

## Three-Dimensional Anatomy of the Anterior Commissure: A Tractography and Anatomical Study

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■ **BACKGROUND:** The anterior commissure (AC) is one of the main commissural fibers of the brain. The commissural fibers are involved in bilateral integration and coordination of any normal brain activity. The AC is an important inter-hemispheric structure that forms a bidirectional communication channel between the frontal, temporal, parietal, and occipital lobes bilaterally.

■ **METHODS:** In the present study, we focused on describing the morphology, relationships, and distribution of the AC using diffusion spectrum imaging-based fiber tracking. The tractograms were compared with the findings from gross anatomical dissection of the AC of adult brains.

■ **RESULTS:** Our findings suggest that the AC found using tracking methods is larger than that found by dissection.

■ **CONCLUSIONS:** The use of tractography added extensions to the main AC structure.

### INTRODUCTION

The anterior commissure (AC) is one of the main commissural fibers of the brain. Commissural fibers are involved in bilateral integration and coordination of normal brain activity. These fibers, by definition, cross the

midline, interconnecting the cerebral hemispheres. Other telencephalic commissures include the corpus callosum (CC), only present in placental mammals and the hippocampal commissure.<sup>1-4</sup> In the present study, we focused only on the AC.

Embryologically, the AC is the first cerebral commissure to appear. It develops during the first 8–11 weeks of gestation.<sup>2,3,5,6</sup> In humans, the AC participates in the transmission of sensory (i.e., visual and auditory input) and language information between the hemispheres.<sup>7</sup> The communication of the 2 amygdaloid nuclei through the AC is well known.<sup>8-13</sup> To date, details regarding the most prominent part of the AC have remained unclear.

In the present report, we have focused on describing the morphology, relationships, and distribution of the AC using diffusion spectrum imaging (DSI)-based fiber tracking. The tractograms were compared with the gross anatomical dissection findings of the AC of adult brains. These dissections were performed before tracing the AC on DSI studies to validate our magnetic resonance imaging (MRI) findings and highlight the differences regarding the previously described anatomy. This aspect should be considered during the interpretation of the correlation between them. In the present study, we did not consider the relationships between the AC and the surrounding white matter.

### METHODS

Six adult brain hemispheres were fixed in a 10% formalin solution for 2 weeks in accordance with the Klingler technique.<sup>14</sup> The

#### Key words

- Anterior commissure
- Connectome
- Diffusion spectrum imaging
- Fiber dissection
- Heterotopic
- Tractography

#### Abbreviations and Acronyms

- 3D:** 3-Dimensional  
**AC:** Anterior commissure  
**CC:** Corpus callosum  
**DSI:** Diffusion spectrum imaging  
**MNI:** Montreal Neurologic Institute  
**MRI:** Magnetic resonance imaging  
**PC:** Posterior commissure

**ROI:** Region of interest

**TLE:** Temporal lobe epilepsy

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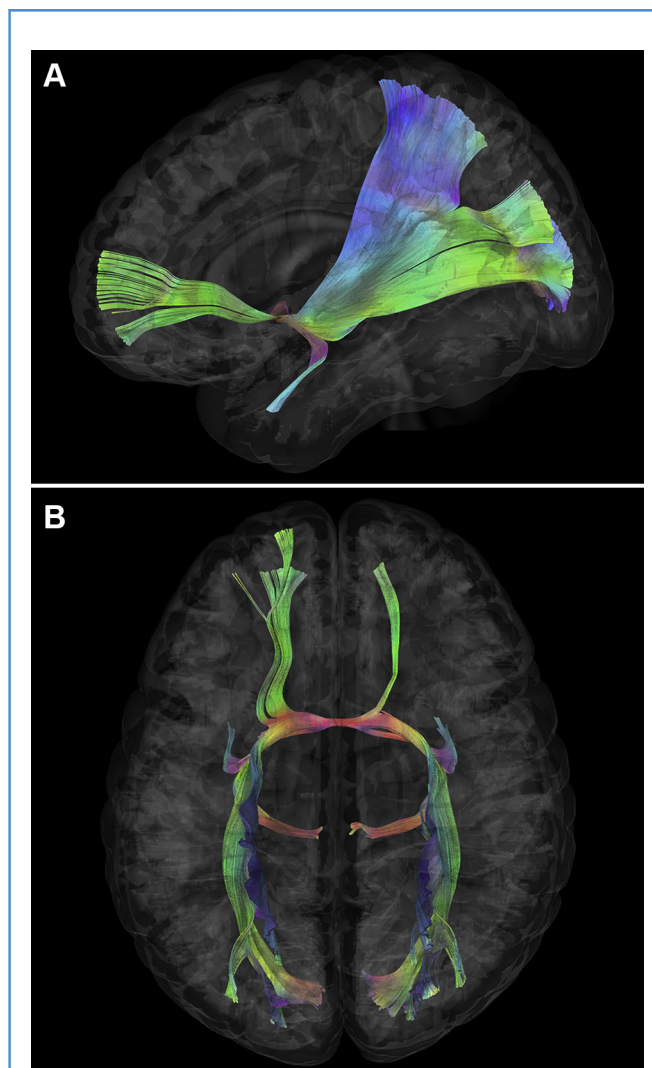
concentration was then lowered to a 5% solution, and the brains were embedded in the solution for an additional 2 weeks. The dura mater had been gently removed before embedding in the formalin solution, and the arachnoid was dissected after this procedure. All the hemispheres were then frozen in water for 2 weeks at  $-14^{\circ}\text{C}$ . Freezing the specimens before dissection aided in the separation of the fibers.<sup>14,15</sup> Fiber dissection was performed using a manually shaped wooden spatula and an operating microscope with magnification that ranged from  $4\times$  to  $16\times$ . The final fiber tract dissections were recorded on digital photographs (D5500 60-mm macro-lens camera with an LED ring flashlight; Nikon Corp., Tokyo, Japan). All the cadaveric specimens were dissected in the Laboratory of Microsurgical Neuroanatomy, Second Chair of Gross Anatomy, School of Medicine, University of Buenos Aires.

