Chirurgia (2014) 109: 80-89
No. 1, January - February

A Modern Minimally Invasive Transcallosal Approach to the Third Ventricle. A personal experience of 30 patients

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Rezumat

O tehnică modernă de abord chirurgical minim invaziv transcalos pentru leziunile ventriculului III. Experiența personală pe 30 de pacienți

Introducere: Procesele expansive intracraniene din regiunea ventriculului III au reprezentat dintotdeauna o provocare neurochirurgicală majoră. În ciuda tuturor progreselor tehnologice și științifice tumorile de ventricul III rămân o patologie de o complexitate formidabilă a cărei tratament implică o bună cunoaștere a anatomiei locale, a fiziopatologiei afecțiunii, a morfopatologiei și nu în ultimul rând o capacitate de integrare a noțiunilor. Abordul optim al acestor leziuni solicită printre altele o dotare extensivă cu mijloace de neuronavigație moderne, ale căror cost este inabordabil pentru multe clinici (1,2).
Obiectiv: Prezentul articol prezintă experiența personală a autorilor folosind un abord chirurgical inedit, gândit să maximizeze rata de success a intervențiilor pentru procesele expansive ale ventriculului III fără folosirea metodelor de neuronavigație.
Materiale și metode: Autorii au realizat în primul rând un studiu neuroanatomic folosind 30 de preparate, creiere adulte umane, fără leziuni patologice, prelevate în cadrul autopsiilor de rutină și analizate după un protocol standardizat. (Protocolul laboratorului de microanatomie al Clinicii de Neurochirurgie din cadrul Universitații Ludwig-Maximilians, Munchen). Au fost urmărite o serie de elemente de microanatomie cu rol de reper pentru construcția câmpului operator neurochirurgical. După realizarea studiului neuroanatomic autorii au trecut la o etapă următoare constând în înregistrarea datelor de morfometrie pentru un număr de 30 de voluntari. S-au folosit achizițiile de rezonanță magnetică nucleară T1-ponderate în plan sagital. Voluntarii au fost atât bărbați cât și femei, toți adulți, cu vârsta medie de 45,3 ani (intervalul de vârstă: 21-83 ani, distribuția pe sexe: 17 bărbați și 13 femei). Imaginile au fost prelucrate digital iar contururile țintelor care interesau au fost evidențiate manual cu ajutorul programului Corel Draw, astfel fiind posibilă o identificare sistematică consecutivă a contururilor și a reperajelor. Fiecare contur a fost înregistrat și salvat ca o secvență de puncte. Etapa următoare a studiului a constat, după examinarea tuturor datelor consemnate, în stabilirea coridorului chirurgical transcalos transforaminal sau interforniceal în mod individualizat la 30 de pacienți omogeni (diferiți de cei 30 de voluntari) și folosirea coridorului creat pentru rezecția tumorilor pentru care pacienții au fost internați. În stabilirea succesului sau eșecului intervenției s-au urmărit datele clinice pre- și post-operator precum și rezultatele examenului neuropsihologic pre- și post-operator.
Concluzii: Rezultatele obținute în urma observațiilor și măsurătorilor anatomice s-au dovedit a fi foarte valoroase în standardizarea căii de acces transcalos. Datele prelevate folosite alături de imagistica pacientului au facilitat în toate cazurile un abord optim al leziunii ventriculului III. În ceea ce privește actul chirurgical, în 23 de cazuri (77%) s-a realizat rezecția totală a tumorii. La 6 dintre cazuri (20%) s-a realizat o rezecție subtotală. La 1 caz s-a realizat doar biopsie (lărgită) întrucât pacientul suferea de neurosarcoidoză. Un număr de 24 de pacienți (80%) au obținut conform scalei Glasgow Outcome Scale un rezultat excelent (GOS V). S-a înregistrat un deficit minor la 5 pacienți

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(17%) (disabled, but independent) GOS IV. Nici un caz nu a fost notat cu deficit grav (GOS III) sau stare vegetativă (GOS II). Un pacient cu gliom anaplazic a decedat la 4 luni postoperator după ce inițial a avut o evoluție favorabilă dar care a fost urmată de o invazie agresivă hipotalamică a tumorii. S-a notat o singură complicație postoperatorie legată de abordul chirurgical – la o pacientă de 73 de ani care a suferit un infarct venos datorat unei tromboze de venă emisară către sinusul sagital superior din zona de acces. Pacientă după recuperare lentă, treptată dar incompletă a parezei a atins din nou un nivel de independență (GOS IV) dar nu similar stării preoperatorii. Alte complicații legate de actul operator nu s-au produs.

Cuvinte cheie: tumori ale ventriculului III, chirurgie minim invazivă, abord nou, rezultate globale

Abstract

Introduction: Expansive processes around the third ventricle have always been a major neurosurgical challenge. Despite all the technological and scientific progress recorded over the last few years, third ventricle tumors are still a very difficult pathology to approach due to their formidable complexity. Treating such a tumor demands a good knowledge of local anatomy, pathophysiology, pathology and a good capacity to integrate all the data gathered from the patient prior to and during surgery. Last but not least, the correct means to approach such a tumor involves using modern neuronavigation technology which might be too expensive to access în certain clinics (1,2).

Objective: This article presents the personal experience of the authors, gathered while using a novel surgical approach, configured to maximize the success rate of interventions for tumors within the third ventricle, without using neuronavigation technology.

