Microsurgical resection of extensive craniopharyngiomas using a frontolateral approach: operative technique and outcome

Clinical article

VENELIN GERGANOV, M.D., PH.D., HUSSAM METWALI, M.Sc., AMIR SAMII, M.D., PH.D., RUDOLF FAHLBUSCH, M.D., PH.D., AND MADJID SAMII, M.D., PH.D.

International Neuroscience Institute, Hannover, Germany

Object. An extensive craniopharyngioma is a tumor that extends into multiple compartments (subarachnoid spaces) and attains a size larger than 4 cm. A wide spectrum of approaches and strategies has been used for resection of such craniopharyngiomas. In this report the authors focused on the feasibility and efficacy of microsurgical resection of extensive craniopharyngiomas using a frontolateral approach.

Methods. A retrospective analysis was performed on 16 patients with extensive craniopharyngiomas who underwent operations using a frontolateral approach at one institution. The preoperative and postoperative clinical and radiological data, as well as the operative videos, were reviewed. The main focus of the review was the extent of radical tumor removal, early postoperative outcome, and approach-related complications.

Results. Gross-total resection of craniopharyngioma was achieved in 14 (87.5%) of 16 cases. Early after surgery (within 3 months), 1 patient showed improvement in hormonal status, while in the remaining 15 patients it worsened. No major neurological morbidity was observed. Two patients experienced temporary psychotic disorders. Visual function improved in 6 patients and remained unchanged in 9. One patient experienced a new bitemporal hemianopsia. Three patients with features of short-term memory disturbances at presentation did show improvement after surgery. There were no deaths or significant approach-related morbidity in this patient series. Only 1 patient required revision surgery for a CSF leak.

Conclusions. The safe and simple frontolateral approach provides adequate access even to extensive craniopharyngiomas and enables their complete removal with a reasonable morbidity and approach-related complication rate. (http://thejns.org/doi/abs/10.3171/2013.9.JNS122133)

Key Words • extensive craniopharyngioma • frontolateral • giant craniopharyngioma • microsurgery • outcome • oncology • skull base

Surgery on giant craniopharyngiomas (more than 4 cm at the largest diameter) has been reported to be associated with high mortality and postoperative morbidity rates, decreased extent of resection, and high rates of tumor recurrence. Not only is the size of the tumor gaining attention, but also its extension into multiple compartments (subarachnoid spaces). Thus, we advocate using the term “extensive craniopharyngioma” for a craniopharyngioma that extends into many compartments other than the chiasmatic cistern and attains a size larger than 4 cm. Surgery for such a configuration raises certain technical difficulties during tumor resection.

Many different approaches have been described for resection of giant craniopharyngiomas based on the tumor extension and surgeon preference. Each approach has its own indications as well as approach-related complications. In this article, we focused on the feasibility and efficacy of microsurgical resection of extensive craniopharyngiomas using a simple and safe frontolateral approach. The efficacy of the approach was evaluated in terms of the possibility of radical resection and early postoperative outcome.

Methods

Patient Population

Between 2000 and 2012, 68 patients with craniopharyngiomas were operated on at the International Neurosci-
ence Institute by the senior authors (M.S. and R.F.). Included in the study were all patients who harbored extensive craniopharyngiomas in whom a transcranial approach was selected. Extensive craniopharyngiomas were defined as those larger than 4 cm at the largest diameter and with encroachment on multiple cisterns other than the chiasmatic cistern. Sixteen patients fulfilled these inclusion criteria (Table 1). The preoperative and postoperative clinical reports, laboratory findings, and images of these patients, as well as the operative videos, were reviewed. The ages of the patients ranged from 5 to 61 years old. There were 7 males and 9 females. Six cases involved recurrence. One patient, a 9-year-old girl with a malignant craniopharyngioma, was excluded from the study. This patient underwent surgery initially via the frontolateral approach and later underwent surgery again via a transventricular approach. The rapidly regrowing invasive tumor was removed via a combined transsphenoidal and frontolateral approach, and radiation therapy was initiated, but the girl died 9 months later from another recurrence.