The tractograms were reconstructed using DSI Studio software (available at: [dsi-studio.labsolver.org](http://dsi-studio.labsolver.org)) using a template from Human Connectome Project (available at: <http://www.humanconnectomeproject.org/>), which includes an average of 842 healthy human brains. All the brains were registered to the Montreal Neurologic Institute (MNI) coordinate space, in which imaging is warped to fit a standardized brain model comparison between subjects. The diffusion images were acquired using a multishell diffusion scheme. The b-values were 1000, 2000, and 3000 seconds/ $\text{mm}^2$ . The number of diffusion sampling directions was 90, 90, and 90. The in-plane resolution was 1.25 mm. The slice thickness was 1.25 mm. The diffusion data were reconstructed in the MNI space using q-space diffeomorphic reconstruction to obtain the spin distribution function.<sup>16,17</sup> A diffusion sampling length ratio of 1.25 was used, and the output resolution was 1 mm. The atlas was constructed by averaging the spin distribution functions of the 842 individual subjects (372 men and 470 women; age range, 20–40 years; 2015 Q4, 900-subject release; available at: <http://brain.labsolver.org/diffusion-mri-templates/hcp-842-hcp-1021>).

Tractography was performed using a region of interest (ROI) approach in 20 patients of the Human Connectome Project to initiate fiber tracking from a user-defined seed region. A multiple one ROI approach was used to isolate the tracts, and all the tracts were tested for reproducibility.<sup>18</sup> The DSI tensors have a color code determined by the eigenvector orientation<sup>18–20</sup> and are blue for the dorsoventral, red for the laterolateral, and green for the rostrocaudal directions.<sup>19,20</sup>

These colors represent diffusion on the 3 orthogonal axes. In the selection of the ROIs, we used the color map as a guide to elucidate which fibers might belong to the AC (expecting to select red vectors on a midsagittal plane). The placement of the ROIs was a dynamic procedure with the aim of including the greatest number of AC fibers as possible and excluding those that belonged to the surrounding structures such as the CC or fornix. Four individual seed regions were finally placed in a midsagittal plane (with the following coordinates: 0, 5, -4; 0, 5, -5; 0, 5, -6; 0, 4, -4; 0, 4, -5; and 0, 4, -6), each with a volume size of  $1\text{ mm}^3$ . Selecting the ROIs in accordance with the MNI coordinates allowed us to accurately retest our tracings.

A deterministic fiber tracking algorithm was used.<sup>21</sup> The anisotropy threshold was 0.09632, and the angular threshold was  $80^{\circ}$ , which allowed for the filling of the structural blanks on



**Figure 1.** (A) Left view of the anterior commissure with its 2 main branches (anterior and posterior) and their subdivisions. (B) Dorsal view of the anterior commissure. Immediately after passing the midline, the anterior fascicle emerges to continue its course in the frontal lobe. The posterior fascicle divides into the temporal and parieto-occipital extensions. Thalamic fibers can be seen coursing toward the midline.

the MRI studies. The change threshold was 20%, and the step size was 0.4 mm. The fiber trajectories were smoothed by averaging the propagation direction with 80% of the previous direction. Tracks with a length  $<5\text{ mm}$  or  $>300\text{ mm}$  were discarded. We also evaluated 2 more parameters: check ending and randomized seeding. An overall quantity of 30,000 fibers was tracked.

## RESULTS

We observed a bilateral communication between the frontal, temporal, and occipital lobes through the AC (Figure 1). The AC crosses the midline ventral to the rostrum of the corpus

