Original Articles

Surgical Anatomy of the Insular Cortex

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Objective. The objective of this study was to investigate the surgical anatomy of the insular cortex, morphology and vascularization of the insula and adjacent opercula in terms of the transsylvian and transcortical approaches and to identify the permissible anatomical boundaries for resection of glial tumors of the insula. Material and methods. The study was conducted on 18 anatomical specimens fixed in an alcohol-glycerol solution. Perfusion of the internal carotid artery with red latex was used to study the arterial system. Dissection of the arteries and Sylvian fissure, investigation of the morphological features of the opercula, as well as simulation of the transsylvian and transcortical approaches to the insula were performed using a surgical microscope.

Results. In the transsylvian approach, the anteroinferior part of the insula (including the limen insulae) is the most technically accessible area, whereas the superior parts of the insula are the least accessible areas. With tumors localized in the superior insula, the transcortical approach may be recommended, which, unlike the transsylvian approach, does not require significant retraction of the brain matter and provides larger surgical corridor. The transcortical approach, regardless of the insular region, provides better surgical view and workspace compared to the transsylvian approach. However, the transsylvian approach requires dissection of the brain matter of the frontal and temporal lobes.

Conclusions. Detailed knowledge of the surgical anatomy of the insular region enables correct intraoperative identification of the number of major anatomical landmarks (limen insulae, peri-insular sulci), and the most distal lenticulostriate artery and facilitates the choice of the proper surgical approach.

Keywords: insular cortex, lenticulostriate arteries, transsylvian and transcortical approaches.

Approach to the insular cortex is one of the most common neurosurgical manipulations, which, along with the insula itself, opens M1 and M2 segments of the middle cerebral artery. The insula can be reached both through the Sylvian fissure and transcortical approach by removing one operculum covering the insula.

Currently, there is no consensus among the neurosurgeons regarding the optimal approach to the insula. Two methodological schools can be conventionally distinguished. The first school prefers transsylvian approach with wide dissection of the Sylvian fissure and without dissection of adjacent opercular area [1]. Adherents of the second one use the transcortical approach through the functionally insignificant opercular area [2, 3]. Both approaches require the detailed knowledge of the morphology of the insula, surrounding opercula, and vessels.

Material and Methods

The study was conducted on 18 anatomical specimens (9 left and 9 right hemispheres) of the brain of adults aged 21 to 79 years, whose death was not caused by intracranial pathology. After isolation of the brain from the skull cavity, catheters were placed to the lumens of the internal carotid arteries to the bifurcation level. Further, the arterial system of the brain was thoroughly washed with saline, followed by injection of the red-colored latex (2–3 ml) [4]. Thereafter, the catheters were removed from the lumen of blood vessels and the vessels were ligated. The preparation was immersed to the fixing liquid (96% alcohol and glycerol in a ratio of 4: 1) for 3 days. Then microdissection of the Sylvian fissure was conducted using OPTON OPM6-SDFC-XY surgical microscope (with 4—10-fold magnification) in the following sequence: dissection of the superficial portion of the Sylvian fissure, dissection of the deep portion of the Sylvian fissure located under the temporal operculum, dissection of the deep portion of the Sylvian fissure located under the frontal and parietal opercula. The most important surgical landmarks were then explored, including the limen insulae, lenticulostriate arteries, peri-insular sulci, M3 and M2 segments of the middle cerebral artery, and insular gyri. The final step included the morphological study of the insular opercula (the size of the opercula and comparing their anatomy at the various portions of the insula), simulation of the transcortical approach by removing parts of the opercula covering 5 areas of the insula, and measuring the size of the peri-insular sulci.

Results

Sylvian fissure

Sylvian fissure is the most important anatomical landmark on the lateral and basal surfaces of the brain located between the frontal, temporal, and parietal lobes. Sylvian fissure includes basal (proximal) and lateral (distal) segments and each of them in turn consists of deep and superficial parts.

The boundary between the basal and lateral segments lies at the anterior Sylvian point (located at the triangular...
part of the inferior frontal gyrus), the place where the basal surface of the hemisphere turns into the lateral one.

The surface of the Sylvian fissure consists of three main sulci (Fig. 1), which are represented by three branches in the lateral segment: horizontal, ascending, and posterior ones. All three sulci begin at the anterior Sylvian point. The posterior sulcus runs in the distal direction between the frontal and parietal lobes at the top and the temporal lobe at the bottom. Horizontal and ascending sulci ascend forward horizontally and upward vertically, respectively, from the Sylvian point and divide the inferior frontal gyrus into three parts: the orbital, triangular, and opercular ones.

