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Neuroanatomical study

Brain sulci and gyri: A practical anatomical review

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ABSTRACT

Despite technological advances, such as intraoperative MRI, intraoperative sensory and motor monitoring, and awake brain surgery, brain anatomy and its relationship with cranial landmarks still remains the basis of neurosurgery. Our objective is to describe the utility of anatomical knowledge of brain sulci and gyri in neurosurgery. This study was performed on 10 human adult cadaveric heads fixed in formalin and injected with colored silicone rubber. Additionally, using procedures done by the authors between June 2006 and June 2011, we describe anatomical knowledge of brain sulci and gyri used to manage brain lesions. Knowledge of the brain sulci and gyri can be used (a) to localize the craniotomy procedure, (b) to recognize eloquent areas of the brain, and (c) to identify any given sulcus for access to deep areas of the brain. Despite technological advances, anatomical knowledge of brain sulci and gyri remains essential to perform brain surgery safely and effectively.

1. Introduction

According to international anatomical terminology, the brain is comprised of six lobes – frontal, parietal, occipital, temporal, insular and limbic [1]. For the purposes of this study, however, we will follow Yasargil's and Ribas's criteria that each brain hemisphere is comprised of seven lobes – frontal, central, parietal, occipital, temporal, insular and limbic [2,3]. Each lobe is made up of several gyri, which are separated from one another by sulci. A sulcus that is deep and continuous is commonly called a fissure, such as the Sylvian fissure. The term "lobe" defines a certain area of the brain separated from the rest, mostly by deep sulcus or fissures. It has no functional meaning but allows us to describe brain anatomy in comprehensive terms. Because sulci and gyri run horizontally in all the lobes but the central one, we prefer Yasargil's classification, which is easier to understand and apply during surgery.

Although brain structure and brain function are not strictly dependent on each other, studies show that they are closely related [3]. Hence, it is essential that every neurosurgeon should have a thorough knowledge of brain microanatomy, not only to understand neuroimages, but to be able to plan and conduct neurosurgical procedures [3]. Nevertheless, brain function varies a great deal between individuals and can be affected by pathology, for example, a slow growing mass within the parenchyma can, by means of neuroplasticity, change the location of relevant brain function allowing the surgeon to safely operate in "eloquent" areas. Neurophysiological testing in the operating room is essential in these kinds of cases but it is not always available, making anatomical landmarks useful tools.

Throughout the second half of the twentieth century, surgeons started to use fissures to approach extrinsic brain lesions, and sulci to access intrinsic lesions [1,4]. Once identified, brain sulci can be used as a microsurgical corridor or simply as an anatomical landmark [5,6]. Hence, thorough knowledge of the shapes and structures of the brain is essential to understand neuroimages, and proves crucial for image-guided procedures [3].

The aim of this paper is to show the threefold utility of anatomical knowledge of brain sulci and gyri, enabling the neurosurgeon to (a) localize the craniotomy procedure, (b) recognize eloquent areas of the brain, and (c) use any given sulcus to approach deep areas of the brain.

2. Methods

We studied 10 human adult cadaveric heads fixed in formalin and injected with colored silicone rubber to determine the relationship between surface osteometric landmark points (coronal

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suture, lambdoid suture, squamous suture, and superior temporal line) and the sulci and gyri of the lateral aspect of the brain. A total of 20 hemispheres were analyzed, the distance between main bony landmarks and cerebral sulci was analyzed. Landmarks on the frontal bone were measured 3.5 cm from the coronal suture, landmarks on the temporal bone were measured 2 cm from the external acoustic channel.

3. Anatomical considerations

The lateral aspect of the brain is comprised of five visible lobes (frontal, central, parietal, occipital and temporal lobes) and a hidden area (the insula) (Fig. 1).

3.1. Frontal lobe

The frontal lobe borders on the precentral sulcus anteriorly and on the Sylvian fissure superiorly. It has two sulci (superior frontal and inferior frontal) and three horizontal gyri (superior frontal, middle frontal and inferior frontal). The inferior frontal gyrus is composed of three parts: the pars orbitalis (anteriorly), the pars triangularis (middle) and the pars opercularis (posteriorly). The pars opercularis of the inferior frontal gyrus in the dominant hemisphere (that is, the left hemisphere in most subjects) often includes the motor speech area commonly known as Broca's area.

