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# Assessment of Direct Signs of Localization of Central Sulcus in Normal Axial Computed Tomography Scan of Brain

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## ABSTRACT

**Background:** Central sulcus is relatively constant in anatomy and provides an important landmark in lesion localization in high convexity-parasagittal region. The purpose of this study was to evaluate various direct signs of localization of central sulcus in normal axial computed tomography scan of brain.

**Methods:** This cross-sectional descriptive study was conducted in 377 patients with normal findings in computed tomography scan of brain. Anatomic relationships of high convexity-parasagittal gyri and sulci that form the base for signs used for localization of central sulcus were assessed. The frequency of visualization of each sign was noted.

**Results:** Sigmoid shape "hook" of central sulcus (87%) was the most frequent sign followed by pars bracket sign (85%), thin postcentral gyrus sign (84.5%) and superior frontal sulcus-precentral sulcus sign (81.3%). Most of the central sulcus signs showed significant positive correlations with the increasing age. Pars bracket sign was the second most common sign and did not show correlation with age.

**Conclusions:** In the absence of anatomic distortion, computed tomography anatomic techniques usually allow identification of the central sulcus on axial section with most useful sign being the sigmoid shape "hook" sign. Application of these signs in combination rather than in isolation helps to identify with near certainty the location of the central sulcus in axial plane.

**Keywords:** Central sulcus; computed tomography; pars marginalis; precentral sulcus; postcentral sulcus

## INTRODUCTION

The better understanding of brain anatomy by various imaging modalities has a leading role in planning neurosurgical approach and deciding whether the lesion can be removed totally with or without a new neurological deficit.[1]

Cerebral sulci have wide individual variation.[2] Among them, central sulcus is relatively constant in anatomy and can be frequently detected in Computed Tomography (CT).[3] Central sulci of either side also show little to no asymmetricity.[4,5] Various signs have been described in the literature for identification of central sulcus in axial image with different accuracy.[1,3,6-13] Description of these signs in isolation is not always possible, hence combination of the major signs helps determine central sulcus with near certainty.[9] The method can also be used in case of lesion obliterating the ipsilateral central sulcus, by correlating the contra-lateral central sulcus.[13]

The aim of the study was to determine the location of the central sulcus and evaluate the frequency of different direct signs in axial CT of the brain for determining central sulcus.

## METHODS

This was cross-sectional descriptive study conducted at Tribhuvan University Teaching Hospital Nepal, from April 2013 to March 2014. The study included patients who were advised to undergo CT scan of head for various reasons and whose CT findings were found to be normal as reviewed by two radiologists (one consultant radiologist with experience of >3years and other 3rd year radiology resident) independently.

CT scan was performed on Neusoft 16 slice MDCT scanner

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using 120 peak kilo voltage (KVp), 210 milliampere second (mAs), 11-12 second exposure, 23cm field of view, "head" calibration and standard image reconstruction. Volumetric CT scan of head was obtained, and then axial images were reconstructed parallel to the tuberculum sellae-occipital protuberance line (TS-OP line) as serial 3mm thick sections in Neuviz software available in the workstation. Brain window was set for window width of 90 and window level of 40.

The true anatomy of the region was taken to be the identification achieved by integration of all the images according to the well accepted anatomic standards.[3,7-10,14,15] In each hemisphere, anatomy of sulci and gyri were identified by its location, its appearance, and its relationships to adjacent gyri, sulci, and the fissures. Each gyri and sulci were scored well visualized or not. Each specific sign when positive was scored "1" and when the sign was not seen then it was scored "0" i.e., negative for that sign. Whenever variations in the anatomical relationships were encountered, those found relevant were also recorded.

The following various signs were recorded. Figure 1 and 2 depict these different signs.

