ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 12, Issue, 01, pp. 53431-53434, January, 2022
https://doi.org/10.37118/ijdr.23866.01.2022

RESEARCH ARTICLE OPEN ACCESS

STRUCTURAL CONNECTIVITY STANDARD OF THE HUMAN SENSORY-MOTOR CORTEX

Júlio César Claudino dos Santos[1,2], Larissa Pontes Correia[3], Rafaella Iughetti da Costa[3], Maria Victória Rocha Fontenele Maia[3], Lia de Oliveira Jereissati[3], Lara Maria de Oliveira Paiva Freitas[3], Isadora Mônica Ponte de Oliveira[3], Victor Oliveira Araújo[3], Aline Moreira Lócio[3], Fábio Antônio Serra de Lima Júnior[4] André de Sá Braga Oliveira[4] and Leandro Freitas Oliveira[1]

[1]Neuroscience Laboratory, Department of Neurology and Neurosurgery, Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil; [2]Professor at the Faculty of Medicine at Centro Universitário Christus (UNICHRISTUS), Fortaleza, CE, Brazil; [3]Medical Student at Centro Universitário Christus (UNICHRISTUS), Fortaleza, CE, Brazil; [4]Federal University of Paraíba, Health Sciences Center, Department of Morphology, Campus I, Zip code: 58.051-900, João Pessoa, Paraíba, Brazil

ARTICLE INFO

Article History:

Received 20th October, 2021
Received in revised form
18th November, 2021
Accepted 15th December, 2021
Published online 30th January, 2022

Key Words:

Anatomy, Neurology, Neuroimaging, Cerebral Cortex, Topography.

Corresponding author:
Eduardo Milléo Baracat

ABSTRACT

In the 19th century, Gratiolet created the term *plis de passage*, which was mapped by the neurosurgeon Jean Regis to describe gyri that were interconnected and anatomically covered by main sulci. Besides, Cunningham characterized the plis de passage, which binds the precentral gyrus, associated to the hand´s primary motor area, and the postcentral gyrus, associated to the hand´s somatosensory area, having become a subject of interest with the advent of imaging tests. This is a descriptive and prospective study which aims to understand the central lobe´s anatomy regarding its morphometry, connectivity patterns, syntopy and presence of fronto-parietal plis de passage, using human cadavers. We analyzed 33 brains with intact cerebral hemispheres looking for the presence of plis de passage in the upper, middle and lower thirds of the right and left hemispheres. In addition, we measured the distance between the *plis de passage* of the upper and middle third, middle and lower, upper and lower thirds, when present. Results showed that in the upper third, the plis de passage was present in all pieces analyzed from both brain hemispheres. In the middle third, 48% did not have the structure in both hemispheres and there was a predominance in the left hemisphere with 24% and a minority in the right hemisphere, with 6%. Regarding the lower third, 88% had plis de passage in both hemispheres. Another finding was that there is a constancy between the distance values when comparing the right and left sides of the brain. It was also found that there was no significant variation in the values between the distances of the plis de passage measured. Thus, the analysis of the results may be an essential factor for the topographic neuronal diagnosis, for the interventions of patients affected by cerebrovascular diseases and to assist in the interpretation of neuroimaging alongside the neurological patient's clinic.

Citation: ***Júlio César Claudino dos Santos, Larissa Pontes Correia, Rafaella Iughetti da Costa, Maria Victória Rocha Fontenele Maia, Lia de Oliveira Jereissati et al.*** "Structural connectivity standard of the human sensory-motor cortex*", International Journal of Development Research*, 12, (01), 53431-53434.

