Insular glioma surgery approaches

- A series of 309 awake surgeries with transcortical approach for IDH-mutant low-grade glioma involving the insula: long-term onco-functional outcomes in 253 consecutive patients
- Safety and Efficacy in the Transcortical and Transsylvian Approach in Insular High-Grade Gliomas: A Comparative Series of 58 Patients
- A Journey into the Complexity of Temporo-Insular Gliomas: Case Report and Literature Review
- The Transtemporal Isthmus Approach for Insular Glioma Surgery
- Transsylvian Insular Glioma Surgery
- Microsurgical anatomy and approaches to thalamic gliomas. Part 2: Maximal safe resection of thalamic gliomas improves outcomes. A single-center experience
- Surgical treatment for insular gliomas. A systematic review and meta-analysis on behalf of the EANS neuro-oncology section
- Factors affecting the extent of resection and neurological outcomes following transopercular resection of insular gliomas

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Transtemporal Isthmus Approach

Transtemporal Isthmus Approach see

see Transcortical approach for insular glioma

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see Transsylvian transinsular approach for insular glioma

General surgical principles and controversies

The state of the art during any neurosurgical procedure remains on completely removing a lesion while sparing the anatomy and functionality of the surrounding normal brain tissue. Following three steps will aid achieving this goal. First, taking a corridor based on anatomical and cisternal principles minimizing the disruption of the neighboring neurovascular structures. Secondly, carrying out an atraumatic manipulation along the narrow surgical corridor, with minimal and if possible no retraction. And finally, preserving the normal surrounding structures and function as much as possible during tumor removal.

The first surgical explorations of the insula were achieved after grossly removing the temporal and/or frontoparietal opercula. Some decades later, and with the advent of microsurgical techniques, the transsylvian fissure approach was shown as an optimal method of exploration for removal of insular tumors. The fundamental principles of this atraumatic approach allow a successful tumor removal without causing damage to the surrounding normal structures. Thus, and supported by the increasing technological developments in the field of neuroimaging and perioperative tools, achieving complete removals of intrinsic insular tumors has become feasible with low rates of permanent neurological deficits, using a meticulous microsurgical transsylvian route based on the regional insular anatomy. However, in the last years some groups have shifted this anatomical concept to a functional resection. In this sense, these authors propose approaching the insular lobe through the removal of healthy tissue from the frontoorbital, frontoparietal and/or frontotemporal opercula during awake procedures, justifying this methodology with a better and faster exposure of the insular surface. The most commonly reported neurological impairments after insular tumor resections are hemiparesis and speech disturbances. These complications are usually attributable to the disruption of the insular surrounding healthy structures or their blood supply, rather than the insula itself. Hemiparesis or speech disturbances may arise in case the rolandic or the precentral arteries or its branches are inadvertently damaged, vasospasm or temporally obstructed. Although uncommon, these mechanisms have been reported. The popularization of awake procedures has allowed notifying intraoperatively some of the causes responsible for speech disturbances. Malak et al. reviewed the temporary evolution of the most common neurological impairments in different series, highlighting two important findings22. First, the incidence of permanent deficit was lower (3% for hemiparesis, and 1.4% in case of speech problems) than immediately after the surgical procedure (17% for hemiparesis, and 16% in case of speech problems). Secondly, all cases of permanent disturbances were related to an infarct in the territory of the lenticulostriate arteries. From the above exposed findings, it becomes clear that most of the transient motor and speech impairments are caused by direct or indirect retraction of the opercular areas and temporary ischemia secondary to M2 and/or M3 branches supplying these cortical regions. A possible risk that should be also considered comes from the fact that the medullary branches arising from the M4 segments travel through the opercula, to feed certain areas of the corona radiata. There is no control of these small vessels during a transopercular approach. Thus, it seems clear that this transgyral or transopercular corridor indefinitely requires of awake surgery to check the available functionality of the alleged opercula. In our opinion the discomfort for the patient and