Original Article

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Anatomy Section

Interhemispheric Asymmetry of Lateral Sulcus and its Significance in Adult Human Brains: A Cadaveric Study from Southern India

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ABSTRACT

Introduction: Cerebral hemispheres are the two main parts of human brain. Though, the cerebral hemispheres may appear to be identical, one hemisphere is functionally dominant over the other. They also exhibit physical variations. The dominance may be due to lateralisation of cortical functions. In about 90% of the total population, the left hemisphere is dominant over the right where the speech and language areas are located. These areas are situated within the Pars Opercularis (PO) and Pars Triangularis (PT) in the dominant hemisphere of the Lateral Sulcus (Sylvian Fissure). The interhemispheric asymmetry of the Sylvian Fissure (SF) may be the basis of cerebral dominance for language, which is less studied in human beings. These asymmetries are relative and vary according to the functions concerned. Therefore, knowledge of the interhemispheric asymmetries is helpful in neurological diagnosis and management.

Aim: To measure the length of the lateral sulcus and its rami on both hemispheres and to study their interhemispheric asymmetry.

Materials and Methods: A cross-sectional pilot study was done on 30 whole brains of embalmed adult human cadavers irrespective of sexes taken from the Institute of Anatomy of Madras Medical College, Tamil Nadu, India, between the months of June to August, 2017. The lateral sulcus was measured on the superolateral surface of the brain. All measurements were taken with the help of a thin copper wire placed on the surface, its ends being held in position with artery forceps. The wire was then placed on a graduated metal scale and the lengths of the anterior ascending, anterior horizontal, posterior rami and total length of the lateral sulcus were noted. A data sheet was made using Microsoft excel software and the mean length of each ramus was calculated.

Results: The mean total length of the SF was noted to be 8.4±0.51 cm on the right side and 8.8±0.56 cm on the left. The mean length of stem of lateral sulcus was 2.5±0.4 cm and 2.6±0.3 cm on the right and left side, respectively. The mean length of the anterior ascending ramus was found to be 2.7±0.3 cm on the right side and 3.13±0.3 cm on the left side. The mean length of the anterior horizontal ramus was found to be 2.34±0.37 cm on the right side and 2.55±0.4 cm on the left side. The mean length of the posterior ramus was found to be 5.6±0.65 cm on the right side and 6.1±0.63 cm on the left side.

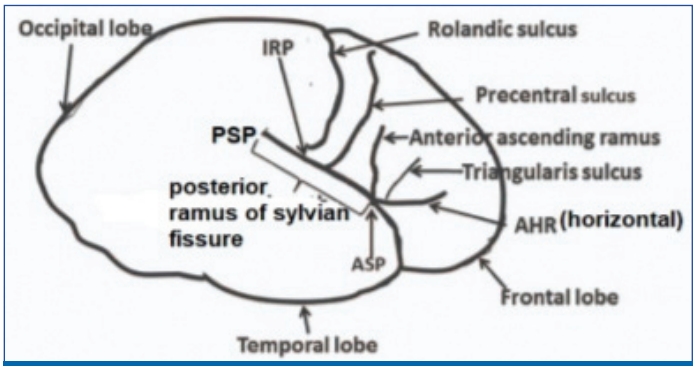
Conclusion: The SF and their rami of the left side were longer than of the right side in most specimens. This signifies the functional asymmetry between right and left cerebral hemispheres which may be related to language lateralisation of human brain. This interhemispheric difference has been implicated in various genetic syndromes and behavioural disorders in children particularly involving language milestone.

Keywords: Cerebral hemisphere, Language lateralisation, Sylvian fissure

INTRODUCTION

Cerebral hemispheres are the two major divisions that form the superior part of the human brain. They form about 83% of the total cerebral mass [1]. Each cerebral hemisphere is considered to have superolateral, medial and inferior surfaces, of which the superolateral surface follows the concavity of the cranial vault. These surfaces of the cerebral hemispheres are marked by alternate ridges of neural tissue and grooves namely gyri and sulci respectively. The gyri represent the functional areas of brain. Though, there are numerous sulci present on the cerebral surfaces, the central and the lateral sulci are the two main sulci present on the superolateral surface. The lateral sulcus is also called the SF. The SF consists of a stem and three rami namely the anterior ascending ramus, the anterior horizontal ramus and the posterior ramus extending into the adjacent cortical lobes. The stem is situated on the inferior surface and extends from the anterior perforated substance to the infero lateral margin (anterior sylvian point) where it trifurcates. The lateral sulcus continues till the posterior sylvian point where it bifurcates [Table/Fig-1] [2].