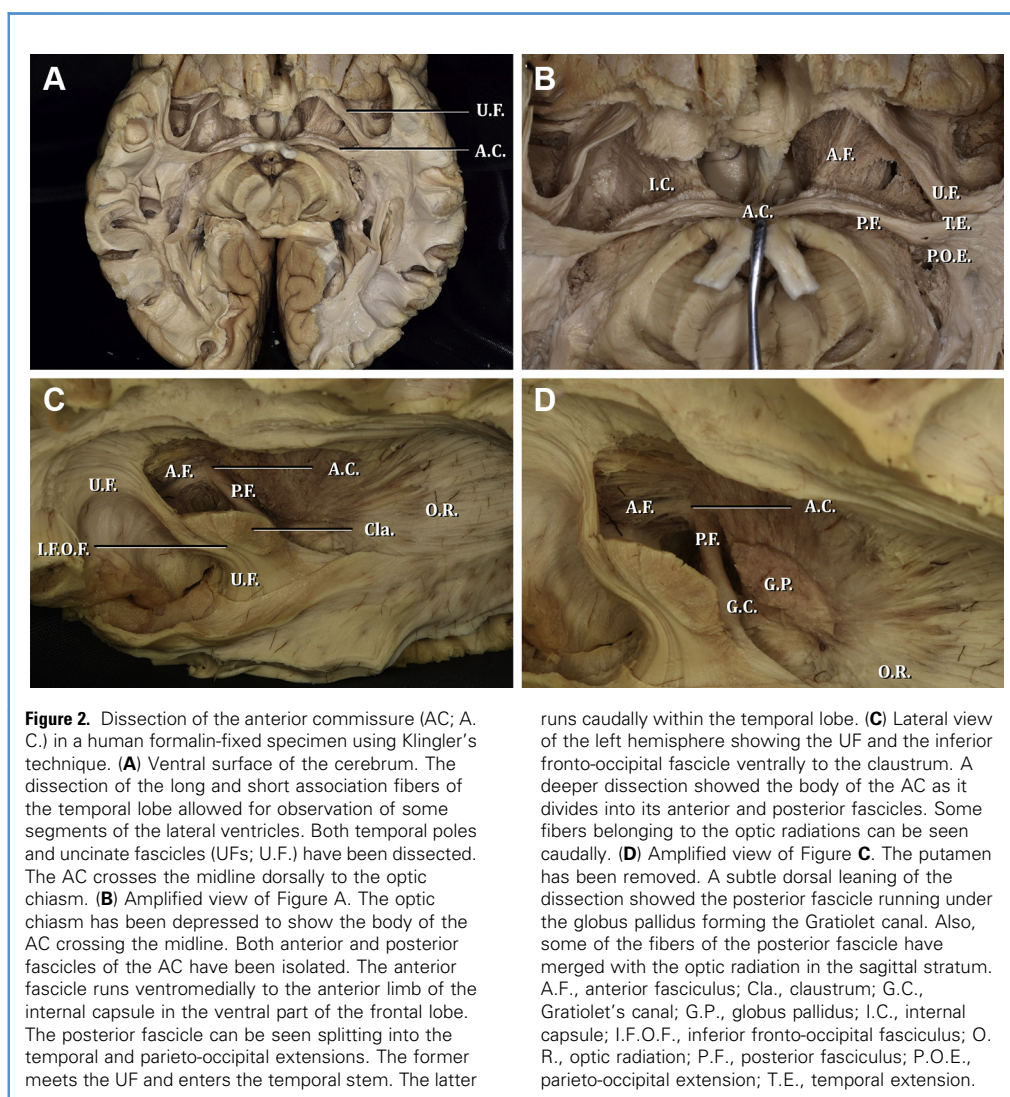
callosum (Figure 2A and B) and contributes to the formation of the anterior wall of the third ventricle, placing itself beneath the columns of the fornix. The septal area is located right in front of the AC; the lamina terminalis arises from the AC and stretches downward to reach the optic chiasm. The rostral edge of the diencephalon is located immediately behind the AC, much the same as the third ventricle (diencephalon cavity). Those relationships agree with those previously described.

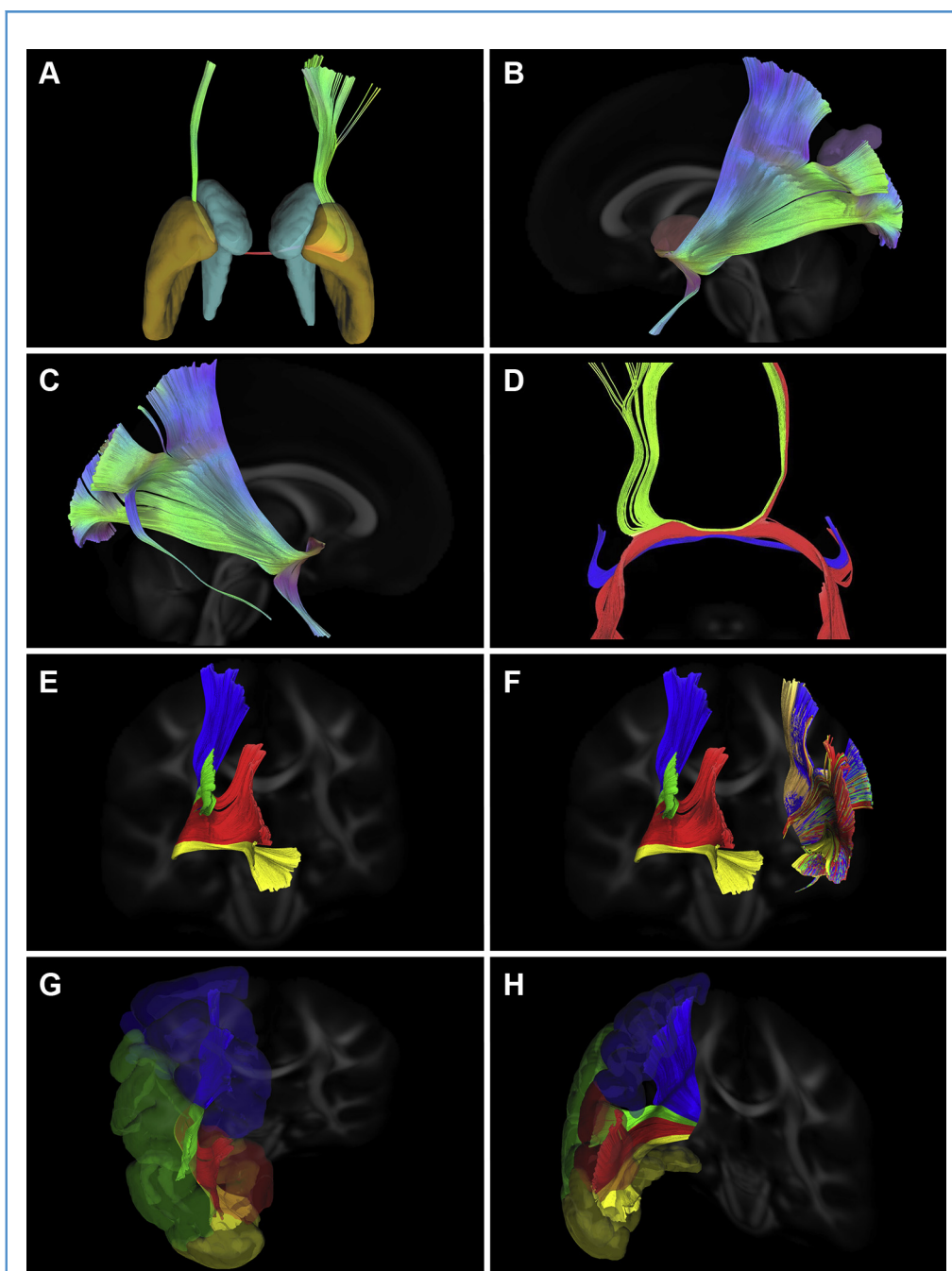
The AC has a body that is divided at each side into 2 fascicles (also known as limbs or crura): anterior and posterior (Figures 1 and 2B, C). The latter is also split into temporal and parieto-occipital extensions (Figures 2B and 3B). The fibers have an anteroposterior arrangement within the body of the AC. The anterior fascicle is located rostrally, following the parieto-occipital extension, and then caudally, following the temporal extension (Figure 3D). The dorsoventral distribution was not clear