surgeon, and the stressful atmosphere that these procedures carry, do not justify removing healthy tissue to get a better initial view of the insular lobe. In our opinion the transsylvian approach followed by a wide splitting of the fissure avoids the use of mechanical retraction, and better accomplishes the microsurgical principles, as it spares the healthy opercular tissues in cases of tumors mostly affecting the insula itself with none or small opercular invasion. Furthermore, the dissection of the MCA branches from the bifurcation provides a direct control and visualization of all its branches, as well as their relationship with the insular, and medial and lateral opercular surfaces. On the other hand, we reserve the transopercular exploration and removal of insular gliomas for those cases in which the tumor encroaches on a certain area of the adjacent opercula, first, attacking them on their neocortical opercular expansions (frontal and/or temporal) and finally performing a subinsular subpial resection through the space created, entering the insular component below the superior, anterior and/or inferior periinsular sulci. Preparing the surgical field The patient is positioned supinely with the chest raised 30 degrees, and the head is secured with the Mayfield and rotated 30-45 degrees to the contralateral side. A classic frontotemporal incision is performed, slightly extending it posteriorly to reach the posterior aspect of the Sylvian fissure. The temporal muscle is fully detached and retracted posterolaterally. One or two burr-holes are placed, 3-4 cm behind the pterion, and at the level of the frontosphenoidal suture. Two semicircular craniotomy lines are performed anteriorly and posteriorly until the level of the lateral aspect of the sphenoid wing, which is finally drilled. Once removed the bone flap, the remaining sphenoid wing is drilled away to allow an appropriate dural flap retraction and a comfortable access to the anterior Sylvian point and adjacent posterior frontobasal region. The durotomy is performed in a semicircular fashion with the base at the level of the sphenoid. A posterior rectilinear extension is performed from the tip of the first incision, and parallel to the Sylvian fissure. This posterior extension allows a larger exposure of the posterior aspect of the Sylvian fissure, and a comfortable view of the frontoparietal and temporal opercula. Once the lateral cortical hemispheric surface is exposed, the first recommended maneuver consists on releasing cerebrospinal fluid (CSF) from the basal cisterns, to relax the brain. This goal can be achieved with the aid of a fine bipolar coagulation forceps and a cotton pledget slightly introduced parallel to the posterior frontoorbital gyrus until reaching the lateral membrane between the optic and olfactory nerves. A small incision is then performed, entering the lamina terminalis cistern and allowing the exit of CSF. This initial maneuver will let us release CSF during the procedure when needed. In our opinion there is nonsense for the use of frameless stereotactic neuronavigation systems to center this craniotomy, so that the anatomical landmarks for this approach are constant. Moreover, the control of resection and intraoperative aid of these systems loses its accuracy after the durotomy and the release of CSF due to the brain shift. After releasing CSF from the basal cisterns and relaxing the cerebrum, a nice view of the lateral cortical surface is achieved. In this step, it is important to identify some anatomical landmarks to orient the next stages of the surgical procedure. The most relevant are the Sylvian fissure and the opercula. Transylvian approach A pure transylvian transinsular route is our favorite approach for tumors mainly affecting the insula (type 3A) and adjacent paralimbic–frontoorbital, temporopolar areas (type 5A) and/or parts of the limbic system (type 5B). Note that all the mentioned extensions are paralimbic – limbic areas, not directly facing the brain lateral convexity. After dealing and decompressing the main insular component through the Sylvian fissure, the neighbor invaded paralimbic – limbic regions are better approached, navigating through the periinsular sulci sparing the adjacent neocortical opercula (frontal, frontoparietal and temporal). Sylvian fissure splitting

With the aid of the current microsurgical techniques and operative tools, splitting the Sylvian fissure can be precisely and successfully carried out, avoiding injury of the adjacent vital structures and thus preserving their functions. Before its opening, the careful preoperative analysis of the available imaging studies and the use of the intraoperative ultrasound, allows the surgeon defining the rostrocaudal tumor borders to determine the extent of the needed Sylvian fissure opening. However, in some cases, mainly when large tumors occupying the entire insular lobe, it may be necessary to open the whole length of the fissure.

