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Original Research Article

Morphometric Analysis of Major Sulci of the Cerebral Hemisphere and their Variations: A Cadaveric and Radiological Study

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ABSTRACT

Background: Sulci are extensions of the subarachnoid space. Accurate knowledge of the brain's sulci is important for neurosurgeons for many reasons: (a) sulci can be used as landmarks for cortical mapping, that is; to identify specific functional areas of the brain, (b) localize the craniotomy procedure, (c) can be used as micro-neurological corridors to access deep areas of the brain. Besides, knowledge of sulci can help reduce the risk of functional deficit after surgery and understand neuroimaging, which is crucial for image-guided procedures. Thus, knowledge of sulci and their variations helps neurosurgeons perform brain surgery safely and effectively.

Objective: To locate and measure the extent of the major sulci of the cerebral hemisphere by using various anatomical landmarks in a cadaveric brain specimen and images of computed tomographic scans of the brain, and to observe their variations.

Material and Methods: The study design was a descriptive cross-sectional survey. Twenty cerebral hemispheres (10 right and 10 left) of cadaveric brain specimens, well preserved in formalin, and one hundred randomly selected computed tomographic scans of the brains were examined meticulously. A total of 19 parameters (eight in cadaveric and eleven in radiological study) were assessed for measurement of sulci and its neighboring areas. The measurements of the various parameters were done using vernier calipers, thread, scale, and beaded pins. An Independent t-test was done to compare the means of the measurements of the parameters between the left and right-sided cerebral hemispheres; p-values were calculated to find if the results were significantly different in the left and right cerebral hemispheres. Variations of the major sulci were also observed.

Results: In the cadaveric study, no significant differences between the parameters of the right and the left hemispheres were observed, except for the posterior part of the calcarine sulcus (p-value=0.0248). On the other hand, significant differences were observed in many parameters of the left and right cerebral hemispheres in a radiographic study (p-value- <0.05). Variations were noted in 15 percent (3/20) of the cerebral hemisphere in cadaveric samples.

Conclusion: The study provides further insights into identifying the important functional area of the brain located near the sulci and their variations which may aid neurosurgeons in planning and executing their surgery safely and effectively

KEY WORDS: Central sulcus, Lateral sulcus, PO sulcus, Calcarine sulcus.

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INTRODUCTION

The sulci and gyri are topological landmarks of the brain that form its folded surface. Gyri are ridge-like elevations on the surface of the cerebral cortex, while sulci are the depressions surrounding them. The cerebrum is folded into various convolutions (gyri)to accommodate extensive functional areas. The fissures between convolutions are known as sulci. The lateral sulcus of Sylvius, Central sulcus of Rolando, Calcarine sulcus, and Parieto-occipital sulcus are the four main sulci that are constant and divide the cerebral hemisphere into five lobes: frontal, parietal, temporal, occipital, and insular [1].

The central sulcus of Rolando, present on the superolateral surface of the cerebral cortex starts from the superomedial border 1 cm behind the midpoint then progresses downward, forward, and laterally and ends just a few millimeters above the posterior rami of the lateral sulcus. It is bounded anteriorly by the precentral gyrus and posteriorly by the postcentral gyrus which are the primary motor and somatosensory areas. [1]. It is worth mentioning that operations over these above-mentioned functional areas are approached via the central sulcus.

The lateral sulcus of Sylvius is another major sulcus present on the superolateral surface of the cerebral hemisphere whose root lies near the insula, and the stem runs along the temporal pole to appear over the superolateral surface giving three branches— anterior, ascending, and posterior rami. Anterior and ascending rami lies in the inferior frontal gyrus, whereas the posterior rami progresses backward in between the parietal and temporal lobe, after that, it ascends upward and ends in the parietal lobe remaining unbranched [1].

The Sylvian cistern beneath the lateral sulcus stem is the most commonly preferred site for micro-neurosurgery [2]. The anterior sylvian point which is the convergence point of the anterior, ascending, and posterior rami of the lateral sulcus [2], is an important landmark for neurosurgery due to the presence of frontal and temporal veins lying 10-15 mm in front and branches of the middle cerebral artery lying in its deeper part. [3,4]. The lateral sulcus is clinically important as Broca's area (motor speech area) is located in the anterior part of the lateral sulcus in the frontal lobe and Wernicke's area (sensory speech area) is located along the posterior rami of the lateral sulcus in the parietal lobe [1]. Likewise, primary and secondary auditory areas are located in the posterior rami of the lateral sulcus in the temporal lobe [1].

On the medial surface of the cerebral hemisphere, two main sulci are present: the parieto-occipital sulcus and the calcarine sulcus [1]. The parieto-occipital sulcus separates the parietal lobe anteriorly and the occipital lobe posteriorly on the medial surface of the cerebral hemisphere. The calcarine sulcus starts from the inferior aspect of the splenium of the corpus callosum and then progresses backward and ends at the occipital pole remaining unbranched. Calcarine sulcus divides into anterior and posterior parts by parieto-occipital sulcus. These two sulci can easily be identified by the letter "Y", whose main stem is formed by the anterior part of the calcarine sulcus, and the two limbs are made up of the parieto-occipital sulcus, and the posterior part of the calcarine sulcus [5]. The parieto-occipital sulcus lies between the two functional areas of the brain — precuneus and cuneus. The precuneus is an area of the brain involved in various cognitive functions like episodic memory, imaging, attention, personal identity, visuospatial processing, and consciousness. Primary and secondary visual areas are located along the terminal end of the posterior part of the calcarine sulcus. The calcarine sulcus separates the cuneus and lingual gyrus, which are involved in visual processing.