enough to provide a proper description because it was intermingled with the fibers of the inferior fronto-occipital fascicle.

The anterior fascicle was the smallest in size (Figure 1). It travels forward to reach the orbitofrontal cortex, passing under the frontal horn of the lateral ventricle. Its fibers blend with the ventral aspect of the anterior limb of the internal capsule, which is located between the head of the caudate nucleus medially and putamen nucleus laterally (Figures 2B and 3A). This fascicle also meets the accumbens nucleus.

The posterior fascicle runs laterally and reaches the ventral aspect of the globus pallidus forming the Gratiolet canal (Figures 2D and 3B), at which the 2 extensions (temporal and parieto-occipital) diverge and become part of the temporal stem and sagittal stratum, respectively (Figure 2). The substantia innominata is located anterior to the posterior fascicle and lateral to the anterior fascicle and anterior limb of the internal





**Figure 3.** Some of the findings from 3-dimensional reconstruction of the anterior commissure (AC) are shown. **(A)** Ventral view of the anterior fascicle of the AC within the caudate nucleus (*blue*) and putamen (*green*). **(B)** The body of the AC passes ventrally to the globus pallidus (*red*). At the level of the parieto-occipital (PO) sulcus (*violet*), the parietal and occipital fibers are well-differentiated from each another. **(C)** Right PO extension. Some fibers leave and course toward the anterior temporal area. **(D)** Dorsal view of a color-segmented AC. The anterior fascicle is shown in *green*. The posterior fascicle includes the temporal extension in *blue*. The PO extension is shown in *red*. **(E)** A caudal view of a color-segmented left PO

extension. These fibers are identified according to their position in a coronal plane. Four fiber bundles can be individualized: superior (*blue*), inferior (*yellow*), lateral (*green*), and medial (*red*). **(F)** A colored caudal 3-dimensional view of the AC. No symmetrical correlation was found in the cortical distribution of these fibers within the hemispheres. **(G)** A dorsocaudal view of a color-segmented PO extension. The superior bundle reaches the superior parietal and postcentral gyri; the lateral bundle meets the angular and middle occipital gyri; the medial bundle reaches the superior occipital gyrus; and the inferior bundle reaches the calcarine sulcus and occipital pole. **(H)** A medial and caudal view of the previously addressed structures.

capsule. The parieto-occipital fibers were always above the temporal fibers during their course (Figure 3B and C).

The temporal extension covers the dorsolateral wall of the temporal horn of the lateral ventricle as it reaches the pole of the lobe. It appeared to have a double-hooked shape on its route. These fibers continue from the body posteriorly and laterally, showing a lesser posterior concavity. Subsequently, the temporal extension rotates anteriorly to follow its course toward the temporal pole. The second hook describes a well-defined and pronounced anterior concavity resembling the curve of a road (Figures 1 and 2A). Because of these curves, this extension can be seen as a discontinuous structure in serial sections of the coronal plane. It connects both amygdaloid bodies, the fusiform and parahippocampal gyri, and a small area of the inferior temporal gyri. All these anatomical regions are included within the temporal pole.<sup>22</sup>

The parieto-occipital extension merges with the sagittal stratum, lateral to the atrium and occipital horn as it courses posteriorly (Figure 2D), and is the largest component of the AC (Figure 1A). The 2 apparent initial groups of fibers revealed 4 real endings using the 3-dimensional (3D) plane for evaluation. We named them according to the position they occupied in the coronal section: superior, inferior, lateral, and medial (hereinafter referred to as bundles; Figure 3E). It was not until we had overlapped these bundles using the Destrieux parcellation that we found that the previously ignored bundles had ended in specific cortical areas. The superior bundle finished its course in the superior parietal lobule and postcentral gyrus. The inferior bundle seemed to be the longest. Its far-reaching middle aspect ended at the deepest portion of the calcarine sulcus. It does not contact the cuneus gyrus, and its relationship with the lingual gyrus could not be specified in the present study. Its lateral aspect seemed to end at the occipital pole. The middle bundle finished in the cortex of the superior occipital gyrus. Finally, the lateral bundle ended its course in the ventral portion of the angular gyrus on its dorsal aspect and in the middle occipital gyri on its ventral part (Figure 3G and H).

A considerable group of fibers could be seen coming from the most ventral aspect of the parieto-occipital extension and running toward the thalamus (Figure 1B). These fibers coursed posteriorly and medially, twisting themselves along the anteroposterior axis. They passed ventrally to the lenticular nucleus, ending in the caudoventral aspect of the thalamus. Another group of fibers was found on the right hemisphere (Figure 3C), too obvious to ignore, that was not present on the left side (Figure 1A). At first, we believed these fibers were associated fibers that might not belong to the AC.

