

Primary Tumors of the Lateral Ventricles of the Brain

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Rezumat

Tumorile primare ale ventriculilor laterali ai creierului

Fundament: Ventriculii laterali sunt localizați în centrul creierului. Fiecare ventricul vine în contact cu cinci structuri neurale critice: nucleul caudat, talamusul, fornixul, corpul calos și genunchiul capsulei interne. Autorul raportează experiența sa cu tumorile primare ale ventriculilor laterali analizând simptomatologia, tratamentul chirurgical, complicațiile și rezultatele postoperatorii.

Obiective: Să determine importanța tehnicii chirurgicale asupra morbidității și recurenței tumorilor ventriculilor laterali. Rezecția chirurgicală totală urmată de radioterapie și/sau chimioterapie la cazurile cu tumori anaplastice a prezentat principalul obiectiv.

Metode: Acest studiu retrospectiv se referă la 202 tumori primare ale ventriculilor laterali operate de Leon Dănăilă între anii 1982 și 2012. Analiza respectivă se bazează pe abordurile operatorii și pe extinderea rezecției. Căile de abordare chirurgicală ale acestora au fost interhemisferică transcaloasă și transcorticală.

Rezultate: Un număr de 177 (87%) din tumorile primare din ventriculii laterali au fost benigne (low grade lesions) și 25 (12,37%) anaplastice. Cele mai frecvente tumori au fost endimoamele, astrocitoamele, subependimoamele, papiloamele de plex coroid și meningioamele. Din totalul celor 202 tumori,

164(81,18%) s-au externat cu rezultate foarte bune și bune, 35 (17,32%) au rămas cu deficite neurologice iar 3 (1,48%) au decedat. La o proporție semnificativă de pacienți s-a dezvoltat postoperator hidro-cefalia, fapt datorită căruia a fost necesară instalarea unor șunturi ventriculo-peritoneale.

Concluzii: Majoritatea acestor tumori au fost benigne cu o rată de creștere relativ înceată. Datorită acestui fapt dimensiunea preoperatorie a tumorilor a fost de câțiva centimetri. Vârsta medie a pacienților a fost mai mică decât a celor cu leziuni asemănătoare situate intraparenchimos. Simptomele au fost determinate de obstrucția lichidului ventricular și de afectarea structurilor periventriculare. Abordurile chirurgicale cele mai bune au fost cel interhemisferic transcalos și transcortical.

Cuvinte cheie: ventricul lateral, microchirurgie, tumori primare

Abstract

Background: The lateral ventricles are located in the center of the brain. Each ventricle lies in contact with five critical neural structures: the caudate nucleus, the thalamus, the fornix, the corpus callosum, and the genu of internal capsule. The authors report their experience in primary tumors of the lateral ventricles of the brain by analysing the symptomatology, the surgical treatment, the complications and the post-operative results.

Objective: To determine the importance of the surgical technique on the morbidity and the recurrence of lateral ventricles tumors. Total surgical resection followed by radiotherapy and/or chemotherapy had been the main objective in the cases of anaplastic tumors.

Methods: This retrospective study makes reference to 202

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primary tumors of the lateral ventricles operated by Leon Danaila between 1982 and 2012. The respective analysis is based on the operative approaches and on the extent of resection. The surgical access routes were the interhemispheric transcallosal approach and the transcortical approach.

Results: A number of 177 (87%) of the primary tumors of the lateral ventricles were benign (low grade lesions), while 25 (12.37%) of them were anaplastic. The most frequent tumors were ependymomas, astrocytomas, subependymomas, choroid plexus papillomas and meningiomas. Out of the total of 202 tumor cases, 164 (81.18%) were discharged with very good and good results, 35 (17.32%) were left with neurological deficits, and 3 (1.48%) died. A significant proportion of the patients undergoing surgery develop cerebrospinal fluid outflow obstruction, and this fact made the postoperative mounting of a number of ventricular shunts necessary.

Conclusion: The majority of these tumors were benign, with a relatively slow growth rate. Owing to this fact, the preoperative dimensions of the tumors were of several centimeters. The average age of the patients was lower than that of those with similar lesions located intraparenchymatously. The symptoms were determined by the ventricular outflow obstruction and by the affectation of the periventricular structures. Interhemispheric transcallosal and transcortical approaches were the best surgical access routes.

Key words: lateral ventricle, microsurgery, primary tumors

Introduction

In 1854, Shaw provided one of the earliest reports of a patient with a lateral ventricular tumor (1). He described a 63-year-old man who had suffered from right leg paresis, aphasia and seizures for 27 years.

The autopsy revealed an irregular, globular, fibrous tumor situated in the left lateral ventricle. Abbott and Courville's analysis reached the conclusion that this tumor had most likely been a meningioma (1).

Subsequently, Dandy estimated that such lesions constituted only 0.75% of intracranial tumors. In Cushing's series of 2000 brain tumors, only 9 had occurred within the lateral ventricle (2,3).

Pendl et al. (1992) (3) observed 55 tumors of the lateral ventricle among 4289 tumors of the brain.

The respective tumors had affected a multitude of anatomical structures involved in the accomplishment of the functions of conscience, memory, emotion and personality, balance, etc.

The majority of the tumors of the lateral ventricles are benign or low grade lesions. Because of their relatively slow growth rate, these lesions may reach sizes of several centimeters before they require medical attention.

The regions of the lateral ventricles can be accessed

through either transcallosal, or transcortical dissection.

For each access route there are multiple options for patient positioning, scalp incision and craniotomy.

However, each procedure must be customized according to the position of the tumor in each individual case.

The anatomic landmarks which are normally used to provide orientation may be distorted by the lesion itself, by the surgical configuration and by the degree of ventricular dilatation.

The careful review of the patient's preoperative imaging studies and the clinical presentation will highlight the salient features and help the surgeon anticipate the operative findings.

Although commonly benign, the tumors of the lateral ventricle pose a formidable challenge to neurosurgeons, because their deep location makes every intervention potentially difficult. All surgical approaches to this region require the transection or the retraction of neurological structures such as the corpus callosum, the cingulate gyrus, the parietal cortex, the temporal cortex or the fornix.

Furthermore, once inside the ventricle, it may be necessary to manipulate or ablate deep arterial or venous structures such as the internal cerebral veins, the anterior choroidal artery, the medial posterior choroidal artery, or the lateral posterior choroidal artery (4).

Material and Methods

Beginning with 1982 and until 2012, Leon Danaila has operated in the Neurosurgery II Clinic in Bucharest a number of 25,035 cerebral tumors, of which 202 (0.80%) were located in the lateral ventricles. The most frequently affected age group was that between 15 and 40 years old (69.30%).

The average age of the patients at the moment of surgery was 41 years old (range 15 to 69).

We found 109 (53.96%) tumors in women, while 93 (46.03%) were in men (*Table 1*).

Therefore, lateral ventricular tumors appear to have a propensity for young patients and for females.

The localization, which in some of the cases was only approximated, is shown in *Table 2*. Extensive tumors are represented by lesions which include two or more regions of the lateral ventricles.

The symptoms encountered in our patients with tumors of the lateral ventricles were both general and localized.

The symptoms from the first category were much more frequent than those from the second one. I will present hereinafter the general symptoms together with the number of affected patients (*Table 3*). The most frequent symptom was acute and subacute headache, often accompanied by nausea and vomiting, which were encountered in 124 (61.38%) patients, followed by memory disorders (98 – 48.51%), epilepsy (47 – 23.26%), behavioural and cognitive deficits (34 – 16.83%) and gait and balance disorders (19 – 9.40%).

