

## TUMOR-THIRD VENTRICULAR RELATIONSHIPS IN SUPRADIAPHRAGMATIC CRANIOPHARYNGIOMAS: CORRELATION OF MORPHOLOGICAL, MAGNETIC RESONANCE IMAGING, AND OPERATIVE FINDINGS

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**Received,** July 21, 2003.

**Accepted,** January 14, 2004.

**OBJECTIVE:** To disclose the relationships of primarily supradiaphragmatic craniopharyngiomas with the third ventricular floor (3rdVF) by means of preoperative magnetic resonance imaging (MRI) and thus to select the surgical approach avoiding the hypothalamic structures.

**METHODS:** MRI findings in 76 consecutive patients with craniopharyngiomas operated on between June 1991 and December 2002 were interpreted on the basis of the results of the authors' own previous microanatomic studies. The assumed tumor-3rdVF relationships were then correlated with the operative findings. MRI features characteristic for different topographical relationships were analyzed in 44 patients (18 children, 26 adults) with exclusively supradiaphragmatic tumors.

**RESULTS:** In 14 of 15 patients with the tumor located below the 3rdVF (suprasellar extraventricular craniopharyngioma), the anterior communicating artery was displaced upward and indirectly indicated the position of the chiasm between the prechiasmatic and the retrochiasmatic tumor portions. Hydrocephalus was absent in 14 patients, including those with giant tumors. The anterior part of the third ventricular cavity was found in front of the level of the foramina of Monro in 6 patients. All 28 tumors growing partially inside and partially outside the third ventricular cavity (intraventricular and extraventricular craniopharyngioma) were retrochiasmatic. They caused severe or moderate hydrocephalus in 20 patients and mild hydrocephalus in 2. One purely intraventricular tumor caused severe hydrocephalus.

**CONCLUSION:** The position of the optic chiasm and the size of the lateral ventricles on preoperative MRI enable us to determine the position of the 3rdVF or its remnants in relation to the supradiaphragmatic craniopharyngiomas and to select the proper surgical approach allowing exposure of the tumor while avoiding the hypothalamic structures.

**KEY WORDS:** Magnetic resonance imaging, Supradiaphragmatic craniopharyngioma, Surgical approaches, Third ventricle

*Neurosurgery* 54:1051-1060, 2004

DOI: 10.1227/01.NEU.0000120421.11171.61

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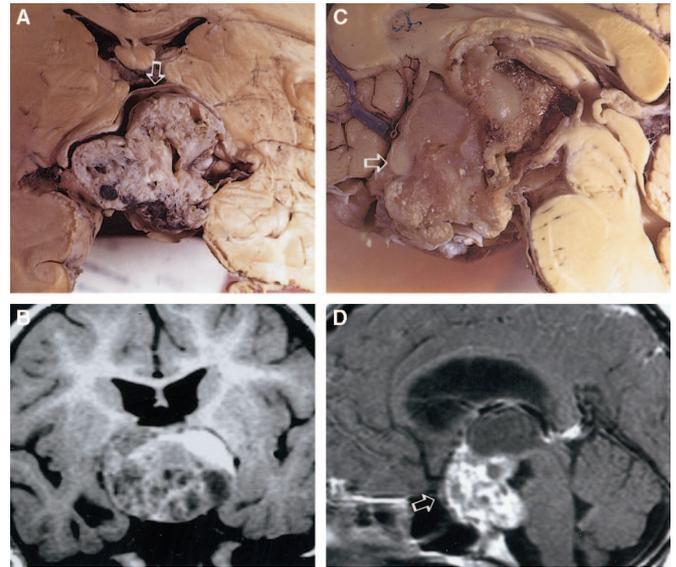
Exceptional variability of the relationships of craniopharyngiomas with the surrounding structures has resulted in numerous topographical classifications. These tumors have been classified according to their relationship with the sella (3) or with the sella and the optic chiasm (22), and most authors also take into consideration the tumor-third ventricle relationship (4, 7, 9, 13, 15, 16, 20, 21, 23, 25, 30), which is of fundamental importance to the surgeon. Nevertheless, a detailed topography of the hypothalamic structures of the third ventricular floor (3rdVF) is usually missing in the literature on craniopharyngioma surgery.

Suprasellar extension of craniopharyngiomas beginning to grow below the sellar diaphragm may cause upward displacement of the 3rdVF similar to intrasellar and suprasellar pituitary adenomas. In cases of primarily supradiaphragmatic craniopharyngiomas, this topographical relationship is more complex. The tumor may also grow below the 3rdVF; however, more often it is located partially inside and partially outside the cavity of the third ventricle, i.e., intraventricularly and extraventricularly (15, 25), or rarely, completely within the third ventricle (4, 6, 9, 12, 19, 25).

The most valuable imaging from the point of view of determining the relationship of the tumor and the 3rdVF is that in the sagittal plane. Because direct sagittal computed tomographic scans are difficult to obtain, the value of the method is limited (26). Visualization of the brain structures by means of magnetic resonance imaging (MRI) is more precise; nevertheless, the structures of the 3rdVF or its remnants in patients with larger suprasellar craniopharyngiomas often cannot be identified directly on preoperative MRI scans (14). The aim of our study was to assess the possibilities of determination of the relationship of supradiaphragmatic craniopharyngiomas with the 3rdVF by means of preoperative MRI and thus to select the proper surgical approach, avoiding the hypothalamic structures.