INTRODUCTION

The central nervous system (CNS) is primarily divided into encephalon and spinal cord. The encephalon is the CNS´s content that is located inside the skull and is characterized as a highly complex structure, coordinating almost every body function. This structure is composed of the brain (telencephalon and diencephalon), brainstem (mesencephalon, pons, and bulb), and cerebellum [1,2]. The brain is divided into two hemispheres, each hemisphere consisting of 5 lobes: frontal, parietal, occipital, temporal, and insular lobes, which are bounded by deep sulci. The lobes of the telencephalon undergo folds of the brain surface (gyri) divided by surface concavities (sulci) [3,4]. The central lobe, composed of the precentral and postcentral gyri on the lateral surface, and of the paracentral lobule in the medial region, is one of the most eloquent areas of the brain and corresponds to the sensory-motor cortex[5]. This morphological unity, along with the functional interaction between motricity and sensibility, justifies the characterization of these gyri as a single lobe[6]. In this context, it has been observed through studies that the pre and postcentral gyri and the paracentral lobule have a morphological and functional anatomy that differentiates them from the rest of their respective lobes. Knowledge about the central lobe anatomy is fundamental for the preoperative and postoperative landmarks, besides locating craniometric points, such as the coronal suture, being one of the first steps in the planning of central lobe neurosurgery[7,8]. Although the central lobe has a relevant anatomical variability, a close inspection evidenced a relatively constant organizational pattern[6]. The development of refined surgical techniques, such as the trans-succal approach, established sulci and gyri as fundamental landmarks of the

brain[9]. The central lobe cortex has a very particular functional location, a fact that justifies the relevance of identifying the sulci and gyri by means of preoperative imaging, since this region, when injured, can cause sensory-motor deficits in the postoperative period.[10] In the 19th century, Gratiolet coined the term *plis de passage*, which was mapped by the neurosurgeon Jean Regis to describe giry that were interconnected and anatomically covered by main grooves, leading him to consider them candidates for a different organizational character of the cortex [11,12]. Thus, each *plis de passage* may be related to an elementary feature of cortical anatomy, having a focal aspect of localization, a clear geometry, and considerable variability between individuals[12]. This feature is classified into "true" interruptions, when it causes a clear discontinuity, and "pseudo interruptions", when it generates a slight deformation of the background [13]. There are several types of *plis de passage*. One of them is the *plis de passage* fronto-parietal Moyen (PPFM), first reported by Broca, which is a protuberance in the middle of the central sulcus, at the level of the medial knee, being located in the middle of the sulcus and requires the separation of the gyrus to be visualized[14]. With the advent of functional imaging, the PPFM has become an attractive subject due to a body of research that has highlighted its relationship with the sensory-motor areas of the hand, as this region brings together a gyrus present in the frontal wall of the central sulcus, related to the motor area of the hand and a gyrus in the post-central region, associated with the sensory area of the hand[15].

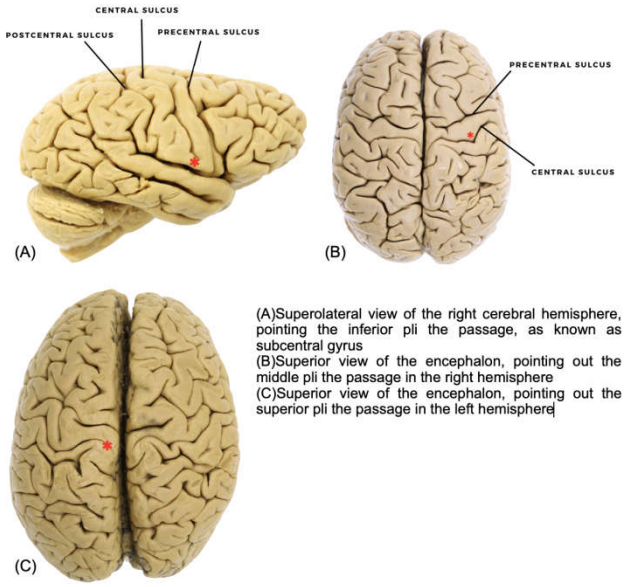
In addition, it has been observed that the surface of the *plis de passage* has a positive impact on reading abilities[16]. Therefore, it is known that marked topographic changes can modify the functional structural relationships of the human brain, a fact that highlights the importance of studying this structure. It has been observed that in the surgical approach to arteriovenous malformations in the central lobe, which can cause sensory and motor deficits, since this region encompasses the pre and postcentral gyri on the lateral surface and the paracentral lobule on the medial surface, the localization points of the superior, inferior, coronal and intraparietal *plis de passage* are used to mark surgical incisions, which demonstrates the clinical applicability of this structure[7]. It has also been noted the use of the *plis de passage* for functional microsurgical resection of intrinsic brain tumors, mapping them by tractography[17]. Consequently, the existence of more studies detailing and specifying these anatomical structures is essential, so that they are more widely used in practice and can facilitate surgical procedures, avoid iatrogenic events and,as a result, would reduce morbidity for the patient.

