

Morphometric Analysis of Crucial Cerebral Sulci by Dissection Method: A Cross-sectional Study

SHIVANI CHAWLA¹, PRACHI SAFFAR ANEJA², SUSMITA SAHA³, NEERU KAPUR⁴, BHAVESH KUMAR⁵, NISHA PAHAL⁶



ABSTRACT

Introduction: Morphometric analysis of cerebral sulci provides critical insights into brain structure, functional organisation, and hemispheric asymmetry. Understanding variations in major sulci such as the Central Sulcus (CS), Calcarine Sulcus (CalS), and Parieto-Occipital Sulcus (POS) is essential for neurosurgical planning and comparative neuroanatomy.

Aim: To analyse the morphometry of crucial cerebral sulci by dissection method.

Materials and Methods: The present cross-sectional study, was conducted in the Department of Anatomy at the Faculty of Medicine and Health Sciences, SGT University, Budhera, Gurugram, Haryana, India, from June 2024 to August 2025, on 30 cerebral hemispheres (15 right and 15 left) of unknown sex, preserved in 10% formalin. The samples were obtained from the dissection hall and the museum of the same department. The data were collected by assessing parameters of the CS, CalS, and POS and were entered into a Microsoft Excel spreadsheet. The mean and standard deviation (M±SD) of all parameters were analysed using Statistical Package for the

Social Sciences (SPSS) software version 21. An independent t-test was used for the comparison of parameters of right and left with a significance level ($p < 0.05$).

Results: The CS was highly conserved, showing no significant right-left differences (Right: 11.32 ± 0.70 cm; Left: 11.49 ± 0.88 cm; $p = 0.55$). The CalS demonstrated significant hemispheric asymmetry, with anterior CalS right > left ($p = 0.02$) and posterior CalS left > right ($p = 0.04$). The POS bifurcation to the subparietal sulcus exhibited right > left asymmetry ($p = 0.04$). Parameters involving the posterior splenium also showed symmetric and hemisphere-related differences, while other sulcal measurements were largely symmetrical.

Conclusion: While the CS remains a stable anatomical landmark, CalS and POS display reproducible hemispheric asymmetries, particularly in posterior regions. These findings were consistent across Indian and international populations and highlight the importance of considering sulcal asymmetry in neurosurgical approaches, radiological mapping, and functional cortical studies. Understanding these morphometric patterns can improve surgical safety, imaging accuracy, and comparative neuroanatomy.

Keywords: Cadaver, Calcarine sulcus, Central sulcus, Cerebral hemisphere, Hemispheric asymmetry

INTRODUCTION

Cerebral sulci are furrows and depressions that divide the highly convoluted external surfaces of the brain hemispheres into a series of folds known as gyri. These sulci are extensions of the subarachnoid space. When they are deep and anatomically consistent, they are referred to as fissures. The major sulci are 1-3 cm deep and have tiny interconnected gyri (transverse gyri) in their walls. The principal cerebral sulci divide the frontal, parietal, occipital, temporal, insular, and limbic lobes [1]. The cerebral cortex is the primary storehouse of memory, and it also governs the activity of lower brain centres. Each area of the cerebral cortex receives specific inputs, which help in eliciting a response in a particular part of the body [2]. In neurosurgery, they act as the main microanatomical borders that serve as a gateway and surgical passage to reach the ventricles or to the deeper lesions [3].

The Rolandic fissure is a limiting sulcus in the cerebrum. It is also known as the Rolandic sulcus, CS, or central fissure and was named after Luigi Rolando, an Italian Anatomist [4]. It distinguishes the precentral gyrus, which has the main motor area 4, from the postcentral gyrus, which houses somatosensory areas 3, 1, 2, and the gustatory area for taste number 43 [5,6]. The central, precentral, and post-CS are considered as a continuous or long principal sulcus [7]. Additionally, the idea of interrupted Rolandic, pre-rolandic, and post-rolandic sulcus was also put forward; hence Rolando sulcus is a long, principal, continuous, and axial sulcus [8]. It is an important anatomical marker in the cerebral hemisphere because it separates the primary motor cortex from the primary somatic sensory cortex [2]. Many researchers, including Campbell

A, Cunningham DJ and White L have studied the CS using post-mortem samples in the past [9-11].

