

# Age related changes in the primary somatosensory area of the cerebral cortex



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## ABSTRACT

**Background:** Age-related changes in structural and functional part of brain have been the motivation of previous and ongoing neuroscientific research. The focus of most studies done, were on different motor areas of the of the cerebral cortex. Very few studies were done on primary somatosensory areas of the brain. **Aims and Objective:** The aim of the study was to investigate the age-related changes in primary somatosensory area of the cerebral cortex of the human brain. **Materials and Methods:** The study was conducted on 50 autopsied brain specimens. The specimens removed were of both sexes belonging to various age groups ranging from 9 months to 75 years. The specimens were collected from the Department of Forensic Medicine, Medical College Kottayam. During the autopsy the meninges were carefully stripped off. The sulci and gyri were then examined carefully. **Results:** The depth of the upper area of the central sulcus is more than the middle and lower areas, both in the right and left halves of the cerebral cortex. The laminae of the primary somatosensory area have shown that as age advances there is a progressive increase in thickness except in the case of lamina IV. From the ages of 61 years onwards, laminar degeneration takes place. The thickest lamina was lamina V. The thinnest lamina was lamina IV. The stellate cells that dominate in lamina II and IV show a difference in their arrangement. In foetal life, the pyramidal cells were almost indistinguishable from the stellate cells. The pyramidal cells were seen mostly in lamina III and V. **Conclusion:** The study results suggest the possibility that in the more advanced stages of aging, the structural integrity of lamina IV is more consistent than other layers present in primary somatosensory area of the cerebral cortex. Further study is needed to examine the impact of ageing on somatosensory area.

**Key words:** Stellate cells; Pyramidal cells; Somatosensory area; Cerebral cortex

## INTRODUCTION

Previous studies have used functional brain imaging techniques to observe age-related changes in the central nervous system (CNS). However, task-related activities have shown that younger subjects tend to be more focused than subjects who were of advancing age.<sup>1,2</sup> Studies focused on the motor system have found that age-related differences are superior when complex tasks are used.<sup>3</sup> Age-related changes in structural and functional part of brain have been the motivation of previous and ongoing neuroscientific research. Physiological ageing has an enormous impact on all stages of sensorimotor

processing, such as changes in cortical functions and peripheral neuronal structures.<sup>4</sup>

Previous studies have illustrated a number of cortical areas that are involved in the median nerve stimulation processing.<sup>5</sup> The cortex of the posterior wall of central sulcus and of the surface of posterior central gyrus forms the primary somatosensory cortex (SI). It was from the primary somatosensory cortex that evoked potentials were first recorded after physiological stimulation of the periphery. The primary somatosensory cortex include within it a topographical map of the contralateral body with most sacral segments medially in the paracentral

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lobule, the trunk and upper limb represented on the lateral surface and with the face, tongue and lips most laterally and inferiorly.<sup>6</sup> Further studies have addressed age-related changes within those areas using magnetoencephalography and evoked potentials demonstrated increased activation within the SI, most likely caused by altered inhibition due to ageing.<sup>7,8</sup> No data are available for regions of somatosensory processing in the ageing human brain. Consequently, this study aims to further investigate the age-related changes in primary somatosensory area of the cerebral cortex.

## MATERIALS AND METHODS

The study duration was of two years. It was done on fifty post-mortem brain specimens. The specimens removed were from both sexes belonging to various age groups ranging from 9 months to 75 years. The specimens were collected from the Department of Forensic Medicine, Medical College Kottayam. A total of fifty specimens were collected. The central sulcus was first identified. Then the post central gyrus was noted. The post central gyrus was dissected from the autopsied brain with a scalpel. Other than the fifty specimens, two aborted foetal specimens were also included in this study. They were obtained from the Labour room, Medical College, Kottayam.