Unilateral localized symptoms were relatively rare. Their type and frequency are presented in *Table 3*. According to this,

Table 1. The age and gender of the 202 patients with primary tumors developed in the lateral ventricles

The patient age group in years	Number of patients	Patients' gender	
		Male	Female
15 – 20	29 (14.35%)	13	16
21 – 30	57 (28.21%)	27	30
31 – 40	54 (26.73%)	25	29
41 – 50	35 (17.32%)	15	20
51 – 60	19 (9.40%)	9	10
61 – 70	8 (3.96%)	4	4
Total	202	93 (46.03%)	109 (53.96%)

hemiparesis was encountered in 18 (8.91%) patients, aphasia in 12 (5.94%), hemihypoesthesia in 11 (5.44%) and homonymous hemianopsia in 3 (1.48%). Generally, localized symptoms had a moderate intensity.

Thus, tumors of the lateral ventricle tend to generate general symptoms such as headache, memory deficit, epilepsy, behavioural and cognitive deficits, as well as gait and balance disorders. They uncommonly result in focal neurological deficits. Changes in recent memory (short term memory) and behaviour, particularly an increasing apathy, can occur in the absence of increased intracranial pressure.

However, patients presenting with intraventricular tumors pose a threat of acute deterioration from occlusion of CSF pathways.

Before discussing the surgery of these tumors, we shall present several notions of the anatomy of the lateral ventricles.

Surgical options

Frontal horn tumors

We had a number of 55 tumors of the frontal horn, of which 19 were approached using the transcallosal inter-hemispheric route, and 36 through the anterior transcortical route.

The transcallosal approach

The transcallosal approach was most suitable for lesions within the frontal horn, especially when the ventricle was of normal size. This route affords access to both the lateral and medial sides of the ventricle. The bone flap should cross the superior sagittal sinus to allow the complete exposure of the interhemispheric fissure. The bridging veins must be preserved. The retractor blade is progressively advanced in the interhemispheric fissure to expose the cingulate gyrus, and then the pericallosal arteries. The small anastomoses between the left and right arterial complex may be coagulated and divided.

Some surgeons advocate for performing the dissection ipsilateral to the lesion, but for lesions within the dominant hemisphere an approach from the contralateral side may be possible in order to minimize the retraction on the dominant

Table 2. The localization of the 202 tumors of the lateral ventricles

The localization of the tumors	Number of patients
Frontal horns tumors	55 (27.22%)
Tumors of the body	37 (18.31%)
Atrium tumors	23 (11.38%)
Occipital horn tumors	17 (8.41%)
Temporal horn tumors	42 (20.79%)
Extended tumors	28 (13.86%)
Total	202

Table 3. The symptoms encountered in the 202 patients with tumors of the lateral ventricles

General symptoms	Number of patients
Headaches	124 (61.38%)
Memory disorders	98 (48.51%)
Epilepsy	47 (23.26%)
Behavioral and cognitive deficits	34 (16.83%)
Gait and balance disorders	19 (9.40%)
Localized symptoms	
Hemiparesis	18 (8.91%)
Aphasia	12 (5.94%)
Hemihypoesthesia	11 (5.44%)
Homonymous hemianopsia	3 (1.48%)

frontal lobe (5,6). However, the transcallosal corridor allows especially the resection of tumors of the median line (Fig. 1, 2, 3, 4) without excessive retraction.

After the performance of the corpus callosotomy and the entrance in the ventricle, landmarks such as the foramen of Monro and the thalamostriate vein can be identified.

However, the callosotomy limited to the genu and the anterior body of the corpus callosum is generally well tolerated and without neurological sequelae (5,6,7,8).

The anterior transcortical approach

The anterior transcortical approach provided access the ipsilateral frontal horn tumors (Fig. 5). The exposure is performed over the middle frontal gyrus which is incised, and the underlying white matter is divided to access the frontal horn. A 2 to 3 cm gyral incision is performed, which is then developed down into the ventricle.

It is difficult to access the contralateral frontal horn unless significant hydrocephalus is present. After the ventricular chamber is opened, the operative microscope is used. Tumor removal is achieved by maintaining the tumor interface with the ependymal surface.

In cases with very large tumors which expand into frontal horn and the body of the ventricle, a combined trans-sulcal and transcallosal approach can be performed, because individual exposure of each has its own limits.

Ventricular approach across the corpus callosum offers us access to the ventricular horn only after an excessive retraction.

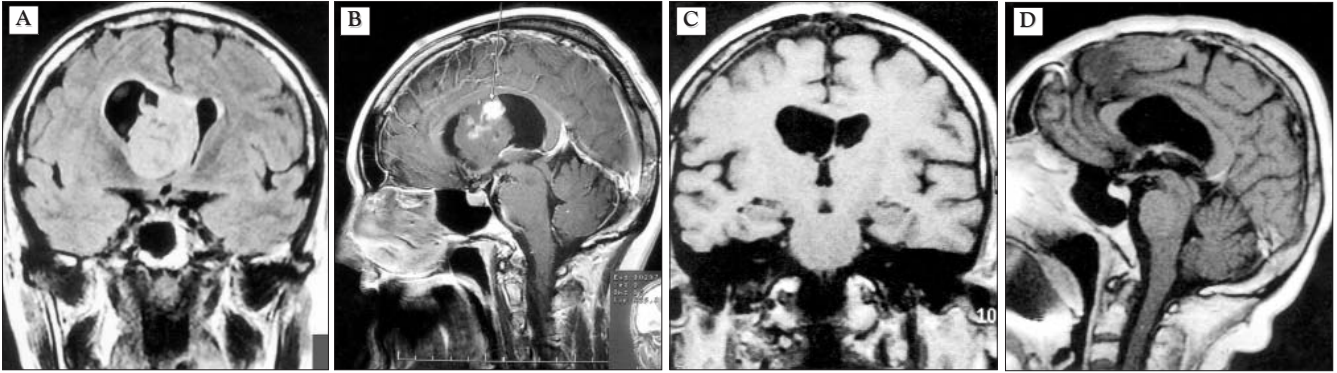


Figure 1. Preoperative coronal and sagittal T1-weight gadolinium-enhanced MRI, demonstrating a subependymoma arising from the left lateral ventricle and extending into the right ventricle and into the third ventricle (A, B). Images C and D had been obtained after the complete removal with excellent results. The excision had been accomplished through an interhemispheric transcallosal approach (surgeon Leon Danaila)

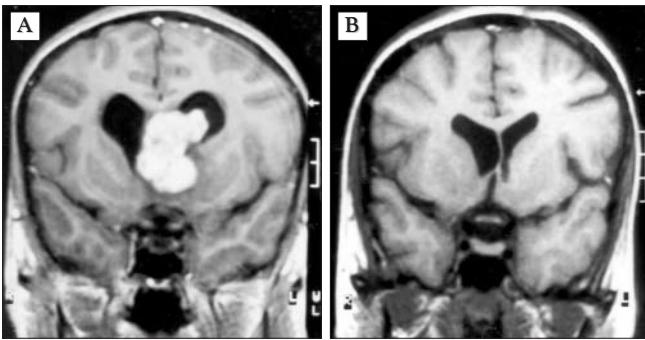


Figure 2. Coronal enhanced magnetic resonance imaging of a subependymoma arising from the left lateral ventricle (the frontal horn) and extending into the third ventricle (A). Image B was obtained after the complete removal of the tumor through interhemispheric transcallosal approach, with excellent results (surgeon Leon Danaila)