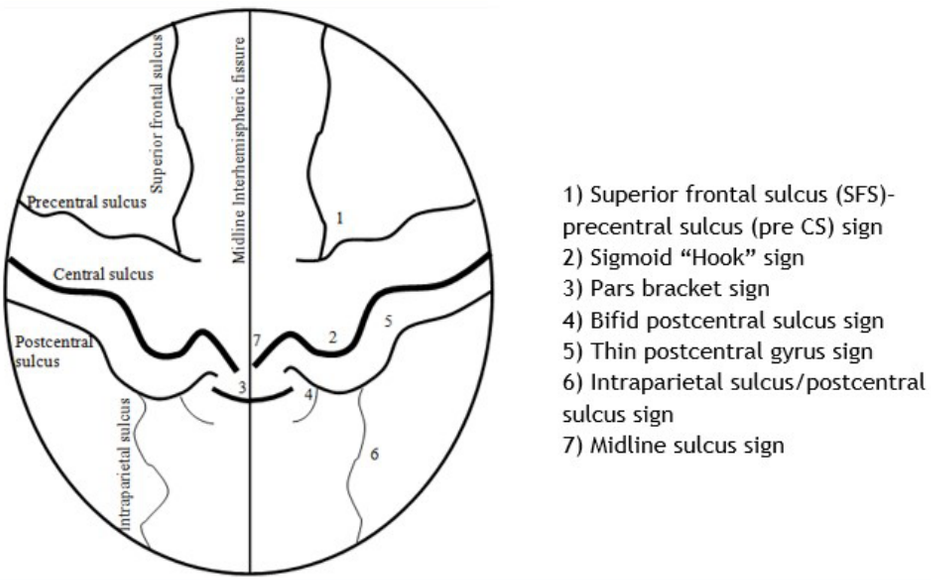


Figure 1. Diagram representing various signs of central sulcus in axial cross section of brain.

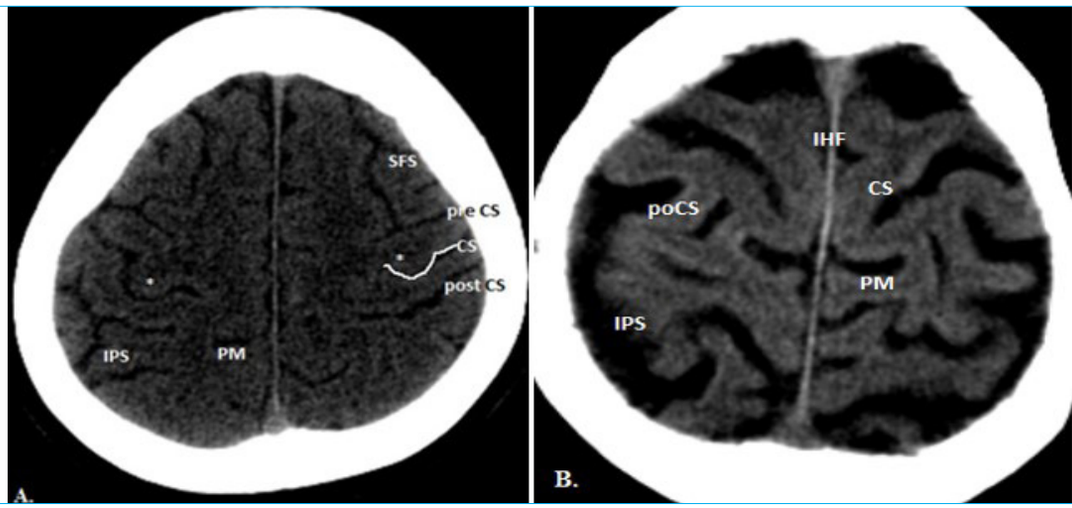


Figure 2. (A, B) Axial CT image of brain at the level of centrum semiovale. A. The posterior end of SFS terminates at precentral sulcus. The central sulcus (CS; white line) has sigmoid (*) configuration. The postcentral gyrus at this level appears thinner than precentral gyrus. The IPS terminates anteriorly at postcentral sulcus (poCS). B. The paired pars marginalis (PM) form a "bracket" where medial ends of both central sulci are seen entering it.

Superior frontal sulcus (SFS)-precentral sulcus sign: If the SFS terminated at the precentral sulcus then it was scored positive for the SFS sign.

Sigmoid "Hook" sign: "Hook" refers to posteriorly directed hook or knob like configuration of the sulcus that follows the posterior surface of the precentral gyrus.