Materials and methods: The authors have developed a study of neuroanatomy using 30 adult human brains, without any pathological lesions, harvested during routine autopsies and analysed using a a standard protocol (Protocol of the Ludwig-Maximilians University Clinic of Neurosurgery, Laboratory of Microanatomy – Munich, Germany). The authors assessed a series of anatomic elements which were later used as landmarks to build the neurosurgical operative field. After completing the anatomic study the authors moved on to record morphometric data for 30 volunteers. The authors used sagittal T1 weighted images. The volunteers were males and females, all adults, with the mean age of 45.3 years. (The age interval: 21-83 years, sex distribution: 17 males and 13 females). The images were digitally enhanced and the specific targets were outlined using Corel Draw, thus allowing for a systematic identification of contours and landmarks. Each contour was recorded and saved as a sequence of dots. The next stage of the study, after having studied all the data recorded, consisted of establishing the appropriate transcallosal surgical corridor (transforaminal or interforniceal) for each of the 30 patients (not to be mistaken with the 30 volunteers) who were admitted for third ventricle tumors and who were included in this study. After having performed surgery for the resection of the above mentioned third ventricle tumors, the authors observed pre- and postoperative clinical data which were corroborated with the neuropsychological examination which was also performed prior to and after surgery.

Conclusions: The results obtained through observation and anatomical measurements have proven to be highly valuable in determining a standard access corridor through the corpus callosum. The data gathered and the patient's MRI exam images helped obtain an optimal surgical corridor of the third ventricle. In what regards the surgical act in 23 cases (77%) the authors managed to achieve a complete resection of the tumor. In 6 cases (20%) the authors managed a subtotal resection of the tumors. In a single case the authors performed only a biopsy. A number of 24 patients (80%) achieved an excellent outcome (Glasgow Outcome Scale - GOS V). Minor deficits were recorded in 5 patients (17%) (disabled but independent) (GOS IV) No cases were recorded with serious impairment (GOS III) or vegetative state (GOS II). One patient with anaplastic glioma died 4 months after surgery after an initial favorable evolution. The tumor had spread to the hypothalamus. A single postoperative complication was linked to the surgical approach in a 73-year-old female patient who suffered a venous infarction due to a venous thrombosis in a tributary vein of the superior sagittal sinus in the access area. The patient, after a slow recovery managed to improve her condition reaching GOS IV. There were no other complications connected to the surgical act.

Key words: third ventricle tumors, new approach, minimally invasive surgery, global outcome

Introduction

The need for a quick and easy diagnosis, little clinical features encompassing only functional signs, the desire to immediately operate or to postpone the surgery, operative and postoperative risks and the lack of family support for the patient are only a slight proportion of the problems that accompany the surgeon during the moments before surgery. The goal of the surgery? Radical resection of third ventricle tumors without any neurologic or psychic deficit.

If 20 years ago the prognosis quad vitam was the main focus for the efforts of a neurosurgeon, today the attention has shifted to the prognosis quad sanationem. This means that a patient undergoing neurosurgery needs make a full recovery without any neurologic or neuropsychic deficit while also being treated for the base lesion. The final purpose of any procedure should be the total reinsertion of the patient in his daily life, social life as well as professional life (3,4,5).

A complete tumoral resection without any morbidity or mortality is hard to achieve in the case of third ventricle tumors due to the profound position of the tumors and their vicinity with critical structures such as the hypothalamus, perforating arteries, profound veins or the pituitary stalk (6). Third ventricle tumors are even a bigger problem especially when they are large in size and benign as a subtotal resection will push the surgical team in the unwanted cycle of recurrences and reinterventions (7).

Dissection, manipulation and injuries to the vital neural structures around the third ventricle during surgery can have devastating effects ranging from mutism and thermal regulation impairment up to death. For example incisions of the corpus callosum can generate difficulties in information transfer, memory impairment, apraxia etc. Dissection of the fornix can generate memory loss. Retraction of the brain can generate mutism and hemiplegia. Manipulation of the lateral walls of the third ventricle will lead to hypothalamic dysfunction. Lesions of the optic chiasm and optic nerves will produce blindness. Edema of the aqueduct of Sylvius will lead to obstructive hydrocephalus. Damaging any profound vein will likely lead to edema in the diencephalon, coma, fever, tachycardia and psychic alterations. Damage to the thalamostriate veins can render the patient hemiplegic, mute or may induce him a hemorrhagic infarction in the basal nuclei (6,8,9,10).

Considering these strict "rules of engagement", any neurosurgeon attempting a resection of any third ventricle tumor not only needs to be a model in knowledge of neuroanatomy, neurophysiology and neuropathology, but also needs to have access to modern means of neuronavigation that facilitate an optimal approach to the third ventricle while protecting critical structures.

As modern neuronavigation solutions may be too expensive for budgets of certain neurosurgical clinics or smaller units, the authors have devised a novel neurosurgical approach to the third ventricle without any use of neuronavigation. Such an approach would firstly improve the outcome for patients suffering from third ventricle tumors and secondly would allow experienced surgeons everywhere to operate on such difficult cases without the need of neuronavigation. Last but not least, such an approach would represent a cost-effective surgical solution with a minimal risk for the patient, and therefore a surgical solution worthy enough to be considered internationally.

Materials and Methods

Prior to any neurosurgical intervention, the starting point of all procedures lies in the mind of the neurosurgeon who has to be able to mentally reconstruct the entire anatomy of the brain and its vital structures (*Fig. 1*). The authors have performed a wide anatomic study of the third ventricle and its adjacent structures through morphometry with the purpose of improving the standard anterior transcallosal approach to the third ventricle by finding microanatomy landmarks on magnetic resonance images (MRI) which were then checked through standardized dissection on human brain specimens. The results and conclusions of the anatomic study were then applied to the surgical technique for each of the 30 patients that had been admitted between 03.01.2000 and 30.06.2009 for third ventricle tumors. Finally the authors drew their conclusions based on pre and postoperative clinical data, pre and postoperative neuropsychological exams and through the findings during surgery.