Accurate knowledge of the brain's sulci is important for neurosurgeons for many reasons: (a) sulci can be used as landmarks for cortical mapping, that is; to identify specific functional areas of the brain, (b) localize the craniotomy procedure, (c) can be used as micro-neurological corridors to access deep areas of the brain. Besides, knowledge of sulci can help reduce the risk of functional deficit after surgery and understand neuroimaging, which is crucial for image-guided procedures. Furthermore, anatomical localization of the sensorimotor cortical areas provides the neurosurgeon with reliable landmarks for brain navigation. Once the central sulcus has been determined, the adjacent sulcal and gyral patterns can be used as landmarks for the overall brain navigation. Thus, knowledge of sulci helps neurosurgeons perform brain surgery safely and effectively.

To study the variations of the sulci, a study on the cadaveric human brain is essential since it gives a clear view of all major sulci: central sulcus and lateral sulcus on the superolateral surface; parieto-occipital sulcus and calcarine sulcus on the medial surface of the cerebral hemisphere. Furthermore, morphometric analysis of the sulci of the brain becomes easier with the cadaveric study. On the other hand, morphometric analysis of the superolateral surface of the brain is not possible by CT scan images as it can only measure axial, sagittal, and coronal sections making it applicable on calcarine and PO sulcus present on sagittally placed medial surfaces. Hence, morphometric analysis of the central and lateral sulcus present on the superolateral surface of the cerebral hemisphere is only possible with a cadaveric study and not with a CT scan or MRI, as it is on an uneven superolateral surface.

Sulci and gyri of the cerebrum can be easily identified with the aid of radiology but are difficult to locate during surgical operations, owing to anatomical variations and the surgical approach of the sulci through a small aperture. Therefore, this study was performed to find the variations in the main sulci of the brain in cadaveric brains.

Even though a considerable number of studies involving cadaveric brain samples and MRI of the brain have been carried out to examine the cerebral sulci, there exists a scarcity of comprehensive data using CT scan images to study the measurements of various parameters of cerebral sulci. CT scans of the brain can be used to study the brain's sulci and gyri because they can provide accurate anatomical landmarks to help neurosurgeons navigate the brain during surgery. By providing a detailed map of the brain's sulci and gyri and important functional areas near it, a preoperative CT scan can help neurosurgeons perform their surgery safely and effectively. It can also help identify the location of lesions. Besides, it can provide intra-operative guidance since the map can be overlaid on the exposed brain to help guide the surgeon.

Since CT scans are less expensive, faster, and can be performed on patients with implantable medical devices, the present study was aimed to measure the main sulci of the brain by using various parameters with the help of CT images of the brain. Understanding the measurements of these sulci should help surgeons approach deeper structures, such as ventricles and subcortical lesions, and perform surgery on the important functional areas located near them. Therefore, the present study aims to provide valuable insights to anatomists, radiologists, and surgeons to localize the sulci and its neighboring functional areas more efficiently.

Objectives:

1. To locate and measure the extent of the major sulci of the cerebral cortex by using various anatomical landmarks in a cadaveric brain specimen and images of computed tomographic scans of the brain

2. to observe the variations of major sulci in cadaveric brains

3. Compare the results of this study with other studies

METHODOLOGY

The study design of the study was a descriptive cross-sectional survey. Formalin-fixed and well-preserved human cadaveric brain samples, of unknown sex and age, available in the two medical colleges of Bihar—Bhagwan Mahaveer Institute of Medical Sciences, Pawapuri, and ESIC Medical College, Bihta, Patna —were included in the study. Out of the 12 cadaveric brain samples available, 2 were excluded from the study as they were damaged. Thus, the study was conducted on 20 cerebral hemispheres (10 right; 10 left) after getting approval from the institutional ethical committee of respective medical colleges. The meningeal coverings were removed from those brain specimens where it was present except the pia mater which was firmly adherent to the brain substance. Blood vessels were also removed from the superficial surface of the brain for clear visualization of major sulci. Due precautions were taken while taking measurements to save the brain from any injury. Four main brain sulci were identified and the following parameters were measured in cadaveric brain specimens:

1. Length of the central sulcus (Figure 1).
2. The distance from the frontal pole to the Central sulcus's origin on the cerebral cortex's medial surface (Figure 2)
3. Length of the stem of the lateral sulcus (Figure 3)
4. The length of the posterior ramus of the lateral sulcus from the anterior sylvian point
5. The length of the anterior part of the calcarine sulcus from inferior to the splenium of corpus callosum up to the meeting point of PO and calcarine sulcus (Figure 4).
6. Posterior part of the calcarine sulcus from the meeting point of PO and calcarine sulcus to the occipital pole (Figure 5)
7. Length of the parieto-occipital sulcus (Figure 6)
8. The distance between the splenium and the parieto-occipital sulcus end (Figure 7).