The CS begins at the superomedial boundary near the vertex or highest point of the hemisphere, just behind the midpoint of the longitudinal fissure. It runs outward, downward, and forward until it reaches the middle of the Sylvius fissure, where it sometimes joins the posterior limb. It runs across the lateral convex surface of the cerebral hemisphere, breaking the typical longitudinal course of the gyri and sulci [12].

The CalS and POS run along its medial surface. The striate cortex (Brodmann area 17), which is located in deep regions and the proximity (surrounding) of the CalS, reaches briefly to the lunate sulcus (LunS) on the lateral side of the cerebrum (about 1 cm). The CalS and POS are easily identified thanks to a "Y" shaped design. The stem of the "Y" represents the anterior section of the CalS, while the two arms represent the posterior parts of the CalS and POS [13]. The POS begins on the CalS's medial surface, extends to the SMB, runs up and back, and eventually terminates on the superolateral surface [14].

The POS divides the CalS into anterior and posterior segments. The anterior segment is regarded as a complete sulcus because it forms the calcar avis on the medial wall of the lateral ventricle. In contrast, the posterior segment is considered an axial sulcus, as its long axis corresponds to the primary visual cortex [15]. The anterior portion of the visual cortex represents peripheral retinal inputs, whereas macular vision is mapped to a disproportionately large posterior region surrounding the posterior CalS [16]. Near the Occipital Pole (OP), the CalS commonly bifurcates in a T- or Y-shaped pattern, known as the retro-CalS [17].

On the medial surface of the cerebral hemisphere, the POS separates the parietal lobe anteriorly and the occipital lobe posteriorly. It lies between two functional areas of the brain- precuneus and cuneus. The precuneus functional area of the brain is associated with various functions like personal identity, visuospatial processing, episodic memory, imaging, attention and consciousness. On the posterior part of the CalS at its terminal end, the primary and secondary visual areas are located. It separates the cuneus and lingual gyrus, which are associated with visual processing [18].

Cerebral sulci serve as critical anatomical landmarks for neurosurgeons, radiologists, and anatomists, making accurate knowledge of their morphology essential for cortical mapping, surgical planning, and interpretation of neuroimaging [18]. However, sulcal dimensions demonstrate considerable inter-individual and ethnic variability. Cadaveric dissection remains the gold standard for anatomical measurement, enabling precise visualisation of sulcal boundaries and depth [2].

The present study offers a unique contribution by providing precise morphometric data of crucial cerebral sulci through direct cadaveric dissection, a method that delivers superior anatomical accuracy. This research comprehensively evaluates multiple major sulci, documenting their length, orientation, and asymmetry in both hemispheres. The present study aimed to study the morphometric analysis of the major sulci of the brain by the dissection method.

MATERIALS AND METHODS

The study was a cross-sectional study, conducted in the Department of Anatomy at the Faculty of Medicine and Health Sciences, SGT University, Budhera, Gurugram, Haryana, India, from June 2024 to Aug 2025. The study was conducted after approval from the ethical committee of the Faculty of Medicine and Health Sciences, SGT University, Budhera, Gurugram (vide letter no. IEC/FMHS/MD/MS/2023-03). Since there was limited prior literature reporting comparable morphometric parameters in the studied population, reliable estimates for effect size calculation were not available; Convenience sampling was used based on the availability of cadaveric cerebral hemispheres. So, 30 cerebral hemispheres were included in the study.

Inclusion criteria: Properly embalmed, intact cerebral hemispheres from cadavers of unknown gender, without visible damage, were included in the study.

Exclusion criteria: Cerebral hemispheres showing gross anatomical abnormalities, evidence of pathology, or physical damage were excluded. Only the main continuous sulcus groove was considered; other accessory sulci or interruptions were excluded.

