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Endoscopic Anatomy of Transcallosal Hemispherotomy: Laboratory Study with Advanced Three-Dimensional Modeling

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BACKGROUND: Epilepsy surgery has an important role in the treatment of patients with medically intractable seizures. Various authors have proposed an endoscopic technique to perform disconnective procedures. A detailed description of intracerebral anatomy seen through an endoscopic transcallosal corridor has not been reported. The aim of this study was to present a cadaveric step-bystep anatomical demonstration of endoscopic transcallosal hemispherotomy using a dedicated threedimensional model.

METHODS: Anatomical dissections were performed on 6 cadaveric heads (12 hemispheres), and the disconnective procedure was performed using an endoscopic transcallosal approach. A dedicated three-dimensional model was used to better illustrate each step. A simulation of the disconnective procedure was performed by recreating the surgical steps on a subject from the Human Connectome Project dataset, and a calculation of the fiber tracts intersected was performed.

RESULTS: Analyzing data extracted from the threedimensional model and tractography simulation, 100% of the fibers (streamlines) of corpus callosum, corticopontine tracts, corticospinal tract, and inferior fronto-occipital fascicle were transected. Moreover, a satisfactory number of fibers (>95%) of the thalamocortical tracts, corticostriatal tracts, corona radiata, fornix, and uncinate fascicle were disconnected. CONCLUSIONS: This anatomical study described the relevant neurovascular structures to enable prediction of feasibility and control of the surgical procedure using the endoscopic transcallosal approach. The quantitative analysis permitted estimation of the theoretical efficacy of the procedure, confirming its relevant role in disconnective surgery.

INTRODUCTION

emispherical seizure disorders usually cause catastrophic epileptic syndromes,¹ especially in children, with significant deleterious effects on neurocognitive development^{2,3} and with an increased risk of mortality.⁴ Epilepsy surgery based on disconnective procedures, such as corpus callosotomy and hemispherotomy, has played an important role in the treatment of patients with medically intractable seizures⁵⁻⁷: several techniques with different anatomical targets have been proposed in recent decades, with the aim to minimize surgical approach and postoperative complications.^{8,9} Various authors have proposed an endoscopic technique to perform disconnective procedures; the surgical steps are similar to the steps used in the microsurgical approach and seem to be associated with fewer complications and high efficacy in terms of seizure control.¹⁰⁻¹² However, to our knowledge, a detailed description of intracerebral anatomy seen through an endoscopic transcallosal corridor has not been reported in the literature.

Key words

- Endoscopic
- Endoscopic surgery
- Functional neurosurgery
- Hemispherotomy
- Transcallosal

Abbreviations and Acronyms

3D: Three-dimensional **HCP**: Human Connectome Project

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1878-8750/© 2022 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/). Therefore, the aim of our study was to present a cadaveric step-by-step anatomical demonstration of endoscopic transcallosal hemispherotomy using a dedicated three-dimensional (3D) model.

MATERIALS AND METHODS

Anatomical Dissections and 3D Model

This study was approved by the institutional review board of the University of Barcelona, Barcelona, Spain. Anatomical dissections were performed at the Laboratory of Surgical Neuroanatomy in the Human Anatomy and Embryology Unit at the University of Barcelona on 6 cadaveric heads (12 hemispheres). The arterial and venous systems of the specimens had been injected with red and blue latex, respectively.

For all specimens, multislice helical computed tomography scans (SOMATOM Sensation 64; Siemens Medical Solutions USA, Malvern, Pennsylvania, USA) consisting of o.6-mm-thick axial spiral sections and a o° gantry angle, were obtained before and after the dissections. Five permanent bone reference markers were previously implanted into the specimen skulls to allow coregistration with the neuronavigation system (Medtronic, Minneapolis, Minnesota, USA). Imaging data were transferred to the laboratory navigation planning workstation, and point registration was performed, in which a registration correlation tolerance of 2 mm was considered acceptable. Further, magnetic resonance imaging with magnetization prepared rapid gradient echo iPAT (Siemens Medical Solutions USA) (repetition time 1800 ms, echo time 301 ms) and T2-weighted (repetition time 3200 ms, echo time 416 ms) sequences was performed and used for the 3D model.