All the parameters were measured separately in the right and left hemispheres using vernier calipers, thread, and beaded pins (used to show reference marks). Vernier caliper was preferred over digital caliper due to non-dependency on battery, cost-effectiveness, and suitability even in robust conditions. Three persons (two medical students, and the author) took the measurements of each parameter separately and independently to reduce the inter-observer's bias. The two medical students involved in taking the measurements were well-trained before taking the measurements. The average of the three readings of each parameter was taken for final statistical analysis. The variations observed in the major sulci were photographed using a digital camera.

In addition to examining human cadaveric brain samples, one hundred (100) computed tomographic scans of the brains, randomly selected out of the available CT scans of the brains in the department of radiology, ESIC, Medical College, Bihta, Bihar (between October 2023 and September 2024), were examined meticulously. The CT scans of the brain included in this study were of patients aged 20 years and above, irrespective of the symptoms for which it was done. Eleven parameters were assessed to measure sulci and its neighboring areas.

Parameters measured in CT scan images were:

1. Distance between the frontal and occipital poles (Figure 8)
2. Distance from the midpoint of the distance between the frontal pole and the occipital pole to the central sulcus (Figure 8)
3. Distance between the frontal pole and the central sulcus (Figure 8)
4. Distance between the central sulcus and the occipital pole (Figure 8)
5. Length of the parieto-occipital sulcus (Figure 9)
6. Distance between splenium to the meeting point of PO sulcus and calcarine sulcus (Figure 9)
7. Length of the anterior part of the calcarine sulcus (Figure 10)
8. Length of the posterior part of the calcarine sulcus (Figure 10)
9. Distance between splenium to PO sulcus end (Figure 11)
10. Distance between splenium to calcarine sulcus end (Figure 11)
11. Distance between the PO sulcus end and the calcarine sulcus end (Figure 11)

All the measurements were taken on the medial surface of the cerebral hemisphere. For measurements on the right and left sides, sections 5mm to the right and 5 mm to the left of the parasagittal plane were taken, respectively.

Photographs of the parameters measured in the CT images of the brain were taken using a digital camera.

Statistical analysis: Mean and standard deviation (SD) of the measurements taken in both the cadaveric brains and images of the CT brains were calculated. Since the data were found to be normally distributed, an independent t-test was done to compare the means of the measurements of the parameters between the left and right-sided cerebral hemispheres in both cadaveric samples and

CT scan images. P-values were calculated to find if the results were significantly different in two independent groups (left and right cerebral hemispheres) using SPSS Statistics 26. The results of this study were compared with other studies.

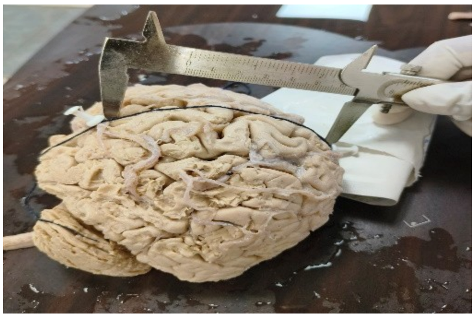

Fig. 1: Measurement of the length of the central sulcus.

Fig. 2: Measurement of the distance from the frontal pole to the central sulcus's origin on the cerebral cortex's medial surface.

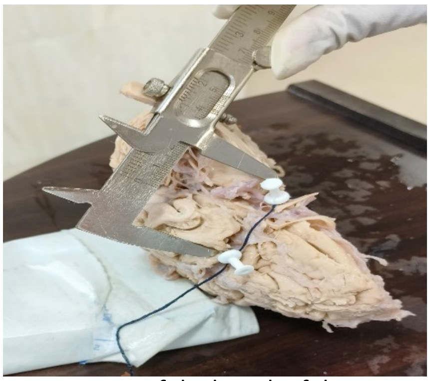

Fig. 3: Measurement of the length of the stem of the lateral sulcus.

Fig. 4: Measurement of the length of the anterior part of the calcarine sulcus

Fig. 5: Measurement of the length of the posterior part of the calcarine sulcus.

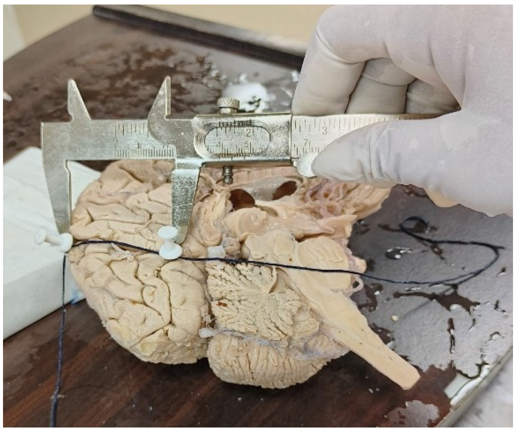

Fig. 6: Measurement of the length of the parieto-occipital sulcus.