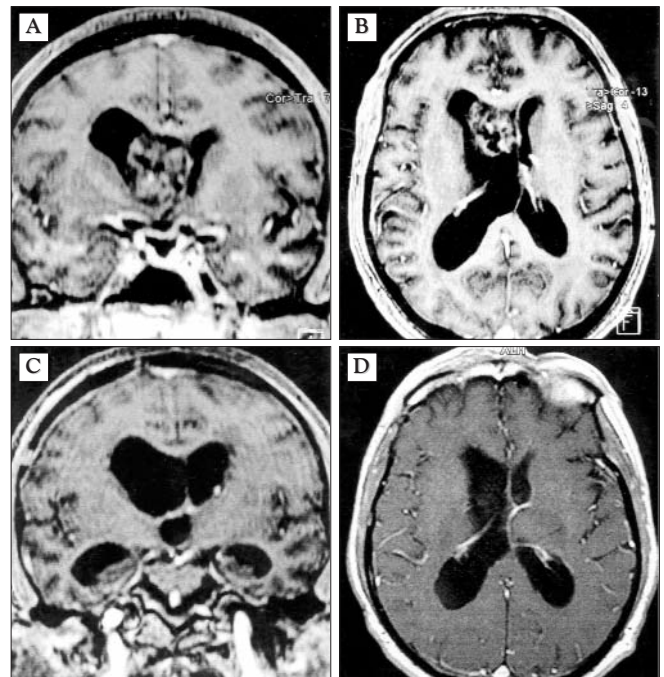


Figure 3. Coronal and axial enhanced magnetic resonance imaging of an astrocytoma arising from the right frontal horn of the lateral ventricle (A, B). Images C and D had been obtained after the complete removal of the tumor through the interhemispheric transcallosal approach, with very good results (surgeon Leon Danaila)

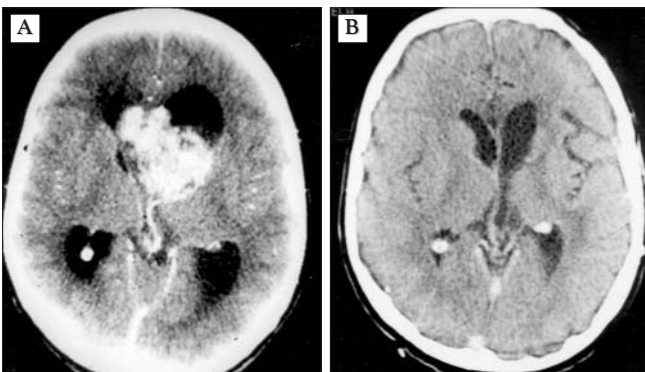


Figure 4. Axial enhanced magnetic resonance imaging of a choroid plexus papilloma arising from the left lateral ventricle (A). Postoperative MRI after the complete anterior transcallosal resection of the tumor (B), with very good results (surgeon Leon Danaila)

The trans-sulcal exposure limits the access to the posterior part of the body of the ventricle.

Consequently, for tumors which occupy the lateral ventricle, the decompression performed through a trans-sulcal corridor leads to the relaxation of the hemisphere and makes interhemispheric dissection possible.

The opening of the transcallosal corridor allows the resection of the tumor without an excessive retraction (9).

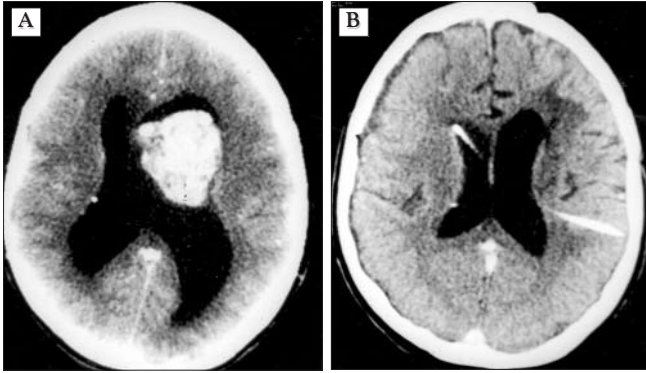


Figure 5. Axial enhanced magnetic resonance imaging of an astrocytoma filling the left frontal horn of lateral ventricle (A). Postoperative MRI after the complete transcortical resection of the tumor with very good results (B) (surgeon Leon Danaila)

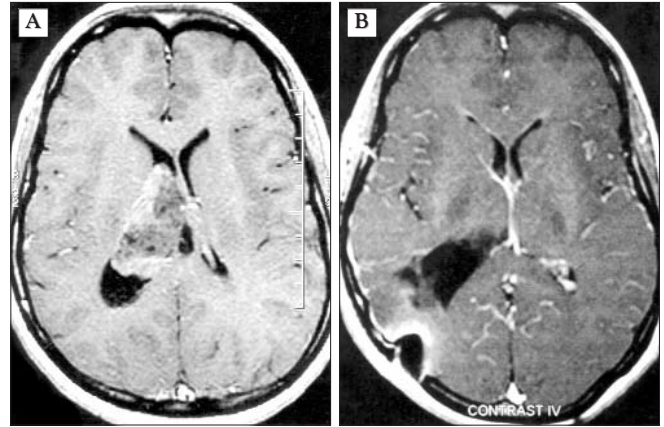


Figure 6. Axial enhanced magnetic resonance imaging of an oligodendroglioma developed in the right body of the lateral ventricle (A). The complete excision was accomplished through an interhemispheric transcortical approach (B) (surgeon Leon Danaila). Postoperatively, the patient had remained in a very good health condition

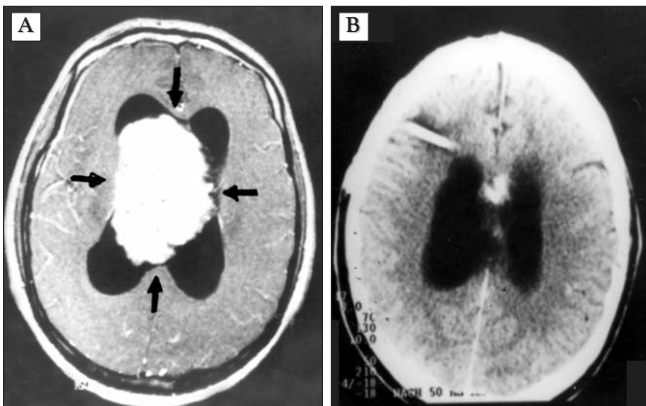


Figure 7. Contrast-enhanced axial CT scan of a central neurocytoma filling the right body of the lateral ventricle and extending into the left one, with ipsilateral obstruction (A). The complete excision had been accomplished through an interhemispheric transcortical approach, with very good results (B) (surgeon Leon Danaila)

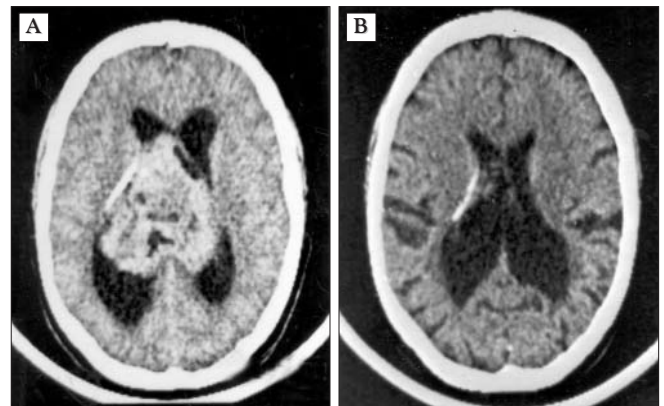


Figure 8. Contrast-enhanced axial CT scan of an astrocytoma filling the right and the left body of the lateral ventricles (A). The patient underwent craniotomy and interhemispheric transcortical approach. The postoperative CT scan demonstrates the resection of the tumor (B) (surgeon Leon Danaila)

Tumors of the body

We encountered a number of 37 tumors of the body of the lateral ventricles, of which 9, which had developed both in the body and in the hydrocephalic frontal horn, were approached using the transcortical route.