In the basal segment of the Sylvian fissure, the deepest part (sphenoidal) is formed by the proximal and medial portions of the superior temporal gyrus (planum polare), medially, and by lateral and posterior orbital gyri of the basal surface of the frontal lobe, laterally. This part of the Sylvian fissure extends from the limen insulae to the bifurcation of the internal carotid artery. It contains M1 segment of the middle cerebral artery, non-parenchymatous portion of lenticulostriate arteries, and deep Sylvian vein.

The deep portion of the distal segment of the Sylvian fissure is represented by the space formed between the contacting parts (opercula) of the frontal, parietal, temporal lobes and the lateral surface of the insula. The inferior wall of the deep portion of the distal segment if formed by the temporal operculum (superior and medial surface of the superior temporal gyrus), which in turn consists of the following components (in anterior-posterior direction): planum polare, anterior Heschl gyrus (anterior transverse temporal gyrus), and planum temporale (Fig. 2).

Planum polare is the most proximal portion of the temporal operculum located between the Heschl gyrus posteriorly and the uncinate gyrus anteriorly. The anterior and posterior portions of the planum polare have different axes with respect to the sagittal plane. The posterior portion (from the Heschl gyrus to the precentral gyrus) is normally disposed to the sagittal plane, while the remaining anterior portion is deflected medially and makes an acute angle with this plane (Fig. 3). Planum polare covers the inferior surface of the anterior portion of the insula and limen insulae (see Fig. 2).

Planum temporale forms the distal portion of the temporal operculum and consists of the middle and posterior transverse temporal gyri (the plane of this portion of the temporal operculum is oriented perpendicular to the sagittal plane, i.e. more horizontally than anterior parts of this operculum (see Fig. 3b).

The anterior transverse temporal gyrus (Heschl gyrus) can be easily identified at the temporal operculum due to pronounced protrusion on its surface. It corresponds to the posterior lobe of the insula and the posterior third of the inferior peri-insular sulcus (see Fig. 2).

The anterior wall of the deep portion of the distal segment is formed by the frontal and parietal opercula (see Fig. 2). The frontal operculum includes the orbital, triangular, and opercular parts of the inferior frontal gyrus and the inferior part of the precentral gyrus. It should be noted that in 7 (38%) specimens, triangular portion was smaller compared to other parts of the inferior frontal gyrus (upward retraction), resulting in the increased width of the Sylvian fissure at this level.

![Fig. 1. The branches of the superficial part of the Sylvian fissure.](image-url)
The parietal operculum is formed by the inferior part of the postcentral gyrus and superior parts of the supramarginal gyrus.

The lateral wall of the deep portion of the distal segment of the Sylvian fissure is formed by the lateral surface of the insula.

M2 and M3 segments of the middle cerebral artery and the deep Sylvian vein are located at the deep part of the distal segment.

The insula

The insula is the only non-surface-exposed lobe of the brain. It is superiorly and inferiorly covered by parts of the frontal, parietal, and temporal lobes, which form 3 opercula, respectively.

Frontal and parietal opercula cover the anterior part of the lateral surface of the insula (the space formed in this way is called the superior insular-opercular fissure). Temporal operculum covers the inferior surface of the insula, which results in formation of the inferior insular-opercular fissure. Superior and inferior insular-opercular fissures are the constituents of the deep portion of the distal segment of the Sylvian fissure.

With removed opercular parts of the frontal, parietal, and temporal lobes, the insula looks pyramid-shaped (Fig. 4 and 5) with its tip directed towards the base of the brain. The insula is separated from the surrounding opercula by three sulci. The anterior peri-insular sulcus separates the anterior surface of the lobe from the frontal operculum. In this study, its length averaged 26 (24—33) mm. The superior sulcus defines the boundary of the lobe with the fronto-parietal operculum, its average length was 56 (52—63) mm. The inferior peri-insular sulcus separates the inferior surface of the insula from the temporal lobe. The average length of this sulcus was 47 (43—51) mm.