Fig. 7: Measurement of the distance between splenium and the parieto-occipital sulcus end

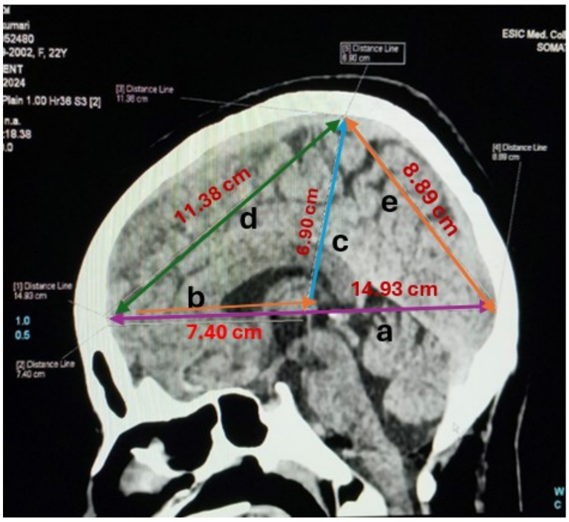

Fig. 8: Distance between the frontal pole and the central sulcus along with adjoining areas.

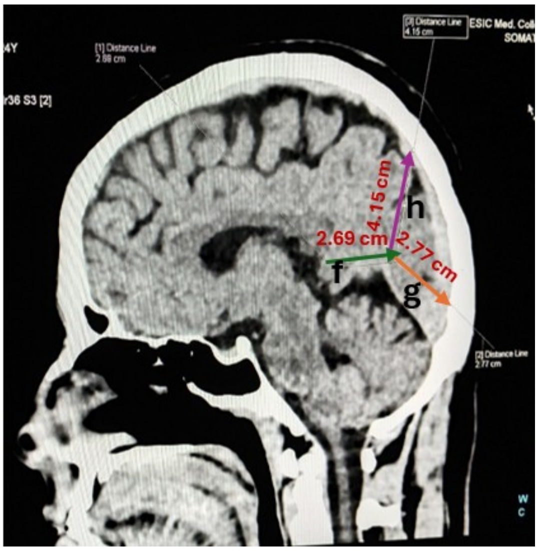

Fig. 9: Length of the parieto-occipital sulcus

Measurement of the parameters in CT images: (**a**) distance between the frontal and occipital poles; (**b**) Midpoint of the distance mentioned above; **(c)** distance from the midpoint to the central sulcus; **(d)** Distance between the frontal pole to the central sulcus; **(e)** Distance between central sulcus to occipital pole**;(f)** Distance in between splenium of the corpus callosum to the meeting point of PO sulcus and calcarine sulcus; **(g)** length of the posterior part of the calcrine sulcus; **(h)** length of the PO sulcus.

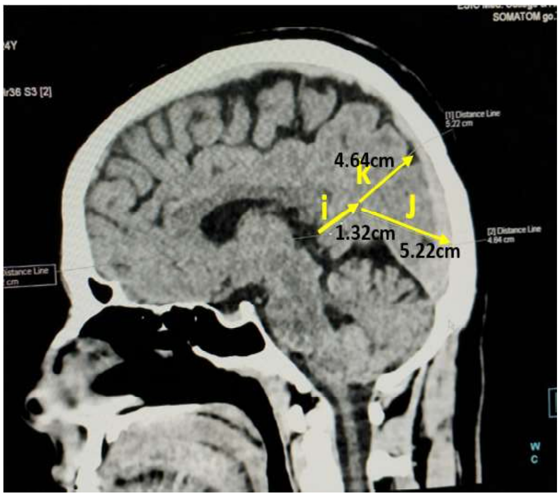

Fig. 10: Length of the posterior part of the calcarine sulcus and adjoining areas.

Measurement of the parameters in CT images: (i) length of the anterior part of the calcarine sulcus; **(j)** Length of the posterior part of the calcarine sulcus; (**k**) Length of the parieto-occipital sulcus; (**l**) splenium to PO sulcus end; (**m**) splenium to calcarine sulcus end; (**n**) distance between the PO sulcus end to the calcarine sulcus end.

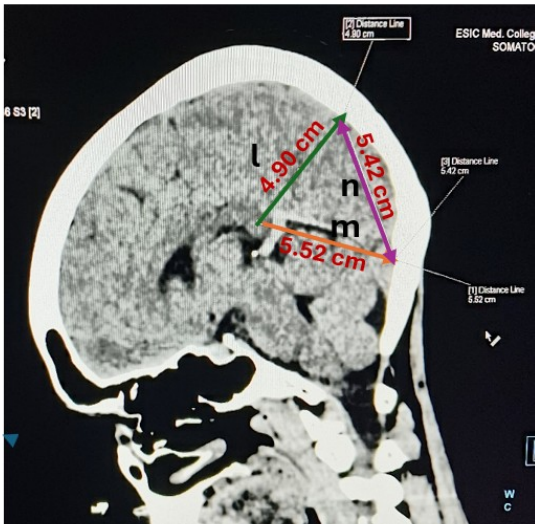

Fig. 11: Distance between splenium to PO sulcus end and adjoining areas.