### PATIENTS AND METHODS

The study was performed in 76 consecutive patients operated on for craniopharyngiomas from June 1991 (when MRI became available to our patients) to December 2002. MRI findings in all the patients were interpreted before surgery by comparison with the results of our microanatomic study (15, 25) of 30 sectional cases of craniopharyngiomas performed in the past (Figs. 1 and 2). We thus preoperatively assumed the relation of the tumor with the 3rdVF. Final classification of the tumors into topographical groups was performed intraoperatively according to their real relationships with the sellar diaphragm and with the structures of the 3rdVF as seen through the operating microscope and, if necessary, by means of an angled mirror or, during the past 3 years, through an endoscope. For the purposes of the present study, only patients with tumors growing exclusively above the sellar diaphragm were included. Eighteen of 44 patients (9 boys, 9 girls) with primarily supradiaphragmatic tumors were children 11 months to 15 years old (mean age, 9.2 yr), and 26 (10 men, 16 women) were adults 16 to 72 years old (mean age, 46.8 yr). Operative findings were then compared with preoperatively



**FIGURE 2.** Comparison of anatomic specimens (A and C) from patients who died of hypothalamic insufficiency after partial removal (A) or without direct surgical attack (C) of the tumor and MRI scans (B and D) of analogous clinical cases of successfully removed supradiaphragmatic craniopharyngiomas. A and B, suprasellar extra-ventricular tumors displacing the 3rdVF upward (arrow). C and D, intra-ventricular and extra-ventricular tumors located behind the chiasm (arrow).

assumed topographical relationships. MRI features characteristic for different types of relationships of the supradiaphragmatic tumors with the 3rdVF were analyzed.

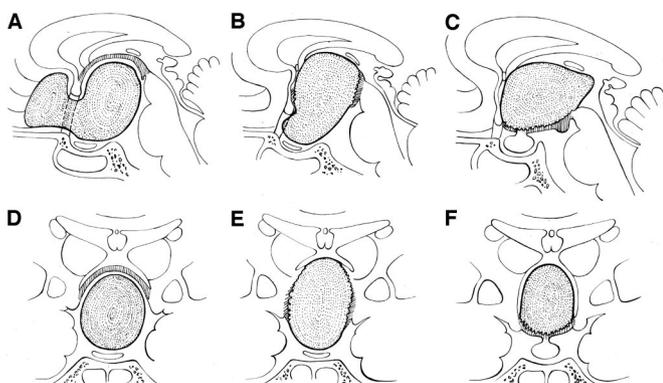
### RESULTS

According to MRI scans, the tumors in 18 patients were expected to be extra-ventricular; in 25 patients, the assumed location of the tumor was partially intra-ventricular and partially extra-ventricular; and in 1 patient, the tumor was preoperatively considered to be purely intra-ventricular. The diameter of the tumor was less than 3 cm in 9 patients but reached 3 to 4 cm in 11 patients. More than half of the tumors were large (exceeding 4 cm; 22 patients) or giant (exceeding 6 cm; 2 patients).

#### Correlation of MRI and Operative Findings

##### Extra-ventricular Tumors

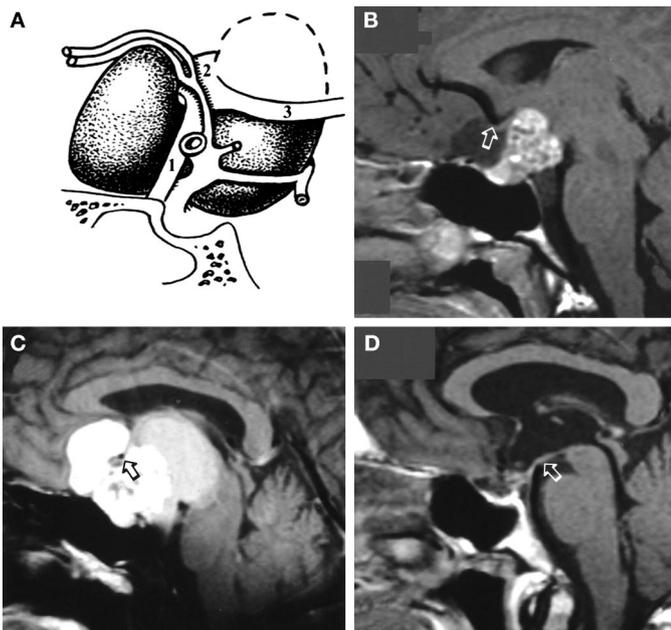
Preserved 3rdVF above the supradiaphragmatic tumor was found at operation in 15 of 18 patients in whom extra-ventricular craniopharyngioma was expected. In another 3 patients, the superiorly displaced 3rdVF was defective, and the upper pole of the tumor was located inside the cavity of the third ventricle. These 3 tumors were classified as intra-ventricular and extra-ventricular (Table 1). Direct MRI visualization of the 3rdVF was usually observed only on postoperative scans (Fig. 3D).



**FIGURE 1.** Schematic representation of relationship of supradiaphragmatic extra-ventricular (A and D), intra-ventricular and extra-ventricular (B and E), and intra-ventricular (C and F) craniopharyngiomas with the floor of the third ventricle (dashed lines).

TABLE 1. Age distribution of patients with supradiaphragmatic craniopharyngiomas

Patients	Tumor location			Total
	Suprasellar extraventricular	Intraventricular and extraventricular	Intraventricular	
Children	3	14	1	18
Adults	12	14		26
Total	15	28	1	44



**FIGURE 3.** Relationship of SEVCs with the structures of the optic pathway, AComA, and third ventricle. A, schematic representation. 1, optic nerve; 2, chiasm; 3, optic tract. B and C, MRI scans showing extension of anterior part of the tumors in front of the chiasm/AComA (arrows). D, MRI scan showing the floor of the third ventricle (arrow) in the same patient as in C, 4 years after tumor removal between the optic nerves and through the right opticocarotid triangle via unilateral subfrontal approach.