Sulci and gyri of the insula

Morphologic study has shown that the central sulcus of the insula was the deepest one and it was present in all specimens. Its length averaged 32 (24—42) mm. The direction and the angle of the central sulcus of the insula almost completely matched the direction of the Rolandoic fissure in 14 cases, and in the remaining 4 cases, there was an antedisplacement of the lower end of Rolandoic fissure by 3—4 mm with respect to the central sulcus of the insula.

The central sulcus of the insula divides its surface into 2 parts: larger anterior and smaller posterior one.

Fig. 2. Opercula of the brain and the insula, side view.

Fig. 3. Frontal sections at the anterior (a) and posterior (b) third of the insula.
A — the thickness of the opercula, B — the length of the antero-superior (a) and postero-superior (b) parts located under the frontal and parietal opercula. The arrow indicates the plane of the Sylvian fissure in its anterior and posterior third.
The anterior part consists of 3 short gyri: anterior, middle, and posterior (separated by the anterior and precentral sulci of the insula) ones, and also accessory and transverse gyri that are not always present. The posterior part is represented by the anterior and posterior long gyri and the postcentral sulcus, which is located in between (Fig. 6).

In 15 hemispheres, anterior, middle, and posterior short gyri were well defined, while the remaining 3 hemisphere were characterized by smaller middle short gyrus.

In all specimens, the posterior portion of the insula consisted of the anterior and posterior long gyri. However, in 13 hemispheres, the anterior long gyrus was larger than the posterior one, in 3 hemispheres both long gyri were similar, and in 2 specimens larger posterior gyrus was observed.

In 14 hemispheres, there was a transverse gyrus located in the anterior portion of the island, at the point of its junction with the posterior part of the fronto-basal region. Accessory gyrus of the insula located above the transverse one was found in 7 hemispheres.

In 2 hemispheres, there were additional gyri (which have no nomenclature names) located along the inferior peri-insular sulcus and separated from the known gyri by shallow sulci.

Apex of the insula, which is usually distinguished on the surface of the insula [5], is the most lateral portion of the lobe and thus closest to the cortical surface, which is usually located near to the middle short gyrus.

Limen insulae forms the antero-basal part of the lobe (“entrance” into the insula); it is the most important surgical landmark in the transsylvian approach to the insula. Limen insulae connects the temporal pole with the basal parts of the frontal lobe and is shaped like a semicircle. The anterior perforated substance is located immediately medial to the limen insulae.

Sulci and gyri of the insula have relatively constant relationship with the gyri of the opercula. The anterior short gyrus of the insula and the corresponding portion of the anterior peri-insular sulcus are projected onto the orbital part of the frontal operculum; middle and posterior short gyri correspond to the triangular and opercular parts. Posterior portions of the short posterior gyrus and the anterior part of the long anterior gyrus correspond to the precentral gyrus. Postcentral gyrus covers the remainder of the anterior long gyrus and anterior portions of the posterior long gyrus. The caudal part of the posterior long gyrus corresponds to the supramarginal gyrus. The inferior peri-insular sulcus approximately corresponds to the superior temporal sulcus. Limen insulae (and therefore the bifurcation of the middle cerebral artery) is located medial to the temporal operculum.

Thus, the anterior lobe of the insula is covered by orbital, triangular, and opercular parts of the inferior frontal gyrus, and inferior portion of the precentral gyrus from above and by planum polare of the temporal superior gyrus from below.

Posterior lobe is covered by the postcentral gyrus from the Sylvian fissure, the anterior portions of the
supramarginal gyrus from above, and Heschl gyrus from below. All the insula is projected onto the lateral surface of the brain from the pars opercularis (horizontal branch of the Sylvian fissure) at the front to the anterior portions of the supramarginal gyrus from behind.

Thus, gyri and sulci of the frontal, temporal, and parietal opercula correspond to certain sulci and gyri of the insula, which can serve as a landmark during the transcortical approach to various portions of the insula.

**The relation between the opercula of the brain and the insula**

The distance between the anterior insular point (the intersection of the anterior and superior peri-insular sulci) and the lateral surface of the cortex at pars triangularis averaged 22 (18—26) mm, i.e. the width of the frontal operculum at this level was 22 mm (Fig. 7).

The length of the straight line connecting the posterior insular point (the intersection of the posterior and superior peri-insular sulci) with the point on the lateral surface of the supramarginal gyrus averaged 31 (28—35) mm (transverse dimension of the parietal operculum).

The thickness of the temporal operculum (the distance between the posterior insular point and the lateral surface of the cortex of the superior temporal gyrus) was 32 (27—35) mm.