METHODOLOGY

33 intact encephalons from the neuroanatomy laboratory of the Centro Universitário Christus - UNICHRISTUS were included and analyzed bilaterally for the presence of *plis de passage* in the upper, middle and lower thirds of the central sulcus. All of them were preserved in 10% formalin solution. We removed the arachnoid membranes and dissected the central sulcus region of each one using a surgical microscope (KAPS model SOM 82, Germany). The distance between the different locations of the *plis de passage* were measured by a digital caliper. The categorical variables were described by absolute and relative frequencies, and the differences between proportions were analyzed by Fisher's exact test. The quantitative variables were described by mean and standard deviation, and the mean difference between sides was analyzed by Student's t test. The significance level was defined as ≤ 0,05.

RESULTS

In the upper third, the *plis de passage* was present in 100% of the 33 pieces analyzed from both hemispheres of the brain (Figure 1 and 2). On the other hand, 48% of the brains did not present a *plis de passage* in the middle third of the two hemispheres. In the hemispheres where they were present, 24% corresponded to their left hemisphere, in contrast to the 6% found in the right hemisphere.



Moreover, 21% of the hemispheres presented concurrently *plis de passage* in both hemispheres in the middle third, a region that corresponded to the *plis de passage* Fronto-Parietal Moyen of Broca. The authors also found *plis de passage* in 1% of the cases present only in the right hemisphere, while in 3% of the cases it was present in the left hemisphere, but in most cases, which corresponds to 80% of its presentation, it was bilateral (Figure 2).