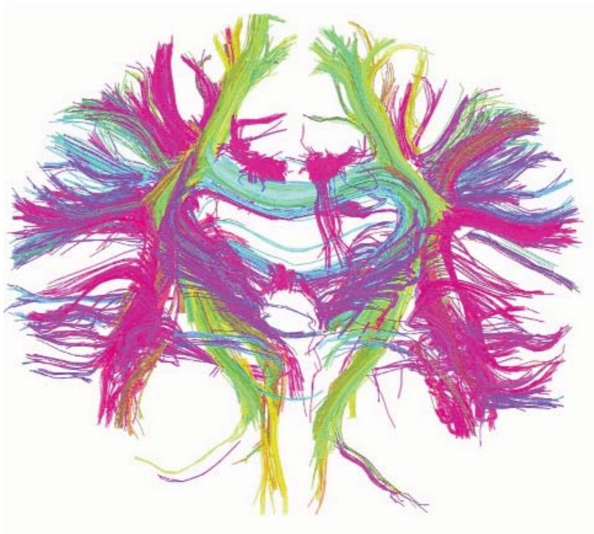

Figure 1. *Diffuse tensor image showing the intricate neural network around the third ventricle*

Method 1: Morphometry

The current morphometric study used sagittal T1-weighted MRI sections from a number of 30 volunteers. The volunteers were 17 adult males and 13 adult females with an age interval ranging between 21 and 83 years of age. The mean age of this first study group was 45.3. The images obtained through MRI scanning were digitally processed and using Corel Draw Graphics Suite (Corel Corporation 2013); all the contours of the targets of interest were highlighted and then recorded as a series of dots.

Two important landmarks were chosen on the surface of the skull, noted P5 and P7. These two landmarks corresponded to two points positioned at 5 and 7 centimeters in front of the sulcus centralis, on the midline of the encephalon. In the P5-P7 anatomical region there are considerably less important veins (8). The position of the bone flap is then carefully chosen by examining the local anatomy, however it is mainly centered on this area (*Fig. 2*). The surgical corridor constructed between P5 and P7 represents a short, and direct vertical access path to the corpus callosum.

A series of measurements of the distances between P5 and the sulcus cinguli and between P5 and the corpus callosum, the height of the corpus callosum, the distance between the anterior commissure and the foramen of Monro as well as the distance between the lower border (the concave surface) of the corpus callosum and the fornix provide the surgeon with valuable data on how to plan his approach in order to protect the corticospinal tract, the fornix and other important structures (11).

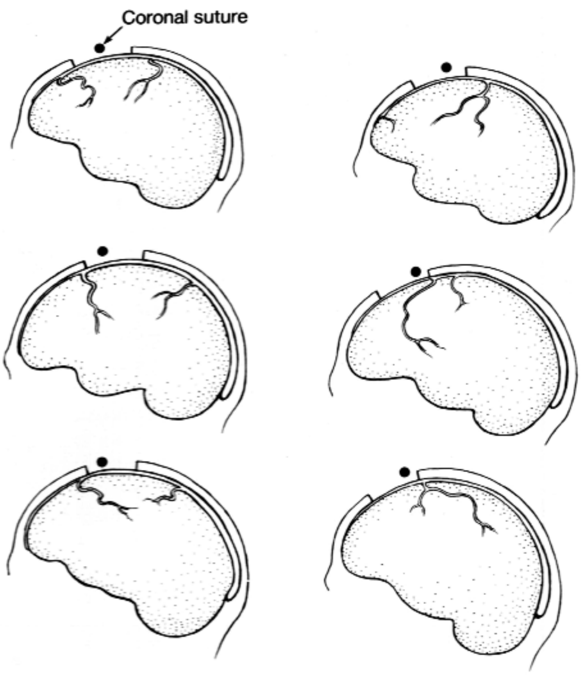

Figure 2. *P5-P7 extended bone flap and its position related to the local anatomy. (taken from APUZZO M. Surgery of the Third Ventricle, Williams & Wilkins, Baltimore 1987)*

A major role in protecting brain function (especially memory) is granted to the protection of the hippocampal commissure. A small lesion in this area would be devastating as the global function of the hippocampus would be compromised. Furthermore, the anterior commissure also requires special attention due to its vicinity to the columns of the fornix and the foramen of Monro as we will later see (9,10,11).

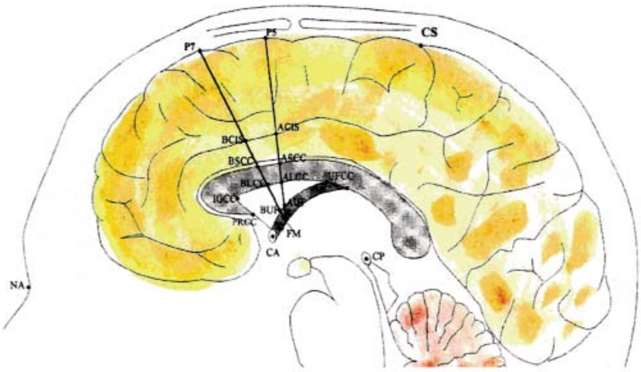

Figure 3. *Image showing the surgical corridor and important landmarks used*

The authors considered the following landmarks which were then identified and noted as fixed points (*Fig. 3*):

- The dimension scale – represented in millimetres;
- The anterior commissure – noted as CA;
- The posterior commissure – noted as CP;
- The lowest point of the rostrum of the corpus callosum – noted as PRCC;
- The lowest point of the splenium of the corpus callosum – noted as PS;
- The intersection between the sulcus centralis and the midline – noted as SC;
- The superior margin of the foramen of Monro – noted as FM;
- The nasion – noted as NA.

