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Review Article

# Impact of Postsurgical Disconnection in Aggression Disorder Treatment, Latin American Single Center Experience: A Neuronal Connectomics Analysis

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## Abstract

Recent advancements in the study of human behavior, along with significant technological progress, have provided a more complete understanding of the neural circuits involved in aggressive responses to external stimuli. Notably, aggression as a voluntary behavior differs from reactive aggression in its neural connections and cerebral connectomics. Aggression is identified as part of a series of responses to stimuli that pose a potential threat to an individual's physical integrity. By identifying the neural pathways involved in pathological aggression, we can modify this behavior by disrupting these pathways through functional neurosurgery. This study aims to demonstrate, through neuronal connectomics, the effects of postsurgical disconnection following functional neurosurgical procedures designed to treat aggression disorders. For many years, brain function was believed to result solely from the activity of specific cortical areas, which conditioned cognitive responses. However, recent advances in neurology, neuroimaging, neuropsychology, and neurosurgery have shifted our understanding of brain function, revealing a more complex network of connectivity. Despite we are now able to predict the location of primary cortical areas, patients may still experience unanticipated deficits in functions like judgment or memory after surgery. This suggests that traditionally silent regions of the brain may be more anatomically intricate and functionally redundant than previously understood. One of the significant advancements in neuroimaging is Diffusion Tensor Imaging (DTI), which has revolutionized psychiatric surgery, neuroendoscopy, and neuro-oncology. DTI enabled the formation of the Human Connectome Project (HCP), a large-scale initiative that provides detailed data on the brain's connectivity in healthy individuals. The most recent HCP findings have reclassified cortical regions previously described by Brodmann, based on functional connectivity, myelination, and cortical thickness. These advancements contribute to a much more detailed framework for studying brain function and its anatomical organization. This paper explores how these developments in connectomics and neuroimaging are being applied to the understanding and treatment of aggression disorders through functional neurosurgery.

## Keywords

Aggression Disorder, Functional Neurosurgery, Human Connectome Project (HCP), Neurosurgery and Aggression, Aggressive Behavior Treatment, Brain Connectomics

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# 1. Background

For a long time, it was thought that brain function was summarized in the work of different cortical areas, which conditioned a cognitive response depending on the brain areas that were specifically activated. However, advances in the study of neurology, neuroimaging, neuropsychology, and neurosurgery have changed our classic view of brain function, as well as the machinery that conditions this function. Typically, neurosurgeons have the ability to predict the location of primary or eloquent cortical areas, such as the language area and motor areas. However, after performing a neurosurgical procedure correctly, patients may notice deficits in functions such as judgment or memory, which were not anticipated when planning the procedure. This suggests that the areas that we traditionally called silent are anatomically much more complex and redundant than what was previously elucidated by them. [1] One of the current advances in neuroimaging is the DTI (Diffusion Tensor Imaging) sequence in magnetic resonance imaging, which is used to perform and develop procedures in psychiatric surgery, as well as in neuroendoscopy and neuro-oncology. [2-5] This technique led to the formation of "The Human Connectome Project" (HCP) which is a large-scale, multi-institutional, publicly-funded program that aims to publish data related to the brain connectivity of healthy individuals. [6] The most recent HCP report gave us a map of cortical regions that reclassified K. Brodmann's cortical areas, based on functional connectivity, degree of myelination, cortical thickness, and correlation with previously published studies on the subject. [7] This effort increased the number of crustal regions from 47 originally described by Brodmann to 180 different crustal parcels. As a result, a much more comprehensive framework was created for the study of brain function and anatomy. [7]

# 2. Cortical Areas and Neural Networks

## 2.1. About the Cerebral Cortex, Cortical Areas and Parcels

The spatial distribution pattern of neuronal bodies is called cytoarchitecture, and of myelinated nerve fibers is called myeloarchitecture. [9] In the cerebral cortex, different layers of neuronal bodies (parallel to the cortical surface) and myelinated fibers (in vertical, horizontal, and oblique orientation) can be identified. Neuronal bodies can also be observed in a vertical arrangement concerning the thickness of the cortex, forming an arrangement of small columns. [8] Most cortical regions have a 6-layer architecture (isocortex), with the notable exception of the motor cortex, where a layer IV is not observed in healthy adult brains [9].

The non-isocortex (allocortex) has a greater number of layers (e.g., the entorhinal cortex) or a smaller number of layers (hippocampus) than the isocortex. These regional differences in the cytoarchitecture of the cerebral cortex allow cortical parceling into defined microscopic areas. Both cytoarchitecture, myelin density maps, and myeloarchitecture show different aspects of connectivity in the cerebral cortex. Taking into account these aspects of the architecture of the cerebral cortex, we can develop current imaging methods that give us information on these three aspects and in turn, be able to measure or represent them volumetrically to be better understood. From this reasoning derives the realization of cytoarchitecture parcels, myeloarchitecture parcels, and myelin density parcels using High-Resolution Magnetic Resonance. As the first reference to specific cortical areas, Brodmann paved the way for later researchers in the field to polish the results he initially published. With subsequent scientific advances, details were observed in Brodmann's cortical description, such as the probable loss of frame of the edges when describing cytoarchitecture. [10, 11]