As it was already described in the anatomy section of the first part of this manuscript, the Sylvian fissure is enclosed in its entire length by the outer arachnoid membrane. The superficial Sylvian veins are present in most of the cases delineating the Sylvian line, providing a perfect reference to identify it. In 80% of the hemispheres, the SSV lays 4 mm below the fissure, allowing an easier and safer frontal entrance into the cistern. These veins are usually boxed between the outer arachnoid membrane and the lateral Sylvian membrane, slightly attached through arachnoid bridges to the latter. Nevertheless, this venous system reveals great variation in location, number, collaterals, length and drainage routes50. The most clear landmarks in order to define the different components of the insuloopercular segment of the Sylvian fissure should be the pars triangularis, opercularis and subcentral gyrus, however, this cortical architectonics is not easily distinguishable in a surgical field during exploration55. Thus, a precise understanding of the regional venous anatomy remains imperative.

Although it is well known that the veins of the brain have a rich collateral system, one cannot predict during surgery whether a vein can be sacrificed without consequences of venous infarction in related areas. A precise knowledge of the vascular patterns at this level remains imperative and may help the surgeon to decide the exact point where performing the arachnoid entrance. In this sense, a deep neuroanatomic study of the most common patterns and anatomical variations of the Sylvian vessels, combined in certain cases with the use of Indocianine Green technique (ICG) is a source of interesting information. The latter intraoperative tool provides information about the arterial and venous architectonics, helping to ensure the Sylvian fissure position. The M3 branches coming from the deep of the Sylvian cistern reach the opercular surface and curve 90º upward and downward in order to become M4. This pattern is constant, and may assess deciding the location for the arachnoid incision in the dorsoventral plane. Moreover, a comprehensive understanding of the venous flow directions, as well as the presence of collaterals can be also achieved through this technique. As it has been mentioned, the incision is safer performed in the frontal aspect of the fissure, however different flow venous patterns may recommend moving the superior Sylvian vein superiorly. In the rostrocaudal line, the fissure is usually incised at the level of the Sylvian point, where the horizontal, ascending and posterior rami of the Sylvian fissure are together just below the tip of the pars triangularis. However, these landmarks are not usually visible, and this is the reason why again the vascular pattern is so important. This area can also be defined as the point where the stem of Sylvian fissure and the insuloopercular compartment join. Yasargil locates the Sylvian venous confluence approximately 10-15 mm distal to this area, where the temporal and frontal tributaries drain into the Sylvian vein. The location of the prefrontal and middle temporal arteries usually emerge in the lateral hemispheric surface at this same level. Ribas et al. demonstrated its constant location, and the natural enlargement of the fissure due to the retraction of the triangular part of the inferior frontal gyrus32. Large tumors, especially when located in the anterior insular lobe, could make the splitting easier and push the insular apex just underlying the outer arachnoid membrane (10% of the cases). The location of the Sylvian point referred to the pterion is just slightly posterior in the horizontal plane. They also demonstrated the projection of the central sulcus into the fissure was located 2.36 cm of average posterior to the Sylvian point, just behind the venous confluence, highlighting the safety of this area to start anteriorly the Sylvian fissure splitting. Moreover, its estimation represents an acceptable mark, because Broca’s area is located just posterior to this point. Thus, the Sylvian point represents an extremely useful landmark to assess the Sylvian fissure splitting. Exploring first in a deep direction soon exposes the insular apex, while the limen insulae and the main MCA division remain deeper, 10-20 mm perpendicular to the Sylvian point itself. These neurovascular structures represent the first reliable deep anatomical reference points. Continuing the dissection over the surface of M1 will lead to the ICA bifurcation, from where the opening of the fissure will be taken from inside to outside, and the suprasellar cisterns can be reached. Every space gained in the depth of the cistern, is maintained opened through round cottonoids, which allow separation of the opercular lips, so avoiding the use of self-retractors. The posterior extension of the splitting will be defined depending on the vascular pattern and the posterior extension of the tumor. This maneuver will be performed in the same manner, working from inside toward outside. This posterior extension exposes the lateral aspect of the insular lobe. Generally, the frontoparietal operculum covers more surface of the insular cortex compared with the temporal operculum46, and the distance from the lateral surface of the hemisphere at the level of the