Pars bracket sign: The pars bracket was taken as the full transverse width of the paired left and right pars marginalis. A central sulcus was considered entered the pars bracket and positive for pars bracket sign if the medial end of that sulcus passed anterior and medial to the lateral edge of the pars marginalis.

Bifid postcentral sulcus sign: If the bifid medial ends of the post central sulcus were found enclosing the lateral end of the pars marginalis then it was scored positive for bifid post central sulcus sign.

Thin postcentral gyrus sign: Thickness of pre and post central gyri were measured parallel to interhemispheric fissure at the level where SFS terminated at precentral sulcus.

Intraparietal sulcus (IPS) -postcentral sulcus sign: The IPS when well visualized appeared as continuous line without a break, and then its junction with the post central sulcus was identified. If IPS appeared as a continuous line and intersected the post-central sulcus then it was scored positive for IPS-postcentral sulcus sign.

Midline sulcus sign: The most prominent convexity sulcus that intersected the midline interhemispheric fissure was identified in both the hemispheres. Midline sulcus sign was considered positive if the intersected sulcus was identified as central sulcus by using various other signs.

The frequencies with which these various above described signs occurred were also recorded in relation to age and sex of the patient.

## RESULTS

Of total 377 patients with normal CT head, 212 (56%) were female and 165 (44%) were male. Age of the patient ranged from 18 months to 81 years, with mean 34.89 years. The highest number of patients were in 21 to 30 years age group (22%) whereas the lowest number of patients were in age group >60 years (9%).

The frequencies of high convexity-parasagittal gyri and sulci in the axial CT scans are tabulated in detail in Table 1. The same table also details the specific anatomic relations and the relevant variants of the high convexity-parasagittal gyri and sulci. Table 2 tabulates the frequencies of visualization of each sign on axial CT.

Table 1. Anatomic relationships in axial CT imaging (n=377 patients; 754 hemispheres.

| | Rt. hemisphere | Lt. hemisphere | Total |
|---|---|---|---|
| Superior frontal sulcus well seen | 349 (93%) | 353 (94%) | 702 (93%) |
| i. Superior frontal sulcus joined precentral sulcus | 306 (88%) | 302 (86%) | 608 (87%) |
| ii. Superior frontal sulcus stopped anterior to precentral sulcus. | 29 (8%) | 37 (10%) | 66 (9%) |
| iii.Superior frontal sulcus reached central sulcus | 13 (4%) | 14 (4%) | 27 (4%) |
| Posteriorly directed sigmoid shape "hook" of precentral gyrus and central sulcus | 330 (88%) | 325 (86%) | 655 (87%) |
| Pars marginalis well seen | 331 (88%) | 345 (92%) | 676 (90%) |
| Central sulcus entered pars marginalis | 309 (93%) | 329 (95%) | 638 (94%) |
| Postcentral sulcus well seen | 360 (95%) | 362 (96%) | 722 (96%) |
| Bifid postcentral sulcus | 167 (46%) | 197 (54%) | 364 (50%) |
| Thinner postcentral gyrus | 318(84%) | 319(85%) | 637 (84.5%) |
| Intraparietal sulcus joined the postcentral sulcus | 210(56%) | 216(57%) | 426 (56.5%) |
| Most prominent convexity sulcus that intersected the midline inter hemispheric fissure was central sulcus | 117 (31%) | 126 (33%) | 243 (32%) |

Table 2. Frequency of visualization of signs of localization of central sulcus

| Direct signs | Rt. hemisphere (n=377) | Lt. hemisphere (n=377) | Total (n=754) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Hook sign | 330(88%) | 325(86%) | 655 (87%) |
| Pars bracket sign | 309(82%) | 329(87%) | 638 (85%) |
| Thin postcentral gyrus sign | 318(84%) | 319(85%) | 637 (84.5%) |
| Superior frontal sulcus-precentral sulcus sign | 306(81%) | 307(80%) | 613 (81.3%) |
| Intraparietal sulcus-postcentral sulcus sign | 210(56%) | 216(57%) | 426 (56.5%) |
| Bifid postcentral sulcus sign | 167(44%) | 197(52%) | 364 (48%) |
| Midline sulcus sign | 117(31%) | 126(33%) | 243 (32%) |