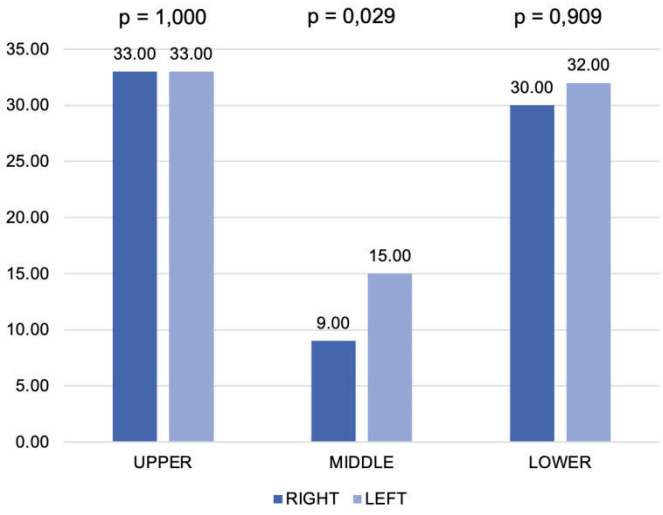


Figure 2. Prevalence of *plis de passage* in each central sulcus third

The distance between the *plis de passage* of the superior and middle third of the right hemispheres varied between 2.5 and 6.0 cm, with an average of 4.5 cm. Furthermore, the distance between the middle and inferior passages, in the respective hemisphere, was 3.2 cm and 5.7 cm, with a mean of 4.4 cm, while the distance between the superior and inferior thirds of the right hemispheres ranged between 7.25 cm and 12.5 cm, with an average of 8.9 cm. The distance between the *plis de passage* of the superior and middle thirds of the left hemispheres ranged between 3.0 cm and 5.7 cm, with an average of 4.2 cm. The distance between the *plis de passage* of the middle and inferior third of the left hemispheres varied between 3.3 cm and 5.15 cm, with an average of 4.1 cm. On the other hand, the distance between the *plis de passage* superior and inferior of that same hemisphere differed among 6.3 cm and 10.4 cm, with an average of 8.5 cm (Table 1).

DISCUSSION

The results presented in this current study reinforce the hypothesis that the *plis de passage* is an important anatomical structure in the

brain´s organization and conexion, being associated with geometric features of size and depth. Furthermore, it's been observed that the *plis de passage* constitutes structures that need more accurate descriptions of its spatial morphology and organization, since it exhibits a complex geometry that depends on surrounding gyri and shapes associated with the adjacent white substance.

Table 1. Distances between *plis de passage* found

Measure (n)	Mean ± SD (mm)	Range (mm)	p-value
U-Mr (7)	4,86 ± 0,70	4,05-6,00	0,230
U-Ml (7)	4,22 ± 1,02	3,00-5,70	
M-Lr (7)	4,06 ± 0,71	3,20-5,10	0,391
M-Ll (7)	4,25 ± 0,70	3,30-5,15	
U-Lr (33)	8,94 ± 1,22	7,50-11,10	0,034
U-Ll (33)	8,47 ± 0,98	6,30-9,70	

U-Mr : distance between upper and middle right plis de passage; U-Ml: distance between upper and middle left plis de passage; M-Lr: distance between middle and lower right plis de passage; M-Ll: distance between middle and lower left plis de passage; U-Lr: distance between upper and lower right plis de passage; U-Ll: distance between upper and lower left plis de passage.

A study reported the presence of the *plis de passage* Fronto-Parietal Moyen in the right and left hemispheres of 96,4% and 89,1% respectively[18]. Our study has detected 27% of the *plis de passage Moyen* in the right hemisphere and 45% in the left hemisphere, considerably divergent numbers. In regard to the description of a small position variation, both studies indicate small media variations between the distance of *plis de passage* compared to a wider distribution in the hand´s somatotropic area.[18] Additionally, the 1999 BOLING study[14] measurement was taken from precentral gyrus beginning to the hand´s activation area described by itself and from it's area to the Sylvian fissure. In this study, all the studied patients through the PET activation had their hands motor activation in the central sulcus middle curve and more specifically in the PPFM. Therefore, it was considered that the distance between the hands´s activation area to the fissure was 61 mm with 5,4 mm of standard deviation. In this current study the findings were 32mm and 57 mm with an average of 41 mm.[14] In the same study, it was also demonstrated the *pli de passage´s relevance* to the functional location, such as the intra-parietal and postcentral. In the fusiform gyrus, the *pli de passage* presence in the visual word formation area was recently associated with the best reading skills and the duration of the interruption were positively correlated with these abilities[14]. Furthermore, another anatomical territory of great importance is Broca's area, also related to the language area, a structure that has a submerged revolving passage. It is noteworthy that, in the central sulcus, the *pli de passage* fronto-parietal Moyen co-localized with the hands' motor area. This correspondence is robust enough for the variation in the position of this structure to be followed by the motor activation throughout the central sulcus.[14]