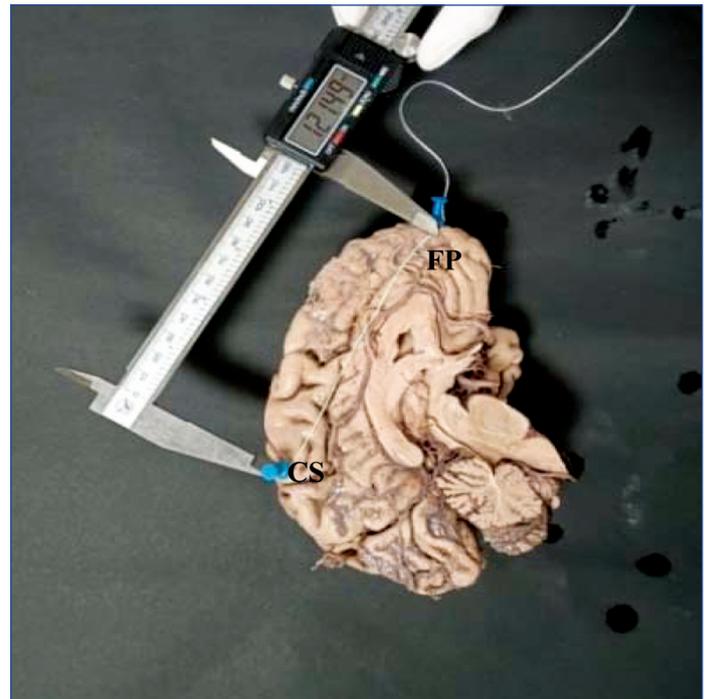
Study Procedure

Each brain was divided into two hemispheres. Meningeal coverings were not present except for the firmly adherent pia mater. Brains were dissected according to Cunningham's Manual of Practical Anatomy [10]. Care was taken to avoid damage to the tissue. The instruments used were a digital vernier caliper, thread, scale, beaded pins, and forceps. The curved sulcal path was traced by identifying the sulcal origin (marked with one beaded pin) and the sulcal termination (marked with another beaded pin). A thin, non-elastic cotton thread was then placed along the sulcus, allowing it to rest passively between the two points under its own weight. Care was taken to avoid any pulling force during placement, and gentle adjustments were made using beaded pins to prevent tightening of the thread.

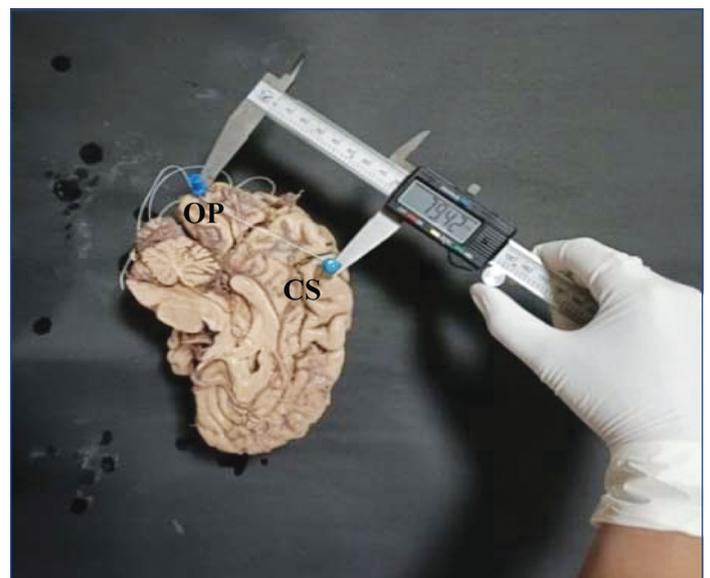
One marked point of the thread was aligned with the fixed jaw of the digital vernier calliper. The other marked point was aligned with the movable jaw. The jaws were closed just enough to touch the thread ends without compressing them. The distance between two marked points was read directly from the digital vernier calliper

scale. Measurements were recorded in mm/cm. Parameters were used on the medial surface of the cerebral hemisphere.