## 2.2. About Brain Fascicles and Neural Networks

Tracts that interconnect cortical areas of the same hemisphere are called association tracts, found in the sagittal plane. The tracts that send axons to subcortical structures are called projection tracts and are located in the axial plane. The tracts that interconnect structures from one hemisphere to the other are called commissural and are located in the coronal plane. Finally, the tracts that interconnect adjacent cortical areas or within the same brain lobe are called short or U-fascicles, these do not have a specific arrangement in any anatomical plane. [13, 14]

Individually, each fascicle is responsible for the connection of structures depending on their direction as mentioned above. However, they can also be part of a set of tracts which, by adding their cortical connections, direction, and anisotropy, become a Neural Network with a specific purpose. In addition, some parcels are spliced systems, and activation between neural networks depends on the cognitive context. [1, 13, 14]

# 3. Complex Theory of Neural Networks

## 3.1. Introduction to the Complex Theory of Neural Networks

The term complex in neural networks does not mean that they contain many parts, are difficult to study, or are difficult

to understand. On the other hand, the term complex network system refers to large networks with adaptive, diverse, interconnected, and interdependent parts. In other words, to call it complex, a system must have a network of interconnected entities that interact with each other, usually in a nonlinear fashion. [1-14]

Complex systems have characteristics that linear, randomly connected, or regularly connected systems do not. One of the most notable properties of complex systems is the so-called emergence, which is when a complex network and its nonlinear dynamic components exhibit macro-scale behavior, which cannot be predicted a priori by performing an analysis of the parts of the network individually and the connections between them. [15] Most higher mental functions have this emergency characteristic that does not allow us to predict their function or behavior by analyzing the basic components of the network that supports that function. [15]

Two other characteristics that are present in networks are segregation and integration. By segregation, we mean how well a network can separate into the community of constituent nodes. A standard measure for determining segregation is the so-called.

Clustering, which we can define as the tendency of nodes to have neighboring nodes that are connected (for example, several of your friends are friends with each other). [16]

The integration of a neural network is measured by the connectivity between different regions. One way to define this term is by the number of Edges required to move an impulse from an undefined node to a given node. The average of these values across all nodes in the network is known as the Average Path Length. [16]

But why can certain areas be sacrificed in brain surgery without presenting an obvious neurological deficit? Or why in functional neurosurgery the result in both non-reversible and reversible procedures in the same places express different postoperative results? These questions have not yet been fully clarified, however, we are on the right track to elucidate these questions, among others, even more in the air of the neurological field.

### 3.2. Nodes, Edges, Hubs and Rich Clubs

Within the components of a neural network, we can define several technical concepts that are analogous to those present in the technical glossary of computer networks and the internet. The terms are as follows; Node, Edge, Hub, and Rich Club.

As a Node, we can define the brain element capable of processing certain information and offering a response according to a weight or value, from which a signal, response, or output result originates. [17] Edge is defined as the junctions between neurons (Nodes) that send a certain result from one Node to another, studying different elements of the sent signal or delving into a final response. Hub can be defined as the (usually high) connectivity between a specific node and other nodes. [17] Rich Club can be defined as the high connectivity that can exist between one node and another node and vice versa (unlike the Hub, Rich Club also determines the reciprocal connection with the home node). [16] There is another term, the so-called Layer, which is defined as the group of neurons that are responsible for a specific process, for which they have been trained. As we have already observed, the concept of Neural Networks can be quite difficult if we do not clearly understand the basic terms that make up this broad topic.

## 4. Human Connectome

### 4.1. About the Human Connectome

As mentioned above, the Human Connectome Project (HCP) is a multi-institutional collaboration with funding from public funds, which aims to map the functional connectivity of the human brain at different stages of life, as well as in different pathologies, to structurally and functionally understand neural networks for different purposes.

The foundations of HCP fall into two advances in neuroscience at the end of the twentieth century. One is the emergence of complementary MRI modalities to non-invasively structure brain structure, function, and connectivity. Such modalities are, for example, resting-state functional MRI (rfMRI), task-evoked functional MRI (tfRMI), and diffusion imaging MRI (dMRI). The second is the advance in techniques to understand the brain wiring system, inspired by the work of pioneers such as Cajal at the beginning of the twentieth century. [18]

### 4.2 About the Human Connectomic Atlas

In recent years, many authors have made an effort to perform a practical imaging count for the connectivity and functional structure of the brain. Cordell M. Baker, M.D. et al., have published the Atlas of Connectomics of the Human Brain, which shows the updated parcels of virtually all brain lobes, as well as the connectivity structure of the vast majority of Complex Neural Networks. This work largely summarizes the connectivity of the cerebral hemispheres, with the characteristic of indicating the function of each parceling described in the atlas, demonstrated by neuropsychological tests, as well as rfMRI and tfRMI. [1]

Based on these findings together with studies of the regions of interest for this study, the structural anatomy, subdivisions and functional connectivity of the reviews in this thesis will be described.