Preoperative Examination

The patients were uniformly subjected to preoperative neurological, ophthalmological, endocrinological, and radiological assessment. Visual deterioration at the time of presentation was detected in 14 (87.5%) of the 16 patients. Nine patients (56%) complained of headache at the time of presentation. Three patients (18.7%) showed short-term memory disturbance at the time of presentation. Two patients (12.5%) showed potential hypothalamic disturbance in the form of progressive obesity (Table 1). Seven patients (43.7%) showed anterior pituitary disturbance at the time of presentation: 2 patients showed panhypopituitarism and 5 patients showed selective anterior pituitary hormonal deficiency. At the time of admission, 4 patients (25%) showed hyperprolactinemia and 2 (12.5%) had diabetes insipidus (Table 1). Five patients had no hormonal deficits.

The main diagnostic imaging modality in this series was MRI with and without contrast enhancement. Tumor extension is presented in Table 2. In the recent cases, diffusion tensor imaging–based reconstruction of the fornix was conducted before and after tumor removal.

Surgical Technique

The suprasellar area has a complicated anatomical configuration, specifically, complicated arachnoid mem-

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>CP at Time of Presentation</th>
<th>Hormonal Status</th>
<th>Previous Treatment</th>
<th>Extent of Resection</th>
<th>Confirmation</th>
<th>Early Postop Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>37</td>
<td>HA, MD, VD</td>
<td>HTH, HG</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, psychotic symptoms, normalized hormonal status, unchanged vision, improved memory</td>
</tr>
<tr>
<td>2</td>
<td>43</td>
<td>HA, MD, VD, attacks of LOC</td>
<td>normal</td>
<td>none</td>
<td>GTR</td>
<td>OM, ED</td>
<td>MD, HTH, HC, improved memory</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>VD</td>
<td>HPN</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, improved vision</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>VD, HA, growth retardation</td>
<td>HAST, HC, HG</td>
<td>none</td>
<td>GTR</td>
<td>OM</td>
<td>DI, PHP, normal vision, improved memory</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>VD, progressive obesity</td>
<td>HG</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, improved vision, CSF leak required operative revision</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
<td>HA</td>
<td>normal</td>
<td>1 operation &amp; VPS</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, bitemporal hemianopsia (visual deterioration)</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>VD</td>
<td>DI</td>
<td>1 operation</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, unchanged vision</td>
</tr>
<tr>
<td>8</td>
<td>48</td>
<td>HA, VD</td>
<td>normal</td>
<td>none</td>
<td>GTR</td>
<td>OM</td>
<td>HC, unchanged vision</td>
</tr>
<tr>
<td>9</td>
<td>43</td>
<td>HA, MD</td>
<td>HPN</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, normal vision, improved memory</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>VD</td>
<td>HPN</td>
<td>none</td>
<td>GTR</td>
<td>OM, ED</td>
<td>DI, PHP, unchanged vision</td>
</tr>
<tr>
<td>11</td>
<td>35</td>
<td>HA, VD, progressive obesity</td>
<td>HG, HPN</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, improved vision</td>
</tr>
<tr>
<td>12</td>
<td>13</td>
<td>VD</td>
<td>PHP, DI</td>
<td>1 operation</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, improved vision</td>
</tr>
<tr>
<td>13</td>
<td>61</td>
<td>VD</td>
<td>normal</td>
<td>1 operation</td>
<td>GTR</td>
<td>OM</td>
<td>DI, subcutaneous CSF collection managed w/ CLD, unchanged vision</td>
</tr>
<tr>
<td>14</td>
<td>37</td>
<td>VD, HA</td>
<td>PHP</td>
<td>none</td>
<td>GTR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, unchanged vision, improved memory</td>
</tr>
<tr>
<td>15</td>
<td>24</td>
<td>VD</td>
<td>normal</td>
<td>2 operations</td>
<td>STR</td>
<td>OM, ED</td>
<td>DI, PHP, unchanged vision</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>HA, VD</td>
<td>HAST</td>
<td>1 operation &amp; Om-</td>
<td>STR</td>
<td>OM, ioMRI</td>
<td>DI, PHP, improved vision</td>
</tr>
</tbody>
</table>