The entire commissure was split into 2 by a midsagittal plane to exclude any extrinsic fibers. A statistical analysis was performed to compare the right and left segments of the AC. The use of the Student paired *t* test with a 2-tailed distribution did not reveal statistically significant differences ( $P = 0.16$ ) in the distribution in the cerebral hemispheres. Thus, no asymmetry was found—as would have been expected from the commissural fibers. Every fiber found on the right was also present on the left. This is in conformity with the definition of commissural fibers, which cross the midline together. Nonetheless, when *in vivo* dissection of the AC subdivisions has been performed (especially for the thalamic

and parieto-occipital fibers), it was not possible to isolate specific tracts (Figure 3D and F).

The laterality index was estimated for both fascicles. The positive result for the anterior fascicle indicated a left lateralization, coinciding with our findings. The negative posterior fascicle value indicated a general right predominance. Neither showed complete single-sided lateralization between the hemispheres.

## DISCUSSION

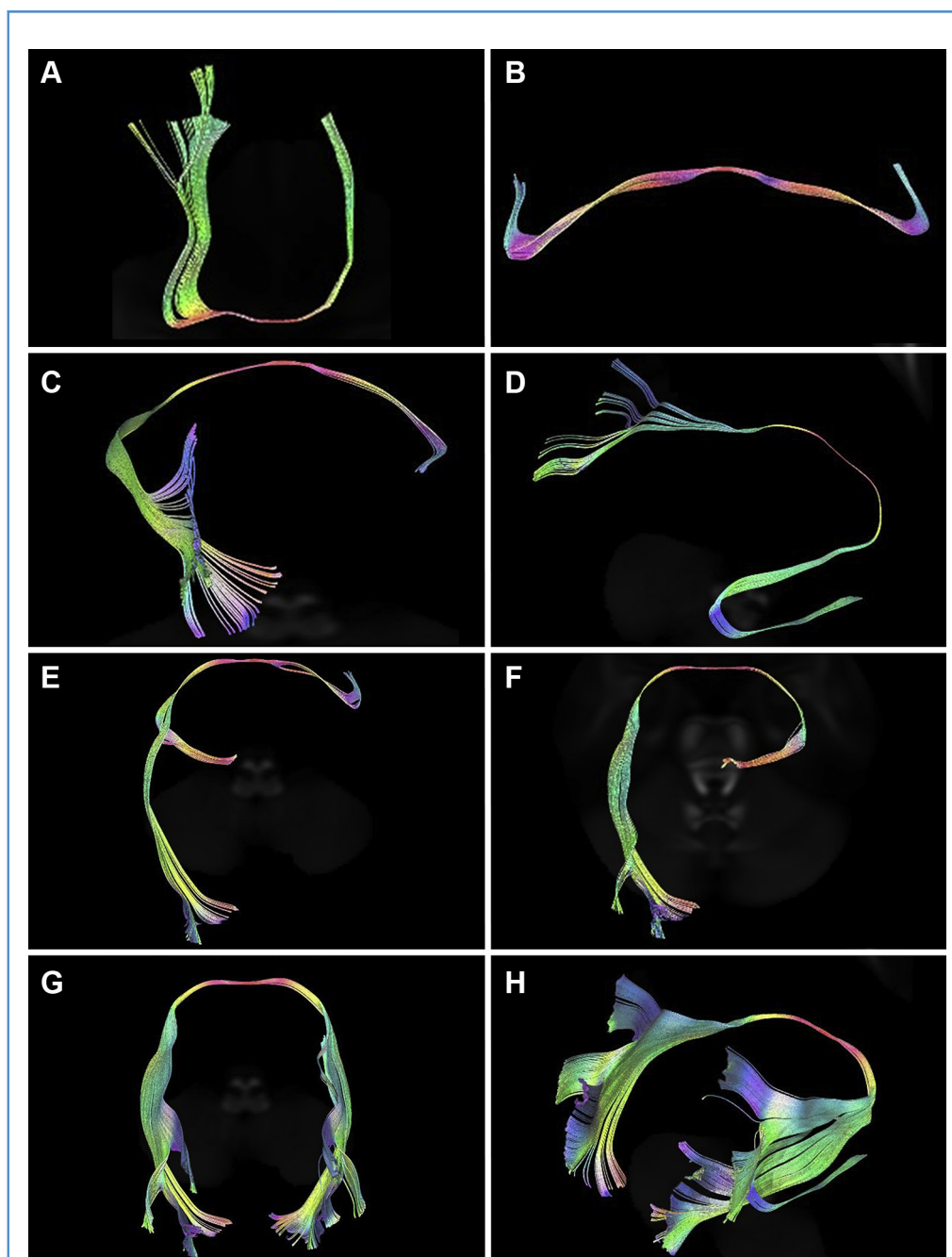
### Anatomical Considerations

We sought to determine how nonstatistically significant differences were found regarding the distribution of the AC despite the asymmetric organization within the AC. It is a common belief that the commissural fibers communicate with homologous areas of the brain (establishing homotopic connections). Nevertheless, that they share a path does not necessarily imply that they will also share their cortical terminations, understanding this connection of nonhomologous cortical areas as heterotopic connections. This attribute has been previously described for the CC.<sup>2,23</sup>

The different components of the AC were isolated to evaluate the topographic arrangement and the nature of their connections. The anterior fascicle was easily individualized. It communicated with both frontal lobes homotopically. When the anterior fascicle is considered separately, it displays an U shape (Figure 4A). The posterior fascicle proved more difficult to individualize compared with the anterior fascicle. We were able to isolate its extensions. However, we encountered difficulties in accurately separating the parieto-occipital bundles (Figure 3F). These fibers appeared to be compact and distinct structures; however, they were truly intermingled with each another, making the success of further dissection improbable. Each part of this fascicle appeared to have a specific disposition. Although some fibers might have had a completely homotopic distribution, others had had an entirely heterotopic distribution, and most had had both. Details of the topographic distribution of this fascicle are specified in Figure 4.