This deep sulcus outlines the temporal lobe and separates it from the frontal and the parietal lobes. It is one of the earliest sulci to develop in the human brain [3]. The perisylvian cortical areas encompassed by these rami are called Pars Orbitalis (cortex anterior to the horizontal ramus of the SF, PT (cortex between the ascending ramus and the horizontal ramus of the SF) and PO (cortex posterior to the ascending ramus of the SF). The SF overlaps a part of the cerebral hemisphere, the insula which is regarded as the fifth lobe of the cerebral hemisphere. The middle cerebral vessels are lodged



[Table/Fig-1]: Schematic representation of the lateral sulcus and its rami.
AHR: Aryl hydrocarbon receptor

within the SF [1]. Though, the two cerebral hemispheres appear to be symmetrical in size, they differ largely in terms of their functions [1]. This phenomenon is called lateralisation of cortical functions [1], which is less studied in humans. Of all the functions, speech and language are known to be most lateralised and their functional areas are situated essentially in the dominant cerebral hemisphere. These areas meant for speech and language are located within the PO and PT of the frontal lobe of the dominant hemisphere which is also called Broca's area (Broadmann area no.45) [4]. In almost 90% of the individuals, the left cerebral hemisphere is known to be dominant over the right and these individuals are principally right handed which may be attributed to the development of the cerebral hemispheres. This asymmetry between the right and left cerebral hemispheres has been correlated with development of age related dementia, schizophrenia, prader-willi syndrome and other genetic syndromes [5-7].

The present study was conducted with an objective to measure the length of the lateral sulcus and its rami and to study their interhemispheric asymmetry. Also, to study its significance in adult human brains.

MATERIALS AND METHODS

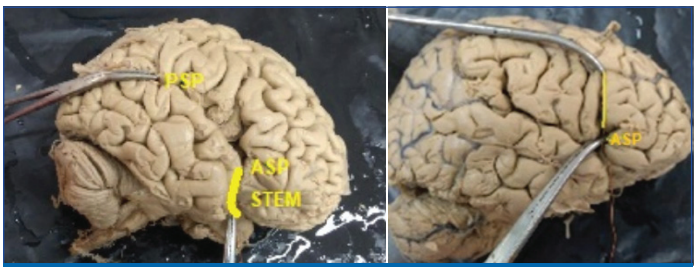
A cross-sectional pilot study was done on 30 whole brains of embalmed adult human cadavers, taken from the Institute of Anatomy of Madras Medical College, Tamil Nadu, India, between the months of June to August, 2017. The study was conducted on formalin-fixed brain specimens procured from the bodies donated for research and study purpose. An informed consent was obtained from the body donors or their authorised legal representatives at the time of donation. Institutional Ethical Clearance was not sought since the study was done using preserved specimens only.

Inclusion criteria: Adult embalmed human whole brains with intact right and left cerebral hemispheres were included.

Exclusion criteria: Grossly deformed brains where the anatomy of the SF was obscure were excluded.

Study Procedure

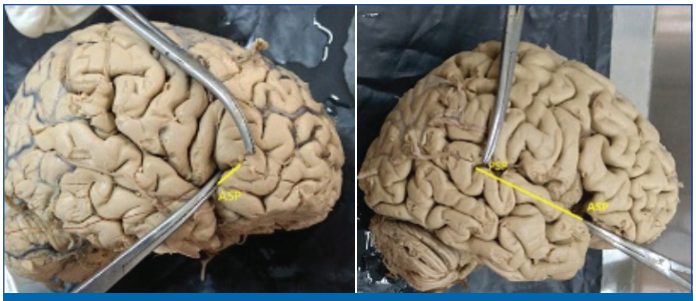
The lateral sulcus was measured on the superolateral surface of the brain. The lateral sulcus was observed for its beginning, anterior sylvian point, anterior ascending, anterior horizontal, posterior limb till posterior sylvian point. All measurements were taken with the help of a thin copper wire placed on the surface, its ends being held in position with artery forceps [Table/Fig-2-5]. The wire was then placed on a graduated metal scale and the lengths of the anterior ascending, anterior horizontal, posterior rami and total length of the lateral sulcus were noted [Table/Fig-6]. Each variable was measured twice and an average of the two was noted.