The distance of the CS from the Frontal Pole (FP) on the cerebral hemisphere [Table/Fig-1] The distance of the CS from the Occipital Pole (OP) [Table/Fig-2].



[Table/Fig-1]: Central sulcus to Frontal Pole (FP).



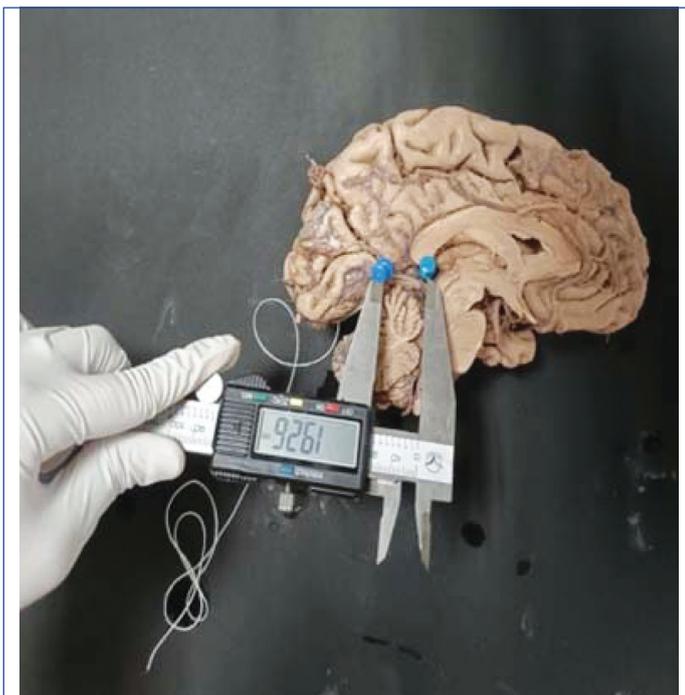
[Table/Fig-2]: Central sulcus to Occipital Pole (OP).

The length of the anterior part of the CalS, defined as the segment extending anteriorly from its junction with the POS toward the splenium of the corpus callosum [Table/Fig-3]. The length of the posterior part of the CalS representing the segment extending posteriorly from its junction with the POS to the OP [Table/Fig-4]. The length of the POS, measured from the bifurcation point to the Superomedial Border (SMB) [Table/Fig-5]. The distance from the posterior end of the splenium to the termination of the CalS at the OP [Table/Fig-6]. The distance from the splenium to the calcarine-parieto-occipital bifurcation [Table/Fig-7]. The distance from the splenium to the parieto-occipital end [Table/Fig-8]. The distance between the POS end and the Calcarine Sulcus (CalS) end [Table/Fig-9].

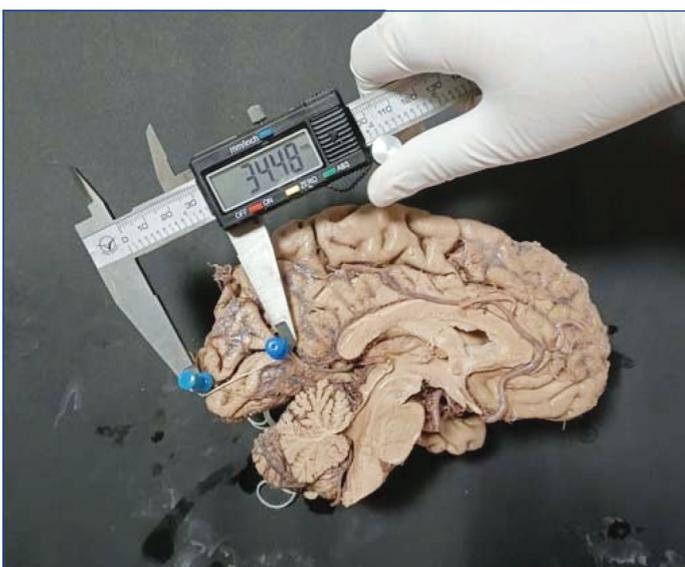
Repeatability bias was minimised by following a standardised protocol, and measurements were repeated to ensure consistency for all cadaveric cerebral hemispheres. All the measurements were

performed by a single trained observer to eliminate inter-observer variations. Observer followed-identification of clearly anatomical

sulcal landmarks, thread placement, and sulci were identified using standard anatomical references to avoid subjective interpretation.