From a surgical perspective, it is important to note that the three frontal gyri run horizontally as do the superior part of the squamous suture and the superior part of the superior temporal line. Hence, the relationships to be considered are as follows: the anterior ramus of the Sylvian fissure is located at the level of the squamous suture, the inferior frontal sulcus is located deep to the anterior aspect of the superior temporal line and the superior frontal sulcus is midway between the midline and the superior temporal line. Consequently, we can state that the superior frontal gyrus is located between the midline and a line that is equidistant to the midline and the superior temporal line, that the middle frontal gyrus is located between the superior temporal line and a line that is equidistant to the midline and the superior temporal line, and that the inferior frontal gyrus is located between the squamous suture inferiorly and the superior temporal line superiorly.

3.2. Central lobe

The central lobe is bounded by the precentral sulcus anteriorly, by the postcentral sulcus posteriorly, and by the Sylvian fissure inferiorly. It has one sulcus (central) and two vertical gyri (the precentral or motor, and the postcentral or sensory).

From a surgical perspective, it is important to note that the two gyri (precentral and postcentral) are vertical, like the coronal suture. The central sulcus – which borders on the precentral gyrus posteriorly – is variably located 2–5 cm behind the coronal suture, the longest distance between both structures occurring at the superior part, and the shortest near the Sylvian fissure. As the distance between the coronal suture and the central sulcus may vary, a more accurate way to locate the gyri of the central lobe is to use imaging to measure the distance from the coronal suture to the lesion requiring treatment [7,8].

The central sulcus presents three curves: the superior and inferior curves show a forward convexity, whereas the middle curve has a backward convexity. The middle curve resembles the shape of an inverted omega symbol, whereas the part of the gyrus located anteriorly to the middle curve corresponds to the hand's motor area and can be easily recognized through MRI [2].

3.3. Parietal lobe

The parietal lobe is bounded by the postcentral sulcus anteriorly, by the lateral parieto-temporal line posteriorly and, at the inferior aspect, by the posterior ramus of the Sylvian fissure anteriorly and the temporo-occipital line posteriorly. It has one sulcus

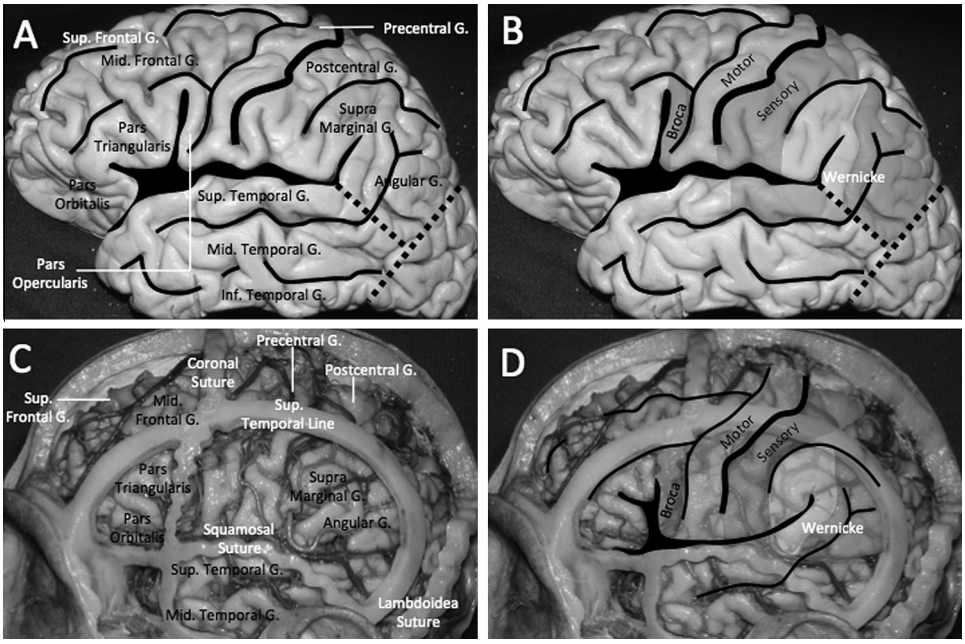

Fig. 1. Lateral aspect of the brain. (A) Sagittal view of the left hemisphere with the most significant sulci highlighted and the most important gyri named. The parietal, temporal and occipital lobes are separated by two lines – one which connects the superior end of the parieto-occipital internal fissure to the suboccipital notch (lateral parieto-temporal line) and one other which runs perpendicularly to the previous line, from the end of the Sylvian fissure to the lateral parieto-temporal line (temporo-occipital line). (B) Eloquent areas of the left hemisphere are colored as follows: red = Broca's area, green = motor strip, blue = sensory strip, yellow and purple = Wernicke's area, orange = language area. (C) Cerebral lobes and (D) eloquent areas of the left hemisphere are colored as in (B) to overlie surface osteometric landmark points (coronal suture, squamous suture, superior temporal line and lambdoid suture). G. = gyrus, Inf. = inferior, Mid. = middle, Sup. = superior.