Sylvian fissure slightly increases in a rostrocaudal direction. Thus, the depth of the inter-opercular sulci at the level of the suborbital gyri and planum polare is 10-20 mm; 25-40 mm at the level of the subopercular gyrus; and 35-50 mm at the level of the subcentral and transverse parietal gyri. This is the reason why the Sylvian fissure splitting is easier when performed starting at the level of the Sylvian point, first directed anteromedially to open the stem, and then posteriorly from the depth to the surface. Subopercular areas exploration After the fissure splitting, the tumor itself on the insular surface, and its relationship with the subopercular aspects will be exposed. Understanding the general patterns of these relationships are helpful to keep important surgical landmarks during all the procedure, but also to decide which area of the Sylvian fissure to be opened in cases of tumors occupying the different regions of the insular lobe. Thus, it could be resumed that lesions mainly centered in the upper anterior portion of the insula would be better approached through the horizontal and ascending rami at the level of the Sylvian point, while the posterior rami and adjacent sulci will provide a direct path to the remaining posterior aspect of the insula. The Sylvian fossa represents the space created between the insular surface and the inner aspect of the opercula, and has two limbs. The superior limb between the insula and the frontoparietal operculum is limited superiorly by the superior peri-insular sulcus, while the inferior limb between the inferior aspect of the insula and the temporal opercula is limited inferiorly by the inferior peri-insular sulcus. In this sense, the dorsoventral extension of insular tumors is also important, so anteriorly located tumors usually extend more superiorly, while posterior tumors extend both superiorly and inferiorly, requiring wider Sylvian fissure openings. Tumor debulking Insular tumors usually stay within the thickness of the subcortical insular region, between the extreme and external capsule, during their growing. Moreover, most of these lesions do not initially transgress the pial surfaces, being their borders usually defined by the peri-insular sulci. This intrinsic nature of insular tumors makes them affect the regional anatomy of this region by expanding the insula confined by the peri-insular sulci, which are usually deepened. The insular apex and surroundings areas are generally pushed away towards the outer arachnoid membrane sharpening the pyramidal shape of the lobe. All these intrinsic features make extremely difficult to expose the peri-insular sulci just splitting the fissure, forcing to develop and carry out a carefully detailed and elaborated surgical strategy. Thus, the next step of the surgical procedure will consist on a central tumoral debulking to relax the voluminous insular region. The transsylvian approach presents the inconvenient of not being able to expose the entire surface of the insula, and forces the surgeon to create limited working spaces of 20-40 mm deep and 15-30 mm wide, depending on the area. These working spaces are maintained opened by using 2-3 round cottonoids placed in strategic positions. When the tumor partially maintains the cortical insular anatomy, the fact of finding anatomical landmarks before starting the resection is easier, and the most appropriate strategy seems localizing the MCA bifurcation at the level of the limen insula, from where the devascularization of the most proximal short and medium insular perforators start. However, some tumors break the pial edge spreading along the Sylvian fossa, or expand so much the insular gyri, that the M2 and its insular branches remain encompassed in the tumoral thickness. In these situations, the tumoral debulking starts without initial devascularization and it must be performed through a slight suction until the subpial level of the first arterial branch is encountered. Then a direct subpial devascularization can be achieved, and that branch can be subpially skeletonized towards its proximal segment, removing pathologic tissue until reaching the MCA bifurcation. In any case the initial debulking is performed at the level of the insular apex, where the MCA superior and inferior trunks start giving their first main branches. Some windows are created between these arteries, always achieving the same deep plane. In this first stage, the depth of all the resection windows should be equal in order not to lose the orientation, and keep certain harmony. The micro-doppler should be used before manipulating any important branch to check its flow, and again after having worked on its surroundings, with the aim of learning and increasing our experience about how to deal with these vessels. Anyway, topic applications of nimodipine are recommended to avoid vasospasm. Once or even during the devascularization and tumor removal, the insular veins are coagulated. Another useful method recently incorporated to our intraoperative armamentarium, is the use of ICG, which in our experience has been extremely helpful to confirm some vasospasm situations. Removal the spreading arms of the insular component After the initial central debulking at the level of the anteroinferior aspect of the insula (inferior extension of anterior and