RESULTS

Variations observed in the cadaveric brains: While in the normal population, the inferior extremity of the central sulcus of Rolando does not meet the posterior ramus of the lateral sulcus as shown in Figure 13, it was found to enter (meet) the lateral sulcus in 10 % of the samples (5 % each in the left and right cerebral hemispheres) out of the twenty cerebral hemispheres examined in the present study (Figure. 12).

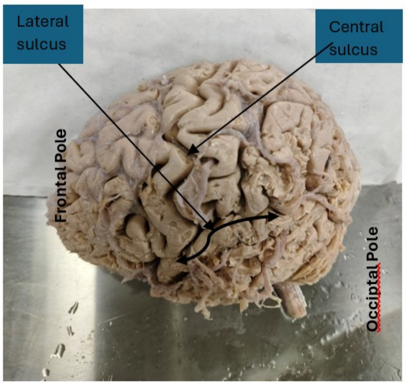

Fig. 12: Central sulcus of Rolando (Present Study).

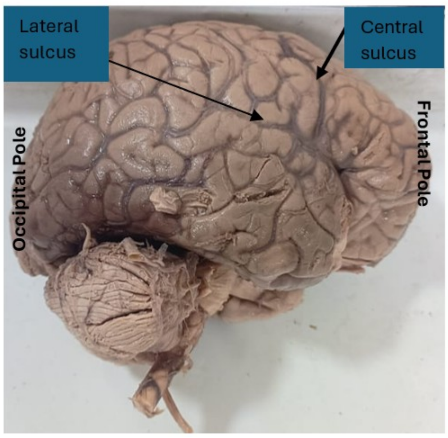

Fig. 13: Central sulcus of Rolando (Normal Population)

Likewise, in a normal brain, the central sulcus of Rolando does not encroach on the lateral sulcus of Sylvius (Figure 14). However, in this study, the central sulcus not only opened but also encroached on the lateral sulcus in one of the right hemispheres (5 percent of the total samples), as shown in Figure 15.

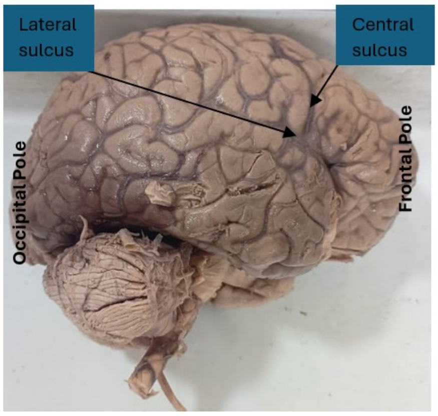

Fig. 14: Central sulcus of Rolando (normal population)

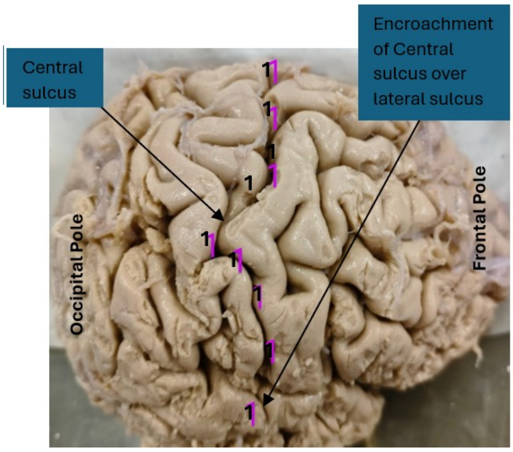

Fig. 15: Central sulcus of Rolando (present study).

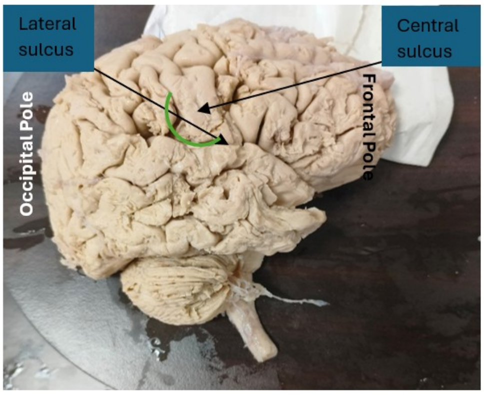

Fig. 16: Lateral sulcus of Sylvius (normal population)

While the posterior ramus of the lateral sulcus runs backward and upward unbranched (Figure 16) in a normal brain, the posterior rami of the lateral sulcus gave the following four branches in one of the left cerebral hemispheres (in 5 % of the total samples) as illustrated in Figure 17:

A. anterior ascending ramus(4c1),
B. posterior ascending ramus(4c2),
C. anterior descending ramus(4c3), and
D. posterior descending ramus(4c4).