Although the homotopic trait was found in the rostral aspect of the hemispheres, it slowly and progressively disappeared as we progressed to the caudal regions of the brain. Heterotopy was predominantly found in the latter region, notably engaging the parietal and occipital lobes. Perhaps this single aspect of the commissural fibers is an indication of neocortical complexity. Further studies are necessary to clarify this question.

Several studies have correlated the anatomy of the AC using tractography with postmortem dissections.<sup>9,24-29</sup> The existence of the anterior fascicle and the temporal extension of the AC have been previously verified.<sup>8-13</sup> Thus, our findings allowed us to confirm the findings determined from dissections.<sup>9</sup> Some studies have recognized a caudal component of the AC, designating it as a commissure that interconnects the frontal, temporal, and occipital lobes. The evidence of those connections was found by microsurgical anatomy,<sup>9,24,25,28,29</sup> the new technique referred to as MRI-guided dissection (*ex vivo*),<sup>30</sup> and, much earlier, using histological sectioning.<sup>10</sup> Moreover, the occipital component of the AC was dissected as the deep layer of the sagittal stratum (a term acquired recently that includes the AC and the optic radiations).<sup>26</sup> These investigators emphasized that its fibers



**Figure 4.** Different heterotopic and homotopic findings in tractographic reconstructions of the anterior commissure (AC). In this aspect, the AC has a role similar to that of the corpus callosum—associating areas between either the same or different cortical regions in both hemispheres. **(A)** Homotopic connections between the frontal lobes through the anterior fascicle. **(B)** Homotopic temporal connections. Only temporal fibers were present in this extension. **(C)** The right temporal extension connects the right temporal pole with the left hemisphere via heterotopic fibers. A caudal view of these heterotopic fibers revealed their incorporation into the inferior and medial bundles of the left parieto-occipital (PO) extension. These heterotopic fibers were also identified when the left PO extension was isolated. **(D)**

The superior and lateral bundles of the left PO extension seem to be the fibers involved in the “association tract” we described in the right hemisphere. **(E)** Dorsal view. The heterotopic fibers in the left PO extension join the right temporal extension and left thalamic fibers. **(F)** Dorsal view. The right thalamic fibers form a part of the left PO extension. **(G)** Dorsal view. The homotopic fibers of the PO extensions from both sides can be appreciated in this reconstruction. **(H)** A right dorsolateral view of the PO extensions, showing a wide range cortical distribution of the homotopic fibers through multiple bundles. Also, heterotopic fibers can be seen connecting the caudal part of the left hemisphere with the anterior part of the temporal lobe.

could not be distinguished from the optic radiations because the fibers were closely intermingled with the optic radiations.<sup>26</sup> Finally, the presence of the 2 fascicles was verified again in 2021.<sup>27</sup> Cavdar et al.<sup>27</sup> demonstrated a smaller anterior limb and a larger posterior limb. These findings are similar to those from our study. A remarkable difference regarding the cited studies was that we observed parietal bundles in continuity with the occipital bundles. This finding was the only discrepancy between the previously described findings from dissections and our findings using tractography.

Parietal fibers have been previously reported as an anomalous tract in patients with CC agenesis using a DTI tractography study.<sup>31</sup> These fibers were referred to as an “aberrant ventral forebrain bundle” and seemed to connect homotopically with the dorsolateral parietal cortices, in particular, the angular gyrus (Brodmann area<sup>29</sup>) and surrounding area.<sup>31</sup> They also provided evidence of functional connectivity between the right and left parietal cortex in those cases.<sup>31</sup> Another group of abnormal fibers was reported in CC agenesis that connected the occipital lobes.<sup>5,6,32</sup> These occipital fibers were also traced in a healthy man.<sup>33</sup> In addition, an anatomical study compared the distribution patterns of the AC in healthy subjects by performing a similarity map.<sup>13</sup> They also reported fibers that communicated with the occipital and parietal lobes.<sup>13</sup> Therefore, our findings have allowed us to confirm the findings from their fiber field map concerning the AC anatomy. Recently, another study reported a structure similar to our AC (containing what we have defined as the parieto-occipital extension).<sup>34</sup> However, the gross anatomy was not described because that had exceeded the purpose of their study.<sup>34</sup> In agreement with our investigators of healthy brains and supported by the findings from previous studies, we would suggest that both groups of fibers are normal components of the AC.

Regarding previously reported findings, the description of the parieto-occipital fibers was our main contribution, in accordance with the available data. This implies a change in the anatomical conception of the AC because we demonstrated that the parieto-occipital fibers represent the major proportion of the entire commissure. It would be interesting to evaluate whether this anatomical description also correlates with specific functionality, which would lead to a redefinition of the AC from a “connection between the 2 amygdaloid nuclei” to a proper bilateral communication pathway within almost every cerebral lobe.

No clear evidence has been reported regarding the presence of the AC thalamic fibers. More studies are necessary to clarify whether those were an artifact of the technique we used for fiber tracking.