* CLD = continuous lumbar drainage; CP = clinical picture; DI = diabetes insipidus; ED = operative endoscope; HA = headache; HAST = hyposomatotropism; HC = hypocorticism; HG = hypogonadism; HPN = hyperprolactinemia; HTH = hypothyroidism; ioMRI = intraoperative MRI; LOC = loss of consciousness; MD = memory disturbance; OM = operative microscope; PHP = panhypopituitarism; STR = subtotal resection; VD = visual deterioration; VPS = ventriculoperitoneal shunt.
branes and cisterns. The surgical anatomy of these membranes and cisterns, discussed in this paper, is consistent with the microscopic and endoscopic anatomy described by Rhoton.21 Supradiaphragmatic craniopharyngiomas are essentially subarachnoid extrapial tumors. Originating from the pituitary stalk in the chiasmatic cistern,35,36 a supradiaphragmatic craniopharyngioma in its early stage of growth is separated from the carotid cistern by the medial carotid membrane and from the interpeduncular cistern by the diencephalic leaflet of the membrane of Liliequist. The tumor grows and compresses the nearby cisterns, while the arachnoid membranes remain intact in early stages. When the medial carotid membrane is incomplete, the tumor can extend laterally into the carotid cistern. The craniopharyngioma tends to insinuate itself into the nearby spaces and cisterns.1,4,5,10,23 Furthermore, extension into the nasopharynx and purely intraventricular lesions have been reported.4,31 These arachnoid planes are less appreciated in the pediatric population, recurrent cases, and cases with previous irradiation.22,26,32

In the following section, the surgical removal of the extensive craniopharyngioma via a small frontolateral craniotomy is described. The process of resection of a craniopharyngioma through the subchiasmatic, opticocarotid, and carotid-oculomotor spaces is illustrated in Fig. 1A–F. Resection of the craniopharyngioma via a trans-lamina terminalis approach is illustrated in Fig. 1G and H. Intraoperative photographs showing the resection of a craniopharyngioma through the subchiasmatic space and lamina terminalis are presented in Fig. 2. The resection shown in Fig. 3 was performed mainly through the carotid-oculomotor and opticocarotid spaces. The translamina terminalis approach is better presented in Fig. 4.

All patients underwent surgery while supine with the head rotated 30° to the opposite side of the craniotomy. The head was fixed in extension using a Mayfield head holder. A standard small (3–3.5 cm × 2–2.5 cm) frontolateral craniotomy is performed after a hemicoronal skin incision. A key point is that the lower edge of the craniotomy should be at the level of the orbital root. After a semicircular dural incision, the medial sylvian or parasellar cisterns are opened using microforceps and cottonoid to drain CSF. The brain retractor is placed only when sufficient CSF is released and the tension of the frontal lobe falls, which usually takes at least 3–5 minutes (Fig. 1A). The right optic nerve and internal carotid artery (ICA) are exposed. In giant craniopharyngiomas, all neurovascular structures are under tension (Fig. 2A). Hence, we avoid performing any dissection or attempting to identify surrounding structures before this tension is released. Only the tumor should be exposed minimally in the midline, its capsule should be opened, and internal decompression should be performed (Fig. 2B and C). Even if the tumor is not cystic, sufficient decompression can be achieved. When the tension is reduced, a nice overview of the surgical anatomy of the region is gained and the contralateral left optic nerve becomes safely accessible. The length of the optic nerve, as well as the subchiasmatic space, determines the further routes of dissection.