[Table/Fig-2]: Total length of the Sylvian Fissure (SF).
[Table/Fig-3]: Length of the anterior ascending ramus. (Images from left to right)
*ASP: Anterior sylvian point; *PSP: Posterior sylvian point

STATISTICAL ANALYSIS

All the recorded values were entered and a data sheet was made using Microsoft excel software. The mean length of ascending ramus, horizontal ramus, posterior ramus and mean total length of left and right SF were then calculated.



[Table/Fig-4]: Length of the anterior horizontal ramus.
[Table/Fig-5]: Length of the posterior ramus. (Images from left to right)
*ASP: Anterior sylvian point; *PSP: Posterior sylvian point

[Table/Fig-6]: Measurement of length.

RESULTS

The SF was observed for its beginning, course, total length and its rami on both sides. The anterior ascending and horizontal rami began from the anterior sylvian point and the posterior rami were seen to run posteriorly till the posterior sylvian point where they turned upwards, surrounded by the supramarginal gyrus in all specimens.

The mean total length of the SF was noted to be 8.4±0.51 cm on the right side and 8.8±0.56 cm on the left. The mean length of stem of lateral sulcus was 2.5±0.4 cm and 2.6±0.3 cm on the right and left side, respectively. The mean length of the anterior ascending ramus was found to be 2.7±0.3 cm on the right side and 3.13±0.3 cm on the left side. The mean length of the horizontal ramus was found to be 2.34±0.37 cm on the right side and 2.55±0.4 cm on the left side. The mean length of the posterior ramus was found to be 5.6±0.65 cm on the right side and 6.1±0.63 cm on the left side [Table/Fig-7-10].

Side of the cerebral hemisphere	Total no. of specimens	Maximum length (cm)	Minimum length (cm)	Average length (cm)
Right	30	9	6.3	8.4±0.51
Left	30	9.7	6.5	8.8±0.56

[Table/Fig-7]: Total length of the Sylvian Fissure (SF).

Side of the cerebral hemisphere	Total no. of specimens	Maximum length (cm)	Minimum length (cm)	Average length (cm)
Right	30	3.5	2.1	2.7±0.3
Left	30	3.8	2.6	3.13±0.3

[Table/Fig-8]: Length of the anterior ascending ramus.

Side of the cerebral hemisphere	Total no. of specimens	Maximum length (cm)	Minimum length (cm)	Average length (cm)
Right	30	3.2	1.5	2.34±0.37
Left	30	3.5	1.8	2.55±0.4

[Table/Fig-9]: Length of the anterior horizontal ramus.

Side of the cerebral hemisphere	Total no. of specimens	Maximum length (cm)	Minimum length (cm)	Average length (cm)
Right	30	7.0	3.5	5.6±0.65
Left	30	7.3	4.0	6.1±0.63

[Table/Fig-10]: Length of the posterior ramus.

DISCUSSION

The cerebral hemispheres are the derivatives of telencephalon that form the most rostral part of brain vesicles at the beginning of fifth week of development. Continuous growth of cerebral hemispheres in anterior, dorsal and inferior directions results in frontal, temporal and occipital lobes respectively. During the later stages of development, the surface of the cerebral hemispheres grows so rapidly that it forms many convolutions (gyri) separated by shallow grooves called sulci [3]. In this process, the right side of the human brain gets warped forward slightly whereas the left side warped backward. This phenomenon is called the Yakovlevian torque which explains the functional asymmetries of the cerebral hemisphere [8,9]. Though, the cerebral asymmetries are less understood and lest demonstrated in human beings, quite a large number of studies have been done in non human primates. A comparative study was done by LeMay M, on cerebral asymmetries of modern man, fossil man and great apes, in which it was reported that left SF was longer than the right in fossil man and modern man [10]. Leftward asymmetry of the SF was found to exist among the great apes especially in orangutans.