The disconnective procedure was performed using a rigid endoscope measuring 4 mm in diameter and 18 cm in length with a o° and 30° lens (Karl Storz, Tuttlingen, Germany). The endoscope was connected to a light source (300 W Xenon; Karl Storz) through a fiberoptic cable and then to had high-definition camera (Endovision Telecam SL; Karl Storz). The microsurgical dissections (i.e., initial steps of the approach) were run with magnification ranging from $3 \times$ to $40 \times$ (OPMI; Carl Zeiss, Oberkochen, Germany).

For the endoscopic interhemispheric-transcallosal approach, the cadaveric head was positioned in the neutral supine position, slightly flexed at about 15°. The surgical steps were similar to those mentioned in the endoscopy-assisted interhemispheric transcallosal hemispherotomy performed by Chandra et al.^{10,13} Afterward, a horseshoe-shaped skin incision was drawn based on the position of the coronal and sagittal sutures. A craniotomy of 3×1.5 cm was performed with the help of the neuronavigation system. Right frontal and parietal parasagittal burr holes were made using a high-speed drill. The frontal burr hole was made just 1 cm in front of the coronal suture, and the parietal burr hole was made 2 cm behind the coronal suture and 0.5 cm away from the midline. The position of the craniotomy, guided by predissection planning and confirmed by the neuronavigator, was ideal to perform all the steps of the procedure, from anterior, lateral, to posterior and hippocampal disconnection. However, in the presence of anatomical variations, such as hypertrophic bridging veins, visible during the preoperative imaging and planning, the craniotomy position could be modified according to surgeon and

patient preference and characteristics. The dura mater was opened in a C-shaped manner and reflected medially, and the endoscope was inserted.

The hemispherotomy was performed in 5 main steps: corpus callosotomy, anterior disconnection, lateral disconnection, posterior disconnection, and hippocampal disconnection. A dedicated 3D model was used to better illustrate each step. The virtual 3D model was created using Amira 3D software for life sciences (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA). Bony structures were segmented from the computed tomography scan, and the different brain structures were segmented from the brain magnetic resonance imaging. Surgical trajectories were then represented using advanced instruments for measurement and quantification provided by the Amira workstation. The hemispherotomy steps and specific disconnection targets are listed in **Table 1**.

Tractography Simulation of Stepwise Disconnective Procedure

A simulation of the disconnective procedure was performed by recreating the surgical steps on a subject from the Human Connectome Project (HCP) dataset.14 An expert anatomist created a virtual representation of the disconnection trajectories for the HCP subject based on the dedicated 3D model. Regions of interest, masks, and image registration procedures were performed using FSL software,¹⁵ and TractSeg software¹⁶ was used to automatically reconstruct 72 white matter tracts using probabilistic tracking¹⁷ on tract orientation mapping. A number of white matter tracts were combined into the analysis for conceptual clarity, and an additional tractography reconstruction of fibers connecting the right hippocampus and amygdala to cortical regions was performed using MRtrix3 software¹⁸ with the iFOD2 algorithm. This software allowed us to simulate the stepwise disconnective procedure on the tractography reconstructions of the HCP subject using MRtrix3 tools to filter the fibers traversing the disconnection trajectories and quantify the disconnections produced at each successive step.

RESULTS

Qualitative Analysis

The rigid o° endoscope was inserted, and the medial part of the hemisphere was dissected from the falx. A spatula was positioned to gently retract the contralateral hemisphere. The first visualized structure was the callosomarginal artery that courses within the cingulate sulcus and arises from the pericallosal artery, which lies on the body of the corpus callosum in the pericallosal cistern. Both pericallosal arteries were spared laterally until the corpus callosum was clearly visualized. The exposure of the corpus callosum was performed from the genu to the splenium (Figure 1A-E).