In 14 of 15 patients with suprasellar extraventricular craniopharyngioma (SEVC) displacing the 3rdVF superiorly, the tumor also pushed the optic chiasm upward (Fig. 3A). The chiasm itself was rarely seen directly on MRI scans, and its position was therefore detected indirectly according to the position of the anterior communicating artery (AComA) lying just above the chiasm on sagittal MRI scans. The AComA thus also showed the border between the prechiasmatic and retrochiasmatic portions of the SEVC (Fig. 3, B and C). In 5 patients, the prechiasmatic part of the tumor represented at least one-third of the whole lesion. Retrochiasmatic location of the entire SEVC was found in only 1 patient.

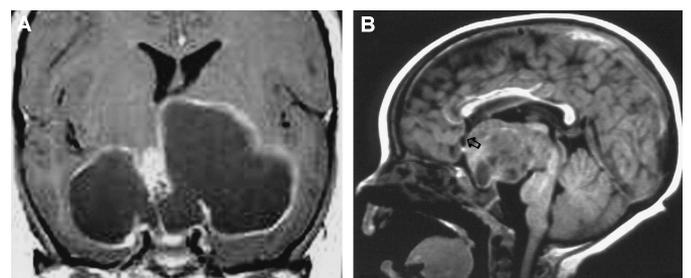
Another characteristic MRI feature of SEVCs was the absence of hydrocephalus (14 patients), even in the presence of a

giant tumor (Fig. 4; Table 2). Enlargement of the lateral ventricles could be seen in only one patient. Extraventricular location of the tumor could also be anticipated by displacement of the anterior part of the cavity of the third ventricle not only upward but also anteriorly in front of the level of the foramina of Monro. This was found in six patients on sagittal or coronal MRI scans (Fig. 4B).

#### Intraventricular and Extraventricular Tumors

In all 25 patients preoperatively considered to be intraventricular and extraventricular and in 3 of 18 craniopharyngiomas considered extraventricular, the upper part of the tumor was located inside the cavity of the third ventricle and its basal portion outside the ventricle in the suprasellar subarachnoid space. In all 11 patients in whom the tumor was exposed via one or both foramina of Monro, no remnants of the 3rdVF were found on its upper pole. The defect of the central portion of the 3rdVF in another 15 patients could be seen directly during tumor removal through the opening of the lamina terminalis and in 2 patients indirectly (angled mirror, endoscope) after tumor removal via extracerebral approaches. Such tumors were classified as intraventricular and extraventricular craniopharyngioma (IEVC). In 17 patients, the tumor was large or giant.

In the majority of IEVCs, the remnants of the 3rdVF were located around the equator of the tumor and represented the borderline between its intraventricular and extraventricular portions (Fig. 5). Rarely preserved infundibulum and the remnants of the tuber covered the lower anterior surface of the



**FIGURE 4.** A and B, MRI scans showing absence of hydrocephalus in giant SEVCs. Anterior displacement of anterobasal part of the third ventricular cavity is seen (B, arrow). Both tumors were successfully removed via unilateral subfrontal extra-axial approaches.

TABLE 2. Lateral ventricles in supradiaphragmatic craniopharyngiomas

Lateral ventricles	Tumor location		
	Suprasellar extraventricular	Intraventricular and extraventricular	Intraventricular
Hydrocephalus			
Severe		11	1
Moderate	1	9	
Mild		2	
Nonenlarged ventricles	14	6 <sup>a</sup>	
Total	15	28	1

<sup>a</sup> Three tumors not reaching foramina of Monro; three tumors growing originally extraventricularly.

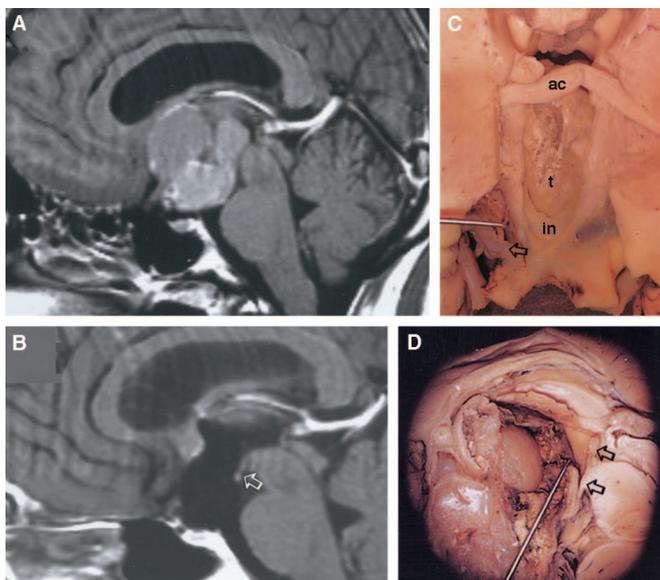


FIGURE 5. A and B, MRI scans (A, preoperative; B, postoperative) of IECV removed through combined transcallosal and trans-lamina terminalis approach. Arrow, mamillary bodies. C, anatomic specimen of intraventricular part of the tumor (t) between anteriorly displaced infundibulum (in) and anterior commissure (ac). Arrow, transected AComA on the lower level of the tumor. The patient died of hypothalamic insufficiency after partial extra-axial removal of the tumor. D, anatomic specimen showing plane of cleavage between the tumor and the compressed mamillary bodies (arrows). Compare with the same specimen in Fig. 2C, where no apparent plane of cleavage can be identified.

IEVC (Fig. 6). In three patients in whom the tumor was preoperatively considered extraventricular, partially atrophied 3rdVF was located above the virtual tumor's equator.

The IEVCs were located behind and by far most often above the chiasm. The latter could be identified directly on preoperative sagittal scans in 15 patients (Figs. 2D and 5A). A small part of the tumor extending below and in front of the level of the chiasm was found in the tumors preoperatively considered to be extraventricular.