# 5. About the Amygdala and Its Connections

## 5.1. Afferents of the Amygdalar Nuclear Complex

The amygdala is reciprocally interconnected with a variety of subcortical regions through the ventral tonsillofugal pathway and the stria terminalis. The fibers of the ventral tonsillofugal pathway accumulate along the dorsomedial border at the rostrocaudal extension of the amygdala, while those of the stria terminalis join at the ventromedial aspects of the caudal amygdala.

## 5.2. Hypothalamus

The caudal regions of the lateral hypothalamic area exhibit a comparable projection pattern, with fibers ending in the medial nucleus, cortical nuclei, anterior tonsillaloid area, and the medial part of the central nucleus. The lateral division of the central nucleus receives a minor projection from the lateral mammillary nucleus, while the medial nucleus of the amygdala is projected from the supramammillary region. The medial part of the substantia nigra has a small projection in both divisions of the central nucleus, whereas the ventral tegmental area has a very limited projection confined to the lateral division of the central nucleus.

## 5.3. Thalamus and Forebrain

The connections between the amygdala and the thalamus are distinctive, as the afferents of the amygdala are not specifically matched by the thalamus. The paraventricular nucleus, the subparafascicular nucleus, the central nucleus Olszewski's complex, the paracentralis nucleus, the rotundis nucleus, and the nucleus reuniens send a projection to the amygdaloid complex; This ends in the magnocellular division of the basal nucleus, the medial nucleus and the central nucleus.

The basal Meynert nucleus of the forebrain causes a strong projection into The amygdala, along with the vertical and horizontal nuclei of the diagonal band, each makes a small contribution to the amygdaloid projection. Most of these projections terminate in the magnocellular division of the basal nucleus and the nucleus of the lateral olfactory tract, but the ventral intermediate division of the lateral nucleus, the parvicellular division of the basal nucleus, the magnocellular and ventromedial divisions of the accessory basal nucleus, the peritonsillaloid cortex, and the central nucleus also receive minor projections.

## 5.4 Connections to the Neocortex

The amygdaloid complex receives projections from numerous cortical areas in the frontal, insular, cingulate, and temporal lobes. Amygdalocortical projections are more widespread, encompassing even more areas than afferent connections, and include areas in the occipital lobe. In general, the deep nuclei, specifically the lateral, basal, and accessory basal nuclei, are the main receptors and originators of neocortical-tonsillaloid connections.

## 5.5. Frontal Cortex and Insular Crust

Afferent inputs to the amygdala primarily come from the orbitofrontal cortices (including areas 11, 13, and parts of areas 10, 12, 14, and 24) and the medial prefrontal cortices (area 32 and parts of areas 9, 10, 14, and 24). The rostral regions of the orbitofrontal cortex send a very mild projection to the amygdala, mostly directed at the magnocellular division of the basal nucleus, with secondary projections to other divisions of the basal nucleus and the lateral and accessory basal nuclei. The projections from the caudal orbitofrontal cortex are more substantial, widespread, and denser in the caudal parts of the amygdala. Projections from both the orbitofrontal and medial prefrontal cortices are moderately dense and focus on the lateral nucleus, basal nucleus, accessory basal nucleus, medial nucleus, anterior and posterior cortical nuclei, peritonsilloid cortex, and central nucleus. The caudal orbitofrontal cortex sends additional projections to the nucleus of the lateral olfactory tract, the anterior amygdaloid area, and the intercalated masses, while the medial prefrontal cortex projects to the tonsil-hippocampal area. The lateral prefrontal cortical areas (8, 45, and 46, along with parts 9 and 12) send a small projection to the basal nucleus. The amygdala also receives a light projection from the premotor cortex, primarily terminating in the basal nucleus. Projections from the prefrontal cortex follow a rostrocaudal gradient: the most rostral prefrontal areas send weak projections to the lateral nucleus, basal nucleus, and accessory basal nucleus, while the more caudal regions send stronger projections that terminate in various amygdaloid nuclei. Most of these projections originate in the superficial layers, though projections from the orbital prefrontal cortex also arise from layer V. A similar topographic and laminar pattern is observed in corticotonsilloid projections from multiple areas.

The insular cortex projects almost all the nuclei of the amygdala. In fact, it provides one of the strongest cortical inputs for the primate amygdaloid complex. Most of these projections originate in the rostral insular cortices, specifically in the agranular (Ia) and rostral portions of the disgranular divisions (Id). The densest projections are the dorsal intermediate division of the lateral nucleus, and the parvicellular division of the basal nucleus and the nucleus. Ia and Id also provide projections to the other divisions of the lateral and basal nuclei, the accessory basal nucleus, the medial nucleus, the anterior cortical nucleus, the lateral olfactory tract nucleus, the peritonsillar cortex, and the anterior tonsilloid area. Projections of the most caudal

divisions of the insular crust (caudal divisions of Id and granular insular crust [Ig]) are less dense and extended; They focus on the dorsal intermediate subdivision of the lateral nucleus and the central nucleus. The parainsular cortex sends projections to the lateral nucleus, the basal nucleus, and the accessory basal nucleus. The frontoparietal operculum, an area of cortical flavor, projects into the dorsomedial part of the lateral nucleus. Most of the island projections are projected in a medium-flow direction.