Step 1: Corpus Callosotomy. The anterior portion was incised first, thus entering the ventricular system at the level of the ipsilateral lateral ventricle. It is essential to perform the callosotomy ipsilaterally to the side of the hemispherotomy, to enter into the ipsilateral lateral ventricle¹⁹: this improves intraoperative orientation and surgical efficacy. The foramen of Monro and the choroid plexus were identified. Next, the head of the caudate

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Table 1. Endoscopic Hemispherotomy Steps and Specific Fiber Targets								
Step	Procedure	Structures	Disconnection Target					
1	Corpus callosotomy	Corpus callosum	Interhemispheric fibers					
2	Anterior disconnection	Subcallosal gyrus	Anterior temporal lobe, amygdala, and fronto-orbital fibers					
3	Lateral disconnection	Thalamo, basal ganglia, insula, claustrum	Fibers of corona radiata, internal capsule, anterior temporal connections, and orbitofrontal connections					
4	Posterior disconnection	Tissue between choroid plexus at the atrium and posterior part of splenium	Fibers of posterior column of fornix					
5	Hippocampal disconnection	Hippocampus	Hippocampal projection and association fibers					

nucleus in the lateral wall of the frontal horn was visualized. The callosotomy continued to the genu following the curve of the anterior cerebral artery until the subcallosal gyrus was reached.

Then, the corpus callosotomy continued posteriorly toward the splenium, by following the inferior border of the falx cerebri as it curved inferiorly and thus onto the velum interpositum

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Figure 1. Right endoscopic transcallosal approach. (A and B) Craniotomy 3×1.5 cm one third anteriorly and two thirds posteriorly to the coronal suture. (C-E) The dura mater was opened in a C shape and reflected medially on the superior sagittal sinus to expose the frontal lobe and the falx (C), and the dissection proceeded through the interhemispheric fissure (D and E). Step 1, callosotomy. (F and G) On Amira three-dimensional reconstruction, the green plane represents the area of the callosotomy. (H-K) The corpus callosum was identified (H), and the callosotomy was started at the anterior part and continued to the genu following the curve of the anterior creebral artery (I and J); the disconnection continued posteriorly toward the splenium by following the inferior border of the falx cerebri (K). Step 2,

anterior disconnection. (**L** and **M**) On Amira three-dimensional reconstruction, the orange triangular plane represents the area of the anterior disconnection. (**N** and **O**) A corticectomy in the subcallosal cortex was performed and directed toward the floor of the anterior skull base (**N**); the corticectomy was directed laterally, passing anteriorly to the head of the caudate nucleus at the level of the lesser wing of the sphenoid (**O**). FL, frontal lobe; DM, dura mater; AB, arachnoidal bends; CC, corpus callosum; PCA, pericallosal artery; CMA, callosomarginal artery; ACA, anterior cerebral artery; ACA, anterior carotid artery; GR, gyrus rectus.

containing the internal cerebral veins and vein of Galen (Figure 1F-K).

Step 2: Anterior Disconnection. The anterior disconnection started anteriorly, at the level of the subcallosal gyrus. A corticectomy in the subcallosal cortex was performed and directed toward the floor of the anterior skull base to the gyrus rectus. Next, the corticectomy was directed laterally, passing anteriorly to the head of the caudate nucleus at the level of the lesser wing of the sphenoid. At this stage, the olfactory tract, first segment of the anterior cerebral arteries, internal carotid bifurcation, and distal part of the optic nerve could be visualized through the arachnoid, and the middle cerebral artery could be followed from proximal to distal (Figure 1L–0). The anterior disconnection cuts the connections,

including those from the anterior temporal lobe, amygdala, and frontal lobe.