### Examination of gross appearance

During the autopsy, the meninges were carefully stripped off. The sulci and gyri were then examined carefully. The central sulcus was identified, and its depth was measured at the upper, middle and the lower parts. After that, the length of the central sulcus was measured with a scale to note any differences in the length on the right and left sides. The depth was measured at the upper, middle and lower parts of the central sulcus, using a scale. Finally, the post-central gyrus was identified, dividing it into upper, middle, and lower areas. Specimens were taken from these three areas and transferred to three labelled bottles containing fixatives. Slides were made from the three different areas. They were stained with haematoxylin and eosin. The different lamina was first identified. The thickness of each lamina was measured. The cells present in each layer were identified as small stellate cells, large stellate cells and pyramidal cells by measuring them using an ocular micrometre where the eye piece lens was 10x and objective lens 100x and 500x. The shape was also noted. The different cells types were individually counted and measured in the different layers and then totalled. The number of cells were counted in the field of vision of that slide. This was done for all age groups.

Slide Serial No:	age.....		
Length of Central Sulcus:	right side .....cms		left side .....cms
Depth of Central Sulcus	1.upper area .....cms	2.middle area .....cms	3.lower area .....cms
Post Central Gyrus sections	1.upper	2.middle	3.lower
Lamina	layer.....	thickness:.....microns	
Cell type	small stellate cell <.5 microns	large stellate cell >.5 microns	pyramidal cells
Size (microns)	.....microns	.....microns	.....microns
Shape			
Total number of cells			
Total no of cells in field of vision			
Observations			

### Statistical analysis

Continuous variables are expressed as means and standard deviations and categorical variables are stated as numbers and percentages. Categorical outcomes were compared using chi-square tests.

## RESULTS

Table 1 showing in our study, age group were 0-10 years to 71-80 years old. Depth of right and left depth of central sulcus were divided into upper, middle, and lower part. The means of right central sulcus was upper 1.5 cms, middle 0.9cms and lower 1.2cms. As well as the means of left central sulcus was upper 1.3cms, middle 0.8 cms, and lower 1cm. The maximum depth of the central sulcus was about 0.3 cm the minimal depth was on the left side, 0.1 cm in fetal specimens. The maximum depth was noted on the upper region of the 71-80 age group which was about 2.4 cms. The grey matter thickness was the most in the upper area of the 61-70 age group, 0.6 cms. In the fetus it was the least, 0.1 cm. The grey matter thickness in the sulci was the least in the fetus, 0.1 cm, and most in the upper area of the 61-70 age group, 0.4 cms.

Table 2: Showing the size of small stellate cells in microns in laminae with age group of 0-10 years to 71-80 years old. A total of hundred fields were taken. Lamina II, IV, V were identified in different age groups and the means was

**Table 1: Depth of central sulcus**

Age groups	Right			Left		
	Upper	Middle	Lower	Upper	Middle	Lower
FETAL	0.3	0.2	0.3	0.2	0.1	0.2
0-10 years	0.4	0.3	0.4	0.3	0.2	0.3
11-20 years	2.4	1.8	2.2	2.2	1.6	2
21-30 years	1.6	1.4	1.5	1.4	1.3	1.4
31-40 years	1.9	0.8	1.2	1.4	0.8	1.1
41-50 years	1.6	1	1.4	1.3	1	1.2
51-60 years	1.4	1	1.1	1.3	1	1
61-70 years	2	1.1	1.2	1.8	0.9	1.1
71-80 years	2.4	1.2	1.9	2	1	1.5
Mean	1.5	0.9	1.2	1.3	0.8	1

taken. The mean sizes of cells in lamina II was 4.3 microns, lamina IV was 4.3, microns and lamina V was 4.3 microns.

Table 3: Showing number of small stellate cells in laminae with age groups of 0-10 years to 71-80 years old. A total of hundred fields were taken. Lamina II, IV, V were identified in different age groups and the means were taken. The mean number of cells in lamina II was 29.8, lamina IV was 20.5, and lamina V was 1.8.