posterior short gyri) is accomplished, the mobilization exploration of the peripheral regions around the peri-insular sulci is facilitated. Exploration of the Inferior Peri-insular Sulcus and Limen Insulae Areas The inferior limb of the insular fossa is usually easier to explore due to its closer relationship with the central aspect of the insula (14.8 mm from the insular apex; 19.1 mm to the superior peri-insular sulcus)46. With the aid of a flat cottonoid, the anteroinferior extension of the long gyri can be pushed downward, and the inferior trunk of the deep sylvian vein within the inferior peri-insular sulci is exposed. This anatomical landmark will represent the inferior limit of our resection. In cases in which a small part of the inner aspect of the temporal opercula, or the parahippocampal and/or fusiform gyri are invaded, we recommend performing this transylvian route, reserving the transopercular one when the tumor reaches the neocortical regions of T1, T2 and/or T3. At this stage, the resection will be performed following the tumoral tissue from the insula millimeter by millimeter. This is the key of the stay within the tumor technique. Exploration of the Anterior Sylvian Point Area Debulking and decompression of the central and inferior insular areas facilitates the exploration of the anterosuperior and superior aspects, located beneath the frontoorbital and frontal aspect of the frontoparietal opercula respectively. It is extremely important to maintain a high level of concentration during all the surgical steps but we must sharpen our orientation especially in these stages, because the tissue removal has already distorted the anatomy and may confuse our vision. To achieve this purpose, remembering some anatomical landmarks is mandatory. The anterosuperior aspect of the tumor represents the area around the anterior Sylvian point, where the anterior and superior peri-insular sulci join. Moreover, the subtriangular and the anterior short insular gyri are in continuity at this level. The prefrontal artery arising from the superior trunk usually takes this path to reach the cortical surface. The orbital and opercular branches also arising from this trunk, follow together the anterior peri-insular sulcus, and can also represent valid landmarks. The anterior peri-insular sulcus can seem quite deep, especially if the insular apex protrudes enough into the fissure13. After devascularizing this region, the tumor is suctioned until reaching its extension at the level of the aforementioned sulcus. Cases where the tumor spreads to the frontoorbital and even rectus gyri, are better managed through transopercular routes in our experience. Exploration of the Posterior Sylvian Point Area The posterior aspects of the superior and inferior peri-insular sulci are the most hidden areas in the insular lobe, and its surgical access remains quite difficult. Some authors propose opercular retraction, or even opercular removal to gain its access. In our opinion, these maneuvers may originate important functional consequences, as has been described by Lang et al., who reported speech impairments during tumor removal in awake patients, and that were solved after the retractors repositioning. Following the transylvian transinsular technique, and after having debulked the central, inferior and anterosuperior aspects of the tumor, a soft maneuver of pushing the posterior aspect downward with the aim of a flat cottonoid and the suction tube, the region of the posterior Sylvian point can be explored. Then the described proceeding for devascularization is performed. In this area, it is of extreme importance to realize the presence of some long perforator insular arteries, which should be spared, as they are demonstrated to reach the corona radiata. This is one of the most challenging steps of the procedure, but it is facilitated by the fact that all the path of the M2 and M3 arteries has been skeletonized. At this point the continuous millimeter by millimiter peeling and subcortical stimulation checking is mandatory, as this is the closest area to the genu and posterior limb of the internal capsule, and here we must achieve a ‘functional resection’. The classic proposal consists on removing thin layers of tissue with the CUSA and checking the relative location of the corticospinal fiber tracts through the subcortical stimulation. As this procedure maybe tiring and may present some pitfalls due to the difficulty to map every single piece of tissue removed, we have recently introduced in our practice the use of the CUSA-stim which lets us remove thin layers of tumoral tissue with the CUSA at low intensities, while having a continuous subcortical stimulation at every single point. Once the posterior tumor extension has been achieved, we use to check the viability of the dissected MCA branches through micro-doppler, and topic nimodipine should be applied in case of vasospasm suspicion. Every step during these procedures increases in difficulty, and probably the most challenging stage arrives when dealing with the tumor borderlines and deep limits resection, and the healthy surrounding tissues. Still nowadays, there is no available definite method to differentiate the borderline between normal and brain tissue, and the surgeon must sharpen all his/her senses on detecting changes