### 5.6. Cingulate Cortex, Temporal Cortex and Occipital Cortex

Moderate projections of the rostral cingulate cortex, particularly areas 24 and 25: end in the amygdala. The lateral nucleus and basal nucleus are the main recipients of these projections, but the accessory basal nucleus, the anterior amygdaloid area, and the central nucleus also receive minor projections. The projections originate mainly in the deep layers of the anterior cingulate cortex with minor projections of the superficial layers. The caudal aspects of the cingulate cortex do not appear to project to the amygdala.

The amygdala has extensive connections with unimodal and multimodal cortical areas in the temporal lobe. Projections from the ET area, a high-level visual cortical region, primarily terminate in the lateral nucleus of the amygdala, with additional projections to the basal nucleus, accessory basal nucleus, and anterior amygdaloid area. The lateral core and basal core also receive moderate projections from the TO visual area. Only the most rostral subdivisions of the TA auditory area project to the amygdala, specifically targeting the lateral part of the middle and caudal regions of the lateral nucleus. The amygdala also receives input from multimodal areas of the temporal cortex. Fibers from the perirhinolar cortex terminate in the lateral nucleus, basal nucleus, magnocellular division of the accessory basal nucleus, medial nucleus, anterior cortical nucleus, posterior cortical nucleus, and peritonsilloid cortex. A weak projection from the parahippocampal cortex targets the lateral nucleus. The polysensory region in the superior temporal gyrus and the dorsal bank of the superior temporal sulcus sends projections to all divisions of the lateral and basal nuclei. The more rostral parts of the superior temporal gyrus send additional fibers to the accessory basal nucleus, anterior tonsilloid area, central nucleus, anterior and posterior cortical nuclei, nucleus of the lateral olfactory tract, peritonsilloid cortex, and medial nucleus.

There is no evidence of projections to the amygdala from any area of the occipital lobe.

### 5.7. Mesencephalon

The peripeduncular nucleus of the midbrain sends a projection to the lateral nucleus and the medial nucleus of the amygdala. The rostral and caudal subdivisions of the linear nucleus and the dorsal raphe nucleus also project towards the amygdala and the periaqueductal gray originates a projection that seems to be centered in the basal accessory nucleus in addition, a dopaminergic entry to the central nucleus originates in the ventral tegmental area; the substantia nigra, pars compacta; and the A8 and A10 cell groups.

### 5.8. Connections with the Olfactory System

The primate olfactory bulb sends a strong, direct projection to the anterior cortical nucleus, the nucleus of the lateral olfactory tract, and the peritonsillar cortex. The piriform cortex also sends a projection to those same divisions of the amygdala. The nucleus of the lateral olfactory tract and the peritonsillar cortex sends a projection to the olfactory bulb.

### 5.9. The Temporal Order in Which the Activation Takes Place

Functionally, the amygdala is considered to be an essential structure for the emotional processing of sensory signals, as it receives projections from all areas of sensory association. It is this convergence of anatomical projections that places the amygdala as the structure responsible for the formation of associations between stimuli and reinforcement or punishment. In addition to cortical projections from the various sensory association areas, the amygdala also receives thalamic afferents. This set of projections, both thalamic and cortical, towards the amygdala is what makes it possible to give an affective meaning to the stimulus characteristics. Through the thalamic-amygdalin connections, there will be a processing of the affective meaning of the very simple sensory stimulus characteristics, while through the thalamic-cortical connections, the complex stimulus processing without affective components would occur.

On the contrary, through the cortical-amygdalin connections, complex information, elaborated in the cortex, is endowed with the emotional component. The temporal order in which the activation of each of these projections takes place is different, suggesting that since the thalamic-amygdalin pathway is shorter and activated earlier than the thalamocortical pathway, the simplest stimulus features would previously activate the amygdaline emotional circuits, preparing this structure to receive the most complex and elaborate information from the cortex and, then, to give it its emotional component.

## 6. About the Cincture and Its Connections

In humans, the cingulate cortex forms an arc, extending from the rostral subcallosal area in its anterior portion following a curved path over the upper surface of the

bilateral corpus callosum in the sagittal plane. The cingulate fasciculus is a 5-7 mm bundle of fibers located above the corpus callosum and below the cingulate cortex. [19] In its ventral and posterior origin, it begins in the cortex of the temporal lobe, goes posteriorly and superiorly within the parietal lobe, then rotates in a ring-belt shape around the corpus callosum within the frontal lobe to end anterior and inferior to the genu of the corpus callosum in the orbitofrontal cortex. [20]

Based on its cytoarchitecture and receptor structure, the cingulate cortex can be divided into anterior, middle, posterior, and restrosplenial (ACC, MCC, PCC, RSC). [19] ACC is characterized by neurons that express high levels of D1 dopaminergic receptors that project to motor control systems in the brain stem and are thought to be involved in emotional responses and autonomic regulation. The MCC has neurons that project to the spinal cord and are related to emotional processing and visceral control. PCC contains a large number of neurons with protein neurofilaments that connect to the parietal lobe, which monitors eye movement and responds to sensory stimuli. RSC is mainly made up of neurons that receive signals from the amygdala and are involved in cognitive function. [21-24] The neural circuitry underlying anxiety, fear, and alarm includes the amygdala as well as brainstem sites, insula, and anterior cingulate. [25]