Thus, there is an increase in the thickness of the operculum in the anterior-posterior direction, which complicates the approach to the posterior parts (long gyri) of the insula both through the transsylvian and transcortical approaches, increasing the depth of the surgical wound.

Measured distance between the limen insulae and the temporal pole averaged 20 (15—24) mm.

Frontal and parietal opercula covered on the average 22 (18—24) mm of the superior surface of the insula (the length of the operculum). The temporal operculum covered the inferior surface of the insula at a distance of 15 (11—18) mm. As a result, it was found that in the case of the transsylvian approach, the structures located under the frontal operculum are less accessible than those located under the temporal one (considering also extremely inconvenient supero-posterior attack angle). This is not the case with the transcortical approach and structures located under the frontal and temporal opercula are equally accessible.

**The projections of the basal ganglia, lateral ventricle, and the internal capsule with respect to the insula**

Claustrum, putamen, globus pallidus, anterior and posterior limb of the internal capsule, and thalamus are located medial to the insula.

Putamen and globus pallidus (lenticular nucleus) extend in the anterior-posterior direction from the level of the middle short gyrus of the insula to the anterior portions of the posterior long gyrus of the insula. Thus, the lenticular nucleus covers only the central part of the internal capsule from the insula-side, while its peripheral portions (anterior, superior, and posterior) lack this natural barrier (Fig. 8).

The foramen of Monro is located medial to the posterior short gyrus and therefore the genu of the internal capsule is projected to the level of the middle third of the insula (see Fig. 8). Thus, the pyramidal tract and thalamus are located **under the posterior portion** of the insula, i.e. the anterior and posterior long gyri.
All parts of the lateral ventricle are projected onto the insula. The anterior portions of the anterior horn of the lateral ventricles are projected onto the anterior peri-insular sulcus. The anterior peri-insular sulcus corresponds to the posterior parts of the anterior horn, body and the anterior part of the vestibule of the lateral ventricle. Posterior 2/3 of the inferior peri-insular sulcus is projected onto the inferior horn and the vestibule of the lateral ventricle.

**The blood supply to the insula**

The insula is mainly supplied with blood from multiple perforating arteries that run from the M2 segment of the middle cerebral artery (Fig. 9).

The arteries that form the M2 segment of middle cerebral artery run along the insular sulci, except for the superior peri-insular sulcus. The arteries cross this sulcus at the right angle (see Fig. 4, blue arrows).

In 17 hemispheres, M1 segment terminates with bifurcation at the limen insulae. In one hemisphere, there was trifurcation. In 15 hemispheres, the anterior stem supplied with blood the anterior, middle, and posterior short gyri, while in the remaining 3 hemispheres, perforating arteries both from the superior and inferior stem ran to the short gyrus. In 14 hemispheres, the anterior long gyrus was supplied by the inferior stem; in 3 hemispheres, it was supplied both by the superior and inferior stems; in one hemisphere, it was supplied by the middle stem. In all specimens, the posterior long gyrus was supplied with blood only by the inferior portion of the M2 segment. In two specimens, we also observed branches running from the M1 segment and supplying the limen insulae.

The results of our study have shown that in 5 (27%) hemispheres, perforating arteries of the M2 segment located at the superior portion of the posterior lobe have larger diameter compared to other perforating arteries (see Fig. 9). Only in two (11%) hemispheres these arteries reached the radiate crown.

**Lenticulostriate arteries**

Small-diameter branches of the middle cerebral artery that perforate the central and lateral parts of the anterior perforated substance are called lenticulostriate arteries. These arteries are usually subdivided into medial and lateral ones, depending of the place of branching from the middle cerebral artery.

Medial arteries supply blood to the head of the caudate nucleus, central medial portion of the putamen, the lateral segment of the globus pallidus, and partially the anterior limb of the internal capsule and antero-superior portion of the posterior limb [6, 7] (Fig. 10a).

The lateral group of arteries supplies the superior part of the head of the caudate nucleus and the anterior limb of the internal capsule, a large portion of the putamen, part of the lateral segment of the globus pallidus, and the superior part of the genu and the posterior limb of the internal capsule with adjacent portion of the radiate crown [6, 7] (see Fig. 10b, Fig. 11).