Several targets were digitally enhanced and their outline was analysed (See *Table 1*).

The analysed targets were:

Table 1. *Key distances measured in millimetres (Personal data)*

	Med val.	Std. Err.	Std. Dev	Min	Max
P5 – ACIS	25,76	0,56	4,82	17,13	42,73
P5 – ASCC	38,67	0,42	3,57	31,76	50,14
ACIS – ASCC	12,91	0,42	3,64	7,19	22,6
ALCC – AUF	12,44	0,6	5,16	2,71	26,13
P5 – FM	62,99	0,53	4,52	51,28	76,72
ALCC – UFCC	29,62	1,15	9,79	9,98	47,72
ASCC - ALCC	6,22	0,15	1,27	3,07	9
P7 – BCIS	25,41	0,58	4,94	12,91	36,29
P7 – BSCC	38,33	0,46	3,96	29,17	50,26
BCIS – BSCC	12,92	0,43	3,67	6,75	23,37
BLCC – BUF	13,34	0,59	5,08	3,73	27,58
P7 – FM	63,84	0,48	4,15	55,26	74,8
BLCC – IGCC	10,17	0,62	5,31	0,16	24,47
BSCC – BLCC	6,92	0,19	1,64	3,5	13,57
BLCC – PRCC	13,58	0,44	3,79	6,15	21,71
BLCC - CA	22,89	0,44	3,74	11,05	33,04
CL	74,93	0,64	5,49	61,86	86,06
CA - FM	6,78	0,31	2,64	1,86	14,57

- The corpus callosum;
- The telencephalon;
- The septum pellucidum;
- The fornix;
- The anterior commissure;
- The mesencephalon;
- The pons of Varolio;
- The medulla oblongata;
- The vermis;
- The IV[th] ventricle;
- The sulcus cingului.

The distances measured were carefully noted and all the relationships between the surgical corridor and adjacent structures were observed. A series of new measurements was noted along the P5-FM and P7-FM lines. The new measurements are as follows (*Fig. 4*):

- P5 – ACIS and P7 – ACIS – the distances between P5 and P7 and the sulcus cinguli;
- P5 – ASCC and P7 – BSCC – the distances between P5 and P7 and the superior surface of the corpus callosum (the pericallosal cistern);
- ACIS – ASCC and BCIS – BSCC – representative for the height of the Gyrus cinguli;
- ALCC – AUF and BLCC – BUF – representative for the depth of the fornix;
- P5 - FM and P7 – FM – representative for the distance between the cortex and the superior margin of the foramen of Monro – as entry point for the third ventricle;
- ALCC – UFCC and BLCC – UFCC – representative for the distance between the surgical corridor and the anterior insertion point of the fornix in the corpus callosum;
- ALCC – IGCC and BLCC – IGCC – representative for the distance between the surgical corridor and the most anterior point of the internal surface of the corpus callosum.

Statistical analysis and results

All the data were statistically processed. Mean values and standard deviation were used as well as mean errors, maximal values and minimal values. The exact morphometry data was relevant for planning the neurosurgical interventions in the third ventricle as it provided valuable information about the fornix and its insertion point. The results of the 30 measurements for the volunteers can be seen in *Table 1*.

Measurement of the surgical corridor

The authors noted the following values for the surgical corridor (see *Fig. 4* for schematic representation suggestive to the neurosurgeon):

- P5 - ACIS = MEAN VALUE 25.76 mm;
- P7 – BCIS = MEAN VALUE 25.41 mm;
- P5 – ASCC = MEAN VALUE 38.67 mm;
- P7 – BSCC = MEAN VALUE 38.33 mm;

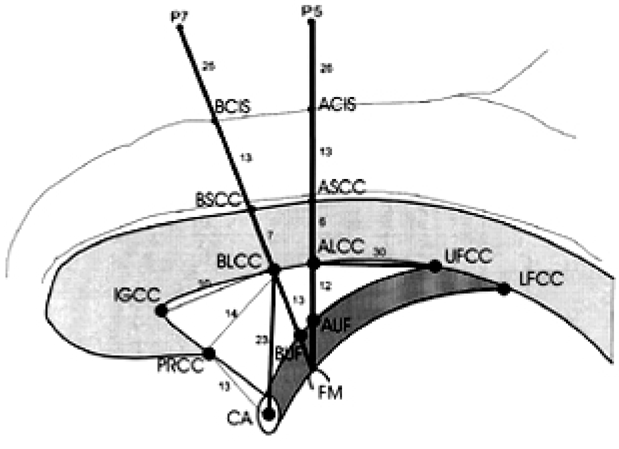

Figure 4. *General diagram showing the measured distances. The numbers represent the value of the distance in millimetres*

- ALCC – AUF = MEAN VALUE 12.44 mm;
- BLCC – BUF = MEAN VALUE 13.34 mm;
- ALCC – UFCC = MEAN VALUE 29.62 mm;
- ASCC – ALCC = MEAN VALUE 6.22 mm;
- BSCC – BLCC = MEAN VALUE 6.92 mm.