Depending on its cortical location, onset, and areas of association, the cingulate fascicle can be divided into 5 portions (CBI, CBII, CBIII, CBIV, CBV). Starting in the subgenual cortex (Area 25), CBI (figure 1) subsequently curves upward enveloping the genu of the corpus callosum, terminating in the orbitofrontal cortex (Area 11). The functional role of CBI is related to nociceptive responses and in conjunction with RSC it is related to global cognitive function and verbal memory. [19]

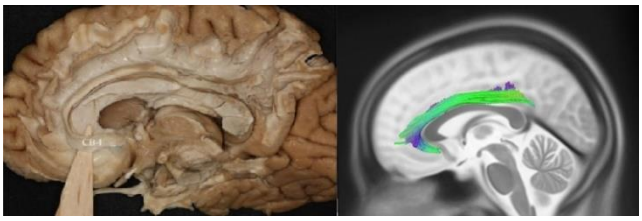

***Figure 1.*** *Cingulate fasciculus CBI segment, tractography, and fiber dissection.*

CBII (Figure 2) begins at the level of the retrosplenial, parahippocampal, and perirrinal cortex, and then extends over the corpus callosum to end in the medial prefrontal cortex. This segment of the CB integrates the previous cortical regions, supporting the mental function that is related to them. [19]

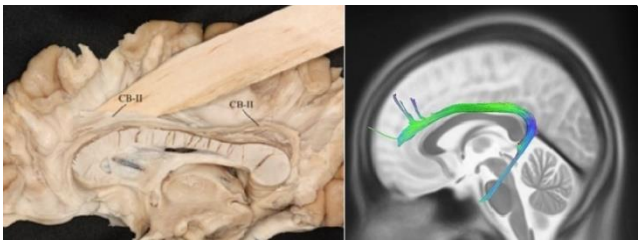

***Figure 2.*** *CBII path calculated by tractography and demonstrated with fiber dissection.*

Tractography and fiber dissection studies have shown that CBIII (Figure 3) is found in the white matter of the superior parietal lobe (SPL) (Area 7), precuneus (medial Area 7), and the medial surface of the superior frontal gyrus (SFG) (Areas 8, 9, and 32) and the supplemental motor area. It is considered the largest segment in the entire CB. In turn, it is considered the most multifunctional segment due to its cortical relationships. It is related to recent human cognitive specializations. For example, its relationship with the response to conflict situations in healthy humans has been demonstrated. Its relationship with neurophysiological dependence on tobacco and tobacco withdrawal syndrome has also been demonstrated. Finally, it is related to tasks that demand attention. [19]

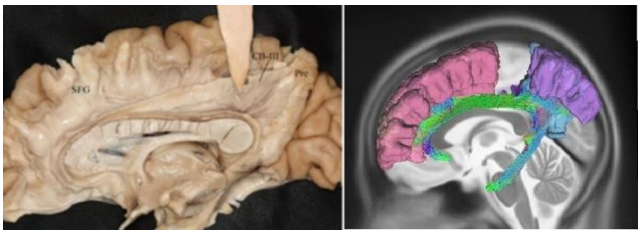

***Figure 3.*** *CBIII and its trajectory by tractography and fiber dissection.*

The CBIV (Figure 4) segment is considered the shortest segment of the entire cingulate fascicle complex, which connects the superior parietal lobe (Area 7) and the precuneus (medial Area 7) with the supplementary motor area and the premotor area (8, 9 and 32). Two portions are identified; the paracingulate portion (para-CB) and the supracingulate portion (supra-CB) in both fiber dissection and tractography. As background, it is described that its trajectory is similar to that described by the Superior Longitudinal Fasciculus (SLF-1). Subsequently, the differentiation of both tracts was carried out employing tractography. However, differentiation in all specimens mainly the para-CB portion. [19]

It is described that the trajectory of the CB V (Figure 4) segment of the cingulate fasciculus, also called parahippocampal cingulate, begins in the posterior and medial portion of the temporal lobe and later reaches the parietal and occip-

ital lobe. Lately, this segment of the cingulate has been studied as an early diagnosis of Alzheimer's disease, since recent studies demonstrate the presence of early neuronal degeneration in this pathology. For all these findings, it is thought that it participates as a pathway for controlling memory, executive function, and cognitive functions. It has also been cataloged as part of the back component of the Default Neural Network. [19]