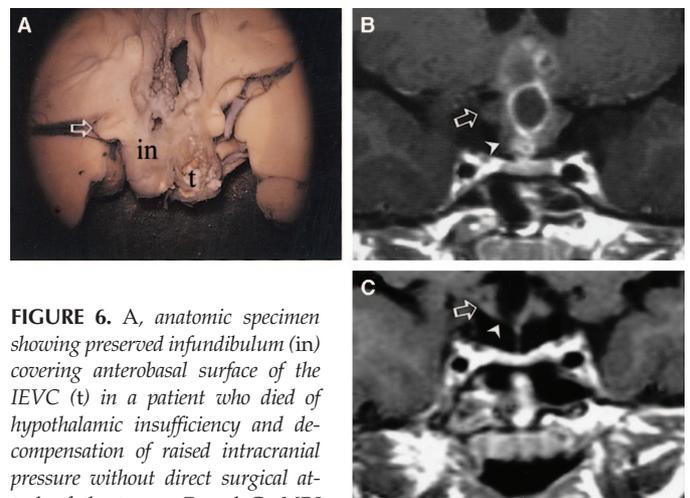
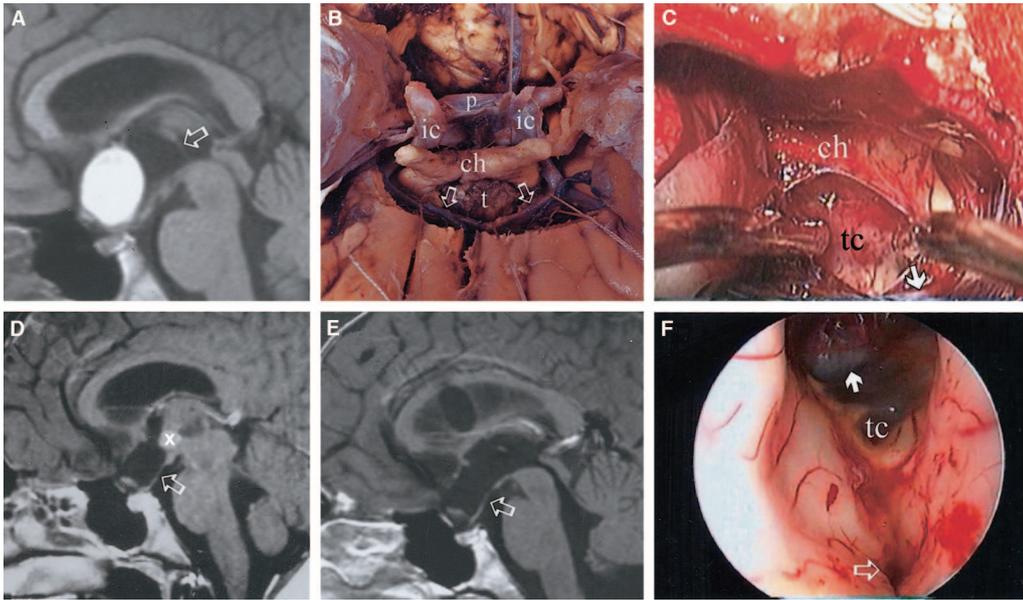


FIGURE 6. A, anatomic specimen showing preserved infundibulum (in) covering anterobasal surface of the IECV (t) in a patient who died of hypothalamic insufficiency and decompensation of raised intracranial pressure without direct surgical attack of the tumor. B and C, MRI scans (B, preoperative; C, postoperative) showing analogous tumor and infundibulum (arrowheads) removed via transcallosal approach. Arrows, right optic tract.

The intraventricular part of the tumor reached the foramina of Monro (9 patients) or even the roof of the third ventricle (14 patients) and caused severe or moderate (20 patients), rarely mild (2 patients) hydrocephalus (Table 2). The absence of hydrocephalus in the other 6 patients could be explained either by the small size of the tumor, which did not reach the foramina of Monro (3 patients), or by primarily extraventricular growth of the tumor (3 patients), which probably allowed passage of the cerebrospinal fluid above the superiorly displaced remnants of the 3rdVF.

#### Intraventricular Craniopharyngioma

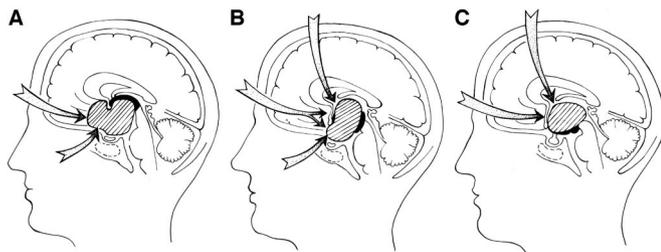
In one patient, the tumor was entirely intraventricular, and its basal surface was covered by the structures of the 3rdVF (Fig. 7). Although a small central part of the tuber with a diameter of a few millimeters and the infundibulum were atrophied, the tumor was classified as intraventricular craniopharyngioma (IVC).



**FIGURE 7.** IVC. A, T1-weighted preoperative MRI scan showing tumor with hyperintense and hypointense parts (arrow). B, anatomic specimen of unoperated tumor (t) in situ with the lamina terminalis removed up to anterior artery/ACoM (arrows). ch, chiasm; p, pituitary gland with the sellar dura; ic, internal carotid artery. C, intraoperative view of the inner surface of the tuber (tc) after incomplete tumor removal through the lamina terminalis opened up to A1 (arrow); ch, chiasm. D, postoperative MRI scan showing tuber (arrow) with residual tumor (x). E, MRI scan after second-stage transcallosal radical removal. F, intraoperative transcallosal endoscopic view of the 3rdVF after total tumor removal. Arrows, dorsum sellae seen through atrophied infundibulum; tc, tuber; open arrow, aqueduct.