Table 4: Showing the size of large stellate cells in laminae with age group of 0-10 years to 71-80 years old. A total of hundred fields were taken. Lamina II, IV were identified in different age groups and the mean was taken. The mean of sizes of cells in lamina II was 6.6 microns and in lamina IV was 6.8 microns.

Table 5: Showing number of large stellate cells in laminae with age group of 0-10 years to 71-80 years old. A total of hundred fields were taken. Lamina II, IV were identified in different age groups and the mean was taken. The mean of the number of cells in lamina II was 1.5 and in lamina IV was 8.

Table 6: In the study, it was seen that pyramidal cells were mainly in lamina III and V. They were mainly small and medium sized pyramidal cells. The medium sized pyramidal cells were the most in the 21-30 and 31-40 age groups.

Table 7: The medium sized pyramidal cells were identified in different age groups in laminae IV and V and the mean value for lamina IV was 29.8 microns and lamina V was 31.6 microns.

Table 8: Showing total cell types from II to V laminae. The total number of stellate cell types were 583 and pyramidal cell types were 618.

Table 9: The thickness of lamina II during fetal life was 65 microns and the maximum thickness was during the 51-60 age group. There was not much of a decline in the older age groups. The thickness of lamina IV in fetal life

**Table 4: Large stellate cells (more than 5 microns)**

Size	(Microns)	
	II	IV
<b>Lamina</b>		
Age groups (years)		
Fetal	0	6.6
0-10	0	6.6
11-20	0	6.7
21-30	0	6.8
31-40	0	6.8
41-50	6.2	6.8
51-60	7	7
61-70	6.8	7
71-80	6.6	7.1
Mean	6.6	6.8

**Table 2: Small stellate cells (less than 5 microns)**

Size	(Microns)		
	II	IV	V
<b>Lamina</b>			
Age groups (years)			
Fetal	4	4	4
0-10	4.4	4.4	4.4
11-20	4.4	4.4	4.4
21-30	4.4	4	4
31-40	4.4	4.4	4.4
41-50	4.4	4.4	4.4
51-60	4.4	4.4	4.4
61-70	3.9	4.4	4.4
71-80	4.4	4	4.4
Mean	4.3	4.3	4.3

**Table 5: Number of large stellate cells**

Lamina	Number/ Field	
	II	IV
Age group (years)		
Fetal	0	5
0-10	0	6
11-20	0	11
21-30	0	15
31-40	0	13
41-50	2	8
51-60	2	5
61-70	1	8
71-80	1	4
Mean	1.5	8

**Table 3: Number of small stellate cells**

Lamina	Number/ Field		
	II	IV	V
Age group (years)			
Fetal	24	24	2
0-10	28	27	3
11-20	24	25	5
21-30	38	24	2
31-40	36	21	1
41-50	37	17	1
51-60	37	16	1
61-70	23	16	1
71-80	22	15	1
Mean	29.8	20.5	1.8

**Table 6: Medium sized pyramidal cell**

Lamina	Number/ field	
	IV	V
Age groups (years)		
Fetal	10	14
0-10	13	15
11-20	12	27
21-30	13	29
31-40	15	29
41-50	11	26
51-60	9	25
61-70	8	26
71-80	8	24
Mean	11	23.8

was about 55 microns. It was noted that the maximum thickness was 80 microns in the 41-50 age group and then a gradual decline to 74 microns in the 71-80 age group. Maximum thickness of lamina V was in the 41-50 age group, 371 microns. This lamina also happened to be the thickest lamina in all age groups. Laminar degeneration was more prominent in this layer. The thickness of lamina IV was the most consistent. The thickness of lamina II, IV and V was measured in microns and the means were taken. Mean of the thickness of lamina II was 95.3 microns, lamina IV was 71.1 microns, and lamina V was 312.8 microns. Lamina IV is the thinnest layer. Stellate and pyramidal cells are similar in size and shape shown in Figure 1. Some cells can be made out to be pyramidal cells due to the triangular shape. The stellate cells are tightly packed shown in Figure 2. Lamina IV is almost indistinguishable from Lamina III. Stellate cells in laminae II are small and are dispersed. Small pyramidal

cells from laminae III are also visible shown in Figure 3. Cells are spherical with similar sizes. Cells are packed close to each other shown in Figure 4. Lamina IV was of similar thickness as of other slides under 100x magnification shown Figure 5. Small stellate cells not as tightly packed as the previous slides under 500x magnification shown in Figure 6.