### Tumor Resection in Cases of Long Optic Nerves and a Postfixed Optic Chiasm

In cases of long optic nerves and a postfixed optic chiasm, the optic chiasm is usually displaced posteriorly and superiorly, creating a wide working space in the subchiasmatic and anterochiasmatic areas (Fig. 1A and B). The surgeon thus gradually internally decompresses the tumor. The contralateral optic nerve is dissected from the tumor first from its medial side, taking into consideration the preservation of the small vascular tree on the surface of the nerve (Fig. 2D). The central part of the suprasellar portion of the tumor is removed, bringing the contralateral sub optic part into view (Figs. 1A–C.

---

**TABLE 2: Tumor extension in the suprasellar area based on preoperative radiological and intraoperative observations**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Suprasellar</th>
<th>Retrosellar</th>
<th>Retroclival</th>
<th>Intraventricular</th>
<th>Parasellar</th>
<th>Temporal</th>
<th>Antechiasmatic</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>CPA, prelamina terminalis</td>
</tr>
<tr>
<td>2</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>7</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>8</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>none</td>
<td>subfrontal</td>
</tr>
<tr>
<td>11</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>12</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>13</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>14</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>16</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>
Fig. 1. Illustrations showing the stepwise resection of an extensive craniopharyngioma via a frontolateral approach. After incision of the sylvian fissure arachnoid (Syf a.) and adequate CSF release (A), the surgeon can expose the right optic nerve (ON R.) and the right ICA (ICA R.). The tumor (Tu) displaces the neurovascular structures, creating a working space in between these structures (B). This part of the tumor can be gradually removed from the suprasellar space, exposing additional tumor in the left suboptic space (C). Resection of the suboptic part of the tumor exposes the left ICA (ICA L.) and the left PCoA. As the microscope attains a more central angle, the retrosellar part of the tumor comes into view (D). After resection of the retrosellar part, the upper CPA cistern comes into view with the left trigeminal nerve in the lowest part of the surgical corridor (TG L.; E). Further resection of the tumor is performed medial and lateral to the right ICA (square, E). Resection of the tumor (F) will expose the right oculomotor nerve (III CN). Attaining a more medially directed trajectory (F) will bring the basilar artery (BA) into view (G). In panel H, the optic nerves are short and the tumor is posterior to the optic chiasm. The lamina terminalis (LT) is exposed. After incision of the lamina terminalis, the tumor can subsequently be removed. III L. = left cranial nerve III; III R. = right cranial nerve III; III CN = third cranial nerve; ACA R. = right ACA; A Com A = ACoA; FL. = frontal lobe; OC = optic chiasm; ON L. = left optic nerve; OT L. = left optic tract; OT R. = right optic tract; Stalk = pituitary stalk; TI = temporal lobe. Figure 1a and b copyright Hassam Metwali. Published with permission.
Frontolateral approach for extensive craniopharyngioma resection

and 2D). The contralateral suboptic part of the tumor is gradually decompressed and dissected from the inferior surface of the optic nerve, the ICA, and the posterior communicating artery (PCoA). After removal of the suboptic part, the contralateral oculomotor nerve can be observed entering the oculomotor trigone (Figs. 1A–D and 2D). After attaining a more central trajectory with the microscope, the retrostellar compartment comes into view and can be dissected relatively easily from the basilar artery and its branch due to the commonly preserved membrane of Liliequist in that area. This membrane is observed to be stretched by the tumor and separates the descending part of the tumor in the preponine and cerebellopontine angle (CPA) cisterns from the nearby structures, especially in nonoperated cases (Figs. 1A–E and 2D).

The retrochiasmatic part of the tumor usually descends after resection of the subchiasmatic part of the tumor. If the tumor has a true intraventricular extension, the translimina terminalis approach (see below) should be used to resect the true intraventricular part (Fig. 2E and F).