**Surgical Approaches, Tumor Exposure, and Extent of Tumor Removal**

The selection of the approach was always made according to the assumed relationship of the tumor with the 3rdVF. The SEVCs were exposed by the extra-axial route (prechiasmatic space, opticocarotid triangle, lateral to the carotid), intraventricular tumor through the opening of the lamina terminalis and transcallosally, and the IEVCs through both transcerebral (trans-lamina terminalis, transcallosal, or transcortical transventricular) and extra-axial routes (Fig. 8).



**FIGURE 8.** Diagrams of surgical approaches to suprasellar extraventricular (A), intraventricular and extraventricular (B), and purely intraventricular (C) craniopharyngiomas, avoiding hypothalamic structures of the floor of the third ventricle (black).

*Extraventricular Craniopharyngiomas*

Upward displacement of the chiasm and prechiasmatic extension of SEVCs allowed sufficient tumor exposure between the optic nerves and through the opticocarotid triangle via unilateral subfrontal craniotomy in 13 of 15 patients, including those with giant tumors. Insufficient exposure of the upper retrochiasmatic part of the tumor in one patient forced us to open the lamina terminalis. However, relatively preserved infundibulum and tuber cinereum above the tumor had to be left untouched. Prefixed chiasm in one patient necessitated dissection of the sylvian fissure via a pterional craniotomy. Radical removal of the tumor was achieved in 11 patients (Table 3). Preclusion of complete tumor removal in four patients (three with primary, one with re-

current tumor) was firm adherence of the tumor capsule to the pia mater of the infundibulum and tuber cinereum, not insufficient tumor exposure. The completeness of the tumor removal and the condition of the 3rdVF was assessed by angled mirror or endoscope.

*Intraventricular and Extraventricular Craniopharyngiomas*

Removal of the IEVCs solely via extra-axial approaches was performed in 2 of 28 patients. In 1 patient, the tumor could be removed completely between the optic nerves because of the high position of the chiasm. In the other patient with prefixed chiasm and extremely low position of the ACoM precluding safe opening of the lamina terminalis, the tumor was removed subtotally exclusively through the opticocarotid triangle. In the other 26 patients, we entered the third ventricle through the opening of the lamina terminalis or through one or both foramina of Monro.

The most frequent route to the IEVCs was the trans-lamina terminalis approach. This was used in 24 patients, in 16 of them combined with other approaches (transcallosal, transventricular, extra-axial; Table 4). Opening of the lamina terminalis allowed good exposure of the anterior and the basal parts of the intraventricular mass and of the entire extraventricular portion of the tumor. After its removal, the brainstem

**TABLE 3. Extent of removal of supradiaphragmatic craniopharyngiomas**

Patients and tumor removal	Tumor location		
	Suprasellar extraventricular	Intraventricular and extraventricular	Intraventricular
Children			
<i>Radical</i>	2	10	1
<i>Subtotal</i>	1	4	
Adults			
<i>Radical</i>	9	11	
<i>Subtotal</i>	3	3	

**TABLE 4. Surgical approaches to intraventricular and extraventricular craniopharyngiomas<sup>a</sup>**

Unilateral subfrontal craniotomy (n = 17)	
<i>Extra-axial (preCH, triangOC)</i>	2
<i>TransLT</i>	8
<i>TransLT + extra-axial</i>	7
Large (“combined”) frontal craniotomy (n = 11)	
<i>TransCC</i>	2
<i>TransCC + transLT</i>	4
<i>TransCC + transLT + extra-axial</i>	2
<i>TransF + transLT</i>	1
<i>TransF + transLT + extra-axial</i>	2

<sup>a</sup> preCH, prechiasmatic (interoptic); triangOC, opticocarotid triangle; transLT, trans-lamina terminalis; transCC, transcallosal; transF, transfrontal transventricular.

came into view, together with the basilar artery and its branches separated from the tumor by Lilliequist’s membrane. If the mamillary bodies were displaced predominantly basally, they were seen in front of the brainstem. The remnants of the infundibulum and the tuber, if present, and their supplying blood vessels originating from the posterior communicating artery could be clearly seen and spared. This approach also provided good access to the posterobasal expansion of the IEVC into the cerebellopontine angle seen in one patient. The extent of the exposure of the intraventricular part of the tumor depended on the position of the AComA. It usually did not allow access to the most posterosuperior part of the cavity of the ventricle. Tumors reaching this area (Figs. 2D and 5A) were therefore exposed through the transcallosal (8 patients) or transcortical transventricular (3 patients) approach. The latter was used in 2 patients at the beginning of the series and in 1 patient because of a huge bridging vein draining into the superior sagittal sinus. In these 11 patients, we performed a large unilateral frontal bone flap crossing the midline by 1.5 cm and reaching or exceeding by 1 cm the coronal suture posteriorly. An opening of the dura approximately 7 cm long

(in anteroposterior diameter) enabled combined one-stage transcallosal and subfrontal tumor exposure. In 2 patients, the tumor was excised totally through the incision of the corpus callosum (Fig. 6); in 9 patients, the anterobasal part of the tumor was also removed through the opening of the lamina terminalis; and in a few patients, extracerebral approaches were also used. The indication for a combined approach was a giant tumor located entirely behind and above the chiasm/AComA, reaching the roof of the third ventricle and causing hydrocephalus.

In the region of the foramina of Monro, the tumor most often touched only the ventricular ependyma. A more intimate relationship was found more basally, sometimes with the lateral walls, most often only with the remnants of the 3rdVF. If the plane of cleavage between the tumor and the remnants of the 3rdVF could not be identified (7 patients), a part of the tumor capsule or even of the tumor parenchyma had to be left in place (Table 3).