The remaining 28 tumors of the body of the lateral ventricle were approached using the transcortical interhemispheric route (Fig. 6, 7 and 8).

However, these tumors developed within the body of the lateral ventricle were best accessed through the anterior transcortical route.

The large tumors which had crossed the septum pallidum and had invaded both lateral ventricles were resected either through a single approach, either using a combined, transcortical and transcortical one and/or in several stages.

In the presence of hydrocephalus, the tumors of the body of the lateral ventricles were also accessed across the frontal horn, using the transcortical route.

The anterior transcortical approach

For this approach route, the main obstacle is represented by the draining cortical veins which lead to the superior sagittal sinus. For this reason, the cerebral angiogram or the magnetic resonance venograms are important in the preoperative planning.

Often, the cortical draining veins enter the dura before reaching the midline. These veins may be preserved by opening the dura on all sides around the veins and leaving it to cover the venous access to the sagittal sinus intact (9). If exuberant arachnoid granulations are encountered, they can be divided by sharp dissection and by using the bipolar cautery.

Furthermore, the ventricular venous and arterial structures can be distorted by the tumor and should be ascertained preoperatively.

When we reach the median line, we go in depth following the falx, and then we use the operative microscope. High magnification is helpful in identifying the anatomy and the vascularization.

At the inferior edge of the falx the small cingulate gyrus veins can be encountered as they drain into the inferior sagittal sinus. These veins may be sacrificed. The arachnoid below the falx may be adherent, and this arachnoid must be sectioned carefully, to avoid the injury to the cingulate gyrus on either side (10). Next, the frontal lobe is retracted laterally and the callosum midline is often demarcated by a very small callosal artery (11).

Once the corpus callosum is reached, the two pericallosal arteries are visualized and the ventricular access between them helps prevent vascular injury. To gain access to the body of the lateral ventricle, the callosotomy can be started just posterior to the genu and developed 3 cm posteriorly.

By performing the callosotomy off the midline and toward the ventricle of interest the opening of the contralateral ventricle can be avoided.

According to Bellotti et al. (1991) (12), Ehni and Ehni (1998) (13) and Patel et al. (2012) (9), occasionally, when the opposite lateral ventricle is accessed, the orientation is achieved by locating the choroid plexus, the septal vein and the thalamostriate vein running to the foramen of Monro. If the vein is to the right of the choroid plexus, the surgeon is in the right ventricle, if the vein is to the left of the choroid plexus, the surgeon is in the left ventricle (9).

During the resection of the intraventricular tumor, the interface between the tumor and the ependymal must be identified and maintained.

Since many lateral ventricular tumors can reach a very large size, the resection begins by first performing internal debulking, followed by the isolation of the tumor capsule away from the surrounding ventricular structures (9,10,11,12,13,14,15,16,17,18,19).

Tumors of the atrium

We encountered 23 tumors of the atrium and 17 which involved both the atrium and the occipital horn.

The majority of these tumors, namely 31 of them, were approached using the posterior transcortical route.

In general, the tumors involving the atrium and the occipital horn can be approached and excised using the posterior transcallosal approach, or transcortically, across the superior parietal lobule.

The posterior transcallosal approach

This route gains access to the roof and medial part of the atrium of the lateral ventricle, and has the advantage of sparing the visual pathways, as well as areas of the parietal lobe that may subserve speech function (8,20,21).

However this approach is achieved at the expense of splitting the splenium of the corpus callosum and is contra-

indicated for patients with preoperative right homonymous hemianopsia because of the risk of alexia.

Preoperatively, it is required to perform a magnetic resonance venogram or a cerebral angiogram which will help us in the accurate positioning of the craniotomy by visualizing the cortical draining veins. The craniotomy exposes the superior sagittal sinus and extends laterally 3 to 4 cm. At the sectioning and the medial reflection of the dura mater, great care should be taken for the preservation of the large draining veins. The parietal lobe is retracted approximately 2 cm from the falx. Once the arachnoid adhesions are opened, the distal pericallosal arteries and the splenium are identified. Below, the internal cerebral veins join to form the Galen's vein, and these can be seen once the splenium is cut. The splenium is incised with a bipolar cautery, and this incision must be made lateral to the midline because the atrium of the lateral ventricle deviates laterally (10).

The lateral ventricles diverge at the level of the splenium.

Consequently the dissection must be continued laterally after the splenium is divided, which results in an impaired view of the lateral portion of the atrium (4).

However, the division of the splenium itself carries many physiological risks. The distal branches of the anterior cerebral artery and the splenial branches of the posterior cerebral arteries may also be injured with this approach (22). Therefore, the tumors which are not positioned in the medial part of the atrium will be hard to resect through this route, and the surgeon should consider the posterior transcortical approach for the lateral tumors of the atrium (4,9,17,12,23,24,25).

One of the contraindications for transcallosal surgery is crossed dominance, a condition in which the hemisphere controlling the dominant hand is opposite the hemisphere mediating language and speech (8,26,27). Crossed dominance can occur when there is evidence of extracallosal dysfunction, particularly after a cerebral injury during childhood resulting in the relocation of the functions.

These patients may be at risk of writing and speech deficits after the callosal sectioning.

The posterior transcortical approach

This route is preferred for the atrium of the lateral ventricle and it allows access to both medial and lateral tumors of the atrium (Fig. 9, 10, 11), as well as to those in the occipital horn (Fig. 12). The patient is positioned in the three-quarter prone position with the parietal area of interest at the highest point in the field.

The craniotomy does not cross the midline. After the craniotomy, the superior parietal lobule is identified and incised.

A preoperative magnetic resonance venogram or a cerebral angiogram is helpful in determining the position of the major draining veins. Once the cortical incision is made, the dissection proceeds along the interparietal sulcus.

A cortical window measuring 1.5 by 2 cm provides the best trajectory to the region of the atrium, while minimizing the retraction and the brain distortion remote from this corridor.



Figure 9. Axial computed tomographic scan of a meningioma developed in the atrium of the right lateral ventricle (A). Postoperative CT scan after the resection of the meningioma through the posterior transcortical route (B) (surgeon Leon Danaïla)

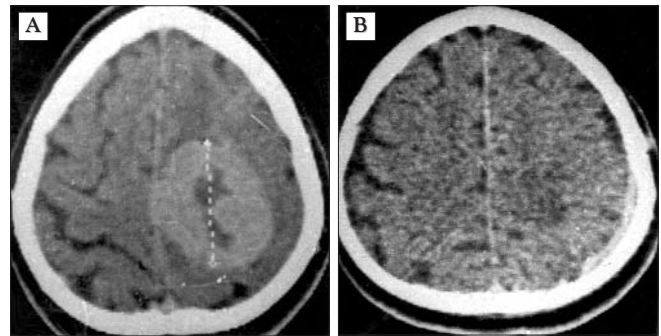


Figure 10. Axial computed tomographic scan of a meningioma developed in the atrium of the left lateral ventricle (A). Postoperative CT scan after the resection of the meningioma through the posterior transcortical route (B), with very good results (surgeon Leon Danaïla)