Step 3: Lateral Disconnection. The lateral disconnection started in the lateral portion of the ventricle beside the thalamus. The procedure was continued posteriorly. The bulk of the basal nuclei lies here. The disconnection was then completed by incising laterally to the thalamus and laterally to the choroid fissure to the atrium, separating the basal ganglia and the claustrum. The middle cerebral artery can be observed in the anterior and inferior portion of the disconnection (**Figure 2A**–**E**). This procedure disconnects the corona radiata and the internal capsule projection fibers.

Step 4. Posterior Disconnection. Posterior disconnection consists of cutting the posterior column of the fornix in the collateral trigone.



Figure 2. Step 3, lateral disconnection. (A and B) On Amira

three-dimensional (3D) reconstruction, the pink plane represents the area of the lateral disconnection. (C) The lateral disconnection started in the lateral portion of the ventricle, beside the thalamus. (D and E) The disconnection was then completed by dividing laterally to the thalamus (D), laterally to the choroid fissure to the atrium, separating the basal ganglia and the insula (E). Step 4, posterior disconnection. (F and G) On Amira 3D reconstruction, the light green plane highlighted by the *black arrow* (F) represents the area of the posterior disconnection (G). Posterior disconnection consists of cutting the posterior column of the formix. (H and I) Each crus of the formix arises as

a continuation of the fimbria; passes between the choroidal fissure, the posterior surface of the pulvinar, and the thalamus; and blends into the lower and posterior part of the splenium. Step 5, hippocampal disconnection. (**J** and **K**) On Amira 3D reconstruction, the violet C-shaped plane represents the area of the hippocampal disconnection. (**L** and **M**) The disconnection was performed in the lateral face of the hippocampus, medial to the collateral eminence (**L**), and was further achieved on the leateral of the hippocampus and at the posterior hippocampus at the level of the lateral mesencephalic notch (**M**). CP, choroid plexus; T, thalamus; F, falx; HH, hippocampus head; HB, hippocampus body; HT, hippocampus tail.

Each crus of the fornix arises as a continuation of the fimbria, passes between the choroidal fissure and the posterior surface of the pulvinar and the thalamus, and blends into the lower and posterior part of the splenium (Figure 2F-I).

Step 5. Hippocampal Disconnection. Once the temporal roof was opened, the hippocampus could be seen as well as the most anterior bulge of the amygdala and the fimbria. The disconnection was performed in the lateral face of the hippocampus, medial to the collateral eminence, and was further achieved on the head of the hippocampus and at the posterior hippocampus at the level of the lateral mesencephalic notch (Figure 2J–M). This step disconnects the projections of the mesial temporal lobe to the limbic structures; the Papez circuit extends from hippocampus and projects via the fornix to the mammillary bodies, thalamus, and cerebral cortex. This is a crucial pathway for epileptic propagation.

Tractography Quantitative Analysis

A simulation of the 5 disconnection steps was performed on the tractography based on the HCP subject. The steps were simulated consecutively: from the original number of streamlines, in each of the 72 reconstructed tracts, the fibers transected with the trajectory plane of step 1 (corpus callosotomy) were counted and eliminated. The remaining fibers were then tested with the trajectory plane of step 2 (anterior disconnection), and so on. This means that every step was tested on the fiber tracts left after the previous disconnection. Analyzing these data, after simulating all the steps, it was possible to transect 100% of the fibers of corpus callosum, corticopontine tracts, corticospinal tract, and inferior fronto-occipital fascicle. Moreover, a satisfactory number of fibers (>95%) of the

corticostriatal tracts, corona radiata, fornix, and uncinate fascicle were transected. The quantity of fibers transected by each step is reported in **Table 2**. The most relevant simulation steps, transected planes, and groups of fibers transected are reported in **Figures 3** and **4**.