[Table/Fig-3]: Length of anterior part of Calcarine sulcus (CalS).



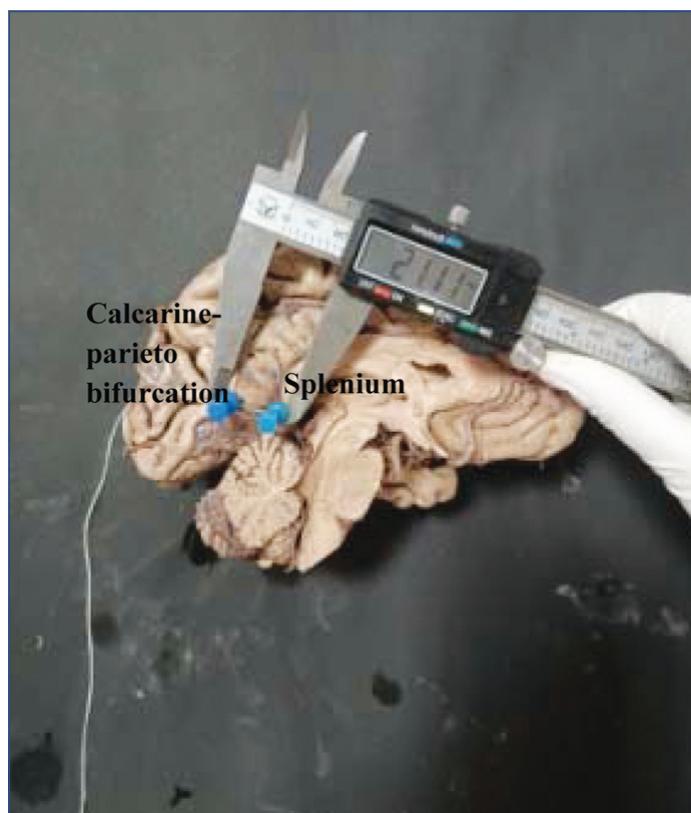
[Table/Fig-4]: Length of posterior part of Calcarine Sulcus (CalS).



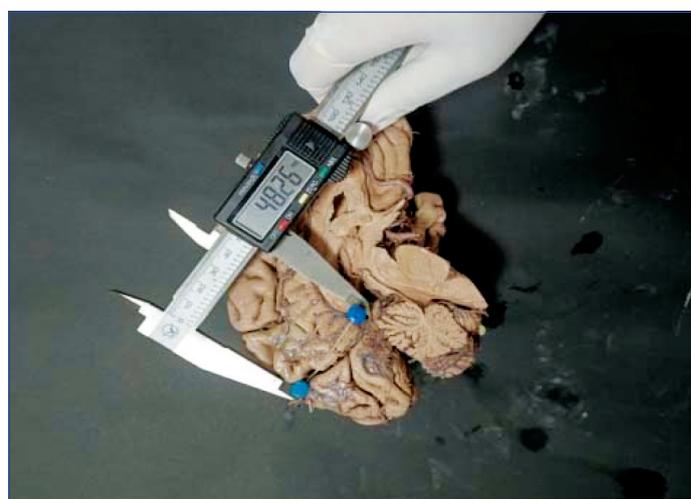
[Table/Fig-5]: Length of Parieto-Occipital Sulcus (POS).