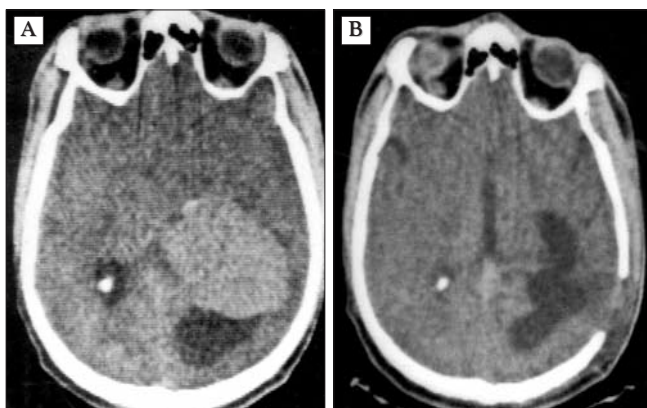


Figure 11. Computed tomographic (CT) scan that shows a large meningioma in the left atrium (A). The excision was accomplished through a posterior transcortical approach, with very good results (B) (surgeon Leon Danaïla)

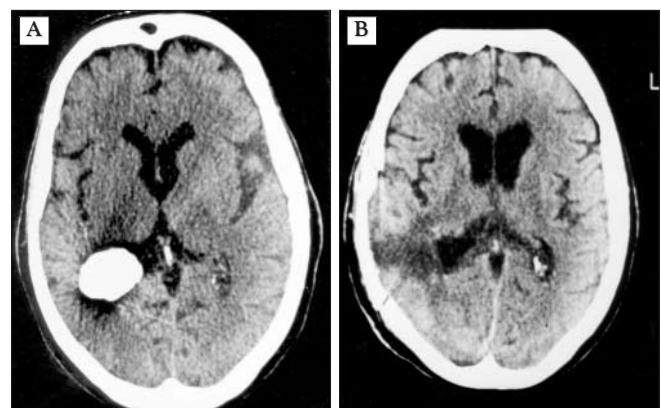


Figure 12. Computed tomographic scan that shows a large meningioma in the right occipital horn (A). The excision was accomplished through a posterior transcortical approach, with very good results (B) (surgeon Leon Danaïla)

Once the ventricle is entered, the surgeon can visualize the thalamus anteriorly, the choroid plexus more medially, the crus of the fornix and the optic radiation that define the lateral wall of the atrium. The surgeon should avoid manipulation of that area. Then, the vascular pedicle of the tumor should be identified and coagulated at the earliest possible time to avoid excessive bleeding (4,9,12,23,25, 28). The egress of cerebrospinal fluid promotes the shifting of the critical brain structures, limiting the utility of the guidance systems referenced to by the preoperative images.

Atrium lesions extending into the occipital lobe may be accessed through the occipital pole cortex. If the tumor extends into the temporal horn, an approach through the posterior portions of the middle and inferior temporal gyri may be considered (4). When the tumor compresses the lateral wall of the atrium, the tumor should be decompressed before separating it from this lateral ependymal surface.

For tumors positioned laterally in the atrium, the posterior temporal approach can be used. The posterior temporal region

is immediately above the transverse sinus. After the sectioning of the dura mater at the level of the non-dominant side, an incision along the axis of the gyrus, into the posterior middle or inferior temporal gyrus will gain access to the atrium. Extreme care should be taken not to injure the vein of Labbé.

Once the ventricle is accessed, the tumor is removed piecemeal and separated away from surrounding ependyma (9). Care should be taken to avoid blood pooling in the ventricles, which leads to postoperative obstructive hydrocephalus.

At the level of the dominant hemisphere, the injury of the speech area must be avoided.

After the removal of the inferior temporal bone and of the mastoid air cells, we can gain access to the subtemporal area, where we incise the cortex at the level of the occipito-temporal gyrus. By using this route, which requires a more accentuated retraction of the temporal lobe, we can avoid the injury to the optic radiation and the speech cortex. The vein of Labbé must also be preserved, while the mastoid air cells should be closed.

The tumors of the temporal horn

We encountered 42 tumors of the temporal horn, of which 28 were excised through the middle temporal gyrus (Fig. 13), 6 through the inferior temporal gyrus, and 8 through the resection of the temporal tip.

Thence, the temporal horn of the lateral ventricle may be accessed by making a cortical incision in the inferior or middle temporal gyrus, traversing the middle temporal sulcus, or by resecting the temporal tip. The former approach allows visualization along the lateral-to-medial axis. In contrast, the resection of the temporal pole exposes the anterior-posterior view line and may be preferable for the tumors of the temporal horn with a significant posterior extension (17). However, in this case, the craniotomy is extended inferiorly to the level of the zygoma.

For the middle gyrus approach, a horizontal cortical incision is made along its anterior portion. The temporal horn is commonly encountered at 3.5 cm posterior to the temporal tip and the sphenoid ridge.

Thus, if rendered in this fashion, the middle gyrus approach avoids the vein of Labbé and the optic radiation (4).

When we operate on the dominant lobe, it is necessary to have a very good knowledge of the map of the temporal cortex which varies from one individual to another (8,20).

The majority of inferior temporal approaches are used for lesions residing in the temporal horn or in the lateral atrium of the dominant hemisphere.

After opening the dura mater, the pia mater is cauterized along the inferior and middle temporal gyri, with a vertical orientation. The resection is performed along the superior edge of the middle temporal gyrus, towards the temporal pole. The dissection is then continued medially, towards the temporal horn. Decompression of the tumor is followed by dissection away from the surrounding ependyma (12).

It is important to preserve the vein of Labbé at the posterior limit of the dissection.

The resection of the anterior 5 cm of the temporal lobe provides a larger field of exposure than the middle gyrus route (4).

Treatment

Because intraventricular surgery requires manipulation

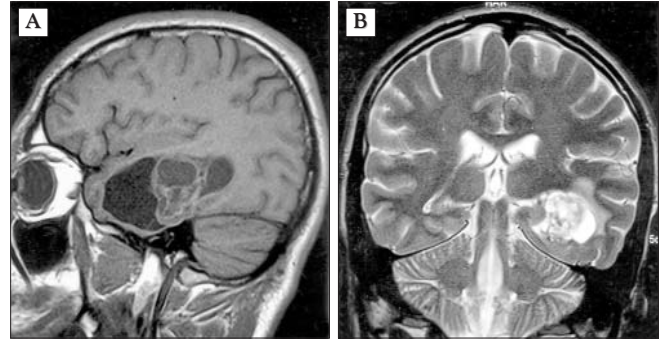


Figure 13. Sagittal coronal contrast-enhanced T1-weighted magnetic resonance imaging of a choroid plexus carcinoma developed in the left temporal horn of the lateral ventricle (A, B)

deep within the hemispheres, proper patient positioning, adequate tumor exposure and brain relaxation are fundamental requirements for successful tumor removal.

There are several published alternative surgical approaches that have been utilized for accessing the ventricular system (interhemispheric, transcortical, trans-sylvian fissure). All the surgical approaches are designed to minimally displace or disturb the normal anatomy. While these alternative approaches may have some merit, Patel et al. (2012) (9). consider them to be of limited value for the vast majority of intraventricular tumors. For this reason, Patel et al. (2012) (9). pleads in favor of using methods which maximize the tumor removal with minimal morbidity.

These include the anterior transcallosal approach, the anterior trans-sulcal approach, the combined approaches, the posterior trans-sulcal approach, the posterior transcallosal approach, the posterior temporal approach and the inferior temporal approach.

All the patients in the present series underwent surgical treatment. Our main goal was that of removing the tumor in its entirety, with the lowest mortality.