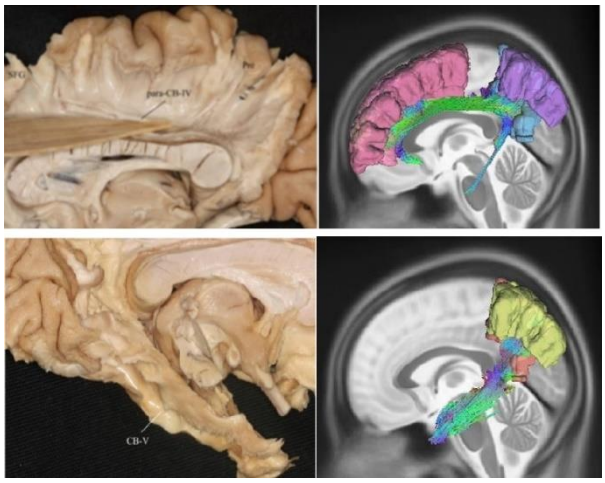


***Figure 4.*** *CB IV and CB V segment demonstrated by fiber dissection and tractography.*

## 7. Material and Method

An observational, cross-sectional, descriptive, retrospective study was carried out in patients operated on with functional neurosurgery based on ablation of the bilateral tonsillar complex and cingulotomy with a diagnosis of drug-resistant aggressiveness disorder at the Centro Médico Nacional 20 de Noviembre ISSSTE. A correlation was made between postoperative imaging studies and the human connectomics map of adult patients registered in the Human Connectome Project database. The criteria for the diagnosis of aggression disorder were given before the study by the psychiatric service, so they are not included in this study. Because the diagnosis of aggression disorder is uncommon, a sample of 3 patients was obtained, who had the relevant imaging and postoperative data for this study. A bibliographic review of the connectomics involved in the pathological aggression response was performed, as well as the cortical and subcortical functional areas involved in this response. The connectivity map was obtained from the https://www.humanconnectome.org/ database, and reconstructed in 3D with the DSI Studio downloaded from the same domain. The anatomical comparison of the tomographic and brain magnetic resonance studies of patients who underwent the described ablations was carried out, and the reconstruction of tractography extracted from https://www.humanconnectome.org/ was performed. Randomized tractography images were fused in Radiant Dicom Viewer in multiplanar MPR projection with axial, coronal, and sagittal windows. Functional coupling with better results is obtained in the sagittal plane with anterior and oblique windows. A type of non-probabilistic sampling was carried out at convenience, where patients with a diagnosis of aggression disorder established by the psychiatry service were selected, who have criteria for functional neurosurgical treatment.

## 8. Results

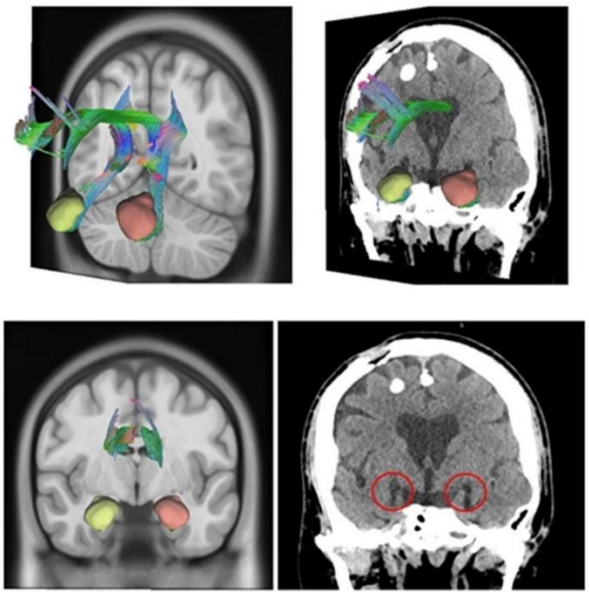

***Figure 5.*** *Fusion of postoperative tomography with tractography extracted from HCP demonstrating the interruption of tonsillar fibers in ablation of the bilateral tonsillar complex. Top left image: 3D reconstruction of the isolated bilateral amygdala complex and complete bilateral cingulate tract in DSI Studio Software in coronal plane. Top right image: Coronal section of a patient with bilateral ablation of the tonsillar complex, medial portion, postoperative image. Bottom left image: 3D reconstruction of the isolated bilateral tonsillar complex and complete bilateral cingulate tract in DSI Studio Software in an oblique coronal plane 3/4 to the right. Lower right image: Fusion of reconstruction of bilateral tonsillar complex and cingulate tract and postoperative image of a patient with bilateral tonsillar ablation and 3/4 oblique coronal plane cingulotomy rotated to the right where the interruption of the bilateral and cingulate medial tonsillar fibers is demonstrated.*

A review of postoperative imaging studies of the 3 patients who underwent surgery was carried out, with tractography fusion, observing that there is total interruption of the tonsillar fibers and the cingulate, which demonstrates that the preoperative planning, transoperative execution, and postoperative imaging results are in agreement with what is structured in the HCP tractography system. In turn, the clinical postoperative outcome of the 3 patients is consistent with the

aforementioned literature. In this study, a range of clinical improvement between 45% and 65% was obtained, following the international literature. [26]

## 9. Discussion

Pathological aggression disorder is part of the spectrum made up of different neurological and psychiatric pathologies. Prefrontal cortex abnormalities especially seem to be involved in aggressive and violent behavior. There is an association between prefrontal volume reduction and aggression as well as antisocial behavior. [27] When performing the preoperative planning of the procedure, it is important to know the cognitive and integration structure of the patients chosen for neurofunctional procedures. The basis of this planning and understanding was based on neuropsychological and neuropsychiatric results. However, there was no connectomic support for the planning of these procedures.

There is currently an extensive bibliography in the isolated description of the functionality of fascicles and interneuronal nodes. There is a documented record of the functions that each fascicle contains, derived from the connections it makes between their respective cortical areas. However, anatomical study by fiber dissection is not practical for preoperative planning because the spatial location of each fascicle varies from individual to individual. By having a connectomic base by tractography, we can have a more precise idea of the location of each fascicle of interest, and consequently, make a more accurate preoperative planning.