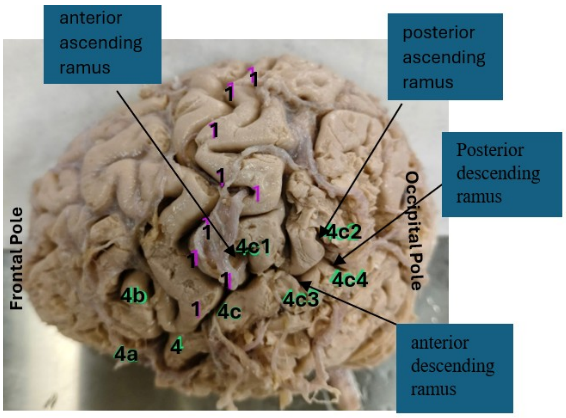

Fig. 17: Lateral sulcus of Sylvius (present study)

In a normal brain, the calcarine sulcus—— present on the medial surface— starts below the splenium of the corpus callosum, ascends in its anterior part, receives the parieto-occipital sulcus, and progresses towards the occipital pole in its posterior part unbranched (Figure 18).

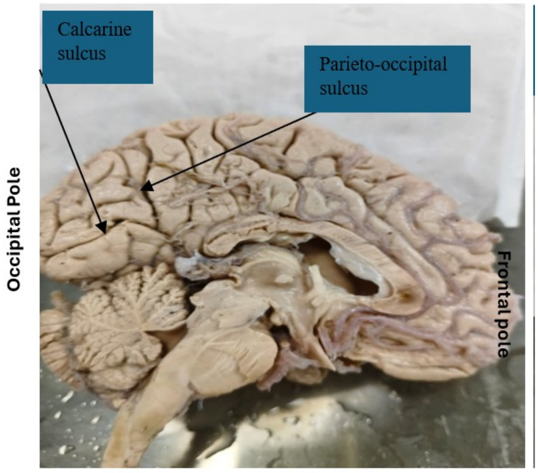

Fig. 18: Calcarine sulcus (normal population).

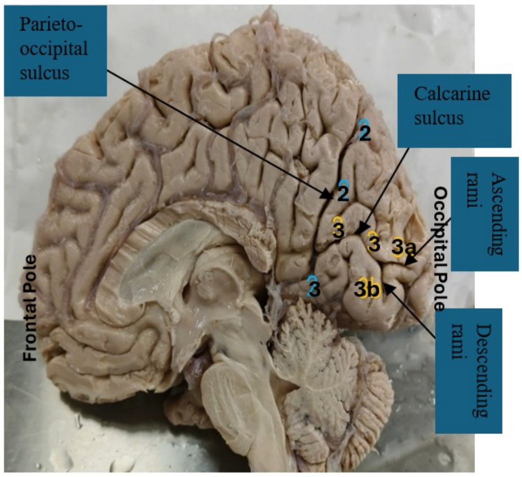

Fig. 19: Calcarine sulcus (present study).

The calcarine sulcus was found to give ascending and descending rami in its posterior part in one of the right cerebral hemispheres (3a and 3b), i.e., in 5 % of the total samples studied (Figure 19).

Morphometric analysis of the parameters in cadaveric samples: Table 1 compares the mean and standard deviation of the anatomical parameters studied in the cadaveric brain samples among the left and right cerebral hemispheres. No significant differences between the means of the parameters of the right and the left hemispheres were observed, except for the posterior part of the calcarine sulcus (p-value=0.0248),

Morphometric analysis of the parameters in CT scan samples: A comparison of the mean and standard deviation of the various anatomical parameters between the left and right cerebral hemispheres in the CT scan samples is shown in Table 2. In a radiological study, significant differences were observed in many parameters between the left and right cerebral hemispheres (p-value-<0.05) as shown in Table 2.

Table 1: Showing comparison of various parameters between the right and left hemispheres in cadaveric brain samples.

Parameters	Right hemisphere (mean ±SD)	Left hemisphere (mean ±SD)	P value
Length of the central sulcus	9.0 cm ±0.9	9.2 cm ± 0.8	0.6058
Distance from the central sulcus to the frontal pole on the medial surface.	10.2 cm ± 1.2	10.0 cm ± 0.8	0.666
Length of the stem of the lateral sulcus	4.9 cm ± 0.51	5.0 cm ± 0.63	0.69
Length of the posterior ramus of the lateral sulcus	6.0 cm ± 0.82	6.2 cm ± 0.63	0.535
Length of the anterior part of the calcarine sulcus	2.1 cm ± 0.32	2.3 cm ± 0.53	0.292
Length of the posterior part of the calcarine sulcus	**3.1 cm ± 0.32**	**4.2 cm ± 0.43**	**0.0248**
Length of the parieto-occipital sulcus	4.1 cm ± 0.42	4.3 cm ± 0.53	0.362
Distance from the splenium to the parieto-occipital sulcus	5.5 cm ± 0.64	5.7 cm ± 0.73	0.523

Table 2: Comparisons of various parameters between the right and left hemispheres in CT scan samples.