We chosen the surgical approach depending on the exact location of the tumor, the tumor's size and the anatomical knowledge.

The tumor excision was performed using the standard microsurgical technique through two major approaches: the interhemispheric transcallosal route in 78 (38.61%) patients,

Table 4. The surgical approach methods used in the 202 patients with tumors of the lateral ventricles

The localization of the tumors	Number of patients	The surgical approach	
		The interhemispheric transcallosal route	The transcortical route
Frontal horn tumors	55	19	36
Tumors of the body	37	28	9
Atrium tumors	23	5	18
Occipital horn tumors	17	0	17
Temporal horn tumors	42	0	42
Extended tumors	28	26	2
Total	202	78 (38.61%)	124 (61.38%)

and the transcortical route in 124 (61.38%) patients. The tumor was removed in its entirety in 174 (86.13%) of the patients. Total or partial removal of the tumor was considered depending on its size and the anatomic location.

The adequacy of a subtotal resection is a matter of judgment and experience. Beyond the diagnosis, the possible goals of the subtotal procedure include cytoreduction in preparation for adjuvant therapy, relief of the mass effect and re-establishment of the CSF circulation (4).

In 38 (18.81%) of the patients, the onset clinical symptoms were dominated by signs of internal hydrocephalus. In all these cases, ventricular drainage was performed prior to surgery. In 5 (2.47%) patients, we performed an external ventricular drainage which was removed at the time of surgery. For the remaining 33 (16.33%) patients, we performed a ventriculoperitoneal shunting in 29 (14.35%) cases, and a ventriculoatrial shunting in 4 (1.98%) cases.

The patients appear to tolerate the manipulation of one fornix; however, injury to both fornices and the nearby thalamic nuclei may result in significant memory impairment (29).

The corpus callosum forms a major boundary for the lateral ventricles. The sectioning of the anterior third of the corpus callosum can generally be performed without significant neurological sequelae.

The division of the posterior corpus callosum may result in a left hemialexia and other potentially debilitating deficits. The concurrent splenial section and injury to the dominant occipital lobe may result in alexia without agraphia (7,30).

There have been no reports concerning endoscopic resection of the tumors of the lateral ventricle, although this is likely to be a promising approach for this entity, as the surgeons become more familiar with the benefits and limitations of this technique.

Histology

The histology of the lesions affecting the lateral ventricle encompassed a wide range of neoplastic processes. The majority of tumors of the lateral ventricles are benign or low-grade lesions.

Therefore, 177 (87.62%) of our primary tumors of the lateral ventricles were benign or low-grade lesions, while 25 (12.37%) were malignant. Because of their relatively slow growth rate, the respective tumors arrived in our clinic when they had reached large or very large sizes.

The most frequent tumors were ependymomas, astrocytomas and subependymomas, choroid plexus papillomas and meningiomas (Table 5) (31,32).

Our primary, or intra-axial, tumors arose directly from the structures within the lateral ventricle itself, such as the ependyma, the subependymal glia, the choroid plexus and embryologic remnants. Therefore ependymomas, astrocytomas, subependymomas, neurocytomas, meningiomas, choroid plexus papillomas, choroid plexus carcinomas, epidermoids, teratomas, cavernomas, oligodendrogliomas are examples of primary tumors of the lateral ventricles (31,32).

Neurocysticercosis is a the most common infection that

Table 5. The histology of the 202 primary tumors in the lateral ventricles

Histology	Number of patients
Ependymoma	57 (28.21%)
Anaplastic ependymoma	11 (5.44%)
Astrocitoma low-grade	27 (13.36%)
Anaplastic astrocytoma	8 (3.96%)
Subependymoma	14 (6.93%)
Neurocytoma	6 (2.97%)
Meningioma	13 (6.43%)
Choroid plexus papilloma	18 (8.91%)
Choroid plexus carcinoma	5 (2.47%)
Epidermoid cysts	6 (2.97%)
Teratoma	1 (0.50%)
Cavernoma	4 (1.98%)
Oligodendroglioma WHO grade I-II	1 (0.50%)
Oligodendroglioma WHO grade III	1 (0.50%)
Inflammatory pseudotumor	1 (0.50%)
Cysticercosis	29 (14.35%)
Total	202

may manifest as an intraventricular mass in 15% to 50% of cases, with larger percentages noted in the series that routinely used magnetic resonance imaging (33,34). Secondary, or extra-axial, tumors arise from structures adjacent to the lateral ventricle and subsequently grow into it by either gentle extension or frank invasion. The periventricular white matter, the caudate nucleus, the internal capsule, the thalamus and other structures lying in close proximity to the lateral ventricle are often the site of origin. The tumors that may develop from these sites and secondarily involve the ventricle include gliomas (astrocytoma, oligodendroglioma, glioblastoma multiforme) and vascular lesions, such as cavernous hemangiomas or arteriovenous malformations. However, we did not include the secondary tumors in the present study.

According to Jelinek et al. (1990) (35), sixty-four per cent of their 47 patients had benign tumors, including subependymoma and subependymal giant cell astrocytoma. Five per cent had intermediate-grade lesions, and the remaining 21% had malignant tumors, including primitive neuroectodermal tumor, lymphoma, and teratoma.

Pendl et al. (1992) (3) observed benign tumors in 56% of their patients; they included neurocytomas, meningiomas, choroid plexus papillomas, cavernous malformations, and arachnoid cysts. Only 13% of their patients had malignant lesions.

Oligodendrogliomas developed in the lateral ventricles are rare. We had 2 (0.99%) cases of such tumors situated in the frontal horn of the right lateral ventricle. Both patients were females, with the ages of 24 and 32 years old. In one of the cases, the oligodendroglioma was low grade, while in the other patient it was anaplastic (WHO grade III).

Our case is the fourth report in the literature to describe a patient with anaplastic intraventricular oligodendroglioma (IVO). In this case, the simple histological staining was insufficient to confirm the diagnosis of IVO. For example, the

oligodendroglioma and the central neurocytoma appear quite similar on the routine smear and at cryostat microscopic examination (31,32,36). Specific immunohistochemical staining methods and electron microscopy were used to confirm the diagnosis.

The staining for GFAP and synaptophysin were crucial in differentiating the IVOs from other types of gliomas and central neurocytomas.

The staining for markers such as neurofilament protein, chromogranin and synaptophysin is positive in the central neurocytoma, whereas it remains negative in oligodendroglioma. GFAP is positive in oligodendroglioma, yet negative in neurocytoma (36).

Likewise, Hasuo et al. (1987) (37) noted that IVOs can also be differentiated from neurocytomas based on electron microscopy, because the latter have mature neuronal cells with well-formed synapses. The possibility of the presence of another type of intraventricular tumor (central neurocytoma, clear cell meningioma, metastatic lesion, subependymoma, astrocytoma, ependymoma, germ cell tumors, and ganglioglioma) needs to be considered.

Oligodendrogliomas originating primarily within the ventricular system have been reported to account for approximately 8% to 10% of all oligodendrogliomas (38).

The first description of an oligodendroglioma occurring primarily within the ventricular system was made by Dickson in 1926 (39).

Between 1926 and 2009 there had been reported 70 cases of patients with intraventricular oligodendroglioma.

Twenty seven (68%) of the 40 cases of IVO with available data were reported to occur within the lateral ventricle (40). Of these cases, IVO were more than twice as likely to develop in the right lateral ventricle than in the left one.