Method 2: Microanatomy

The authors used as additional research material a number of 30 human adult specimens without any lesions which were routinely harvested during autopsies. The analysis of the specimens was carried out at the Lodwing Maximilians University Clinic of Neurosurgery in Munich, Germany. All the specimens were submerged in 4% formaldehyde solution for 24 hours. The formaldehyde determined a 5% shrinkage of the cerebral volume. The specimens were then placed on a plastic surface, similar to the internal skull base, which allowed the brain to be correctly positioned as it would be during surgery. The authors measured only relevant neurosurgical distances according to MRI results.

Vascular studies

The authors carefully analysed the vessels around the surgical corridor. Care was given to the pericallosal arteries, the median vessel of the corpus callosum and their anatomic variations (12,13).

Statistical analysis and results

Both the MRI recorded data and the microanatomy recorded data were processed using the SPSS (Statistic Package for Social Sciences) software and thus mean values, standard deviation, standard errors and minimal and maximal values were obtained.

Results and conclusions

During the dissections the authors observed that in 83% of the cases Cavum Septi Pellucidi was present. One specimen showed a large Cavum Vergae. The two sheaths of the septum pellucidum are easy to pull apart in the specimens showing Cavum Septi Pellucidi. This further allows for an optimal construction of the surgical field.

Method 3: Clinical data

This prospective study included 30 patients admitted for third ventricle tumors between 03.03.2000 and 30.06.2009 and operated through an interhemispheric transcallosal approach (interforniceal or transforaminal) (see *Table 2*). The authors performed a thorough assessment of MRI imaging, a complete clinical check-up (including possible endocrine dysfunctions), an assessment of the neurological status, a psychiatric check-up (which often showed subtle personality modifications noticed by relatives). MRI scans were performed in all patients as it is the gold standard for intracranial tumors around the third ventricle. Three-dimensional reconstruction further aids the surgeon by offering a better perspective of the third ventricle.

The authors performed angiography scans in 80% of the patients. The MR images were used in T1-weighted and T2-weighted sections. The exact aspect of the fornix, anterior commissure and other structures involved in constructing the surgical corridor were visualized in a sagittal plane. The coronal suture was also visible. Using the Talairach method (14) the authors localized the sulcus centralis and the surgical corridor to the lesion was drawn. Cerebral angiography images were performed for 3 reasons:

- They create a clearer picture on the nature of the pathology.
- A potential vascular lesion will alter the treatment algorithm.
- Vascular lesions have to be excluded if surgery is to be

Table 2. *Data concerning our patients*

Patient	Name	Sex	Age	Histopathology Lesion ϕ in cm.	Surg. Approach	GOS	Control	Sympt. pre-op	Sympt. post-op
1	P.F.	M	55	Paraganglioma(5)	TC – IF	V	8	Chiasmatic sdr..	-
2	G.M.	F	18	Pilocitic Astrocytoma (4)	TC - TF	IV	8	Hemianopsy Hemianopsy	
3	F.M.	F	42	Colloid cyst (2,5)	TC - TF	V	7	Headache	-
4	V.I.	F	56	Colloid cyst (2,1)	TC - TF	IV	7	Headache	-
5	S.C.	F	48	Colloid cyst (2)	TC - IF	V	7	Headache	-
6	A.R.	M	68	Ependimoma WHOII(3)	TC - IF	IV	7	Headache	-
7	S.N.	M	57	Hypothalamic glioma (4)	TC-IF	I	7	Hypothal insuff. Hypothal insuff.	
8	N.T.	M	17	Hypotalamic hamartoma	TC-IF	V	7	Headache	-
9	L.S.	M	55	Colloid cyst (2)	TC-TF	V	6	Headache	-
10	M.M.	F	48	Meningioma (5,3)	TC	V	7	Hemiparesis	-
11	S.M.	M	33	Colloid cyst (2)	TC-TF	V	8	Headache	-
12	G.E.	F	44	Colloid cyst (2,8)	TC-TF	V	8	Headache	-
13	S.F.	M	44	Colloid cyst (2)	TC -TF	V	6	Headache	-
14	G.F.	F	38	Colloid cyst (1,8)	TC-TF	V	6	Headache	-
15	N.C.	M	37	Disembryoplastic tumor (5)	TC-IF	V	6	Headache	-
16	S.T.	M	19	Ependimoma WHO II (5)	TC-IF	V	5	Headache	-
17	B.E.	F	35	Colloid cyst (2)	TC-TF	V	6	Headache	-
18	R.M.	F	23	Colloid cyst (2,5)	TC-TF	V	6	Headache	-
19	Z.E.	M	43	Ependimoma WHOII (3)	TC-TF	V	5	Raised ICP Scotoma	
20	R.E.	F	73	Epidermoid cyst (3)	TC-TF		3	Headache Hemiparesis	
21	H.P.	M	32	Sarcoid granuloma (6)	TC		3	Raised ICP	-
22	I.A.	M	17	Ganglioglioma (5)	TC-IF		3	Hypothal insuff.	-
23	P.I.	F	29	Ependimoma(5,3)	TC-TF		2	Headache	-
24	C.G.	F	45	Cavernoma (4)	TC		4	Hemiparesis	-
25	G.O.	M	28	Endodermal cyst	TC-TF		3	Headache	
26	H.M.	M	55	Astrocitoma WHO II (6)	TC-SCH		3	Headache	-
27	S.I.	F	31	Ependimoma WHOII (2)	TC-TF		2	Visual impairment	-
28	K.A.	F	54	Colloid cyst (2,5)	TC -TF		2	Headache	-
29	V.A.	F	44	Colloid cyst (2,1)	TC - TF		2	Headache	-
30	L.M.	M	25	Colloid cyst (2,9)	TC - TF		2	Headache	-

performed for third ventricle tumors.