In the axial CT, the most frequently visible sign was posteriorly directed sigmoid shape "hook" of central sulcus which was found in 655 (87%) of the hemispheres. Pars bracket sign was found in 638 (84.5%) of the hemispheres. Thin postcentral gyrus was found in 637 (84%) of the brain. SFS was found to join the precentral sulcus and hence identified the central sulcus in about 613 (81%) of the hemispheres. IPS joined the postcentral sulcus in approximately 426 (56.5%) of the cases. Bifid postcentral sulcus that enclosed the pars marginalis was found in approximately 364 (48%) of brains. Lastly, the midline sulcus sign i.e. the central sulcus intersecting the interhemispheric fissure was found in only 243 (32%) of cases.

Frequency of most of the signs of central sulcus showed significant correlations with age of the study population ($p < 0.05$) (Table 3). The significant correlations with age were shown by thin postcentral gyrus sign, hook sign, SFS-pre central sulcus sign and bifid post central sulcus signs. However, pars bracket sign, IPS sign, and midline sulcus sign did not show significant correlations with age. There was no significant association between the gender variation and signs of central sulcus ($p > 0.05$) as shown in Table 4.

Table 3. Correlations between age and central sulcus signs

| Direct signs | r-value | p-value |
|---|---|---|
| Hook sign. | 1.45 | 0.005 |
| Pars bracket sign | 0.66 | 0.204 |
| Thin postcentral gyrus sign | 0.256 | 0.000 |
| Superior frontal sulcus-precentral sulcus sign | 1.49 | 0.004 |
| Intraparietal sulcus-postcentral sulcus sign | 0.036 | 0.491 |
| Bifid postcentral sulcus sign | 0.124 | 0.016 |
| Midline sulcus sign | 0.044 | 0.392 |

Table 4. Signs of central sulcus and gender association. (Chi-Square test).

| Direct signs | p-value |
|---|---|
| Hook sign. | 0.894 |
| Pars bracket sign | 0.637 |
| Thin postcentral gyrus sign | 0.853 |
| Superior frontal sulcus-precentral sulcus sign | 0.083 |
| Intraparietal sulcus-postcentral sulcus sign | 0.327 |
| Bifid postcentral sulcus sign | 0.294 |
| Midline sulcus sign | 0.324 |

## DISCUSSION

Attempts to identify central sulcus and surrounding gyri and sulci in high convexity-parasagittal region in axial images have been made by several authors. There are various signs that have been described for central sulcus localization and these signs have varying accuracy.[1,3,7-12] Each description of the signs assumes that the anatomy of the brain remains constant. The anatomic variability limits the accuracy and utility of each described signs.[9]

The typical junction of the SFS and the precentral sulcus can be clearly seen in 76-88% of axial CT head.[1,3,9] In Magnetic Resonance Imaging (MRI) this connection can be visualized in almost 88%;[9] while in anatomical specimen it is seen in 92-100%.[15] These studies show the variation in the determining the connection of these sulci depends upon the modality used. The present study had findings similar to the study of Naidich and Brightbill[9] in their MRI axial images and Kido and colleagues in their axial CT images.[3]

The medial end of central sulcus frequently enters bracket of pars marginalis and can be seen in CT and MRI in 94-96% of head.[7,8] This sign is regarded as the most useful direct sign of central sulcus.[7] It was the second most frequently visible sign in this study. As pars marginalis tends to lie at defined positions in axial CT and MRI, identifying the relationship of the central sulcus to the pars marginalis is usually a helpful first step toward integrating all the visualized gyri and sulci into a coherent pattern.[9]

Hook like sigmoidal configuration of central sulcus is one of the most frequently detected signs and can be seen in upto 89-100% of cases in CT and MRI.[1,9] This sign should be used with caution as the posterior border of

the postcentral sulcus can also manifest an equivocal bulge that could potentially be mistaken for a sigmoidal hook.[9] This sigmoid hook is highly reliable sign for the central sulcus and was the most frequently visualized sign in this study.