Of the 26 patients with available data concerning the degree of the surgical resection, 15 were reported to have undergone a subtotal resection, whereas 9 were reported to have undergone a gross total resection. Most of the surgical procedures for the resection of oligodendrogliomas originating in the lateral ventricles were performed using the transcortical transventricular approaches. (36,40,41,42,43,44,45, 46,47,48).

Nioka et al. (1987) (49) and Romero et al. (1986) (50) have used the interhemispheric transcortical approach, especially when the third ventricle was involved. Morita and Kelly (1993) (51) described the use of a stereotactic approach for the resection in 2 cases of oligodendrogliomas confined to the lateral ventricles.

All the patients with anaplastic lesions had experienced recurrence.

Among these cases, most have been reported as low-grade neoplasms. The anaplastic (WHO grade III) IVO is an extremely rare entity with only 3 previous cases reported in the literature (40,48,52).

The precise origin of the IVO remains unclear. Maiuri et al. (1982) (42) postulated that these tumors originate in the subependymal region, and are actually of neuronal origin. Sakai et al. (1980) (53) reported that these lesions originate

from a precursor that is common to both the oligodendroglial cells and the ependymal cells.

Electron microscopic studies have demonstrated that these lesions have microtubules measuring 20 to 25 nm in diameter, dense-cored vesicles measuring 100 to 200 nm in diameter, and simple maculae adherents, yet no well-formed synapses (37). They have thus referred to these lesions as intraventricular neurocytomas, to more accurately reflect the neuronal origin of these neoplasms. On the other hand, Yuen et al. (1992) (36) reported that IVOs do not have neurotubules or neurosecretory granules.

Dupuy et al. (1970) (54) reported a patient with a voluminous calcified oligodendroglioma situated in the left lateral ventricle.

Significant advances in the treatment of oligodendrogliomas have been made in the recent in years, based primarily on the molecular subtyping of the lesions.

Deletions resulting in the loss of heterozygosity of the 1p and 19q segments of the intratumoral chromosomes have correlated closely with a favorable response to chemotherapy. The standard chemotherapeutic regimen for such lesions now includes procarbazine, lomustine, and vincristine (40).

However, the outcomes for patients with intraventricular anaplastic oligodendroglioma remain poor.

The treatment based on targeted chemotherapy, perhaps using an intrathecal route, remains a possibility for the patients diagnosed with these lesions (40).

The inflammatory pseudotumor of the lateral ventricle is an extremely rare lesion, with an uncertain etiology in most cases. Our case pertains to a female patient aged 58 years old who began 10 years ago to exhibit rhythmical movements of the head, repeated dental abscesses, bilateral maxillary sinusitis operated by an otolaryngologist, and in the last 8 months, headaches and vomiting.

Computed tomography disclosed a solid tumoral mass with maximal dimensions of 3.5 cm, located in the right lateral ventricle, accompanied by hydrocephalus (Fig. 14). Removal of the tumor through a transcortical transventricular approach was performed. An ill-defined fibrous and granulomatous lesion that was tightly attached to the choroid plexus was totally removed.

The histological examination revealed diffuse infiltrates with small lymphocytes, plasma cells, and eosinophils, with interstitial vascular proliferation. The cuboidal epithelial cells indicated the presence of the choroid plexus within this formation.

These histological findings in the brain lesion were identical to those observed in the maxillary sinus.

Steroid treatment was necessary to control this inflammatory lesion. After the surgery, the general health condition and the neurological status were good, with the exception of the persistence of some slow movements of the head.

Intraventricular inflammatory pseudotumors (IP) are very rare lesions that may be present at various ages in either sex (55,56).

Their correct diagnosis depends on the histological evaluation. With respect to the differential diagnosis, the

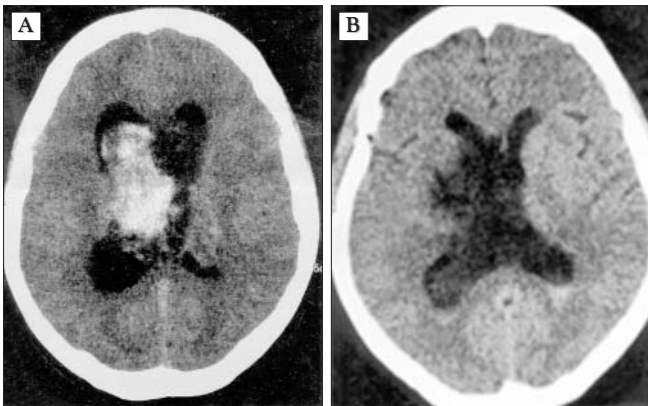


Figure 14. A 58-year-old woman presented with rhythmical movements of the head, headaches and vomiting. The CT scan demonstrated a solid tumoral mass with maximal dimensions of 3.5 cm, located in the right lateral ventricle (A). The postoperative CT scan demonstrated the complete excision (B) (surgeon Leon Danaila). The histological examination had revealed that it had been an intraventricular inflammatory pseudotumor

distinction between lymphomas, lymphoplasma cell-rich meningiomas, Rosai - Dorfman disease, and intracranial fibromatosis must be made (56,57,58).

The inflammatory pseudotumor shows heterogeneous features that explain this variety of synonymous expressions (56,59). Primary intraventricular IP was reported in 7 cases, 5 of which were presumably derived from the choroid plexus (55,57,58,60).

The absence of the blood-brain-barrier, as well as the richly vascularized secretory epithelium in the choroid plexus may serve as a portal for the entry of pathogens into the central nervous system, a target for various systemic disorders or a reflector of various diseases that affect the brain and meninges (59,61).

Arber et al. (1995) (62), Fukunaga et al. (1998) (63) and Nishioka et al. (2009) (59) suggested that the Epstein-Barr virus infection plays a role in a significant number of IP cases. It is considered that many factors such as systemic (auto) immune responses and infection are involved in the development of IPs (55,56,62).

Chang et al (1991) (60) reported a case of IP of the choroid plexus associated with Sjogren's disease.

Results

A favorable outcome (GOS 5 and 4) at discharge was seen in 164 (81.18%) of the 202 patients who were subjected to surgery. Out of the remaining 38 patients, 5 (2.47%) entered a coma immediately after the surgical intervention, and 3 (1.48%) of them died.

The coma was caused in 2 patients by postoperative hematomas, by deep brain softening in 2 others (0.99%), and to pulmonary embolism in 1 (0.49%) patient.

The other 35 (17.58%) patients survived with the

following deficits: 2 (1%) with homonymous hemianopsia, 3 (1.50%) with memory disorders, 6 (3.01%) with aphasia, 10 (5.02%) with disconnection syndrome, 13 (7.53%) with hemiparesis, and 1 (0.55%) in vegetative state.

One year follow-up was possible for 173 (86.93%) of the patients. The outcome analysis at the time of the follow-up recorded neurological impairments (hemiparesis, aphasia, visual field deficit, memory deficits, and disconnection syndrome) in 21 (12.13%) of the patients. At the one year follow-up two (1.15%) new deaths related to tumor re-growth and the negative state were recorded. The overall recorded mortality for whole series of 202 patients was 2.47% (5 patients).

At the one year follow-up there were 158 (91.32%) patients with good neurological evolution or mild neurological deficits. They were considered with reference to their social independence (Table 6). However, since the cognitive deficits are the most commonly encountered preoperative signs of an intraventricular lesion, the persistent postoperative cognitive liabilities and hydrocephalus deserve a closer attention.

Recurrences

One year follow-up was possible for 173 of the patients. Recurrences of the tumors were recorded in 21 (12.13%) patients who had survived more than a year after the first surgery.