in color, consistency, and texture of the tumor tissue because this is often critical in determining when the resection should be stopped. This is usually the last part of the procedure, not only in the transylvian routes, but also when a transopercular approach is the choice. Thus, this stage will be covered at the end of the transopercular approach Transopercular approach A transopercular subinsular route is our main choice for the less common tumors confined to the insula and expanding to the inner border with the adjacent opercula (3B), which seem to grow mainly in more complex insular regions (middle and posterior). Note that unlike the 3A, 5A and 5B lesions, all the mentioned extensions are directly affecting the opercula at the brain lateral convexity on one or both sides of the Sylvian fissure. This is also our favorite strategy when dealing with opercular tumors invading the insula. In these cases, we start removing the opercular part, generally after having mapped the cortical areas close to the lesion, in awake conditions when language functions are at risk of being present near these regions. Once the opercular part has been decompressed, we cross the periinuslar sulci and start performing a subinsular subpial removal. Transopercular tumor entry Following our line of reasoning, insular tumors invading the orbitofrontal, frontoparietal and/or temporal opercula, are better approached in our experience through the transopercular route. Thus, the first step consists on choosing the best strategy to remove the opercular compartments and then create a field wide enough to enter the subinsular aspects through the periinsular sulci. Therefore, a strong neuroanatomic knowledge combined with a careful preoperative study is the key. Moreover, and independently of the number of opercular sub compartments affected by the tumor extension, when dealing with lesions in the dominant hemisphere, we use to perform an awake mapping of the whole opercular extension to mark the functional and non-functional areas. When the tumor involves the non-dominant hemisphere, we prefer deciding an awake or non-awake mapping depending of the patient’s features and predisposition. After awake or non-awake intraoperative cortical stimulation, the opercular surface is labelled and the cortical entry points are chosen based on anatomic and fuctional features. When only one of the opercula is affected, the strategy is clear, this operculum will be removed until reaching the related periinsular sulcus. However, when two or even more sub compartments are affected (ie. the superior temporal gyrus and the pars orbitalis and triangularis), the strategy may be difficult. In these cases, unless other conditions affect our decision, we prefer to start the removal through the temporal side of the fissure, as this will lead us to expose the MCA bifurcation and the MCA inferior trunk at the level of the inferior periinsular sulcus. If the whole neocortical aspect of the temporal lobe is invaded a temporal lobectomy is performed, sparing the structures medial to the collateral or the lateral occipitotemporal sulcus, depending of the fusiform gyrus invasion. When the temporomesial structures are also affected, the temporal lobectomy will be complete, removing the parahippocampal gyrus always below the level of the temporal horn floor with the aim of sparing as much as possible the optic radiations. At this stage, the P2 component of PCA is generally exposed laterally above the free edge of the tentorium once the uncus is removed. Once the temporal lobe invaded areas have been removed, a part, or the whole inferior periinsular sulcus is exposed as well as the inferior third of the insular surface with the inferior and sometimes also the superior trunk of the MCA. The next step will consist on attacking the orbitofrontal and/or frontoparietal opercula. Most of these 3B tumors affect anterior pars of the frontal operculum as the pars orbitalis, triangularis and even sometimes opercularis. A few of them may affect the supramarginal gyrus. The pars triangularis and orbitalis may be removed in cases in which the mapping did not show any functional response. This will lead us to the posterolateral frontoorbital gyrus and to the anterior insular point, where the superior and anterior periinsular sulci join. Lesions invading the frontooribital gyri will require a deeper subfrontal removal, and some of them may even affect the gyrus rectus, which will finally guide our resection to the interhemispheric basal compartment with the A2 parts of the ACA. When moving posteriorly and deeply our removal, the CUSA will guide us to the straight angle formed by the anterior and superior periinsular sulci at the anterior insular point. As generally F2 is not invaded by these tumors, the inferior frontal sulcus represents a good anatomical landmark to guide our superior subpial resection. At this stage, the opercular tumor removal will be completed, and the inferior, anterior and part of the superior periinsular sulci will remain exposed just dorsal to the MCA bifurcation. The insular component itself will stay covered by two layers of arachnoid, theoretically protecting the MCA branches from potential vasospasm. However, in one of our cases the grid over the primary motor area detected a progressive fall of the