Parameters	Right hemisphere (mean ±SD)	Left hemisphere (mean ±SD)	P value
Distance between the frontal pole and the occipital pole	14.93 cm ± 0.70	15.21 cm ± 0.83	0.071
Distance from the midpoint between the frontal pole to the occipital pole to the central sulcus	6.90 cm ± 0.32	7.12 cm ± 0.41	**0.003**
Distance between the frontal pole and the central sulcus	11.38 cm ± 0.42	11.55 cm ± 0.53	0.078
Distance between the central sulcus and the occipital pole	8.59 cm ± 0.52	**8.84 cm ± 0.43**	**0.0102**
Length of the anterior part of the calcarine sulcus	1.32cm ± 0.16	1.43 cm ± 0.19	**0.0023**
Length of the posterior part of the calcarine sulcus	2.77 cm ± 0.28	2.82 cm ± 0.32	0.407
Length of the parieto-occipital sulcus	4.27 cm ± 0.52	4.21 cm ± 0.45	0.526
Splenium to the meeting point of PO sulcus and calcarine sulcus	2.69 cm ± 0.82	2.54cm ± 0.75	0.3422
splenium to PO sulcus end	4.90 cm ± 0.49	4.87 cm ± 0.46	0.753
Splenium to calcarine sulcus end	5.52 cm ± 0.57	5.27 cm ±0.52	**0.0241**

DISCUSSION

Table 3: Comparison of mean lengths of the central sulcus in the right and left hemispheres by various researchers.

Name of the researcher	The mean length of the central sulcus in the right cerebral hemisphere (in centimeters)	The mean length of the central sulcus in the left cerebral hemisphere (in centimetres)	Sample size
Nayak S. et. al. 2023 [6]	7.16	7.27	31
Ono et. al. 1990 [7]	10.5	9.4	100
Singh P K et al. 2015 [8]	9.47	9.6	34
Present study	9	9.2	20

Table 4: Mean length of the posterior part of the calcarine sulcus along with SD, found to be statistically significant by various researchers.

Name of researcher	The mean length(cm) of the posterior part of the calcarine sulcus in cadaveric brain samples. ±SD	Sample size (n)
Mandal et. al. 2014 [10]	4.21 ±1.44	106
Nayak S. et. al. 2023 [6]	3.44 ± 0.4152 (R) 3.75 ±0.3777 (L)	31
Present study	3.1 cm ± 0.32(R) 4.2 cm ± 0.231(L)	20

R-Right cerebral hemisphere; L-Left cerebral hemisphere

Table 5: Comparison of mean lengths of the lateral and parietooccipital sulcus in the right and left hemispheres.

Name of researcher	Length of the stem of lateral sulcus in centimeters ± SD	Length of the posterior ramus of lateral sulcus in centimetres± SD	Length of parieto-occipital sulcus in centimetres± SD	Sample size (n)
Nayak S. et al. 2023 [6]	3.66 ± 0.50 (R) 3.59 ±0.66 (L)	5.49± 0.82(R) 5.68± 0.54(L)	3.34 ± 0.41(R) 3..31± 0.50(L)	31
Present study	4.9 ± 0.51(R) 5.0 ± 0.63(L)	6.0± 0.82(R) 6.2± 0.63(L)	4.10± 0.42(R) 4.30± 0.53(L)	20

R-Right cerebral hemisphere; L-Left cerebral hemisphere

Table 6: Comparison of the mean length and standard deviation of different parameters found to be statistically significant between the right and left hemispheres with another radiological study.

Name of researcher	The mean distance between the midpoint between the frontal and occipital lobe to the central sulcus	The mean distance between the central sulcus and the occipital pole	The mean length of the anterior part of the calcarine sulcus	The mean distance between splenium to calcarine sulcus end
Na●yak S. et. al. 2023 [6]	6.14 ± 0.536(R) 6.27± 0.499(L)	8.59 ± 0.693(R) 8.81 ± 0.679(L)	1.61 ± 0.269(R) 1.58 ± 0.248(L)	3.97 ± 0.462(R) 3.93 ± 0.512(L)
Present study	6.90 cm ± 0.32(R) 7.12 cm ± 0.41(L)	8.59 cm ± 0.52(R) 8.84 cm ± 0.43(L)	1.32cm ± 0.16(R) 1.43 cm ± 0.19(L)	5.52 cm ± 0.57(R) 5.27 cm ± 0.52(L)

R-Right cerebral hemisphere; L-Left cerebral hemisphere

Since the central sulcus separates the motor and sensory areas of the brain and helps define the primary motor and sensorimotor cortices, it is an important landmark for brain navigation during surgery. Hence, accurate knowledge of its length and location is crucial for the neurosurgeon to identify the location of the lesion and brain functional regions and plan their surgery safely. In this study, the mean length of the central sulcus was 9.0 cm and 9.2 cm in the right and left sides respectively, which is comparable with the findings of Singh P.K et al. [8] and Ono et al. [7].

However, Nayak S. et al. [6] found the mean length of the central sulcus at a lower value than the present study, as detailed in Table.3

The calcarine sulcus is a prominent landmark on the medial surface of the occipital lobe where the primary visual cortex is concentrated. The posterior part of the calcarine sulcus is important in neurosurgery because it is the region where the central visual field is located, and lesions in this area can cause visual loss. Hence, precise knowledge about its length and location is essential for surgeons to locate the primary visual cortex and access the occipital lobe. In this study, the mean lengths of the posterior part of the calcarine sulcus were 3.1cm and 4.2 cm in the right and left cerebral hemispheres, respectively, comparable with Nayak S. et al.'s findings [6] as illustrated in Table 4. Out of all the parameters studied in cadaveric samples, it was the only parameter that was found to differ significantly on the left and right sides after statistical analysis. Similar observations were noted by Nayak S. et al. in their study [6]. While more research is needed to elucidate the reasons for significant differences in the left and right sides, surgeons should be cautious while performing surgery in the occipital lobes due to the possibility of substantial differences in the length of the posterior part of the calcarine sulcus in the left and right sides.