According to Rubens AB et al., who studied the asymmetry of the lateral fissures in man, a distinctive pattern of deviation of posterior ends of the lateral fissures was observed in most specimens [11]. The lateral fissures of the right side were found to angulate sharply upward into the parietal lobe and the left lateral fissures were found to continue posteriorly as the posterior rami, as a result of which the posterior sylvian points were higher on the right side. However, this was contradicted by Ide A et al., who did a study on bifurcation patterns in the human SF, in which it was stated that the left posterior sylvian points were at a higher level than the right [12].

Witelson SF and Kigar DL, did a study on morphology of the SF and its bilateral differences in relation to handedness and reported that the horizontal rami were longer on the left side whereas the ascending rami were longer on the right side [13]. Similar study was done by Foundas AL et al., in his study on sex linked differences in SF morphology reported that there was a significant leftward asymmetry of the horizontal rami in right-handed males and females whereas there was no such asymmetry of the ascending rami [14]. Boni RC et al., did a study on the cerebral asymmetries of the temporal lobe and reported that the left temporal lobes were anatomically different and the mean total length of the SF was more on the left side (79.94 mm) than on the right side (65.11 mm) which was supported by Idowu OE et al., who did a study on morphometry, asymmetry and variations of the SF [9,15]. Sudakshina Chakrabarti V, in their study reported that the mean length of the anterior horizontal rami on right side (1.97 cm) was found to be greater than on the left side (1.96 cm). The mean lengths of left anterior ascending rami and the posterior rami were greater than on the right [16].

Rani A et al., did a similar study and reported in their study that the mean total length of the SF was more on the left side (6.43 cm) than on the right (5.64 cm) [17]. In the present study, the anterior ascending, horizontal rami and the posterior rami began from the anterior sylvian point. The mean total length of the SF was noted to be more on the left side [Table/Fig-7]. The mean length of the anterior ascending, horizontal and posterior rami were found to be more on the left side only [Table/Fig-8-10]. Various functional asymmetries in brain have been long noted and such anatomical asymmetries are very prominent in infants and children under two years of age. These findings imply that such asymmetries are to be considered as a normal radiological finding and not to be mistaken for atrophy or brain substance loss secondary to other disorders [18]. According to a recent study done by Mallela AN et al., the development of the cerebral hemispheres is majorly controlled by transcription factors which explain why these asymmetries are prominent in infants [19]. The SF forms by the relative overgrowth of the frontal and temporal lobes over the insula, corresponding to domains of highly expressed transcription factors involved in neuroepithelial cell differentiation [19]. Interestingly, loss of such asymmetries has been implicated in syndromes like prader-willi maternal uniparental disomy, which could be a cause of language problems in them [7]. Loss of interhemispheric asymmetry has also been frequently observed in schizophrenics, more commonly in male patients [6]. The aforementioned findings and inferences show that leftward asymmetry of SF is inevitable for language and speech in human beings.

Limitation(s)

The present study was exclusively done on cadaveric brain specimens. Therefore, sex differences could not be made out. Radiological studies showing accurate measurements and asymmetries in living subjects will have more validity. Furthermore, this study only confirms the findings of various studies done previously.

CONCLUSION(S)

The SF, which is one of the most conspicuous and the earliest developing sulci of the human brain divides the frontal lobe and parietal lobe from the temporal lobe. The speech and the language areas are situated within the perisylvian cortex of the dominant hemisphere. The present study showed that the mean total lengths of the SF and its rami were more on the left side which may be related to language and speech lateralisation. These findings coincide with the findings of the studies done previously. More extensive studies based on the development of cerebral sulci and factors controlling their growth are to be done to confirm this association and its clinical implications. The present study thus adds to the existing literature. More research in the area of developmental genetics can be done based on interhemispheric variations which will throw light on such grey areas.

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