### Intraventricular Craniopharyngioma

Difficult accessibility of the most posterior part of the tumor through unilateral subfrontal craniotomy via opening of the lamina terminalis was the cause of its incomplete removal. A second-stage transcallosal approach was necessary for residual tumor removal (Fig. 7).

### Surgical Outcome

During the early postoperative period (within 1 mo after surgery), four patients died after radical tumor removal. One adult with SEVC died after reoperation for postoperative hematoma in the tumor bed. Of three patients with IEVCs, 1 adult died of myocardial infarction and another two patients (one child, one adult) died of severe metabolic disorders and hyperpyrexia. Acute postoperative hypothalamic insufficiency manifested by fluid and electrolyte imbalance in another four patients after radical and in one patient after subtotal removal of the IEVC could be successfully managed.

During follow-up ranging from 5 to 141 months (mean follow-up, 54.5 mo), seven patients died. One adult died after reoperation for residual IEVC 8 months after the initial sur-

gery, and two children and one adult with IEVC died later in regional hospitals, presumably from metabolic disorders after inappropriate replacement therapy. Another three adults died of causes unrelated to the tumor.

Seven tumors recurred in 14 to 76 months (mean, 43.3 mo), in three children and one adult after radical removal and in one child and two adults after subtotal excision of the tumor. All of them underwent uneventful reoperation. In two children, the tumor recurred again. It was radically removed, with severe unilateral visual impairment in one patient. The second recurrence in the other child could be removed only partially and subsequently was treated radiosurgically.

Of 33 surviving patients evaluated at the time of follow-up, 30 were independent and 2 were partially and 1 totally dependent because of bilateral blindness that had been present before surgery. Normal visual fields and visual acuity found before operation in 7 patients were preserved after tumor removal. Preoperatively impaired visual functions improved in 10, remained stable in 12, and deteriorated in 3. Permanent diabetes insipidus was found in 28 and anterior pituitary insufficiency of different degrees in all but 3 patients. There were no postsurgical neuropsychological sequelae, except for episodes of emotional lability and aggressiveness in 1 child. Impaired cognitive functions present before surgery in 2 children improved.

There was no surgical mortality in the group of 32 patients with originally infradiaphragmatic craniopharyngiomas (3 intrasellar, 29 intrasellar and suprasellar), including giant tumors operated on during the same period. Surgical mortality in the whole series thus represents 5.3% and in the group of supradiaphragmatic craniopharyngiomas, 9.1% (6.7% in SEVCs and 10.3% in IEVCs).

## DISCUSSION

Supradiaphragmatic craniopharyngiomas differ substantially from originally infradiaphragmatic and thus extracranial tumors. The surgical outcome of the craniopharyngiomas growing in the suprasellar subarachnoid cisterns or within the third ventricle is less favorable than in the originally infradiaphragmatic tumors (11, 18, 29). Less favorable results also are achieved in large or giant tumors (30). The present series consists of supradiaphragmatic tumors, the majority of which were large or giant. However, supradiaphragmatic craniopharyngiomas also do not represent a homogeneous group. Some of them are extraventricular, whereas the others are located partially inside the cavity of the third ventricle; some cause hydrocephalus, whereas the others do not (4). According to our experience, acute postoperative hypothalamic insufficiency occurs much more often in patients with tumors in direct contact with the brain tissue of the diencephalon (IEVC, IVC), which prevailed in our series, than in patients with extrapial SEVCs. Hydrocephalus, which has been reported as an unfavorable prognostic factor (10), may, according to our results, indicate an intraventricular location

of the tumor. Therefore, a distinction between SEVCs and IEVCs is of practical value.

### Topography of Tumors Growing in the Third Ventricle

Intraventricular and extraventricular location of the craniopharyngiomas as the consequence of the disruption of stretched and thinned-out 3rdVF is rather rare. Much more often, it is caused by a different point of original growth of the tumor (25). In the series of 90 sectional cases of craniopharyngiomas studied by Grekhov (13), the basal surface of 50 tumors was covered by the remnants of the 3rdVF and/or by pial membrane. These tumors start to grow within the brain tissue of the infundibulum and are intrapial (8, 9). Our morphological (15, 25) and clinical observations of the IEVCs showed that the structures of the 3rdVF undergo atrophy of different degrees. The most affected structure is the tuber: its central part is usually absent, and its remnants are located on the lateral or laterobasal surface of the IEVC. The infundibulum is destroyed less frequently, whereas compressed mammillary bodies covering the posterior pole of the tumor can be found in all cases of IEVCs. The structures of the 3rdVF most often cannot be identified on preoperative MRI scans of large IEVCs. Its remnants can be seen on postoperative scans (14). The defect in the 3rdVF found on postoperative MRI scans may be not the consequence of surgery, as it is sometimes interpreted, but rather the result of pressure atrophy caused by the tumor growing in its center.

Some tumors classified in the literature as purely intraventricular have been described as protruding into the interpeduncular cistern (17). We classify such tumors as IEVCs, reserving the term intraventricular to rare craniopharyngiomas lying entirely within the ventricular cavity covered from below by 3rdVF (6, 12, 19).