Table 7: Medium Sized Pyramidal Cell		
Size (Microns)		
Lamina	IV	V
Age group (years)		
Fetal	30.3	30.3
0-10	30.3	30.3
11-20	30.3	30.3
21-30	29.5	30.3
31-40	27.4	30.3
41-50	30.3	33.3
51-60	30.3	33.3
61-70	30.3	33.3
71-80	30.3	33.3
Mean	29.8	31.6

Table 8: Cell total		
Cell Type	Stellate	Pyramidal
Lamina		
Lamina II	275	27
Lamina III	34	268
Lamina IV	257	99
Lamina V	17	224
Total	583	618

Table 9: Thickness of laminae (Microns)			
Lamina	II	IV	V
Age group (years)			
Fetal	65	55	200
0-10	78	61	216
11-20	83	67	247
21-30	88	73	354
31-40	94	77	355
41-50	110	80	371
51-60	117	78	365
61-70	113	75	360
71-80	110	74	348
Mean	95.3	71.1	312.8

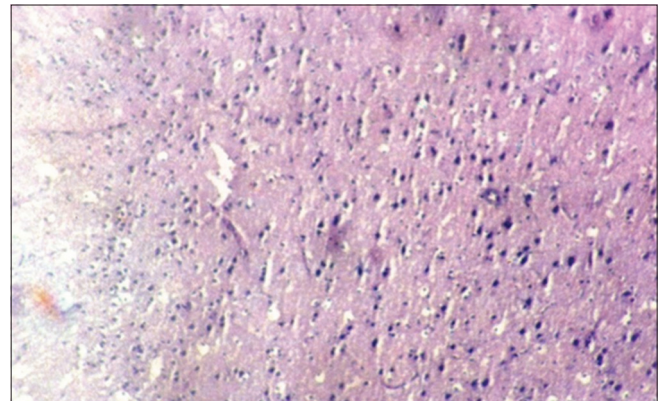


Figure 1: Lamina IV is the thinnest layer. Stellate and pyramidal cells are similar in size and shape

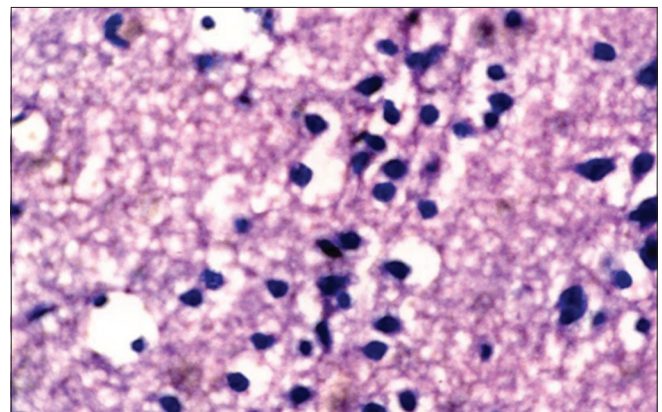


Figure 2: Some cells can be made out to be pyramidal cells due to the triangular shape. The stellate cells are tightly packed