## 10. Conclusion

In the vast literature in which the neurosurgical management of aggression disorder is mentioned, factors such as neuropsychiatric, neuropsychological, and neurological assessment are taken into account for the subsequent neurosurgical planning of the procedures to be performed. However, the connectomic assessment of the areas to be intervened is not taken into account, due to the lack of technology or the current database. There is currently vast information in the literature on human neural connectomics. The importance of this information derives from the premise of integrating human connectomics in preoperative planning since the anatomical and functional information of the HCP would help us to improve our postoperative results.

## Abbreviations

| | |
|---|---|
| MRI | Magnetic Resonance Imaging |
| DTI | Diffusion Tensor Imaging |
| HCP | Human Connectome Project |
| rfMRI | Resting-state Functional MRI |
| tfMRI | Task-evoked Functional MRI |
| dMRI | Diffusion Imaging MRI |
| ET | Entorrinal |
| TO | Temporoccipital |
| TA | Anterior Temporal |
| ACC | Anterior Cingular Cortex |
| MCC | Middle Cingular Cortex |
| PCC | Posterior Cingular Cortex |
| RSC | Retrosplenial Cingular Cortex |
| CB | Cingulum Bundle |
| SPL | Superior Parietal Lobe |
| SFG | Superior Frontal Gyrus |
| SLF | Superior Longitudinal FasciculusHuman |
| Para-CB | Paracingulate Portion |
| Supra-CB | Supracingulate Portion |

## Conflicts of Interest

The authors declare no conflicts of interest.

## References

[1] Baker CM, Burks JD, Briggs RG, Conner AK, Glenn CA, Sali G, McCoy TM, Battiste JD, O'Donoghue DL, Sughrue ME. A Connectomic Atlas of the Human Cerebrum-Chapter 1: Introduction, Methods, and Significance. Oper Neurosurg (Hagerstown). 2018 Dec 1; 15(suppl_1): S1-S9. PMID: 30260422; PMCID: PMC6887907. https://doi.org/10.1093/ONS/OPY253

[2] Versace A, Graur S, Greenberg T, et al. Reduced focal fiber collinearity in the cingulum bundle in adults with obsessive-compulsive disorder. Neuropsychopharmacology. 2019; 44(7): 1182-1188. https://doi.org/10.1038/s41386-019-0353-4

[3] Garcia-Garcia S, Kakaizada S, Oleaga L, Benet A, Rincon-Toroella J, Gonz âlez-S ánchez JJ. Presurgical simulation for neuroendoscopic procedures: virtual study of the integrity of neurological pathways using diffusion tensor imaging tractography. Neurol India. 2019; 67(3): 763-769. https://doi.org/10.4103/0028-3886.263199

[4] Ozgural O, Al-Beyati ESM, Kahilogullari G. MR navigation and tractography-assisted transcranial neuroendoscopic aspiration of pediatric thalamic abscess. Pediatr Neurosurg. 2019; 54(5): 354-358. https://doi.org/10.1159/000501914

[5] Wu JS, Zhou LF, Tang WJ, et al. Clinical evaluation and follow-up outcome of diffusion tensor imaging-based functional neuronavigation: a prospective, controlled study in patients with gliomas involving pyramidal tracts. Neurosurgery. 2007; 61(5): 935-948; discussion 948-9. https://doi.org/10.1227/01.neu.0000303189.80049.ab

[6] Marcus D, Harwell J, Olsen T, et al. Informatics and data mining tools and strategies for the human connectome project. Front Neuroinform. 2011; 5: 4. https://doi.org/10.3389/fninf.2011.00004

[7] Glasser MF, Coalson TS, Robinson EC, et al. A multi-modal parcellation of human cerebral cortex. Nature. 2016; 536(7615): 171-178. https://doi.org/10.1038/nature18933

[8] Amunts K, Zilles K. Architectonic Mapping of the Human Brain beyond Brodmann. Neuron. 2015 Dec 16; 88(6): 1086-1107. PMID: 26687219. https://doi.org/10.1016/j.neuron.2015.12.001

[9] Brodmann K. Vergleichende Lokalisationslehre der Grosshirnrinde in ihren Prinzipien dargestellt auf Grund des Zellenbaues. Barth; 1909.

[10] Vogt C, Vogt O. Allgemeine ergebnisse unserer hirnforschung. JA Barth; 1919.

[11] von Economo CF, Koskinas GN. Die cytoarchitektonik der hirnrinde des erwachsenen menschen. J. Springer; 1925.