The ipsilateral suboptic part of the tumor is usually not in the direct line of vision. This portion can be removed by opening the carotid cistern via an incision in the medial carotid membrane and removing the tumor through the space created between the ipsilateral optic nerve and the ICA (the optiocarotid triangle; Figs. 1A–E and 3A–C). An endoscope can also help to resect hidden parts of the tumor (Fig. 3D) The tumor can be pushed with a microdissector to the midline and enucleated. With sufficient enucleation, the capsule can also be mobilized medially, dissected, and excised. All hidden tumor parts can be removed in a similar way. This pathway can provide an access up to the basilar bifurcation (Fig. 1B–G). Until the end of the procedure, the space created by tumor growth remains open and the tumor bed does not collapse (Fig. 1A–E, 1G).

Tumor Resection in Cases of Short Optic Nerves and a Prefixed Optic Chiasm. The prechiasmatic and subchiasmatic spaces in cases of short optic nerves and a prefixed optic chiasm (located anterior to the tumor and pituitary stalk) are usually very narrow and do not allow one to access the tumor in the suprasellar region. In this situation, further arachnoid dissection is required in the lamina terminalis cistern. The A1 and A2 segments of the anterior cerebral arteries (ACAs) on both sides are exposed (Fig. 4A). The A1 segments are dissected from the optic nerves on both sides and from the chiasm, keeping them attached to the frontal lobe to minimize injury to the perforators (Figs. 1H and 4A). The anterior cerebral artery (ACA) complex is elevated with the frontal lobe, exposing the...
lamina terminalis. The lamina terminalis is opened in the midline, keeping in mind its relation to the optic chiasm and the branches of the ACA and anterior communicating artery (ACoA) running to the hypothalamus (Fig. 4B). If wider exposure is necessary and the vascular anatomy allows it, the ACoA can be cut.

The next step depends on the condition of the floor of the third ventricle. The craniopharyngioma either penetrates the floor of the third ventricle, creating a true intraventricular extension, or elevates it, leaving it thin and atrophic. In cases of a prefixed chiasm, the tumor usually penetrates the floor of the third ventricle, creating a true intraventricular extension.

In cases of true intraventricular extension, the resection starts from this part of the tumor, and then the suprasellar part can be resected through the defect in the floor of the third ventricle. The contralateral suboptic part will be dissected in this condition from the inferior surface of the optic tract as well as from the ICA and PCoA. Through this window, the retroclival and upper CPA compartments can be resected as well (Fig. 4C). The ipsilateral suboptic part can be accessed only by opening the carotid cistern through the medial carotid membrane (Fig. 4D). After internal decompression of the tumor, the higher/cranial part of the tumor usually descends in the suprasellar space and can be gently resected (Fig. 4E). An endoscope can be used to confirm tumor resection (Fig. 4F). Surgery for the intraventricular part of the tumor could endanger the fornix.

An incision in the floor of the third ventricle is then made, keeping in mind the optic tracts on both sides. The central part of the tumor is removed, and the surgeon proceeds with tumor resection sequentially (Fig. 4).

Surgery Around the Pituitary Stalk. Craniopharyngiomas can originate completely or partially from any part of the pituitary stalk. Only in cases in which the stalk is extensively involved by the tumor is it justified to resect it for the sake of radicality. In cases in which it is involved to a lesser extent, however, an attempt is made to preserve the continuity as well as its blood supply by performing a

---

**Fig. 3.** This tumor extended into the suprasellar, retrosellar, retroclival, and left parasellar compartments. The tumor was elevating the floor of the third ventricle and encroaching on the cavity without true intraventricular extension. After a left frontotemporal craniotomy, the tumor began to be decompressed between the left optic nerve (ON l) and the left ICA (ICA l; A). Further decompression proceeded in the suprasellar part of the tumor, exposing the right optic nerve (ON r) and the right ICA (ICA r; B). The tumor was dissected from the optic chiasm (OC), right optic nerve, right ICA, and floor of the third ventricle. The suprasellar and right parasellar parts were completely resected (C). An endoscopic inspection of the operative field (D) revealed a small remnant above the bifurcation of the right ICA (arrow) that was removed using the operative microscope. Radiological images of this case are shown in Fig. 7. Aal = left A1 segment.
partial stalk sectioning (one-third to one-half of its diameter; Fig. 2).