### Anatomic Rationale of the Choice of Surgical Approach

#### *Extraventricular Craniopharyngiomas*

Primarily supradiaphragmatic craniopharyngiomas in general are known to grow retrochiasmatically (4, 29). However, our results show that great majority of SEVCs displace the chiasm upward, and the tumor has a prechiasmatic portion. These tumors evolving in the region of the pituitary stalk and growing within the subarachnoid space are sufficiently exposed by common extra-axial routes along the base of the brain as subfrontal or pterional craniotomy (5). We prefer the unilateral subfrontal approach through a frontal craniotomy, which incorporates the whole frontal floor from the midline to the sphenoid wing, similar to the approach of Apuzzo et al. (2). This allows removal of the tumor through the prechiasmatic space and the opticocarotid triangle. Rarely occurring completely retrochiasmatic SEVC should be approached lateral to and behind the carotid artery through a pterional craniotomy, allowing more extensive dissection of the sylvian fissure than unilateral subfrontal craniotomy. Safe removal of large SEVC requires gentle pulling of the tumor from below,

which brings into direct view the upper pole of its retrochiasmatic part. Removal of such “infraventricular tumor via transventricular access through a nonfunctional glial nervous tissue that corresponds to the stretched out and lifted infundibulum” (27) may cause damage to the hypothalamus (1, 9). MRI scans obtained after extracerebral removal of large SEVCs in our patients showed preserved 3rdVF even in cases in which one would expect its total atrophy.

### *Intraventricular and Intraventricular and Extraventricular Craniopharyngiomas*

A wide opening in the 3rdVF between the hypothalamic structures displaced around the “equator” of the IEVCs allows the use of both extra-axial and transcerebral approaches. Extra-axial access to the IEVCs hidden behind the chiasm displaced against the sellar tubercle is most often extremely limited or even impossible. Opening of the lamina terminalis allows good exposure of the anterior part of the third ventricle (28). This approach allowed direct visualization of the basal part of the IVC or intraventricular portion of the IEVC, the 3rdVF, and the branches of both posterior communicating arteries. Disruption or coagulation of these vessels may lead to severe hypothalamic insufficiency even without mechanical damage to the hypothalamus (23). A disadvantage of this approach is insufficient exposure of the superoposterior part of a large or giant IEVC or IVC limited by the position of the AComA. This might be better reached by opening of the lamina terminalis above the AComA between the A2 segments of the anterior cerebral arteries and the perforators (24). We prefer to reach the superior part of the third ventricle through the foramina of Monro.

All the basal approaches provide limited superior access or visualization (2). Suprasellar masses with simultaneous third ventricular involvement should be exposed by an approach that combines features of both basal and superior exposures (2). Removal of the tumor may be staged (11, 12) or performed at one sitting through two separate (30) or one larger (7, 16) craniotomy. In large or giant IEVCs reaching the roof of the third ventricle posterior to the foramina of Monro and causing hydrocephalus, we prefer a combined transcallosal and subfrontal approach through one unilateral craniotomy. We start to remove the upper pole of the tumor through one or both foramina of Monro, where it usually does not adhere, and proceed downward toward its lateral surfaces, which merges with the lateral walls of the third ventricle and the hypothalamus (25). The transcallosal exposure of the tumor eventually may allow removal of the whole tumor. If not, the evacuation of cerebrospinal fluid from the lateral ventricles and removal of most of the ventricular portion of the tumor provides a comfortable subsequent subfrontal approach. One large craniotomy makes repeated alternative transcallosal and subfrontal exposure easier, if necessary. The exposure of the IEVC via a combined approach is as a rule sufficient, and no endoscopic assistance is necessary.

## CONCLUSION

Comparison of the MRI scans with operative findings revealed characteristic features indicating the location of the structures of the 3rdVF in relation to the supradiaphragmatic craniopharyngiomas. Tumors encroaching upon the third ventricle or even reaching its roof, which do not produce hydrocephalus and at the same time displace the chiasm/AComA upward, grow below the 3rdVF, i.e., extraventricularly. They may be safely removed by extra-axial routes. A trans-lamina terminalis approach may jeopardize the hypothalamic structures within the 3rdVF. Craniopharyngiomas growing entirely retrochiasmatically with the chiasm/AComA located on the tumor’s anterobasal surface and enlarging the lateral ventricles grow at least partially intraventricularly. They also may be approached through the lamina terminalis or through the foramina of Monro. Optimal exposure of large and giant IEVCs reaching the roof of the third ventricle behind the foramina of Monro can be achieved through a one-stage combined transcallosal and subfrontal (trans-lamina terminalis and extra-axial routes) approach via one unilateral craniotomy. Direct view of the entire tumor allows us to recognize the extent of its adherence to the hypothalamus and to make the right decision concerning the radicality of the tumor removal.

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## COMMENTS

The authors present a series of 44 supradiaphragmatic craniopharyngiomas operated on between 1991 and 2002. Eighteen patients were children. The authors achieved radical removal in 87%, with a surgical mortality of 9.1%.

The authors classify the tumors according to pathological examinations and radiological imaging, i.e., deviation of the optic nerve and anterior cerebral artery and occurrence of hydrocephalus. Intraventricular tumors and tumors with intraventricular extension can be approached by the trans-lamina terminalis approach. In larger tumors with intraventricular extension, the authors prefer combined subfrontal and transcassal approaches through one large craniotomy. Extraventricular tumors are removed through a subfrontal or pterional craniotomy.

To reduce surgical morbidity, neurosurgeons should be aware of the possible sequelae with extensive approaches. Transcassal

approaches are necessary only in large septated craniopharyngioma reaching the corpus callosum. Approaches through the lamina terminalis are in most instances sufficient even in large craniopharyngiomas and carry a lower risk of fornix injury. Meticulous microsurgical dissection of involved vessels is crucial, because surgical mortality results predominantly from vascular injuries of penetrating vessels supplying the brainstem.