superior limb and face motor response. As the subinsular aspect had not been approached and the LSAs where not exposed yet, we decided to look for vasospasm from some of the MCA branches and the ICG confirmed that the MCA superior trunk was completely occluded. The use of topic nimodipine and a careful massage through a nimodipine – impregnated cottonoid resulted on the ICG and neurophysiologic improvement. Subinsular transopercular resection After removing the opercular compartments, the insular component of the tumor is directly faced just crossing below the exposed periinsular sulcus. At this stage, certain changes on the scope angulation will be required to look for the better view of the subinsular aspects of the tumor. This subpial resection will be carefully carried out through the CUSA-stim at very low intensities, and even only with the normal suction pipe (also with a tip implemented electrode). As the subpial resection advances, the MCA branches will stay together surrounded by the subopercular and insular arachnoid layers in a bunch – fashion. When the temporal as well as the frontal opercula are removed, this work may be accomplished through the temporal and frontal sides, making it easier and safer to be completed. Deep limits resection As it was previously mentioned, this is usually the last and probably the most difficult stage on the tumor removal. It can be accomplished through the ultrasonic aspirator, peeling away the tumor layer by layer. However, this inability to perceive the tumor borderlines may ruin the rest of the surgical procedure mainly due to a pair of reasons. Firstly, it can be responsible for incomplete resections. This is an important drawback when dealing with insular low-grade gliomas, in which a total resection has been demonstrated to have the most impact on patient's long term survival, preventing the transformation to higher grades, and solving the seizures. Secondly, this inability may also be responsible for damaging the surrounding healthy neurovascular structures, originating in certain cases important, and sometimes definitive, neurological impairments. The functionality of the insula itself has not been clearly understood yet, and although some authors have demonstrated certain degrees of speech arrest after direct cortical stimulation of the anteroinferior region of the insula, the large number of reported series confirm the safety of total removal of insular tumors. Thus, it seems obvious that most of the avoidable complications are related with the disruption of the surrounding structures and mainly their vascular supply. The tumor border is difficult to be understood, but two main intraoperative weapons are useful for this purpose. The 5-ALA could lead us to the tumor invasion limit in cases of high grade lesions, and the CUSA-stim will show the fuctional limit. Depending on the relative deep location at the subinsular compartment, different strategies may be followed. Central edge Inside the region defined by the normal projection of the peri-insular sulci, the claustrum is very difficult to distinguish. This is the reason why a basic anatomical landmark to stop the deep resection is the lateral face of the putamen. Theoretically, the only available technology that can accurately define this structure during the surgical procedure is the intraoperative MRI. The feelings and experiences gained after having performed brain dissections and surgical procedures in this area, provides the surgeon the capability to appreciate the change of the consistency, color and vascular pattern when the putamen has been exposed. Moreover, and due to the different architectonics between these compartments, the tumor limit is always sharply defined in this region, fact that allows following this dissection plane along the entire length of the putamen. Inferior Edge Acceptable anatomical landmarks deep into the anterior half of the inferior peri-insular sulcus are the dorsal surface of the amygdala, and the ependymal layer of the temporal horn. Posterior Edge It has been previously mentioned, that the posterior and anteroinferior edge of the tumor represent the most challenging points during this kind of procedures. The posterior half of the superior peri-insular sulcus is found to be in close relationship with the fibers from the corona radiata entering the internal capsule. Damaging these fibers could also lead to serious postoperative neurological impairments. Some intraoperative tools have been developed to avoid these problems. However, no intraoperative device has allowed distinguishing this highly functional fiber system. The motor evoked potentials seem an adequate tool to promptly detect any motor problem. However, vascular damage cannot be solved even when fast detected. On the other hand, manipulation and retraction maneuvers causing motor impairments, represent the ideal situations that can be solved with the use of intraoperative motor evoked potentials. The direct subcortical stimulation can theoretically predict the deep position of the motor fibers in the posterior limb of the internal capsule. Duffau et al. used this intraoperative tool in a series of 51 awake patients, carrying out the tumor removal as far as a positive response was found. In the same series, the authors could stimulate certain subcortical