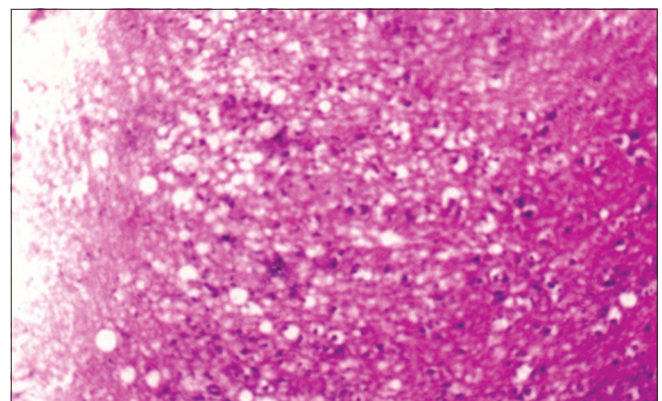
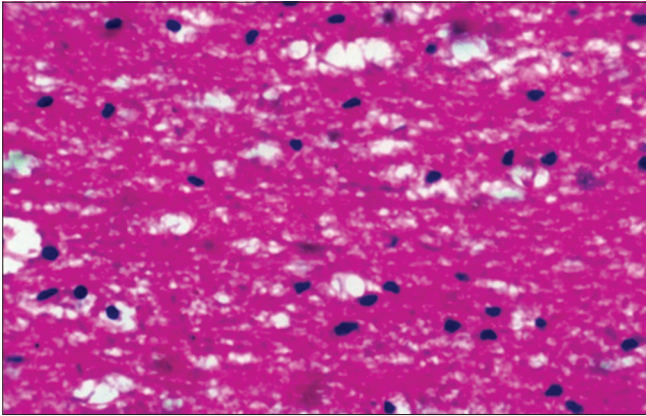
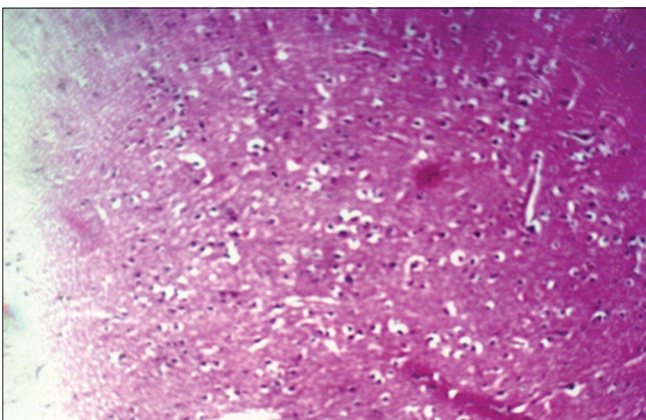


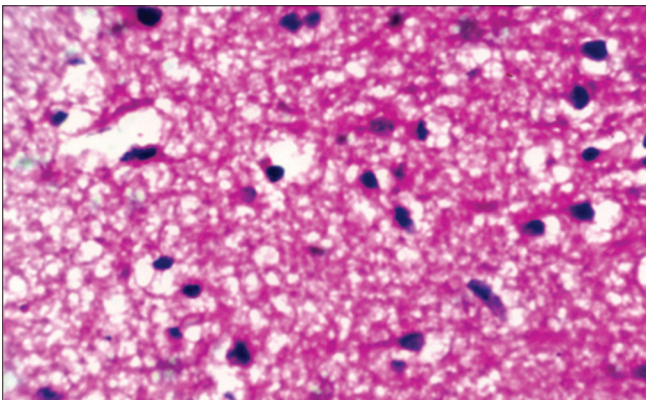
Figure 3: Lamina IV is almost indistinguishable from Lamina III. Stellate cells in laminae II are small and are dispersed. Small pyramidal cells from laminae III are also visible



**Figure 4:** Cells are spherical with similar sizes. Cells are packed close to each other



**Figure 5:** Lamina IV was of similar thickness as of other slides under 100x magnification



**Figure 6:** Small stellate cells not as tightly packed as the previous slides under 500x magnification

## DISCUSSION

The Tables 1-7 show age-related changes in primary somatosensory area of the cerebral cortex. This is consistent with Conel's findings (1939), of period of maximum maturation of the cerebral cortex in postnatal development.<sup>9</sup> The decrease was from 371 microns to 348 microns. Lamina I there was some decrease in the thickness of the layer