Great value was placed on the assessment of venous circulation.

Method 4: Microsurgery

The modified standard approach was used for the 30 patients. The approach was carefully customized for every patient. While planning the surgery we considered the planned surgical corridor and its relationship with the critical structures in the vicinity.

We calculated the P5 and P7 for each case and the P5-FM AND P7-FM lines which were transposed on sagittal MRI. The surgical corridor looks like an isosceles triangle (ΔP5P7FM) with the two equal sides formed by the P5-FM and P7-FM lines and with the base at the P5-P7 line. Using magnetic resonance we determined the position of the coronal suture, and the sulcus centralis. All cases were trephined using 4 burr-holes – two anterior and two posterior. The two posterior holes can be positioned on the coronal suture, in front of it or behind it. The two anterior burr holes were then executed 5 cm in front of the posterior ones to allow for an appropriate surgical field. Note that the base of the surgical corridor is only 2 cm wide.

Prior to surgery the patients and relatives were informed about the experimental nature of the procedure and all patients signed an informed consent. They were informed about the risks and the benefits as well as the other feasible options. Tumors that manifested peritumoral edema received corticosteroid treatment and diuretics. No anticonvulsive drugs were used whatsoever.

After general anesthesia all patients received a lumbar puncture and a subdural spinal catheter connected to a closed drainage circuit. The drainage circuit was activated during dural incision and a volume of 40-60 ml. of cerebrospinal fluid (CSF) was drained. In this manner a perfect retraction of the brain was achieved while also anticipating the need for CSF drainage after the surgery (3,4,5).

The patients were positioned in the supine position (see *Fig. 5*), on their backs with the torso and feet slightly elevated. The patients' head was elevated 45 degrees above the jugular veins to reduce venous resistance. While using the Mayfield frame the right side (the access side) received a single fixation thorn while the contralateral side received the other two thorns. A small frontal incision was performed with the posterior limit on the coronal suture and the anterior limit at the hairline, avoiding the extensive dissection of muscles. The craniotomy was performed using 4 burr holes and the Gigli bone saw, thus protecting the superior sagittal sinus (SSS). After elevation of the bone flap 250 ml of 20% mannitol were administered, the lumbar CSF drainage was activated and 40-60 ml. of CSF were drained. The dura mater was incised in a semicircular manner with the base positioned towards the SSS. After incision the dura was gently dissected using dural scissors and cotton strips for protecting the cortex and subdural veins (3,4,5,15).

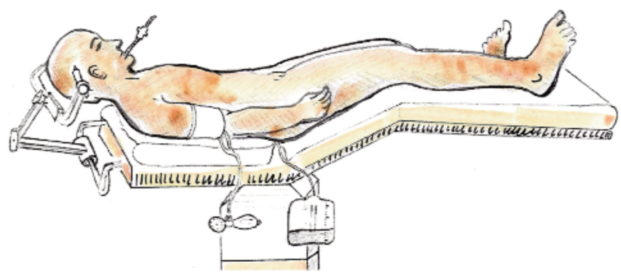

Figure 5. *Image showing the supine position of the patient*

Once the lumbar drainage system was activated the hemispheres lost their tension. However, care must be taken not to exert pressure on the veins in the pons. Under microscope magnification the girus cinguli and sulcus cinguli were exposed. Two cotton strips are then placed on the midline to act as rudimentary landmarks for the future surgical corridor. Once the right side girus cinguli is separated from the falx cerebri, the pericallosal artery can be identified and protected. The pericallosal cistern can then be opened and the corpus callosum examined (8,9,10,11,16,17). Once the maximum power of the surgical microscope is used the superficial vessels of the corpus callosum can be inspected. The incision of the corpus callosum will be made exactly on the middle line of the corpus callosum through the striae longitudinales mediales. After a one-sided retraction and careful coagulation, a 2 cm long segment of the superior layer of the corpus callosum can be incised using a microscope scalpel. The cavum septi pellucidi can be accessed as the color of the tissue turns to a diffuse grey. The dissection of the corpus callosum will now be continued using a bipolar electrocautery to avoid any possible bleeding from the venous network situated under the corpus callosum (6). During a planned transcallosal interforniceal surgical approach to the third ventricle the two sheaths of the septum pellucidum can be dissected and split from the inferior surface of the corpus callosum, thus facilitating the surgeon's access to both lateral ventricles. On the other hand, during a planned transcallosal transforaminal access (which is the other surgical option) only the lateral ventricle on one side can be accessed.

The surgical option: transforaminal vs. interforniceal

During preop. planning of all operated cases presented the possibility of choice between a transforaminal approach or an interforniceal approach. In small lesions such as colloid cysts with lateral ventricles enlarged as a consequence of hydrocephalus and a wide foramen of Monro, the transforaminal approach was the logic choice (18,19,20). On the other hand, in more severe cases which presented large tumors in the third ventricle and a reduced diameter of the foramen of Monro the interforniceal approach is desirable. In extreme cases a third option is present by going in a subchoroidal manner, through velum interpositum (8). We used only the interforniceal and the transforaminal approach, considering only as a back-up solution the subchoroidal approach.