Despite the fact that the number of the lenticulostriate arteries ranges 5 to 24 [8], occlusion of just one artery may cause the extensive infarction at the area of the basal ganglia and the internal capsule [9]. In the study of 18 hemispheres, the average number of arteries was 8 (3—20).

In 7 hemispheres, 1 to 3 perforating arteries branched from the medial third of M1 segment in the caudo-dorsal-lateral direction. In 18 specimens, 2 to 5 these arteries branched from the middle third in the caudo-dorsomedial direction.

Lateral lenticulostriate (LLS) arteries branched from the dorsal (or caudo-dorsal) part of the terminal third of M1 (Fig. 12) and were detected in all specimens. The average number of these arteries was 4. From the branching point, these arteries first run medially behind the M1 segment, then turn posteriorly, superiorly, and, before entering the anterior perforated substance, laterally.

In 5 (28%) hemispheres, LLS arteries branched from the M2 segment of the middle cerebral of artery in the immediate vicinity of the bifurcation (see Fig. 12a).

It is important to note that in 7 (38%) hemispheres, lateral lenticulostriate arteries branched from the M1 segment as a single stem, which then split into separate branches.

The average distance between the entrance point of the most lateral lenticulostriate artery to the anterior perforated substance and the limen insulae was 16 mm (see Fig. 12b), and the average length of the lateral lenticulostriate arteries from the place of origin on the M1 segment to the entrance to the anterior perforated substance was 4 mm.

**The anatomical boundaries of resection of insular gliomas**

The knowledge of the anatomical features of the insula and possible anatomical boundaries of resection...
Fig. 8. a — horizontal section at the level of the fornicomissure; top view. Red arrows indicate the portions of the internal capsule that are not protected by the putamen; blue arrow — the area of the internal capsule, covered by the putamen; b — insular gyri.
Fig. 9. a — the insula and M2 and M3 segments of the middle cerebral artery. Blue arrows indicate numerous small-diameter perforating (insular) arteries; white arrow — long perforating artery in the postero-superior part of the insula; b — long perforating vessel running from the M2 segment of the middle cerebral artery (white arrow) in the postero-superior part of the insula.

(mainly medial) is extremely important in surgical treatment of diffusely growing gliomas of the insula.

The following anatomical structures are, in our opinion, possible boundaries for resection of glial tumors of the insula: **supero-medial** boundary — radiate crown (intraoperative landmark — anterior peri-insular sulcus); **infero-medial** boundary — retrolenticular part of the internal capsule; **postero-medial** — posterior limb of the internal capsule (no intraoperative landmarks); **centro-medial** — the extreme and external capsule or the subcortical nuclei (claustrum/putamen) depending on the degree of spread of the tumor in the medial direction (intraoperative landmark — the emergence of the gray/beige substance of the basal ganglia); **antero-medial** — the anterior part of the anterior limb of the internal capsule (no intraoperative landmarks); **antero-basal** — the anterior perforated substance (intraoperative landmarks — the limen insulae, M1 segment of the middle cerebral artery, and the most distal lenticulostriate artery).

**Approach simulation**

Transcortical (9 hemispheres) and transsylvian (another 9 hemispheres) approaches were simulated.
During simulations of the transsylvian approach, the following steps were performed: dissection of the surface portion of the Sylvian fissure, dissection of the deep portion of the Sylvian fissure located under the temporal operculum, dissection of the deep portion of the Sylvian fissure located under the frontal and parietal opercula.

During simulations of the transcortical approach, we removed opercular parts located above one of the 5 zones (Fig. 13): limen insulae, the superior portions of the anterior lobe (under the frontal operculum), the inferior portions of the anterior lobe (under the temporal operculum), the superior portions of the posterior lobe (under the parietal operculum), and inferior portions of the posterior lobe (under the temporal operculum).

**Discussion**

Despite the practical significance (up to 25% of all low-grade gliomas and up to 10% of all high-grade gliomas are located in the insula [10]) and functional complexity (the insula is surrounded by Broca and Wernicke speech centers arranged around the Sylvian fissure, primary motor and sensory cortex of the facial area, as well as pathways connecting these areas) of the insula, only several publications devoted to the study of the anatomy of this area of the brain are currently available [5, 8, 9, 11, 14]. Moreover, it has currently been shown that the insula plays a key role in many processes, from viscerosensory processes and perception of pain to the motivational processes, cognitive control of emotions, and speech [15—18]. T. Wager said that the insula is a key connecting thinking and affective sphere, while A. Craig believed that the anterior part of the insula that gets rich interoception and has strong connections with limbic structures is responsible for consciousness. [19]

In our study, we focused on morphological features of the insular gyri and opercula, the specifics of the vascular system of the insular region from the viewpoint of two basic approaches used to reach the insula: transsylvian and transcortical.