Resection of the Parasellar and Middle Fossa Parts. The part of the tumor extending lateral to the ICA and PCoA can be addressed by incising the intracarotid membrane and dissecting between the uncus and the ICA (Fig. 1A–G). As described earlier, the hidden tumor parts are enucleated, mobilized, dissected from surrounding structures, and excised under direct visual control. During resection of this part of the tumor, the course of the anterior choroidal artery should be taken into consideration.

Confirmation of Resection. Inspection of the tumor bed with the operating microscope is the main confirmatory method for verification of complete resection. In 4 of the cases included in the study, an endoscopic inspection of the surgical field was performed to confirm complete resection. Since 2007, we have used intraoperative MRI as another confirmatory method, as well as preservation of structures such as the fornix in 10 patients (Figs. 5–7).

Results

Resection Outcomes

Although the presented series is heterogeneous, including 10 newly diagnosed cases and 6 recurrent cases, all patients harbored extensive craniopharyngiomas. Gross-total resection (GTR) was achieved in all patients but 2 (14 of 16, 87.5%). In 1 patient, a part of the tumor was very adherent to the ICA, and in another patient the tumor capsule was adherent to the hypothalamus. These remnants were left to avoid injury to the structures. The frontolateral approach was able to provide access to all parts of the tumor (Figs. 5 and 7). All tumors in the series were found to be adamantinomatous craniopharyngiomas.

Early Postoperative Hormonal Status

Of the 5 patients with selective anterior pituitary deficiency, 4 showed early laboratory features of panhypopituitarism (25%), and 1 patient showed normalization of hormonal status. Eight patients (56.2%) with normal anterior pituitary functions before surgery showed worsening of their hormonal state after surgery in the form of panhypopituitarism in 6 patients and isolated hormonal deficiency in 2 patients. Twelve patients (75%) experienced a new occurrence of diabetes insipidus.

Early Postoperative Visual Status

In the early postoperative period, visual status showed improvement in 6 cases (37.5%). In 9 patients (56.2%),
there was no change in visual status after surgery. Meanwhile 1 patient, with extensively calcified tumor, showed worsening of the preoperatively jeopardized visual condition after surgery in the form of bitemporal hemianopsia.

Postoperative Neurological Status

There was no major neurological morbidity in the series. One patient (6.2%) experienced temporary psychotic disorders during the first 2 weeks after surgery. Another patient (Case 14) showed short-term memory disturbance that improved partially before discharge from the hospital. Three patients (81.2%) who showed features of short-term memory disturbances at the time of presentation did show improvement after surgery.

Surgery-Related Complications

Two of our patients (12.5%) experienced subcutaneous CSF collections, but only 1 of them required open surgical repair. The second patient was managed using CSF lumbar drainage. Two patients showed deep venous thrombosis in the lower limbs that was managed accordingly.

Discussion

Variable modifications and combinations of approaches have been used for resection of giant or extensive craniopharyngiomas, with the presumption that sufficient exposure of all parts of the tumor is essential for its safe and complete removal. The pterional, basal interhemispheric, and bifrontal approaches were used to access the tumor from an anterolateral trajectory (pterional approach) or anterior trajectory (basal interhemispheric and bifrontal approaches). The transcallosal approach has also been used in selected cases. The senior authors’ concept evolved over the years due to their experience with various extensive approaches. The paradigm change from more extensive approaches to the frontolateral approach was initiated by Dr. Samii and followed by Dr. Fahlbusch. Cerebopharyngiomas originate from a midline location, then begin to insinuate into the nearby low-resistant locations such as the arachnoid cisterns and third ventricle. One reason that giant craniopharyngiomas can be resected through a small frontolateral craniotomy is because they grow slowly over decades, with continuous stable displacement of the neurovascular structures, providing a potentially large preformed space for resection corridors. These corridors remain more or less stable during and after tumor resection through the classic subchiasmatic, optico-carotid, carotid-oculomotor, and transcallosal terminalis pathways and do not collapse, allowing resection of deeply located parts of the tumor. This provides the surgical advantage