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Šteňo et al. present their surgical experience in the management of 76 craniopharyngiomas and make observations relating to the position of the optic chiasm and ventricular size that may have outcome implications. In the experience of the senior commentator (MGY) in the management of 180 craniopharyngiomas, the best long-term control is achieved by complete removal of the tumor at the initial presentation. Incomplete tumor resection makes subsequent attempts at complete removal more technically difficult and worsens the long-term outcome of the patient. The selection of the surgical approach is based on the size of the tumor and its anatomic extension. The subfrontal approach without opening of the sylvian fissure, in our opinion, provides limited access and can cause frontal lobe injury resulting from retraction. A more versatile trajectory can be achieved by the pterional-transsylvian-parachiasmatic and trans-lamina terminalis approach, which can be combined with the anterior interhemispheric transcassal-transforaminal approach for cases with unilateral or bilateral occlusive hydrocephalus; in the latter cases, as the present article suggests, the foramen of Monro may be obstructed by the superior extension of the tumor, which may be adherent to the choroid plexus (1). Adherence of tumor to the infundibular area, or in some cases, frank invasion, is not usually apparent on the preoperative magnetic resonance imaging (MRI) scan, and therefore, the tumor-tissue interface relationships are best appreciated during the microsurgical resection.

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This article is devoted to what is probably the most important aspect of craniopharyngioma surgery: the tumor-third ventricle relationship. On the basis of an anatomic-topographical study by Grekhov from the Burdenko Neurosurgery Institute, Šteňo et al. suggested that supradiaphragmatic craniopharyngiomas be grouped into extraventricular, extraventricular and intraventricular, and intraventricular. Their vast clinical experience proved the validity of this classification. In this article, the au-

thors show some important details of MRI that help to outline the relationship between craniopharyngioma and third ventricle structures and select an appropriate approach. For approximately 20 years, the classification described by Šteňo et al. has been used in the Burdenko Neurosurgery Institute and proved to be important practically. I agree with all the main points of this article and wish only to stress that craniopharyngiomas are very variable tumors with regard to structure, size, and localization, and sometimes, especially in giant tumors, it is not easy to understand their real topography and the tumor-third ventricle relationship.

**Alexander N. Konovalov**  
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On the basis of their earlier autopsy work, the authors have attempted to subclassify supradiaphragmatic craniopharyngiomas into sub-third ventricle, intra- and extra-third ventricle, and purely intra-third ventricle tumors. They have attempted to use MRI to define these groups preoperatively and tried to confirm this on the basis of operative findings and postoperative MRI anatomy. They suggest that this aids in planning the surgical approach.

The photographs are striking. Still, I am not convinced that, with these large tumors, the authors can really tell, either on the MRI scan or even at surgery, whether or not the floor of the third ventricle is really intact. One sees the floor only once the tumor has been removed (if at all), and the process of tumor removal may well disrupt a thin floor. Much of the reasoning they use for the MRI classification is retrospective and depends on the postoperative study, which obviously is not available for surgical planning.

I am also not sure how much it really matters. One would normally approach these large tumors through a combined pterional and subfrontal craniotomy, which allows a choice of approaches based on the anatomy one finds: interoptic, opticocarotid, carotid-tentorial triangles, or trans-lamina terminalis, on the basis of the findings at surgery. Virtually all of these large tumors require extensive dissection of the sylvian fissure. It is useful to consider largely anteriorly projecting tumors, which may be accessed via an interoptic approach, and posteriorly projecting tumors, which frequently require a lamina terminalis approach. I am not sure that further subclassification is really useful. The only way in which detailed preoperative anatomy would really change the approach is in the very rare circumstance of a purely intra-third ventricle tumor, in which case one might consider a transcallosal approach at the initial operation. I have encountered this only once and was assured of the intraventricular nature of the tumor because it projected into the lateral ventricle. If the tumor is not purely intraventricular, the hypothalamus intervenes between the foramen of Monro and the tumor, and the transcallosal approach is hazardous.

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The authors have worked continuously on the sophisticated topic of craniopharyngioma for more than 2 decades. In this article, the authors concentrate on approaches to supradiaphragmatic craniopharyngiomas in a series of 44 patients operated on during a 10-year interval. Their key structure is the location of the chiasma on the sequential MRI scan to determine indirectly the position of the third ventricle: the court of the hypothalamus. They differentiate 15 suprasellar extraventricular and 28 intraventricular and extraventricular tumors as well as one intraventricular tumor. The risk of surgery in these large tumors clearly depends on the position of the hypothalamus. In the first group, the authors were able to use unilateral approaches and only with exceptions the translaminar approach. This is indicated in the second series in all cases mainly by midline approaches and preferentially by a bifrontal approach.

The authors have tried to classify these approaches in a very difficult entity of tumor, supradiaphragmatic craniopharyngiomas originating from the pituitary stalk. The benefit of their anatomic observations is also presented in the Discussion: a group of tumors start to grow from the pituitary stalk within the brain tissue and are intrapial. The postoperative defect of the floor of the ventricle is not affected by surgery but rather by the tumor itself. The infundibulum is destroyed less frequently.

A disadvantage of this “simplifying classification” is that it does not allow the integration of all cases: tumors that develop both supradiaphragmatically and infradiaphragmatically and sometimes also need, perhaps in a second operation, transphenoidal surgery. If the choice of the approach is adequate and in the authors’ opinion may be the optimal one, then we need discussion about the early postoperative mortality of 5% altogether (4 of 76 patients), which is higher than in the published surgical series of recent years. I wonder whether the key structure of the optic chiasm can always be used as a clear landmark: in one case, the prefixed chiasm and extremely low position of the arteria communicans anterior were not recognized, leading to a subtotal tumor resection via the unilateral translaminar terminalis approach. The frequency of the combined approaches, with 16 of 24 being intraventricular and extraventricular tumors, seems too high.

Unfortunately, we receive only minimal information on complete tumor resection as well as its limitations, which is 13 of 18 in children and 20 of 26 in adults, the recurrence rate being 7 of 33 totally removed tumors in patients with a mean follow-up of 54.5 months, in which 7 patients died. This is equivalent to other series. The limited data on ophthalmological and especially endocrinological outcome are obviously not the topic of this article; however, for the patient’s physician, endocrinological management is the leading challenge and lifelong burden.

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