Tumor resection

After laborious dissection and exposure of the tumor using bipolar dissection only, the tumor will be carefully removed using the same bipolar coagulation. The content of colloid cysts will be evacuated using suction and after careful coagulation the capsule of the cyst will be dislodged and removed using classical microneurosurgical methods (21). After exeresis a small time window of 5 to 10 minutes can be left for haemostasis (3,4,5). At the end of the 10 minutes the ventricle will be inspected once more and ventricular drainage can be instated. The CSF has to be externally drained as blood cloths which might appear in the post-op period will block the aqueduct of Sylvius and occlusive hydrocephalus might appear. Secondly, in the early postop period, while using the ventricular drainage system the surgeon has a very clear picture about the processes taking place inside the ventricle. Intracranial pressure can be measured and the management of possible complications can be rendered easier. Extreme emphasis should be placed on preventing infections and the drainage system will be left in place no more than 48 hours (3,4,5,21). During the post-op period all the patients were transported to the neurosurgical intensive care unit for two days and after the ventricular CSF drainage system was removed the patients were transferred back to the neurosurgical ward.

Neuropsychological assessment

Out of the 30 patients included in our prospective study (17 males and 13 females with the mean age of 45.3) due to various reasons including lack of interest or failure to communicate, only 19 patients were able to undergo postoperative neuropsychological evaluation. The tests included attention testing, general attention, visual functions and hand-to-eye coordination, selective attention tests, short term memory evaluation, and disconnection evaluation.

Clinical results

The results of the anatomic and morphologic evaluation were applied in our 30 patients. The major preoperative symptoms included cognitive impairment, headache and personality disorders, however, the complete list of symptoms can be observed in *Table 3*. We managed to achieve a complete resection of the tumor in 23 cases (77%). In patient no. 7 a subtotal resection (~90%) was achieved. In patient 8 who suffered from a hypothalamic hamartoma adhering to the posterior hypothalamic wall complete resection was impossible. Patient no. 21, suffering from neurosarcoidosis (in which we performed only a biopsy) had a favorable outcome after corticosteroid treatment. Patient no. 22 who had a ganglioglioma received Gamma-Knife therapy for a small tumoral residue. After Gamma Knife therapy the patient was tumor free – GOS V. In patient no. 26 who suffered from a WHO II astrocytoma only a subtotal resection was possible. Patient no. 28, who had a giant polylobulated colloid cyst, showed on MRI follow-up the presence of a tumoral residue. The other colloid cysts in this patient were completely resected.

Table 3. *Major symptoms present in our patients*

Symptoms	N=30	%
Cognitive impairment	28	94
Headache	23	77
Personality disorders	18	60
Vomiting	10	34
Impaired walking	9	30
Hemiparesis	6	20
Impaired eyesight	6	20
Endocrine dysfunction	4	13
Epileptic seizures	3	10
Singultus	1	3
Pavor nocturnus	1	3

Complications

One early complication was recorded in the postoperative period due to the surgical act. In a 73-year-old patient (no. 21) a venous infarction occurred through the thrombosis of a vein in the area of the surgical corridor. The patient suffered a hemiparesis which recovered slowly and incompletely and which necessitated a ventriculo-peritoneal shunt for secondary obstructive hydrocephalus.

Neuropsychology

The most important parameters (22) that we assessed were attention, memory and disconnection. In what regards attention, at four weeks after surgery the ratio of normal attentive versus abnormal attentive patients was 13/1. We noticed an obvious improvement in attention for patients that had complete tumor resections. Memory, another important parameter was also assessed at 4 weeks after surgery. Just like in the case of attention the majority of the patients had overcome the memory impairments after surgery. Regarding the subject of disconnection no patient manifested any important signs of disconnection.

Discussions

In this study of morphometry for the improvement of the surgical approach of the third ventricle we collected extremely valuable data from healthy individuals. We assessed the relationships between different landmarks and parameters and their interindividual variability. Naturally, the laboratory study will never be equivalent to the actual surgical situation of the patients that need surgery, as any expansive process in the third ventricle will invariably shift the positions of the normal anatomic structures and landmarks. It is therefore easy to understand the necessity of more in-depth studying of the problem concerning how tumors in the third ventricle modify the local anatomy.

In MRI images of the studied patients we measured the distance between the P5 and the sulcus cinguli, the P5 and the corpus callosum which averaged 26 and 39 mm, however the dispersion of noted values was very wide which comes as an argument for interindividual variability of the height of the interhemispheric fissure. Regardless of the variability of the parameters, the importance of the measurements remains unaltered since they help determine the position of the calosomarginal artery and other critical structures, therefore protecting them against any possible lesion.

The most relevant data we collected show that the thickness of the corpus callosum is about 6.16±1.13 mm (dispersion: 4-8 mm) up to the level of P5 and 6.6 ±1.4 (dispersion 4-9 mm) up to the level of P7. In patients with hydrocephalus the corpus callosum can be thinner. The ALCC – AUF (average 12.44 mm) and BLCC – BUF (average 13.34 mm) represent the height of the septum pellucidum and indicate the insertion spot of the raphe fornicis (*Fig. 4*) Being aware of these dimensions is mandatory for the preparation of the transforniceal approach.

Certain areas around the foramen of Monro are of immense importance and therefore should not be tampered with. For example, the anterior commissure must be mandatory preserved as it represents the most important connection between temporomesial regions and frontobasal regions. In one of our cases the distance between the foramen of Monro and the anterior commissure was only 2.5 mm, with a dispersion of 3.5 to 10 mm and an average value of 4.7±1.8 mm. The hippocampal commissure must also be preserved at all costs due to the decussation of all efferent via the fornix. A minute lesion in this area would have tremendous effect on the whole hippocampus.