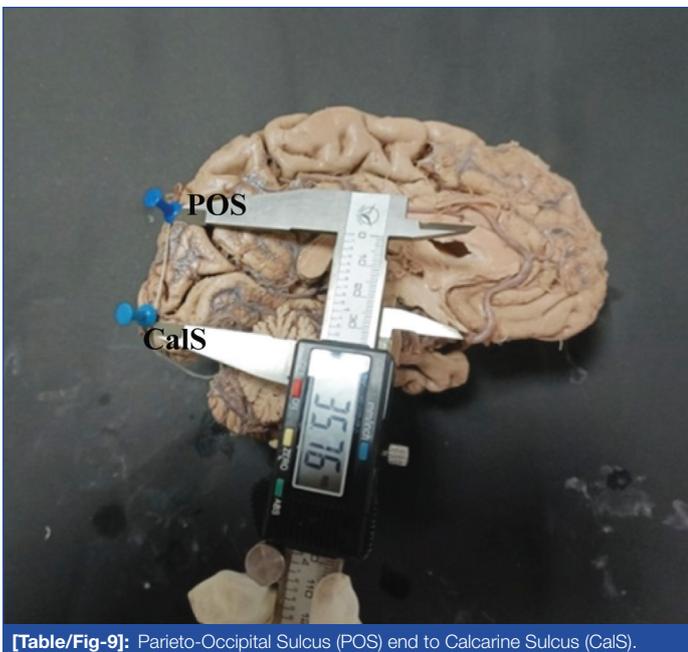
[Table/Fig-6]: Posterior end of splenium to terminator of Calcarine Sulcus (CalS).



[Table/Fig-7]: Splenium to the calcarine-parieto-occipital bifurcation.



[Table/Fig-8]: Posterior end of the splenium to the termination of the Calcarine Sulcus (CalS).



[Table/Fig-9]: Parieto-Occipital Sulcus (POS) end to Calcarine Sulcus (CaS).

The same vernier calliper and the same type of thread were used throughout the study. Measurements were recorded using coded specimens, and the observer was blinded to side (R/L) during measurements to reduce subconscious bias, consistency in handling specimens.

STATISTICAL ANALYSIS

Statistical analysis was performed using Microsoft Excel 2007 and IBM SPSS Statistics, version 21.0. Descriptive analysis, including means, was calculated for the right and left cerebral sulci. Independent-samples t-tests were performed to compare the mean values of the measured parameters between the right and left-sides. A p-value < 0.05 was considered statistically significant.

RESULTS

The measured CS from the frontal and Occipital Poles (OPs) showed no significant differences, indicating overall symmetry. However, specific segments of the CaS and the POS exhibited significant lateral differences, with the posterior CaS and the POS from the bifurcation point to the superior marginal branch being longer on the left hemisphere [Table/Fig-10].

Parameters	Right	Left	p-value
	Mean±SD (cm)	Mean±SD (cm)	
CS from FP	11.32±0.70	11.49±0.88	0.55
CS from OP	9.12±0.02	9.10±0.13	0.45
Anterior part of CaS	2.35±0.03	2.27±0.12	0.02*
Posterior part of CaS	3.36±0.41	3.68±0.40	0.04*
Length of POS from the bifurcation point to SMB	3.42±0.08	3.20±0.38	0.04*
Distance from posterior end of the splenium to the termination of the CaS in the OP	5.17±0.20	5.37±0.34	0.07
Splenium to the calcarine-parieto-occipital bifurcation	2.05±0.02	1.91±0.28	0.07
Splenium to parieto-occipital end	4.72±0.33	4.43±0.51	0.07
POS end to CaS end	4.13±0.25	4.01±0.28	0.20

[Table/Fig-10]: Illustrates the mean results of sulci between right and left cerebral hemispheres on the medial surface in cadaveric tissue.

An independent-samples t-test was used

*A p-value < 0.05 was considered statistically significant

DISCUSSION

In the present study, the mean distances for both the anterior (to FP) and posterior (to OP) measurements were statistically similar

between the right and left cerebral hemispheres, as indicated by the Non-Significant (NS) p-values (0.55 and 0.45, respectively). This lack of significant asymmetry is consistently observed when compared to the findings of Nayak S et al., who also reported NS right-left differences for both measurements (p=0.22 and p=0.82), suggesting a bilaterally symmetrical anatomical pattern for the CS's relative position [12].