in older age groups. In fetal life it is about 40 microns. It decreased from 115 microns in the 51-60 age groups to 105 microns in the 71-80 age groups. Lamina II was seen in all age groups. Its thickness was the maximum in the 51-60 age group, 117 microns and then the thickness declined gradually to 110 microns in the older groups. Thickness was the least in the fetal stage, 65 microns. Lamina III was the second thickest lamina of the six layers. The thickness in the fetal life was about 40 microns. It was the maximum in the 51-60 years, 220 microns. The thickness declined after this age group and in the 71-80 microns. Lamina IV was the thinnest of all the layers. Its was the thinnest in the fetal life, 55 micron and the thickest in the 41-50 age group, about 80 microns. Lamina IV in fetal life had plenty cells packed in its area. This shows that the cells develop here first. Berry (1974), say that the first migration of cells begins from lamina IV and V to III and II sequentially; an inside to outside model.<sup>10</sup> Hatten in 1990 described that neurons were capable of migrating ten times in vivo.<sup>11</sup> The main difficulty of visualizing this lamina was that there was no distinct boundary between it and lamina III. Therefore, measurements taken showed that this was the thinnest lamina present. This is in concurrence with 38<sup>th</sup> edition of Gray's Anatomy, that mentioned that this was the thinnest layer despite of its high density of stellate cells. The thickness of lamina V in 71-80 age group was 348 microns. Lamina VI also showed laminar degeneration in the older age groups. The study showed that stellate cells were seen more in number in lamina II and IV. The small type was seen the most in 11-20 age groups in lamina II and the 21-30 age groups in lamina IV. The large stellate cell was seen the most in 21-30 age group of IV and 41-50 age group of laminae II. Their size was the maximum in the 71-80 age groups, 7.1 microns. In fetal life these cells were almost indistinguishable from the stellate cells as most of them were also spherical in shape except for an apical projection, the apical dendrite. Their size was about 10 microns. In the middle age groups, the cells were broad and triangular. However, in the ages of 61 years and above the pyramidal cells are more elongated and thinner. The number of cells decreased after the age of 61 years. The maximum number of cells decrease was on lamina V. There was a fall in number of medium sized pyramidal cells after 51 years. Goldensohn in 1993 observed that neuronal death accounted for the many cognitive deficiencies of normal aging.<sup>12</sup> Bu J et al., findings on calcium binding proteins in the cerebral cortex in 2003, described three calcium binding proteins; calbindin-D, calretinin, parvalbumin.<sup>13</sup> In their studies they noticed that there was a substantial neurochemical specific loss of calbindin-D in the course of normal aging which is prevalent in all areas. This depletion according to them may deprive the neurons the ability to buffer intracellular calcium leading to their degeneration. This may be reason for the decrease in the number of cells in the primary somatosensory area.

## CONCLUSION

The depth of the central sulcus was more in the upper region on both sides of the cerebral cortex and in all age groups. The lamina of the primary somatosensory area has shown that as age advances there is a progressive increase in thickness except in the case of lamina IV. Lamina thickness decreases after the age of 61years. In fetal life, the pyramidal cells were almost indistinguishable from the stellate cells. Pyramidal cells decrease in number after the age of 41years. There is a decrease in the number of small stellate cells in lamina II after the age of 51years but the number of stellate cells in the lamina IV was more or less same through the different age groups.

This study suggests the possibility that in more advanced stages of aging, the structural integrity of lamina IV, of primary somatosensory area, is more consistent in its thickness and number of cells present when compared to other layers in the cerebral cortex. Further studies are needed to examine the impact of ageing on somatosensory area.

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### Authors Contribution:

**SGJ-** Concept and design of the study. Review of literature. Collection of specimens and identifications of areas of brain. Preparation of slides using H&E stain. Categorizing the slides. Identified the different layers, cells, measurements, data analysis interpretation, statistics, and preparation of manuscript; **AG-** Review of literature. Data analysis, interpretation, statistics, and revision of manuscript.

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