In the BOLING study [14], the hand's motor function localization, identified through PET activations studies, is inside the central sulcus´s apex. The precentral gyrus knee apex leads to a deep cortical fold connecting the precentral and postcentral gyrus and raising the floor of the central sulcus. This deep fold was described by Paul Broca as the fronto-parietal Moyen passage plan. Each activation demonstrates the sensorial hands function, which occurs posteriorly to the superior frontal sulcus between the superior frontal gyrus and medio central gyrus, inside or surrounding the *pli de passagem fronto-parietal de Moyen.* [14] Thus, a tridimensional 3D reconstruction of the brain's surface became common in the neurosurgical operation room as an integral part of magnetic resonance based on stereotaxy frameless. Furthermore, the sulcus and gyrus pattern are way more visualized as a 3D image of the patient´s cortex because the leptomeninges and pial vessels are not present in the 3D reconstruction. Being important in the planning of resection surgery to identify the relation between the sensorial, functional and specific motor areas, recognizing the reference points of the cortical surface exhibited in the image orientation planning station. [14] Besides that, less craniotomies have been executed because of the use of image orientation and the capacity of recognizing trustworthy anatomical landmarks which identify the functional ones. Whenever the awakened craniotomy is performed with cortical stimulation, cortical landmarks guide the stimulation, improving the procedure's efficiency. This minimizes the seizure incidence, since there are few stimulation attempts.[15] Furthermore, Van Essen[19] formulated a hypothesis in his morphogenetic cerebral theory. It explains that the tension along the axons in the white substance can explain cortex cerebral characteristic folding. For example, a gyrus could develop itself inside a cortex area related to function, to allow efficient axonal connectivity between their opposite cortical walls the parallel activation observed from both opposite lateral and medial cortex from the *pli de passage* fronto parietal Moyen during the movement of a only body part possibly reflex this connections through the gyrus[19]. This may even develop in a case of anatomical variation to allow subtle and organized movements.

This way, it is evident that the average distance between the plis de passage of the superior and middle, and middle and inferior thirds of the right hemisphere, approximately, varied only 0.1 cm. Also, the mean distance between the superior and middle third, and middle and inferior thirds of the left hemisphere was similar, concluding that there is a constancy between the distance values. Furthermore, the mean distance between the superior and inferior thirds of the right and left hemispheres varied only 0.4 cm. Thus, it was possible to imply a hypothesis that there is no great variation in values between the distances of the plis de passage, which may result in new forms of surgical management due to the knowledge of these anatomical structures. In relation to the limitation in this study, we could identify the small number of encephalus samples as well taking time consuming manual steps that are operator dependent, which decreased the effectiveness. Therefore, it was not observed the depth of each *pli de passage.*

CONCLUSION

In conclusion, the present authors hypothesize that there is no statistically significant variation in values between the distances of the plis de passage. The thorough understanding of the *pli de passage* and its implications in the neurosurgical field are tremendously important. New surgical techniques are created daily and to do so, we must consider every new anatomical and functional description.

REFERENCES

Alkadhi H, Kollias SS. Pli de passage fronto-pariétal moyen of broca separates the motor homunculus. AJNR Am J Neuroradiol. 2004 May; 25 (5):809-12. PMID: 15140726; PMCID: PMC7974465.

Boling W, Olivier A, Bittar RG, Reutens D. Localization of hand motor activation in Broca's pli de passage moyen. J Neurosurg. 1999 Dec;91(6):903-10. doi: 10.3171/jns.1999.91.6.0903. PMID: 10584833.

Boling WW, Olivier A. Localization of hand sensory function to the pli de passage moyen of Broca. J Neurosurg. 2004 Aug; 101(2):278-83. doi: 10.3171/jns.2004.101.2.0278. PMID: 15309919.

Cachia, Arnaud, Margot Roell, Jean-François Mangin, Zhong Yi Sun, Antoinette Jobert, Lucia Braga, Olivier Houde, Stanislas Dehaene, et Grégoire Borst. 2018. « How Interindividual Differences in Brain Anatomy Shape Reading Accuracy ». Brain Structure and Function 223 (2): 701-12. https://doi.org/ 10.1007/s00429-017- 1516-x.