### Clinical Considerations

The AC is involved in the transmission of sensory and cognitive information between the cerebral hemispheres. The anterior fascicle allows for the interhemispheric connection between both olfactory systems.<sup>9,11,35</sup> This fascicle could be, phylogenetically, the oldest commissure of the brain.<sup>8,27,36</sup> Some investigators have referred to the anterior fascicle as the olfactory commissure,<sup>36,37</sup> olfactory chiasm,<sup>38</sup> and paleopallial commissure<sup>3,9,36</sup> because of the connections with paleopallial structures, such as the septal area or entorhinal cortex.<sup>3</sup> It might

be the only commissure in primitive vertebrates whose brains are mainly olfactory, usually termed “olfactory brains”<sup>3</sup> or macrosomatic animals.<sup>10</sup> However, because the vertebrate’s cerebral cortex evolution is in continuous discussion,<sup>11</sup> it might be proper to refer to this fascicle simply as an allocortical commissure. Use of the term “allocortical commissure” would allow us to consider this fascicle and the hippocampal commissure collectively as non-isocortical (not 6-layered) commissures without necessarily comparing them within a timeline. The anterior fascicle includes interbulbar and intertubercular components, which maintain communication between the olfactory bulbs and anterior tubercles, respectively.<sup>9</sup> The olfactory tubercles are not very distinctive eminences in humans; however, their anatomical location is in the anterior perforated substance just as in many other animals.<sup>11</sup>

The temporal extension is involved in the transmission of auditory information.<sup>4</sup> Experimental evidence has been reported of locomotor hyperactivity, aberrant social interactions, and impairment of auditory fear memory resulting from the transection of the interamygdalar connections of the AC.<sup>39</sup> Another example of the important role of this extension is in temporal lobe epilepsy (TLE), in which seizures usually propagate interhemispherically through this pathway.<sup>13,34,37</sup> Also, some tumors can disseminate throughout this extension, which explains the gliomatosis cerebri phenomena.<sup>9,37,40</sup>

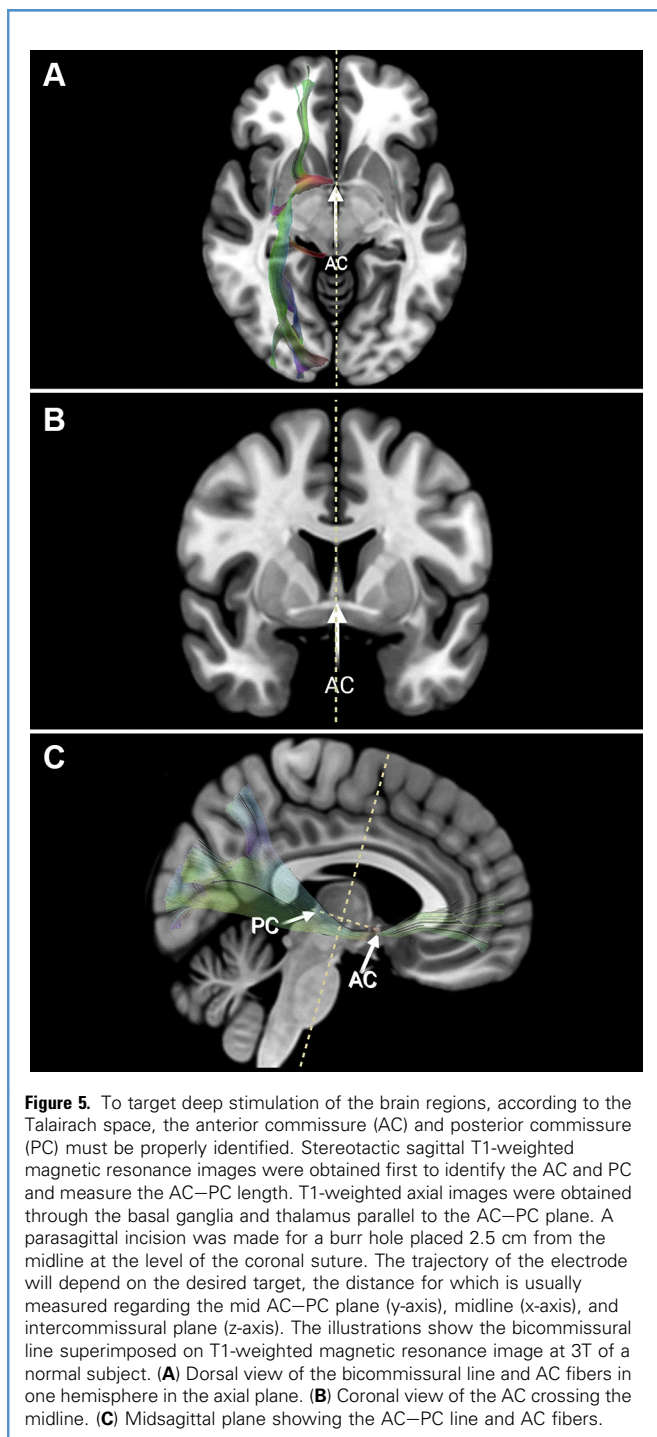
The AC connects the regions from the temporal lobe that are not connected by the CC (i.e., the right and left temporal language areas).<sup>9,38,41</sup> Language impairment in adolescents born preterm has been correlated with a decreased volume of the commissural fibers such as the AC and CC.<sup>42</sup> The connectivity of the anterior temporal lobe is dependent mainly on the AC.<sup>41</sup> It has a relevant impact on the semantic aspects of language<sup>41</sup> and memory.<sup>43</sup> This pathway could be critical for retaining comprehension ability after stroke in adults.<sup>41,42</sup>

Visual information is partially processed through the occipital fibers of the AC,<sup>5,24</sup> which might have an additional role in motivated behaviors related to fear and stress, similar to what has been observed in the temporal extension.<sup>9</sup> Interoccipital communication is essential for maintaining normal binocularity.<sup>5,32</sup> Occipital connections communicating with the most caudal part of the brain are supported mainly by the splenium of the CC but also by the AC.