areas, whose stimulation originated different speech problems. Although in a late postoperative period the neurological impairment rates for this group were equivalent to other reports, in the immediate postoperative, the 59% of the patients demonstrated worsening of their previous neurological conditions5. In our opinion there is no need to extreme the subcortical resection to these healthy tissues, and that is the reason why we argue for an anatomic approach (stay within the tumor volume) during the subcortical resection. Moreover, insular tumor resection requires a calmed atmosphere, and a high concentration level of the surgeon to keep the orientation during every step of the procedure, fact difficult to achieve when dealing with awake surgical procedures. Leclercq et al. recognized in a more recent study the number of intraoperative stimulations they performed was limited because of patients in this condition couldn't easily afford a long surgical procedure. Recently we have started to routinely use the continuous direct subcortical stimulation through the tip of the CUSA (CUSA-stim) in the posterosuperior limit of the lesion under general anesthesia, to check our thinking and the previous 3D picture we elaborated in our mind. The recent advent of DTI-based tractography has represented a great advance in neurosurgical planning. This technique allows the surgeon to study him or herself the 3D relationships between the posterior limb of the internal capsule and the tumoral volume itself. In our experience, this technique is still increasing its accuracy, and has its main value as a preoperative and postoperative tool. We do not use to trust neuronavigation devices in cases of deep resections of intrinsic brain tumors due to the lose of accuracy during the superficial removal and CSF release (brain shift). The preoperative tractography is carefully analyzed to understand the deep relationships, but for the time being we are paying special attention to the postoperative tractography, which allows us to integrate the preoperative thinking, with the intraoperative findings and the result, so increasing our surgical experience and the anatomical knowledge in real conditions. Anteroinferior Edge The lenticulostriate arteries (LSAs) represent the most appropriate anatomic landmark in this region. Certain tumors may envelop the LSAs, however, none of them goes medially. A careful examination of this region under high microscope magnification is mandatory with the goal of preserving all these arterial branches. It has been largely reported that most of the definitive neurological impairments after insular tumors resection are related with ischemic events. The obliteration of these branches may originate different degrees of motor disturbances including hemiplegia due to a deep stroke in the internal capsule. Again, the anatomical knowledge and its combination with the available preoperative images and some intraoperative tools is the key to manage this stage. The use of intraoperative micro-doppler as well as the ICG can be helpful to assess the position of the LSAs. Moreover, the emergence of a group of radiating small veins indicates the close proximity to this deep arterial system57; however, this finding cannot be realized in every case. Some authors defend the use of awake procedures to check possible worsening of certain functions; although, it seems clear that those procedures cannot predict ischemic events. Summary A direct surgical approach is nowadays the most appropriate way to treat insular gliomas. The technical development has provided many tools to assist the pre- and intraoperative management of these lesions. However, surgeons must assume that none of these devices is enough to take a decision by itself, and the key point remains on learning but also criticizing their results. The most severe complications after insular gliomas removal are some postoperative neurological impairments, mainly motor and speech disturbances. These problems may appear due to parenchymal and/or vascular reasons. Awake procedures provide information about the functionality of certain brain areas and may assist the resection of non-functional opercular regions to achieve wider exposure of the insular surface. However, these mapping techniques cannot predict the neurological impairments caused due to vascular reasons, which should be carefully taken into consideration. In our opinion, the transopercular and transylvian approaches should never be understood as opposite, and the controversies about each of them should be overcome. Both surgical routes are complementary, and both should be studied and understood as tumors reaching the opercular regions are more likely to be removed through a transopercular approach, while purely insular and insulo limbic tumors could be better faced after splitting the Sylvian fissures in different degrees. Despite the feasibility to remove these tumors without damaging the important microanatomical environment in which they are included, the surgeon's anatomical knowledge and understanding of the pre, intra and postoperative available modern devices, aided by the neuroanesthesist and neurophysiologist assessment will result on improving the surgeon's experiences and reaching a comprehensive understanding of this complex anatomical region.