DISCUSSION

Anatomical hemispherectomy was introduced in 1928 by Dandy for infiltrating gliomas in the nondominant hemisphere. This technique consisted of total resection of a brain hemisphere with the basal ganglia, cutting the anterior and middle cerebral arteries distal to the bifurcation: the limits of this removal were the corpus callosum, falx cerebri, tentorium medially and posteriorly, and olfactory tract and optic nerves inferiorly. This technique was subsequently modified by Gardner,²⁰ who preserved the basal ganglia and resected the anterior and middle cerebral arteries distal to the origin of the deep perforators, allowing a better postoperative motor outcome.

In epilepsy, the procedure was performed for the first time by McKenzie²¹ in 1938 to treat seizures in patients with infantile hemiplegia. After 1950, when Krynauw reported the cases of 12 children with epilepsy and behavioral changes who were operated on with a successful outcome regarding seizure control, this technique started to gain popularity. Subsequently, Penfield and Rasmussen began performing this procedure in 1952 at the Montreal Neurological Institute.

At the present time, anatomical hemispherectomy is a wellknown and accepted procedure that results in seizure control in 43%-90% of cases.²² However, complications including hydrocephalus and a superficial cerebral hemosiderosis with

Table 2. Data Collected from Simulated Disconnection									
	Total Fibers Transected (%)	Fibers Transected by Step 1 (%)	Fibers Transected by Step 2 (%)	Fibers Transected by Step 3 (%)	Fibers Transected by Step 4 (%)	Fibers Transected by Step 5 (%)			
Corpus callosum	100.0	99.7	0.3						
Corticopontine tracts	100.0			100					
Corticospinal tract	100.0			100					
Thalamocortical tracts	99.6			100					
Corticostriatal tracts	95.7	0.2	9.5	90.4					
Corona radiata	98.2	0.1	3.4	96.5					
Superior longitudinal fascicle	10.2			100					
Cingulum	3.2	68.3	7.9			23.8			
Anterior commissure	38.4			100					
Fornix	96.5	36.6			63.4	0.1			
Inferior fronto-occipital fascicle	100.0		11.3	88.8					
Inferior longitudinal fascicle	9.4			27.3		72.7			
Uncinate fascicle	99.1		30.3	69.7					

Bold numbers represent percentages of each group of fibers transected at the end of the simulated disconnection steps. All other numbers represent the percentage of fibers of that group disconnected from a single step (step 1, corpus callosotomy; step 2, anterior disconnection; step 3, lateral disconnection; step 4, posterior disconnection; step 5, hippocampal disconnection).



from the Human Connectome Project dataset using MRtrix3. Step 1, corpus callosotomy. (**A** and **B**) Trajectory reconstruction (**A**) and the group of fibers (streamlines) transected (green color) (**B**). Step 2, anterior disconnection. (**C** and **D**) Trajectory reconstruction (**C**) and the group of fibers transected (orange color) (**D**). Step 3, lateral disconnection. (**E** and **F**) Trajectory reconstruction (**E**) and the group of fibers transected (red color) (**F**). Step 4, posterior disconnection. (**G** and **H**) Trajectory reconstruction (**G**) and the group of fibers transected (yellow color) (**H**). (**I** and **J**) Step 5, hippocampal

transected (violet color) (J). (K) 3D reconstruction of all the trajectory planes. Step 1, corpus callosotomy (green color); step 2, anterior disconnection (orange color); step 3, lateral disconnection (red color); step 4, posterior disconnection (yellow color); step 5, hippocampal disconnection (violet color). (L) Coronal plane 3D reconstruction of fibers tracts transected at the end of the simulated procedure. Fibers transected by step 1 trajectory (green color), step 2 trajectory (orange color), step 3 trajectory (red color), step 4 trajectory (yellow color), and step 5 trajectory (violet color).