The CC is the major telencephalic commissure. In cases in which it is absent or defective (i.e., congenital agenesis or surgical transection), the exchange of information between the hemispheres can be compensated for by the remnant commissures to maintain normal functional interhemispheric connectivity.<sup>2,44-49</sup>

Disruption of the interparietal connections can lead to deficits in visuospatial perception, such as tactile object recognition,<sup>2,31</sup> and selective attention processes (i.e., orienting, alerting, and executive attention).<sup>50,51</sup> Patients with CC agenesis will develop functionally superior connections supported via the AC since birth. This could explain the better performance in these domains compared with patients who had undergone callosotomy.<sup>2,31,51</sup>

It is noteworthy that the interhemispheric transfer of information will show recovery after total callosotomy within the first year postoperatively if the patient has an intact AC.<sup>52</sup> Disconnection



syndrome will usually be transitory in such cases.<sup>2,52,53</sup> Investigators reported faster recovery in communication between the frontal and temporal lobes and eventual improvement of function within the parietal lobes and visual cortices.<sup>52</sup> Our findings have provided the anatomical substrate for this finding, supporting the key role of the AC in maintaining whole brain interhemispheric connectivity.

### Surgical Considerations

The intercommissural line (between the AC and posterior commissure [PC]) is an essential landmark (Figure 5A and B) for the indirect localization of neuroanatomical structures during deep brain stimulation procedures and stereotactic and functional surgery (Figure 5C).<sup>9</sup> Identification of the intercommissural line could be useful for identifying the basal nuclei and diencephalon.<sup>54,55</sup> The AC and PC are both easy to visualize on a midsagittal section (Figure 5C), although seen as poorly defined fibers at 1.5T and well-delineated structures at 7T.<sup>56</sup> Thus, dramatic changes can occur in the accuracy of the line formation using different MRI systems.<sup>56</sup>

Anatomical knowledge of the AC is important when planning several approaches to the supratentorial ventricles or other deep neurological structures.<sup>27,28,57</sup> Its fibers can be damaged during passage through the deep white matter to reach a specific neurosurgical target.<sup>28</sup> The body of the AC can be used as the anterior edge of the passage in the transcallosal interforaminal approach to the third ventricle.<sup>27,57</sup> The AC fibers can be impaired during approaches to the lateral ventricles to treat hydrocephalus or periventricular lesions.<sup>28</sup>

In patients with refractory generalized TLE who had undergone callosotomy, residual seizure activity can be explained by the interhemispheric propagation through any remaining commissures,<sup>9</sup> such as the temporal extension of the AC, the largest commissure, and, less importantly, the PC or intermediate mass of the thalamus.<sup>2,9,24,34</sup> An alternative surgical treatment of refractory focus TLE is selective amygdalohippocampectomy.<sup>12,25</sup> This procedure is commonly performed using a transinsular<sup>12,25,37</sup> or temporal gyri transcortical approach.<sup>12,58</sup> It is possible to cause lesions to the temporal extension or parieto-occipital fibers of the AC and other periventricular white matter tracts during surgery.<sup>12,25,28,37,58</sup>

### CONCLUSIONS

In our study, we were able to develop a 3D model of the AC and its respective components via DSL. This allowed us to elaborate a more accurate analysis of its anatomy and its relationships. Our findings were not dissimilar from those of previous studies. Nevertheless, we found a distinct and newly described distribution of the parieto-occipital extension—the 4 major subdivisions that we called bundles and thalamic projections that had not been previously described. Furthermore, we related the termination of these bundles to specific cortical areas in each hemisphere.

These findings must be considered within the context of certain limitations. It is conceivable that, in our attempt to exclude fibers coming from the CC or fornix, we had subtracted AC fibers at the midline. Consequently, it is possible that future studies will show a larger AC than the one we found in our tracings. Our interpretation of the results was based on previously acquired anatomical knowledge of 3D images, which is not unailing. The use of the connectome could also have been a limitation, and studies of diffusion data from individual subjects and increasing the number of tests to a statistically significant quantity are needed.

In addition, our dissections had been performed before tractography. We did find the same results between the 2 methods. Our results suggest that the AC delineated using tracking methods will be larger than that found by dissection, with tractography



adding extensions to the main AC structure. To the best of our knowledge, no evidence has been reported concerning those extensions. It is possible that the lack of information about them could have influenced their absence during dissection. We cannot seek what we do not know. It is also possible that our tracings could have overestimated their presence. We hope that future studies will clarify these questions.

In the present study, the AC was shown to have an extensive and complex cortical distribution within the cerebral hemispheres. Detailed anatomical knowledge of the different cortical areas communicated with through these fibers could offer a better approach for the treatment of certain neurological disorders. Further studies are necessary to correlate the functional and structural connectivity of the cortices linked by the AC to provide a better understanding of the interhemispheric networks.

### CRediT AUTHORSHIP CONTRIBUTION STATEMENT

**Melanie Catena Baudo:** Study conception, Tractographies, Writing, Data extraction, Performed the analysis, Image editing, Bibliographic research. **Ezequiel Emanuel Colombo:** Study conception, Tractographies, Writing, Data extraction, Performed the analysis, Image editing, Bibliographic research. **Martina Arfilli Pérez:** Study conception, Writing, Bibliographic research. **Santiago Iván Rahn:** Study conception, Writing, Bibliographic research. **Nicolás Cristian Domenech:** Study conception, Writing, Bibliographic research. **Joaquín Chuang:** Dissection. **Valeria Forlizzi:** Dissection. **Pablo Buosi:** Dissection. **Matías Baldoncini:** Dissection, Image editing. **Mariana Bendersky:** Study conception, Tractographies, Writing, Data extraction, Performed the analysis, Image editing, Bibliographic research, Supervision.

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