Fig. 5. Preoperative (A–C) and intraoperative (D–F) MR images of the case shown in Fig. 2. The axial image (A) shows the extension of the tumor into the suprasellar, left parasellar, retrosellar, and prelamina terminalis cisterns. The coronal image (B) shows further intraventricular extension of the tumor. The sagittal image (C) shows the retroclival extension of the tumor. The intraoperative images (D–F) show complete resection of the tumor.
that the tumor bed does not collapse after the early steps of tumor resection and remains open, providing access to deeper parts of the tumor (Fig. 7–9). The approach therefore should provide access primarily to the area of tumor origin. Initially, the bifrontal craniotomy was confined to 1 side, but later its size was further reduced to protect the frontal lobe, which is especially vulnerable in giant tumors. Moreover, we did not require a larger opening at the skull surface to remove a deep-seated lesion. The approach should therefore provide access primarily to the area of tumor origin. Once sufficient internal decompression is achieved, the more peripheral tumor portions can be mo-

![Fig. 6. Preoperative tracking of the fornix (green) based on diffusion tensor imaging shows the relation between the fornix and the tumor (A). The reconstruction of the fornix after resection of the tumor (B) shows preservation of the fornix together with resection of the tumor. Operative images of this case are shown in Fig. 2, and radiological images in Fig. 5.](image)

![Fig. 7. Preoperative (A–C) and intraoperative (D–F) sagittal, coronal, and axial MR images of the case shown in Fig. 3, showing complete removal of all tumor compartments after surgery.](image)
bilized and brought into view by slight traction. A second requirement to the approach is that it should not be related to a high risk of approach-related morbidity. The frontolateral approach meets these criteria and is the one favored by our group in cases of giant craniopharyngiomas.28 Giant craniopharyngiomas tend to develop suprasellar extensions and rarely have intrasellar extensions (Table 2). A subset of craniopharyngiomas, even of large size, can be successfully removed via a transnasal transsphenoidal microscopic, endoscopic, or combined approach.18 The discussion of these cases and of the indications for surgery of craniopharyngiomas, as well as a detailed endocrinological evaluation, is beyond the goal of the current study. We focused on the usefulness of the frontolateral approach for resection of giant or extensive craniopharyngiomas in terms of accessibility to every part of the tumor, feasibility of tumor resection, early postoperative outcome, and approach-related complications.

Hoffmann et al. were the first to report the possibility of radical resection of craniopharyngiomas; afterward, many trials for complete resection of craniopharyngiomas were conducted using different approaches.17 The commonly described approaches include pterional, unilateral, or bilateral frontal interhemispheric approaches,5,33,34,37 Other approaches include the transcallosal or translamina terminalis approaches for intraventricular craniopharyngiomas,25,37 and the orbitozygomatic approach,13 endoscopic transsphenoidal approaches, and the petrosal approach for retrochiasmatic craniohypophyseal embolias.1,5,6,10–12,16

Accessibility of the Tumor

The approach described in this study afforded access to all parts of the craniopharyngioma. Tumor expansion widens the spaces between the neurovascular structures, providing sufficient working space. Thus, the small frontolateral craniotomy proved to be sufficient to access the tumor core in the midline and provided multiple trajectories for resection of the tumor extensions. Following the principle of initial internal decompression or enucleation, mobilization of the hidden parts of the tumor to the midline, and dissection of the capsule under direct visual control, the whole tumor can be safely removed. Nevertheless, tumor extensions into the lateral ventricle, sella, and sphenoid sinus, or into the posterior fossa below the trigeminal nerve, cannot be removed using the frontolateral approach; these extensions of the tumor require a combination with other transcallosal approaches (lateral ventricle extension), a transsphenoidal approach (sella and sphenoid sinus extensions), or a retrosigmoid approach (posterior fossa extension).