significant mortality rates have been reported.^{23°26} To overcome these limitations, the surgical technique has been modified with the development of functional hemispherectomy and hemispherotomy. The latter could be performed with 2 different techniques: the vertical approach proposed by Delalande et al.²⁷ and the peri-insular approach by Villemure and Daniel.²⁸ In both techniques, cortical resection is minimized, and the rest of the hemisphere is functionally isolated by disconnecting the neuronal fibers of the entire epileptic cortex from the subcortical structures,²⁹ showing excellent seizure control (75%–90% of cases) with significantly less morbidity³⁰ and low rate of postoperative hydrocephalus.³¹

In 2015, Chandra et al.¹⁰ published the first article about endoscopy-assisted interhemispheric transcallosal hemispherotomy, which was performed in 5 pediatric patients with well-established criteria, with 81.1% of the patients having an Engel class I outcome. Subsequently, Sood et al.¹¹ performed an interhemispheric approach supported by an endoscope equipped with mounted suction for the bimanual technique in ² pediatric patients, with definitive seizure control and diffusion tensor imaging showing complete disconnection. In the literature, there is only I article to our knowledge describing endoscopic hemispherotomy in cadaveric specimens. Bahuleyan et al.³⁰ described an endoscopic transventricular approach for hemispherotomy, but the disconnection was performed using an anterior and posterior burr hole, without a neuronavigation system. Nevertheless, this approach would be difficult to perform in the presence of small ventricles.

Therefore, our study aimed to present a cadaveric step-by-step anatomical demonstration of endoscopic transcallosal hemispherotomy with a dedicated 3D model. This procedure is based on the vertical hemispherotomy described by Delalande et al.²⁷ The commissural structures in the brain are responsible for functionally connecting both hemispheres. The goal of hemispherotomy is to disconnect the commissural tissues and projection bundles: epileptic activity can spread to the contralateral hemisphere and the central core through these



step 3 lateral disconnection (red plane). (F) Fornix fibers transected by step 1 corpus callosotomy (green plane) and by step 4 posterior disconnection

disconnection (red plane). (L) Uncinate fascicle fibers transected by step 2 anterior disconnection (orange plane) and by step 3 lateral disconnection (red plane).

tracts and the limbic system. Therefore, the main commissural fibers (corpus callosum, anterior commissure) and the main projection fibers, including the fornix, optic and auditory radiations, corona radiata, and internal capsule (corticospinal tract), were transected.

Our procedure was performed through a horseshoe-shaped incision in the skin because cadaveric skin is very thick; the skin of patients, especially younger patients, is flexible, so a parasagittal linear incision can be done followed by a craniotomy 3×1.5 cm. We did not perform cortical resection of the superior frontal gyrus, but instead accessed the ventricular corpus through the interhemispheric corpus callosotomy. In addition, patients who are candidates for hemispherotomy usually, owing to chronic neurological insults, present with atrophy of the cerebral cortex, basal ganglia, and corpus callosum; this can cause ventriculomegaly favoring ventricular navigation and the manipulation of endoscopic instruments within the ventricular chambers.

Disconnection is made between the external capsule, which is the limit between tissues supplied by the lenticulostriate arteries, and the insular arteries. There are no anastomoses among these arteries,³² which decreases bleeding risk. Moreover, at the level of the insula, the uncinate fascicle crosses the anterior-inferior part of the external capsule and claustrum and connects to the temporal lobe with the frontal cortex. Meanwhile, the insular cortex can be disconnected more easily and definitely with the disconnection of the insulo-opercular fibers traveling in the outer layer of the extreme capsule and the temporal stem, which connect the anterior short gyrus and the insular pole to the inferior frontal and lateral orbital gyri.³³ In fact, the disconnection of the temporal stem is crucial to obtain a satisfactory clinical outcome: it has been demonstrated that its residual connections is one of the most frequent causes of recurrent seizures.³⁴