Forniceal insertion

A first systematic study of the fornix was carried out by Lang and Ederer (23) on 100 autopsied brains. The authors had divided the corpus callosum in 4 equally long segments. In 77% of all cases the fornix was inserted in the third segment which was considered to be standard. In 19% of cases the fornix was inserted in the 4^{th} segment (the so called posterior insertion type) while in 4% of all cases, the insertion appeared in the 2^{nd} segment (anterior insertion).

Our morphometry technique divided the corpus callosum in 10 equally long segments (longitudinally) using the CA-CP line as it is already used in planning of the surgical corridor. We also distinguished 2 halves (superior and inferior). Our method allows for a better standardization of the fornix insertion and is a valid argument for the clear separation of cases which have anterior insertions of those having posterior insertions of the fornix. Anterior insertions of the fornix to the corpus callosum must be clearly outlined prior to surgery as any lesions to the fornix will produce permanent damage to the short term memory of the patient. Therefore we consider that our improved transcallosal approach to the third ventricle allows for adequate identification and protection of critical structures during surgery. This is a key element for the outcome of future patients to be operated for tumors in the third ventricle. Since 94% of all our patients manifested memory impairment, the surgery pursues not only to remove the tumor but also to decompress the fornix.

The surgical corridor

Magnetic Resonance Imaging is in our opinion the gold standard for determining the optimal surgical corridor. The lateral ventricles will be inspected and carefully evaluated. The foramen of Monro, both columns of the fornix and the insertion of the fornix will have to be clearly noted. After evaluating the MRI the optimal approach – transforaminal or transforniceal will be chosen. In patients with enlarged ventricles or hydrocephalus due to the obstruction of the foramen of Monro the transforaminal route will be chosen. In a patient with a small foramen of Monro or a large tumor without ventricular enlargement the preferred route will go between the columns of the fornix. The incision of the corpus callosum will be performed immediately behind the genu. Any patient manifesting cavum septi pellucidi (noticeable on MRI) will allow the surgeon the possibility to dissect the sheaths of the septum and access the lateral ventricles through fenestration of their ceiling.

Surgical results

The study comprised of 30 patients with lesions in the anterior region of the third ventricle. Some of the patients were treated when the tumor had reached an advanced state of evolution and extension and therefore the results in their cases were difficult to assess regarding the usefulness of the surgical technique. Patient no. 7 for example was 61 years old and had an anaplastic glioma with hypothalamic invasion. Despite the surgical effort, the subtotal (~90%) resection of the tumor and the initially good outcome, the tumor had grown back in a geometric pattern and 4 months later the patient was dead. In all patients with colloid cysts the results were excellent (GOS V). In patient no. 20 (73-year-old female) due to the lesion of a pontine vein a venous infarction occurred postoperative. The patient suffered left hemiparesis which gradually recovered, but not entirely.

Conclusions

We consider that the highly variable distance between the intersection point of the posterior limit of the surgical corridor (P5-FM line) and the inferior surface of the corpus callosum – ALCC and the insertion point of the fornix to the corpus callosum – UFCC (ALCC-UFCC) corroborated with the insertion type of the fornix has a tremendous importance for the neurosurgeon. Another highly important distance is that between the foramen of Monro and the anterior commissure (averaging at 4.7 mm). Morphometry can thus contribute to the better understanding of anatomic variants and improving the outcome for neurosurgical patients. In what regards microanatomy, it showed that for cases with cavum septi pelucidi, the sheaths of the septum pellucidum can easily be separated allowing for a nearly perfect surgical approach. A clean interforniceal approach was possible in 77% of studied specimens. In 92% of all specimens we came across a very thin vessel positioned in the groove between the striae longitudinale medialis. This vessel marks the middle of the corpus callosum and probably is an anastomosis between the artera corporis calosi mediana and artera choroidea posteromedialis (24). This vessel is the perfect landmark for any calosotomy and therefore is to be granted with a very important role. The results we gathered from observing and measuring our specimens helped us standardize the surgical approach corridor in our 30 surgical patients.

The surgical technique's most important step is correctly analysing the MRI imaging and venograms in order to maximize the information the surgeon possesses prior to surgery. The P5 –P7 corridor is then drawn and adapted to local topography and/or local venous circulation. The next step – which is very important - consists of searching for the middle of the corpus callosum using the vessel described above, positioned between the striae longitudinalis medialis. This vessel is a great landmark for any callosotomy. For the interforniceal approach both sheaths of the septum are opened and both lateral ventricles are accessible.

An impressive proportion (80%) of all patients obtained excellent outcomes (GOS V). A number of 5 patients scored (GOS IV). No cases were recorded in GOS III or II. A single patient died as a consequence of tumor regrowth with hypothalamic invasion. All patients with colloid cysts obtained perfect results (GOS V). Complete tumor resection was achieved in 77% of all patients. In 6 cases (20%) only subtotal removals were possible. A single case was biopsied as the patient was suffering from neurosarcoidosis. A single complication was connected to the surgical approach as one patient aged 73 suffered a venous infarction due to a thrombosis in a tributary to the SSS in that area. The patient's final outcome score was (GOS IV). No other complications were recorded.

The modified transcallosal surgical approach of the third ventricle does not cause any cognitive function, attention or memory loss when carefully planned. Minor disconnection signs were recorded in two cases but were transient and by the time of the second neuropsychologic consult had disappeared completely. Neuropsychologic consults pre and postop are highly valuable in the management of rehabilitation and reintegration of the patient.

Conflicts of interest

We the authors declare that no funding was used for this research and that there are no conflicts of interest.

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