Extent of Tumor Resection

Based on the understanding of the changes of surgical anatomy caused by the expanding craniopharyngioma and using a stepwise tumor resection, total tumor removal could be achieved in 14 (87%) of 16 patients. In 2 patients small remnants were left because of the risk of neurovascular injury. This rate of total tumor removal is very consistent with the published data. Elliott and Wisoff reported a 77% complete resection rate in a series of 26 children harboring giant craniopharyngiomas using the pterional approach.8 Fahlbusch and Hofmann reported an 83% total resection rate in a series of 12 resectable giant craniopharyngiomas, using the subfrontal interhemispheric midline approach as the main approach.9 In the recently published series of Hofman et al.,18 GTR was able to be achieved in 88.5% of cases in which a transsphenoidal approach was used, and in 79.5% of those in which a transcranial approach was used. Yaşargil et al. achieved a 90% resection rate of craniopharyngiomas of variable sizes and extensions using a variety of approaches, but the mortality rate in this historical series was 16.7%.77 Al-Mefty et al. reported a 90% rate of giant craniopharyngioma resection in those operations he personally performed using a sophisticated petrosal approach, and a 30% resection rate in a series of patients previously operated on by other surgeons.13 Gardner et al. reported complete resection in 8 of 11 patients in whom total resection was planned, in a total series of 16 patients with variable tumor sizes and extensions.11

Early Postoperative Outcome

Endocrinological deficits are reported in up to 90%
Frontolateral approach for extensive craniopharyngioma resection

of patients after surgery, which corresponds to our findings.8,10,13 In regard to vision, postoperative worsening occurred in only 1 patient, whose tumor was extensively calcified and adherent to the optic chiasm. The visual status was improved in 6 patients and unchanged in 9 patients.

Approach-Related Complications

The only approach-related complications were subcutaneous CSF collections in 2 patients, and only 1 required operative revision. Compared with the interhemispheric approach, the frontolateral approach offers the chance to avoid venous injuries or olfactory nerve injury. The risk of bilateral frontal lobe injuries is obviated.3,33,34 Also there is no risk of injuring the frontal branch of the facial nerve or the temporalis muscle compared with the perional approach. Giant craniopharyngiomas cause compression of sensitive neurovascular structures, such as the anterior choroidal artery, PCoA, and oculomotor nerve, in the tentorial notch. If the tumor is approached from a lateral perspective, it lies medial to these structures. In contrast, when craniopharyngiomas with a large parasellar or even middle fossa extension are approached from the anterior aspect (the frontolateral perspective), the surgeon does need to cross the tentorial notch and its contents. The tumor can be enucleated and then its capsule dissected from the nerves and vessels. The frontolateral approach lacks the complications associated with the petrosal approach, such as the possibility of venous injuries and CSF leakage.1,2,16

Other options for managing craniopharyngiomas include stereotactic aspiration and Ommaya reservoir insertion for continuous aspiration, conservative resection followed by radiosurgery, radiotherapy, and intracavitary treatment for cystic tumors with radioisotope or chemotherapeutic agents.14,20,27,29,30 However, the long-term consequences of these methods as primary treatment are unclear, and they are not without complications.1,11,12,15,17,21,24–26

Conclusions

The safe and simple frontolateral approach can be successfully used in craniopharyngiomas with a wide spectrum of extensions. This approach provides adequate access to the tumor and enables its complete removal with a reasonable morbidity and approach-related complication rate.

Acknowledgments

We would like to thank Dr. A. Brandis (Neuropathology, Hannover Medical School) and Dr. R. Buslei (Department of Neuropathology, University of Erlangen-Nuremberg) for performing the histopathological examinations, and Dr. Moradi and Dr. Mohamadi for the ophthalmological workup of the patients.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specific in this paper. Author contributions to the study and manuscript preparation include the following. Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Metwali. Statistical analysis: Metwali. Administrative/technical/material support: all authors. Study supervision: Gerganov, A Samii, Fahlbusch, M Samii. Surgeons: Fahlbusch, M Samii.

References

17. Hoffman HJ, De Silva M, Humphreys RP, Drake JM, Smith...