The amygdala complex has connections through 2 major fiber bundles: 1) the stria terminalis along the tail of the caudate and 2) the diagonal band of Broca. The stria terminalis and the fibers of the anterior commissure lie on the temporal horn roof, just lateral to the choroid fissure. The removal of the temporal horn roof from the choroid plexus effectively disconnects this fibrous system. Finally, the diagonal band of Broca, from the amygdala, runs over the middle cerebral artery, just anterior to the optic tracts. On the anterior perforated substance, a corticectomy can then expose the entire anterior cerebral artery to the middle cerebral artery sections of this band. Thus, we do not need to section the anterior commissure at the midline because once the disconnection of the frontobasal surface is done, the anterior commissure is disconnected. However, this is the step where the possibility of insufficient disconnection is greatest, and the postoperative seizure freedom outcome is poor.

We have proposed performing the hippocampal disconnection once the temporal horn roof is removed, thereby achieving complete disconnection of the limbic system, which was done initially in the posterior disconnection. The complete anatomical separation of the hippocampal formation from surrounding structures inhibits the propagation of seizures from the hippocampus, especially in patients with an associated hippocampal lesion.35 Moreover, a simulation of the 5 disconnection steps was performed on the tractography based on the HCP subject, using MRtrix3 tools to filter the fibers (streamlines) traversing the disconnection trajectories and quantify the disconnections produced at each successive step. Analyzing these data, after performing all the steps, it was possible to transect 100% of the fibers of corpus callosum, corticopontine tracts, corticospinal tract, and inferior fronto-occipital fascicle. Moreover, a satisfactory number of fibers (>95%) of the thalamocortical tracts, corticostriatal tracts, corona radiata, fornix, and uncinate fascicle were transected. Analyzing these data, which are clarified and reported in Table 2, it was predictable that the majority of the fibers of corpus callosum were transected during step 1. Moreover, the lateral disconnection is responsible for the transection of the corticopontine, corticospinal, and thalamocortical tracts.

Clinically, the efficacy of this technique has been demonstrated by Chandra et al.³⁶ In a series of 59 patients comparing open (n =27) and endoscopic (n = 32) hemispherotomy, the authors found equal efficacy in terms of seizure outcomes, with a smaller amount of blood loss and a shorter hospital stay in endoscopic hemispherotomy compared with the open technique. With aims to develop minimally invasive treatments, recent studies have described the use of robotic assisted radiofrequency ablation or

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an ultrasonic aspirator to facilitate blood loss control and to reduce surgical timing. $^{\rm 37}$

Study Limitations

The main difficulty of our study was to perform the procedure in a specimen with normal ventricular size. As already reported by previous studies, generously sized ventricles and thin cortical mantles allow for a larger operative corridor and wider working space as well as help to maintain orientation during the disconnection because of clearer anatomical landmark visualization.³⁸ A wider surgical field was obtained as the size of the ventricle increased.³⁹ Hence, this technique should be reserved for atrophic cases, especially for inexperienced surgeons until the learning curve is achieved. Also, silicone-injected brains lack the elastic characteristics of living tissue, such as reproduction of tissue retraction, and this is an inherent drawback of all cadaveric studies. The quantitative analysis was done in a 3D simulation model with all the consequent limitations.

CONCLUSIONS

The endoscopic transcallosal hemispherotomy approach affords good visualization and comparable disconnection compared with conventional approaches. This anatomical study described the relevant neurovascular structures to enable prediction of feasibility and control of the surgical procedure using the endoscopic transcallosal approach. The endoscopic transcallosal hemispherotomy approach appears to be limited to select surgical settings. However, this approach appears to address some of the shortcomings of conventional approaches and may constitute a valuable addition to the established surgical options. More surgical case series are needed to establish the clinical value of this approach to better determine its place in the armamentarium of epilepsy surgery. The quantitative analysis based on a 3D simulation model permitted estimation of the theoretical efficacy of the procedure, confirming the relevant role of endoscopic transcallosal hemispherotomy in disconnective surgery.

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