Naidich and Brightbill found that the postcentral gyrus was thinner than the precentral gyrus in 87% of CT and 98% of MRI.[9] The finding of this study was similar to previous study and thinner postcentral gyrus can be used as a criterion to determine the central sulcus when in doubt.

IPS anteriorly intersecting the postcentral sulcus can be seen in 88% of CT and in 99% of MRI.[10] In present study this sign was seen in just more than half of the cases. The differences could be atributed to population variation, age distribution (mean age was 45.5years vs 34.89 years in this study); and differences in the slice thickness of CT image (5mm slice thickness Vs 3mm in present study). In the specimen study the frequency of this intersection was seen in 72% of left hemispheres and 64% of right hemispheres.[15] In the present study the visualization of the IPS sign was lower than the study done by Ono and colleagues[15] which is probably due to difference in study methods. Ono and colleagues studied in the anatomical specimen, while findings of this study was not confirmed with anatomical specimen.

Central sulcus is one of the most prominent sulci that reaches the midline and intersects the interhemispheric fissure. However, it is not always the central sulcus that reaches interhemispheric fissure. Precentral sulci, postcentral sulci and superior parietal sulci may at times reach the midline and appear as the most prominent sulci in the higher convexity. The frequencies with which these different sulci may reach the interhemispheric fissure have a wide range of variation as shown by different studies.[1,9-19] Hence careful interpretation is required while using midline sulcus sign to determine central sulcus. The visibility of the midline sulcus sign was highest in specimen study where the frequency was upto 72% in left hemisphere and 56% in right hemisphere.[15] In CT scan head, it is seen in almost half (54%) of the cases.[9] While in this study midline sulcus sign is seen in only one third of cases. The possible reasons could be due to variation in study methodology and age distribution.

The medial end of the postcentral sulcus is often bifid and these bifid ends enclose the pars marginalis in more than half of the hemispheres.[7,15] The bifid postcentral sulcus enclosing the pars marginalis were seen highest in specimen study where it was seen in 88% of the left hemispheres and 72% of right hemispheres.[15] In imaging study, MRI demonstrates this sign with higher frequency (81%) than axial CT (56%).[7,9] Similar findings were recorded in this study. When the postcentral sulcus has single medial end, one or more superior parietal sulci in place of the posterior arm of the bifid postcentral sulcus may bear the similar relationship to the pars marginalis.[7] This sign when well visualized helps in central sulcus localization. However, bifid precentral and central sulcus though occur less frequently; can be a potential source of misinterpretation. In even fewer cases the postcentral sulcus may merge with the lateral end of pars marginalis limiting the utility of this sign.

This study showed the significant positive correlations of most of the signs of central sulcus with the age of the study population. The positive correlation may be due to age related decreased brain volume and prominence of the extra-axial cerebrospinal fluid (CSF) spaces.[16-19] Younger the age more packed are the cerebral sulci and less prominence are the extra-axial CSF spaces. The significant correlations with increasing age were shown by thin postcentral gyrus sign, hook sign, SFS-precentral sulcus sign and bifid postcentral sulcus sign. Pars bracket sign, IPS sign and midline sulcus sign however did not show significant correlations with age. IPS and midline sulcus signs were the least frequently visualized signs. Pars bracket sign was the second most frequently observed signs of central sulcus after “hook” sign and occurrence of this sign were not affected by age; hence, this sign can be considered as one of the most reliable signs.

## CONCLUSIONS

CT anatomic techniques usually allow identification of the central sulcus on axial sections. The application of direct signs of localization of central sulcus in isolation is not always possible because of anatomic variability and brain pathology. Hence, combination of various morphological features helps to identify its location with near certainty. If the commonly observed signs of central sulcus are not simply demonstrable, we recommend pars marginalis to be identified first, for its simplicity. This should be followed by identification of the hook like configuration of central sulcus which should be further confirmed with termination of the superior frontal sulcus with the precentral sulcus and thin postcentral gyrus.

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## CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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