In the classical works, the insula is described as a pyramidal-shaped fifth lobe of the brain bounded from the surrounding frontal, parietal, and temporal lobes by the peri-insular sulci. Most authors [5, 11, 14] distinguish the anterior, superior, and posterior peri-insular sulci. A somewhat different view is presented in A. Afif et al. [13], where the insula is represented as a trapezoid, and the authors describe 4 peri-insular sulci: the anterior, superior, posterior, and inferior ones. When studying our anatomical material, we adhered to the description of the anterior, superior, and posterior peri-insular sulci.

It is known that the insula is supplied with blood by multiple perforating arteries branching from the vessels of M2 segment of the middle cerebral artery that lie on the insula. However, there is an important practical question, whether they can be coagulated during the
resection of the tumor? How deep these arteries extend medially and where is the margin of the area they supply. Some authors report data on the presence of long perforating arteries having different diameter that branch from the M2 segment and occur predominantly in the posterior portion of the insula. Prior to our study, these arteries were described only in three works and G. Varnavas et al. [14] was the first who observed large-diameter perforating arteries in the superior portion of the posterior lobe of the insula in a quarter of hemispheres under study. Supply area of these arteries was not specified. Tanriover et al. [11] described the large-diameter perforating arteries not only at the supero-posterior portion of the insula, but also at the inferior regions of the posterior lobe. Ture et al. [8] have shown that approximately 85—90% of the insular (branching from the M2 segment) arteries are short and supply with blood only insular cortex and extreme capsule, 10% of arteries have an average length and reach the claustrum and external capsule, and 3—5% of arteries are long (they can be found in the posterior lobe of the island) and supply the radiate crown. Injury to the latter during the resection of insular tumors can lead to hemiparesis. When examining our material, we observed large-diameter perforating arteries of M2 segment only in the superior portions of the posterior long gyri. They supplied the radiate crown only in 2 (11%) hemispheres. In all other cases, they branched not further than the lateral part of the putamen. Consequently, the external capsule is the medial boundary of blood supply area of insular arteries, except for the supero-posterior parts of the insula, where in few cases perforating artery reach the radiate crown.

Since gliomas of the insula are supplied with blood by perforating arteries of the M2 segment, one of the stages of tumor resection [1] is its devascularization by coagulation of perforating arteries of M2. However, given the results of anatomical studies, we suggest that, in the posterior portions of the insula, this stage of approach (if a large perforating vessel is coagulated) may lead to ischemic damage to the radiate crown and, as a consequence, neurological deficit. Preservation of the lenticulostriate arteries is one of the greatest challenges of surgery of the insula and damage to these arteries is considered to be the main cause of persistent neurological deficit [1, 20]. In this regard, the most lateral lenticulostriate artery becomes important as the intraoperative landmark [21], which is available only in transsylvian approach and allows determining the lateral margin of the anterior perforated

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**Fig. 11.** Schematic representation of the arterial system of the insular region.  
1 — long perforating artery of the M2 segment of middle cerebral artery; 2 — medial lenticulostriate arteries; 3 — lateral lenticulostriate arteries; 4 — short perforating arteries of the M2 segment of the middle cerebral artery.

**Fig. 12.** a — lateral lenticulostriate arteries branch from the M1 and M2 segments of the middle cerebral artery; b — lateral lenticulostriate arteries branch only from the M1 segment of the middle cerebral artery.
The insula is characterized by the lack of surface exposure of its cortex, which complicates direct surgical approach. The insula is covered by opercula, i.e. portions of the temporal, frontal, and parietal lobes, located above and below the insula. In the literature, there are differences in the notation of insular opercula. Some authors believe that there are three opercula: frontal, parietal, and temporal ones [11] (or fronto-orbital, fronto-parietal, and temporal [5]), while others describe only two opercula: fronto-parietal and temporal [12]. In our view, the notation of the frontal, parietal, and temporal opercula is optimal, since in this case, the names and boundaries of the opercula match the lobes, in which they are located.