The precise knowledge of the lateral sulcus is important for neurosurgeons as Broca's area (motor speech area) is located in the anterior part of the lateral sulcus in the frontal lobe and Wernicke's area (sensory speech area) is located along the posterior rami of the lateral sulcus in the parietal lobe. Likewise, primary and secondary auditory areas are located in the posterior rami of the lateral sulcus in the temporal lobe. The mean lengths of the stem, posterior ramus of the lateral sulcus, and parietooccipital sulcus in the right and left hemispheres found in the present study were comparable with the results of Nayak S. et al. [6] as illustrated in Table 5.

In the present study, of the twenty cerebral hemispheres examined, the inferior extremity of the central sulcus was found to enter (meet) the lateral sulcus in 10 % of the samples—5% each in the left and right cerebral hemispheres. Ono et al. observed the inferior extremity of the central sulcus meeting the lateral sulcus in 16% of the right and 19% of the left hemispheres.[9], whereas Ribas et al. found the same in 17% of specimens [3]. In contrast, Nayak S. et al. did not observe the CS and LS meeting in their study [6]. The central sulcus encroached /extended into the lateral sulcus in 5 % of the cerebral hemispheres in this study, much lower than that observed by Chung et al. [12], Ebening [11] et al., Retzius et al. [13], and Kumar et al [15]. They observed that the central sulcus encroached the lateral sulcus in 16,15,17 and 17 percent of the cerebral hemispheres respectively. These differences may be attributed to differences in the sample size studied.

In the present study, the calcarine sulcus gave two terminal branches— ascending and descending rami— in its posterior part, in 5 % of the samples which was comparable (3.77%) to the findings of Mandal et al. [10]. However, Malikovic et al. [14] and Flores et al. [9] reported variation of calcarine sulcus in 10 and 14 percent of the samples respectively, much higher than the present study.

Analysis of the means of various anatomical parameters studied in the CT scan samples of the cerebral hemispheres showed significant differences when compared between the left and right sides in many of the parameters (p-value- <0.05). A similar observation was noted by Nayak S et al. [6], where many of the parameters studied in CT scans of the brains showed significant differences in the left and right sides (Table 6).

The significant differences between the various parameters of the left and right hemispheres in both cadaveric and radiological studies may be due to structural or functional differences between the left and right sides of the brain [16,17,18,19].

These differences underscore the major organizational principle of the brain, also known as Cerebral dominance, functional lateralization, or hemispheric specialization. Many factors evolutionary, genetic, environmental, and even pathological factors are known to contribute to laterality [17,19,20].

However, more research involving animal models is needed to elucidate the reasons for significant parameter differences between the left and right sides of the brain.

Limitation: Since the total number of cadaveric brains included in this study was small, non-random, and based on availability, the results of this study cannot be extrapolated to a larger population. Similarly, the CT scan images used in this study were from the patients irrespective of the symptoms for which it was done, therefore if there had been any pathology present in it, it might have skewed the measurements in either direction. Furthermore, even if the samples of the CT scan images used for measuring the parameters were selected randomly, it was still small for making any definitive inferences.

CONCLUSION

In the cadaveric brain samples, the mean lengths (in centimeters) and the standard deviations of the central sulcus, lateral sulcus, parieto-occipital sulcus, and posterior part of the calcarine sulcus were 9.0±0.91,6.0 ±0.82,4.1± 0.42,3.1± 0.32 among the right, and 9.2 ±0.8,6.2 ± 0.63, 4.3±0.53 4.2±0.43 among the left cerebral hemispheres respectively, which was consistent with the result of other studies. In the present study involving cadavers, no significant differences between the parameters of the right and the left hemispheres were observed, except for the posterior part of the calcarine sulcus in the cadaveric study (p-value=0.0248). On the other hand, in the radiological study, significant differences were observed between the right and left cerebral hemispheres in many parameters (p-value- <0.05), which is consistent with the results of a similar study by Nayak S. et al. [6] involving CT scan images of the brain. Variations are noted in 15% (3/ 20) of the cerebral hemispheres. Most of the measurements of sulci in both the cadaveric and radiological studies were higher in the left hemisphere justifying the right-handedness of the larger population.

The significant differences between the various parameters of the left and right hemispheres in both cadaveric and radiological studies may be due to structural or functional differences between the left and right sides of the brain. These differences underscore the major organizational principle of the brain, also known as Cerebral dominance, functional lateralization, or hemispheric specialization. However, more research involving animal models is needed to elucidate the reasons for significant parameter differences between the left and right sides of the brain.

The significant differences between the various parameters of the left and right hemispheres in both cadaveric and radiological studies should provide valuable insights to neurosurgeons to plan and execute their surgery safely and effectively. This should be equally helpful to radiologists for the accurate interpretation of the CT scans of the brain.

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