Cykowski MD, Coulon O, Kochunov PV, Amunts K, Lancaster JL, Laird AR, Glahn DC, Fox PT. The central sulcus: an observer-independent characterization of sulcal landmarks and depth asymmetry. Cereb Cortex. 2008 Sep;18(9):1999-2009. doi:

10.1093/cercor/bhm224. Epub 2007 Dec 10. PMID: 18071195; PMCID: PMC2733306.

de Oliveira JG, Massella CR Jr, de Holanda CVM, Giudicissi-Filho M, Borba LAB. Microsurgical management of a high-grade brain arteriovenous malformation in the central lobe after unsuccessful radiosurgery. Neurosurg Focus. 2017 Jul; 43 (VideoSuppl1):V3. doi: 10.3171/2017.7.FocusVid.17128. PMID: 28669269.

Frigeri T, Paglioli E, de Oliveira E, Rhoton AL Jr. Microsurgical anatomy of the central lobe. J Neurosurgery. 2015 Mar;122(3):483-98. doi: 10.3171/2014.11.JNS14315. Epub 2015 Jan 2. PMID: 25555079..

González-Darder JM, González-López P, Talamantes F, Quilis V, Cortés V, García-March G, Roldán P. Multimodal navigation in the functional microsurgical resection of intrinsic brain tumors located in eloquent motor areas: role of tractography. Neurosurg Focus. 2010 Feb;28(2):E5. doi: 10.3171/2009.11.FOCUS09234. PMID: 20121440.

Machado ABM. Functional Neuroanatomy. 3 ed. São Paulo: Atheneu Editora, 2014. p.57-70

Mangin JF, Le Guen Y, Labra N, Grigis A, Frouin V, Guevara M, Fischer C, Rivière D, Hopkins WD, Régis J, Sun ZY. "Plis de passage" Deserve a Role in Models of the Cortical Folding Process. Brain Topogr. 2019 Nov;32(6):1035-1048. doi: 10.1007/s10548-019-00734-8. Epub 2019 Oct 3. PMID: 31583493; PMCID: PMC6882753.

Moore KL, Dalley AF, Agur AMR . Clinic-oriented anatomy. 8 ed. Rio de Janeiro: Guanabara Koogan, 2011.p 807-960

Ono, Michio, Stefan Kubik, and Chad D. Abernathey. *Atlas of the cerebral sulci*. Thieme Medical Publishers. 1990.

Ribas GC. The cerebral sulci and gyri. Neurosurg Focus. 2010 Feb;28(2):E2. doi: 10.3171/2009.11.FOCUS09245. PMID: 20121437.

Santos JCC, Oliveira LF, Rodrigues LD, Barreto JEF. Clinical Neuroanatomy. 1 ed. Fortaleza: Editora Caminhar, 2021. p 48

Sarmento SA, Jácome DC, de Andrade EM, Melo AV, de Oliveira OR, Tedeschi H. Relationship between the coronal suture and the central lobe: how important is it and how can we use it in surgical planning? Arq Neuropsiquiatr. 2008 Dec;66(4):868-71. doi: 10.1590/s0004-282x2008000600017. PMID: 19099127.

Spasojević G, Malobabic S, Pilipović-Spasojević O, Djukić-Macut N, Maliković A. Morphology and digitally aided morphometry of the human paracentral lobule. Folia Morphol (Warsz). 2013 Feb;72(1):10-6. doi: 10.5603/fm.2013.0002. PMID: 23749705.

Thau L, Reddy V, Singh P. Anatomy, Central Nervous System. 2021 May 8. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan–. PMID: 31194336.

Van Essen DC. A tension-based theory of morphogenesis and compact wiring in the central nervous system. Nature. 1997 Jan 23;385(6614):313-8. doi: 10.1038/385313a0. PMID: 9002514.

White LE, Andrews TJ, Hulette otor system. I: Morphology and cytoarchitecture of the central sulcus. Cereb Cortex. 1997 Jan-Feb;7(1):18-30. doi: 10.1093/cercor/7.1.18. PMID: 9023429.

****