However, the variants of notation of the opercula have no fundamental (practical) value, as opposed to the features of their structure in their anterior/posterior and superior/inferior portions, which determine different accessibility of the regions of the insula in the transcortical and transsylvian approaches.

In our view, the insula can be naturally divided into several sections (see Fig. 14). The central sulcus divides the insula into the anterior and posterior lobes. In both of them, the superior part is located under the frontal/parietal operculum and the inferior part is located under the temporal operculum. Thus, the insula is divided into four sections: antero-superior, antero-inferior, postero-superior, and postero-inferior ones. We also believe that it is appropriate to distinguish the limen insulae in the antero-inferior section due to its anatomical proximity to the anterior perforated substance.

The thickness of the opercula at the anterior lobe of the insula is smaller than that at the posterior one, and the height of the frontal and parietal opercula is larger than that of the temporal one. Therefore, the surgical wound is deeper in the posterior parts of the insula compared to that in the anterior parts.

In addition, the axis of the planum polare, which covers the antero-inferior section of the island, is orientated at an acute angle to the sagittal plane and declined laterally (see Fig. 4). Together with upward retraction of the triangular part, this increases the free space of the Sylvian fissure at this level and facilitates retraction during the transsylvian approach to the antero-inferior portions of the insula.

Therefore, when modeling the transsylvian approach on the anatomical preparations with allowance for the morphology of the cerebral opercula covering the insula, we came to the conclusion that inferior parts of the lobe are more accessible than the superior ones (due to extremely inconvenient supero-posterior attack angle and greater height of the frontal and parietal opercula compared to the temporal one).

The accessibility of the antero-superior and postero-superior parts is also different. Despite the smaller depth of the wound during the approach to the antero-superior parts of the insula compared to that during the approach to the postero-inferior parts (see Fig. 3 and 7), the distance to the superior peri-insular sulcus (the length of the antero-superior and postero-superior parts located under the frontal and parietal operculum (see Fig. 3, distance B) is larger in the antero-superior part of the lobe, which leads to equally inaccessible antero-superior and postero-superior parts during the transsylvian approach. Smaller thickness of the opercula in the antero-superior portions is compensated by the longer distance to the superior peri-insular sulcus (see Fig. 3, distance B), which makes this part the least accessible during the transsylvian approach.

Therefore, the inferior areas of the insula (including the limen insulae) are the most accessible, while the superior areas are the least accessible ones during the transsylvian approach. For this reason, in the cases when a tumor is located in these areas of the insula, transcortical approach may be recommended, since, unlike the transsylvian approach, it does not require significant retraction of the medulla and provides greater surgical corridor.

When simulating the transcortical approach, the greater depth of the surgical wound in the posterior regions compared to the anterior ones was the only difference in the accessibility of the parts of the insula.
Since the transcortical approach includes resection of the part of the operculum located above the tumorous region of the insula, the attack angle (and therefore the accessibility) to the superior and inferior portions of the lobe is similar, unlike the transsylvian approach.

Regardless of the part of the insula, the transcortical approach provides greater surgical visibility and workspace compared to the transsylvian one. However, in cases when a tumor is located at the limen insulae, it does not provide a reliable proximal control of the lenticulostriate arteries. For this reason, transsylvian approach may be advisable for localization of tumor in this area.

Summary

Detailed knowledge of the surgical anatomy of the insula enables the correct intraoperative identification of a number of major anatomical landmarks (the limen insulae, peri-insular sulci, and the most distal LLS-artery) and facilitates the correct selection of the surgical approach.

REFERENCES


Commentary

This study deals with surgical anatomy of the insular region of the brain from the perspective of the transsylvian and transcortical approaches to the insula during resection of the glial tumors of this area. This in an academic-style study. The study was conducted on 18 anatomical brain preparations with vessels filled with colored latex according to the method adopted at the Burdenko Neurosurgical Institute. The work mainly focuses on the morphological features of the insular gyri and opercula, the specifics of the vascular system of the insular region when conducting two commonly used approaches, transsylvian and transcortical ones. When simulating these approaches, the authors concluded that in the transsylvian approach, the inferior areas of the insula, including the threshold, are the most accessible ones. When the tumor is located in the superior regions of the insula, the transcortical approach is more appropriate, as it does not require significant retraction of the medulla and provides greater surgical visibility. The work is illustrated with color images of the anatomical structures of the insular region.

The article is of great interest for neurosurgeons and can be recommended for publication in the neurosurgical journal.