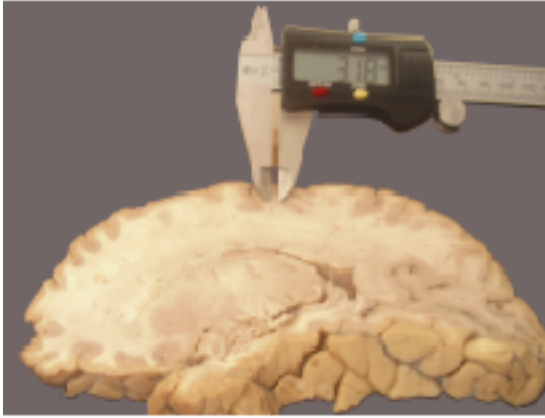


Fig-2: Photograph of measurement of thickness of the anterior bank of the central sulcus by using a digital slide calipers

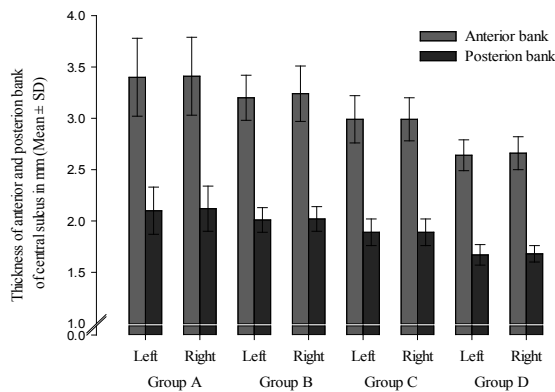


Fig-3: Thickness of anterior and posterior bank of central sulcus of left and right hemispheres in different age groups

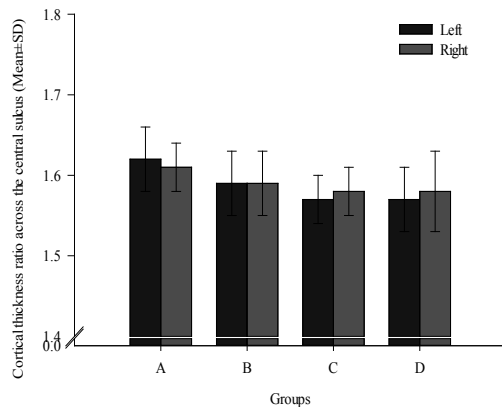


Fig-4: Cortical thickness ratio along central sulcus of left and right hemispheres in different age groups

Discussion

The mean \pm SD thickness of anterior bank of left and right central sulci were 3.40 ± 0.38 and 3.41 ± 0.38 mm in group A, 3.20 ± 0.22 and 3.24 ± 0.27 mm in group B, 2.99 ± 0.23 and 2.99 ± 0.21 mm in group C and 2.64 ± 0.15 and 2.66 ± 0.16 mm in group D respectively. The mean \pm SD thickness of the posterior bank of left and right central sulci were 2.10 ± 0.23 and 2.12 ± 0.22 mm in group A, 2.01 ± 0.12 and 2.02 ± 0.12 mm in group B, 1.89 ± 0.13 and 1.89 ± 0.13 mm in group C and 1.67 ± 0.10 and 1.68 ± 0.08 mm in group D respectively.

An MRI study done by Meyer et al (1996) on 6 men and 4 women with mean age 31 years (29-36 years) found that mean cortical thickness measurement in left hemisphere for the anterior and posterior banks of the central sulcus were 2.69 and 1.81 mm respectively and in right hemisphere 2.69 and 1.70 mm respectively⁵. The findings of same age group of the present study were higher than the findings of Meyer et al (1996). This difference may be due to variation for method used for measurement. An MRI study on 12 persons conducted by Biega, Lonser and Butman (2006) revealed cortical thickness of the anterior bank was 3.34 ± 0.46 mm and that of posterior bank was 1.80 ± 0.36 mm and the cortical thickness ratio across central sulcus was 1.98 ± 0.36 ¹⁷.

The mean \pm SD cortical thickness ratio across the central sulcus were found 1.62 ± 0.04 and 1.61 ± 0.03 in group A, 1.59 ± 0.04 and 1.59 ± 0.04 in group B, 1.57 ± 0.03 and 1.58 ± 0.03 in group C and 1.57 ± 0.04 and 1.58 ± 0.05 in group D for the left and right cerebral hemisphere respectively.

Mayer et al (1996) found that the cortical thickness ratio across the central sulcus was 1.53 in left hemisphere and 1.64 in right hemisphere⁵. These findings were similar to findings of the present study. The present study revealed that thickness of anterior and posterior bank decreased with advancing age. Salat et al (2004) studied precentral gyrus and found that gradual decrease in thickness of precentral gyrus¹⁸.

Conclusion

In the present study, it was revealed that difference in thickness of anterior and posterior bank of central sulcus was statistically significant in all age groups. The thickness of cortex along the central sulcus showed gradual decreasing values with advancing age. The cortical thickness ratio across the central sulcus was almost same in different age groups.

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