The imaging (CT or MRI) follow-up performed at discharge demonstrated the partial resection of the tumor in all 21 patients, of whom 13 had been operated through the inter-hemispheric transcallosal route and 6 using the transcortical route.

In conclusion, in all patients with recurrences, partial resection of the tumor was performed.

Eighteen of them underwent re-operation, with good neurological evolution in 88.88% of the cases (16 patients out of 18 patients).

Discussion

The most common clinical manifestations of tumors of the lateral ventricles include headache, loss of memory and cognitive and gait disorders (64).

Pend's group observed chronic or subacute headaches in 47% of their patients (3), and Nishio's group found the

Table 6. The general outcome at discharge and at one year follow-up

Outcome	At discharge	At one year
GOS 5 (good recovery)	116 (57.42%)	135 (78.03%)
GOS 4 (moderate disability)	52 (25.74%)	23 (13.29%)
GOS 3 (severe disability)	30 (14.82%)	13 (7.51%)
GOS 2 (vegetative state)	1 (0.49%)	0
GOS 1 (death)	3 (1.48%)	2 (1.15%)
Total	202	173

headaches to be the presenting symptom in 58% of their patients (65). Other signs and symptoms caused by these tumors are dependent on the localization and the extent of the brain infiltration. Those developed in the frontal horn cause subtle behavioural manifestations and headaches. At the level of the dominant hemisphere, they cause various degrees of speech disorders. Lesions developed more posteriorly cause hemiparesis and occasionally discrete sensory deficits.

Tumors in the occipital horn lead frequently to the development of visual field deficits.

The tumors of the lateral ventricles can be approached using the transcortical route or the interhemispheric transcallosal route. The cortical incisions can lead to the emergence of epileptic seizures. Fornari et al. (1981) (66) reported the incidence of this complication in 29% of their patients in whom the transcortical approach through the parieto-occipital fissure had been used.

According to Kempe and Blaylock (1976) (67), Ehni (1984) (68), and Jun and Nutik (1985) (69), the transcallosal route may reduce the risk of postoperative seizures. Ehni observed seizures in only 2% of his patients who were managed using an interhemispheric transcallosal approach.

Lawton et al. (1996) (6) reported no postoperative seizures among their 32 patients treated using a contralateral interhemispheric approach. They did not report any clinically significant neurological deficits among their patients related to the division of the anterior corpus callosum. However, the anterior callosotomy cannot always be performed with impunity.

Sass et al. (1990) (70) found that epileptic patients with crossed cerebral dominance were at risk of developing significant language impairments after partial or complete callosotomy. Four of them had crossed cerebral dominance, with right-handedness and right hemisphere speech dominance, or left-handedness and left hemisphere speech dominance. However, the anterior callosotomy appears to be an otherwise safe and effective way to approach tumors of the lateral ventricle (4).

In contrast, the division of the posterior portion of the corpus callosum inevitably results in some form of neurological deficit that may or may not be disabling.

After the surgical approach of an atrial meningioma, Jun and Nutik (1985) (68) observed the postoperative development of various deficits concerning the processing of the tactile information which had not been linked to the disconnection of the sight, hearing or tactile areas.

The division of the posterior third of the corpus callosum may result in language impairment as well. The dissection of the fibres located in the splenium really demonstrated that the inferior fibres which are located in the splenial area go towards the striate region and form the major forceps (8).

The superior splenial fibers go towards the occipitotemporal and temporal regions and form the tapetum.

Sass et al. (1990) (70) identified three distinct syndromes following the posterior callosotomy.

The first is manifested by a paucity of spontaneous speech, impaired spelling and reading comprehension, as well as dysgraphia.

The second is characterized by mutism and buccofacial apraxia.

The third is manifested by isolated dysgraphia.

The section of the splenium of the corpus callosum may also cause left hemialexia (7). Frequently, none of these deficits is disabling.

The manipulation of the fornices during surgery may result in postoperative memory impairment, especially if these structures were compromised preoperatively by the tumor itself (71).

Classically, the syndrome of interhemispheric disconnection or the callous syndrome consists of a series of symptoms in which the transfer defects of elementary sensorial information, dysfunctions of the elaborate cognitive functions (speech, praxias), and even psychiatric symptoms with a dissociative character can be included (8).

Patients with tumors of the lateral ventricle may develop hydrocephalus and ultimately require a permanent CSF shunt. In the series of Lena et al. (1990) (72), 78% of all the children with intraventricular choroid plexus tumors underwent permanent shunt placement.

The same surgeons advocate for preoperative placement of a permanent shunt in patients with tumors of the lateral ventricle and hydrocephalus (72).

In contrast, Amar et al. (2004) (4) prefer to place a ventriculostomy at the time of the surgery whenever hydrocephalus is present. This allows the surgeon to achieve excellent interhemispheric exposure while minimizing the relation of the cortex. In addition, a significant number of patients will recover the CSF circulation after the removal of the tumor and this reduces the need for a permanent shunt dramatically (4).

Lawton et al (1996) (6) used ventriculostomy catheters preoperatively and reserved the shunts for the patients who continued to have impaired CSF circulation after surgery. In their series, ventriculoperitoneal shunts were required in only 12.5% of the patients.

Other complications that can develop after surgical interventions on the lateral ventricles include hemiparesis, aphasia, coma, infections and death.

In this respect, Lawton et al. (1996) (6) observed transient hemiparesis in 6% of their patients and aphasia and hemiparesis in 3% of them after the transcallosal approach of the tumors in the lateral ventricles.

Ehni (1984) (68) reported that postoperative hemiparesis had been present in 9% of the patients with tumors of the lateral ventricles for which the interhemispheric transcallosal approach was used.

The injuries of the deep arteries and veins during the excision of the tumors in the lateral ventricles can lead to the development of devastating complications.

In 1963, De La Torre et al. (2) reported a surgical mortality of 50%. The deaths among pediatric patients had been due to the excessive blood loss during the surgical procedure.

In the modern series, the mortality ratio was further reduced due to the use of the operative microscope and the refinement of the techniques of neuroanesthesia.

In 1984, Ehni (68) had reported one postoperative death in 23 patients with tumors of the lateral ventricles.

Pendl et al (1992) (3) had a surgical mortality ratio of 5%. Two of their patients died because of intracerebral hemorrhage, while another because of cerebral edema.

Nishio et al (1990) (65) did not registered any postoperative deaths, but 10% of their patients were left with important neurological deficits.

In the 11 children with choroid plexus tumors of the lateral ventricles, Lena et al. (1990) (72) did not register any postoperative deaths.

Among the 32 patients operated by Lawton et al (1996) (6) there were no postoperative deaths registered, but 2 of them had transient neurological deficits.

Conclusions

The average age of the patients with primary tumors of the lateral ventricles of the brain is generally younger than that described for patients harboring intraparenchymal lesions.

These patients presented with clinical symptoms and signs of ventricular outflow obstruction and elevated intracranial pressure.

The short-term memory loss was encountered in our patients, as well as in others with tumors originating in the septum pellucidum, which was considered to be secondary to the fornical compression and/or invasion.

The interhemispheric transcallosal and the transcortical routes remain the best surgical approaches for tumors of the lateral ventricles, but other factors, including the tumor's localization, the surrounding neural and vascular anatomy, the patient's medical condition and the surgeon's familiarity with the various techniques must be taken into consideration.

The attempted gross total surgical resection remains the main method of treatment, followed by adjuvant radiotherapy and/or chemotherapy.

A significant proportion of the patients undergoing treatment for tumors of the lateral ventricles will develop cerebrospinal fluid outflow obstruction and will require perioperative ventricular shunting.

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