The present study found statistically significant asymmetry in both the anterior (p=0.02) and posterior parts (p=0.04) of the sulcus, a finding that aligns with the significant posterior asymmetry consistently reported in the literature (Nayak S et al., 2023, p=0.03) [12]. Specifically, the left posterior CaS was found to be longer in all studies showing significant asymmetry, suggesting a potentially consistent leftward lateralisation for the visual cortex associated with this region [Table/Fig-11] [10,12,18]. While the anterior part's asymmetry is more variable across studies, the consistent posterior finding highlights a stable anatomical difference that may correlate with functional hemispheric specialisation in visual processing.

Sulcus/Study	Right (Mean±SD)	Left (Mean±SD)	R-L Significance (p-value)	n
Anterior part of Calcarine Sulcus (CaS) (present study, 2025)	2.35±0.03	2.27±0.12	0.02 (S)	30
Posterior part of Calcarine Sulcus (CaS) (present study, 2025)	3.36±0.41	3.68±0.40	0.04 (S)	
Anterior part of Calcarine Sulcus (CaS) and posterior Calcarine Sulcus (CaS) (Nayak S et al., [12], 2023)	2.29±0.28 3.44±0.42	2.19±0.43 3.75±0.37	0.48 (NS) 0.03 (S)	31
Posterior part of Calcarine Sulcus (CaS) (Mandal L et al., [10], 2014)	4.21±1.44		NA	106
Posterior part of Calcarine Sulcus (CaS) (Sudarshana S [18], 2025)	3.1±0.32	4.2±0.23	NA	20
Splenium to parieto-occipital end (present study, 2025)	4.72±0.33	4.43±0.51	0.07	30
Splenium to parieto-occipital end (Nayak S et al., [12], 2023)	4.79±0.32	4.56±0.47	0.13	31

[Table/Fig-11]: Comparison of central, parieto-occipital and Calcarine Sulcus (CaS) parameters with previous studies [10,12,18].

n= No. of samples

In the present study, the anterior part of the CaS showed significant right-side predominance, while the posterior part was significantly longer on the left, indicating distinct lateral asymmetry. Nayak S et al., reported a similar pattern, with NS asymmetry in the anterior segment but significant left dominance in the posterior part [12]. The posterior CaS lengths reported by Mandal L et al., and Sudarshana S were higher but also demonstrated asymmetry, suggesting population or methodological variation [14,18]. The splenium to parieto-occipital end distance showed no significant side difference in the present study, comparable to Nayak S et al., indicating relative bilateral symmetry [12].

The present findings broadly align with Rhoton AL Jr., who described the calcarine and parieto-occipital sulci as consistent posterior cerebral landmarks, with minor hemispheric variations and relative symmetry in gross distances from fixed points such as the frontal and Ops [19]. The significant left-right differences observed in the anterior and posterior parts of the CaS in the current study support Mangin JF et al., who emphasised regional variability in cortical folding patterns despite overall structural organisation [20]. Furthermore, the asymmetry noted in the posterior CaS and POS length corresponds with MRI-based observations by Yücel M et al., who reported hemispheric differences in POS morphology, suggesting inherent lateralisation rather than pathological variation [21].

Limitation(s)

The present study had several limitations such as sample size calculation was not performed, and convenience sampling was used, restricting generalisation of findings. Age-related changes were ignored due to the missing age/medical details of cadavers. The clinical background of the specimens was unknown, which may have influenced sulcal morphology. Post-mortem changes and fixation artefacts may have affected morphometric measurements. Ethnic and regional limitations restrict the application to global populations.

CONCLUSION(S)

The present cadaveric study demonstrates that the CS is a relatively constant anatomical landmark with minimal hemispheric variation, whereas the calcarine and parieto-occipital sulci exhibit consistent and statistically significant hemispheric asymmetries. These variations are more pronounced in the posterior cerebral regions, highlighting the inherent structural lateralisation of the cerebral cortex. The findings correlate well with existing Indian and international literature, reinforcing their anatomical validity. Such morphometric data are valuable for neurosurgical orientation, anatomical education, and comparative neuroanatomical studies.

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