[12] Baker CM, Burks JD, Briggs RG, Conner AK, Glenn CA, Robbins JM, Sheets JR, Sali G, McCoy TM, Battiste JD, O'Donoghue DL, Sughrue ME. A Connectomic Atlas of the Human Cerebrum-Chapter 5: The Insula and Opercular Cortex. Oper Neurosurg (Hagerstown). 2018 Dec 1; 15(suppl_1): S175-S244. PMID: 30260456; PMCID: PMC6924540. https://doi.org/10.1093/ons/opy259

[13] Jennings, Jonathan E MD; Kassam, Amin B MD; Fukui, Melanie B MD; Monroy-Sosa, Alejandro MD; Chakravarthi, Srikant MD; Kojis, Nathan MBA; Rovin, Richard A MD. The Surgical White Matter Chassis: A Practical 3-Dimensional Atlas for Planning Subcortical Surgical Trajectories. Operative Neurosurgery 14(5): p 469-482, May 2018. | https://doi.org/10.1093/ons/opx177

[14] Sporns O, Chialvo DR, Kaiser M, Hilgetag CC. Organization, development and function of complex brain networks. Trends Cogn Sci. 2004; 8(9): 418-425. https://doi.org/10.1016/j.tics.2004.07.008

[15] Bassett DS, Gazzaniga MS. Understanding complexity in the human brain. Trends Cogn Sci. 2011; 15(5): 200-209. https://doi.org/10.1016/j.tics.2011.03.006

[16] Hart, Michael G., Rolf J. F. Ypma, Rafael Romero-Garcia, Stephen J. Price, and John Suckling. "Graph theory analysis of complex brain networks: new concepts in brain mapping applied to neurosurgery". Journal of Neurosurgery JNS 124.6 (2016): 1665-1678. https://doi.org/10.3171/2015.4.JNS142683

[17] Martin R. Understanding Memory Systems in TLE: Networks, Nodes, and Hubs. Epilepsy Curr. 2016 May-Jun; 16(3): 153-5. PMID: 27330439; PMCID: PMC4913845. https://doi.org/10.5698/1535-7511-16.3.153

[18] Elam JS, Glasser MF, Harms MP, Sotiropoulos SN, Andersson JLR, Burgess GC, Curtiss SW, Oostenveld R, Larson-Prior LJ, Schoffelen JM, Hodge MR, Cler EA, Marcus DM, Barch DM, Yacoub E, Smith SM, Ugurbil K, Van Essen DC. The Human Connectome Project: A retrospective. Neuroimage. 2021 Dec 1; 244: 118543. Epub 2021 Sep 8. PMID: 34508893; PMCID: PMC9387634. https://doi.org/10.1016/j.neuroimage.2021.118543

[19] Wu Y, Sun D, Wang Y, Wang Y, ou S. Segmentation of the Cingulum Bundle in the Human Brain: A New Perspective Based on DSI Tractography and Fiber Dissection Study. Front Neuroanat. 2016 Sep 7; 10: 84. PMID: 27656132; PMCID: PMC5013069. https://doi.org/10.3389/fnana.2016.00084

[20] Agrawal, A., Kapfhammer, J. P., Kress, A., Wichers, H., Deep, A., Feindel, W., et al. (2011). Josef Klingler's models of white matter tracts: influences on neuroanatomy, neurosurgery and neuroimaging. Neurosurgery 69, 238-252; discussion 252-234. https://doi.org/10.1227/NEU.0b013e318214ab79

[21] Vogt, B. A. (2016). Midcingulatecortex: structure, connections, homologies, functions anddiseases. J. Chem. Neuroanat. 74, 28-46. https://doi.org/10.1016/j.jchemneu.2016.01.010

[22] Vogt, B. A., Derbyshire, S., and Jones, A. K. (1996). Pain processing in four regions ofhuman cingulate cortex localized with co-registered PET and MR imaging. Eur. J. Neurosci. 8, 1461-1473. https://doi.org/10.1111/j.1460-9568.1996.TB01608.X

[23] Vogt, B. A., Finch, D. M., and Olson, C. R. (1992). Functional heterogeneity in cingulate cortex: the anterior executive and posterior evaluative regions. Cereb. Cortex 2, 435-443. https://doi.org/10.1093/cercor/2.6.435-a

[24] Vogt, B. A., and Laureys, S. (2005). Posterior cingulate, precunealand retrosplenial cortices: cytology and components of the neural network correlates ofconsciousness. Prog. BrainRes. 150, 205-217. https://doi.org/10.1016/S0079-6123(05)50015-3

[25] Bystritsky A, Spivak NM, Dang BH, Becerra SA, Distler MG, Jordan SE, Kuhn TP. Brain circuitry underlying the ABC model of anxiety. J Psychiatr Res. 2021 Jun; 138: 3-14. Epub 2021 Mar 25. PMID: 33798786. https://doi.org/10.1016/j.jpsychires.2021.03.030

[26] Hernández Salazar M, Zarate Méndez A, Meneses Luna O, Ledesma Torres L, Paniagua Sierra R, Sánchez Moreno MC, Serrato Avila JL. Ablative stereotactic neurosurgery for irreducible neuroaggressive disorder in pediatric patients. Neurosurgery (Astur: Engl Ed). 2018 Nov-Dec; 29(6): 296-303. English, Spanish. Epub 2018 Jun 18. PMID: 29914842. https://doi.org/10.1016/j.neucir.2018.05.003

[27] Bogerts B, Schöne M, Breitschuh S. Brain alterations potentially associated with aggression and terrorism. CNS Spectr. 2018 Apr; 23(2): 129-140. Epub 2017 Aug 14. PMID: 28803592. https://doi.org/10.1017/S1092852917000463