7 Cystic Craniopharyngiomas: Endoscopic Endonasal Transsphenoidal Approach

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7.1 Introduction

Craniopharyngiomas (CPs) are uncommon, benign, extra-axial, epithelial neoplasms of the sellar and parasellar region. They represent 3–4 % of all intracranial neoplasms and occur without any sex predilection [2, 25, 35]. Among children CPs are the most common intracranial tumors of non-glial origin, accounting 6–13 % of all childhood brain tumors and representing more than 90 % of the tumors of the pituitary region in childhood [33, 36]. Clinical presentation may occur at any age but with a bimodal age distribution, with peaks at 5–14 years and 50–74 years [2]. The properties of secretion in squamous epithelium account for the fact that approximately 90 % of CPs have a cystic portion containing secreted fluid, cholesterol crystals, and epithelial cells. According to the different series, CPs are defined as purely or predominantly cystic in 46–64 % of cases [18, 20]. Despite their benign histological nature, CPs frequently display a locally aggressive behavior and cause damage to critical neural and vascular structures in the sellar and parasellar regions. This can cause endocrine, behavioral, and visual deficits. These tumors have a high propensity to recur after resection and, given their site, are associated with significant morbidity and mortality rates.

The pioneering neurosurgeons of the turn of the twentieth century considered the region of the hypothalamus and suprasellar space to be virtually inaccessible and attempts at transcranial removal of tumors in this region met with failure. Contemporary approaches were presaged by the recognition that they could be approached via a transsphenoidal approach and in 1909 Albert Halstead performed the first successful resection of a CP, via the transsphenoidal route. Despite this early success, the transsphenoidal approach was not widely adopted; rather various transcranial approaches were developed [13, 15, 18, 21]. The renaissance of transsphenoidal surgery for pituitary adenomas opened the way to resect sellar CPs via this route and smaller midline suprasellar CPs via the extended transsphenoidal method. The use of endoscopes has thrown open the door to using this approach for a far wider range of CPs, and in many centers this is now the preferred approach [3, 5, 15].

Historically the benign histology and high initial survival rates were seen as supporting complete resection as the method of choice. However, adhesion to the optic chiasm and hypothalamus limited

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true gross total resection (GTR) and morbidity was high [27, 33]. The modern surgical approach is more concerned with preserving total quality of life [34], and recent data suggests that selective subtotal resection (STR) followed by adjuvant therapies can provide similar rates of tumor control to GTR, without the endocrine and behavioral morbidity associated with aggressive resection [31, 33]. CPs are now viewed more as a chronic condition [10], and in this context, endoscopic transsphenoidal surgery has a clear role in achieving less invasive, safe, and accurate GTR/STR.

7.2 Pathology

CPs are epithelial neoplasms that develop from remnants of Rathke's pouch. These rests occur from the sella to the floor of the third ventricle. Two principal subtypes are described: adamantinomatous and papillary. The adamantinomatous CPs are more frequent and are the main form encountered in the pediatric population. These are mixed cystic and solid lesions. The papillary type is less frequent, more often seen in the adult population (14–50 % of CPs in adults, 2 % of CPs in children), and these tumors are mainly solid [10, 35]. The cysts of CPs contain turbid, yellow-brown, cholesterol-rich fluid containing phospholipids and keratin. The solid component consists of clusters of organized palisading columnar cells [25]. Desquamated cells form masses called "wet keratin." The papillary type does not calcify and usually is a well-circumscribed lesion. The genetic basis of CPs has not been fully elucidated, but aberrant patterns of β-catenin expression are seen [34].

7.3 Radiology

On MR imaging, the solid elements are usually iso- or hypointense on T1-weighted series, exhibit inhomogeneous high intensity on T2-weighted images, and heterogeneously enhance following gadolinium (Gd) administration. The cystic elements of adamantinomatous CPs typically display a high intensity on T1-weighted images, high or mixed intensity on T2-weighted images, and contrast enhancement of the cyst wall. Several topographic classifications have been described based on relationship to surrounding structures. These provide a guideline to the most appropriate surgical approach [17]. These however are modified via reference to individual high-definition imaging.

7.4 Presenting Symptoms

Given their site, CPs may present with a spectrum of clinical symptoms, mainly related to visual problems, endocrine dysfunction, headaches, and hypothalamic involvement. In a series of 309 patient, Shi et al. found a decrease in visual acuity or a visual field deficit in 133 patients, moderate to severe headache in 107 patients, diabetes insipidus (DI) in 27 patients, amenorrhea in 21 women, and growth retardation in 11 patients [29]. Children (<18 years old) are significantly less likely to present with visual symptoms than adults and tend to present with endocrine dysfunction [37]. Comparing transcranial with endoscopic series, presenting features were visual disturbance in 53 % and 75 %, headache in 52 % and 35 %, hypopituitarism in 28 % and 55 %, and DI in 12 % and 32 % [22].

7.5 Indications and Aims

Stalk or suprasellar CPs of a modest size and mainly midline can readily be approached by several routes, both transcranial and transsphenoidal. The choice is often dictated by the surgeon's experience as much as the anatomy. The transsphenoidal route has the advantage of avoiding brain retraction, better visualization, and no driving ban. Also, the transsphenoidal procedure can be performed regardless of the position of the chiasm. Tumor and capsule extending into the third ventricle present a formidable challenge to access transcranially, and major retraction is often required even with a wide Sylvian split and orbito-zygomatic disassembly. In contrast, the third ventricle is readily accessed via the extended

transsphenoidal route, lying directly along the surgical pathway. Lateral extension into the temporal lobes and basal ganglia is difficult to resect via either route and will possibly require a combined approach. In some cases however transsphenoidal removal is feasible as deflation of the cysts relaxes the temporal compression bringing the capsule into view for dissection. Encasement of the suprasellar carotid or anterior cerebral arteries is very difficult to deal with safely via the endoscopic transsphenoidal approach, so in such a case the favored approach would either be purely transcranial or combined with transsphenoidal subtotal resection [9, 8, 22, 32].

7.6 Equipment

While it is feasible to operate with minimal endoscopic equipment that is available in most large hospitals (ENT endoscopes, FESS sets), having the full range of special equipment transforms the level of control the surgeon has, enables far greater dissection and delicacy of technique, and opens further possibilities, indications, and potential procedures.

Rigid Hopkins lens endoscopes with irrigation sheaths are used, most often the 0° of 4 mm diameter and 18 cm length. A small diameter 2.7 mm scope is useful for narrow nostrils and children, but the illumination is a little compromised. For lateral and superior viewing, an 18 cm scope of 30° angle is needed, and for extended transsphenoidal cases scopes of 30 cm length, both 0° and 30° are required. Currently 3-D endoscopes are in their infancy and are still either rather large or of inferior image quality. The irrigation system with pump provides a means of clearing the lens without removing the scope. There are several designs of holding arm available of equal merit, but most important are a low profile attachment and sufficient length to allow positioning away from the surgical access (Fig. 7.1).

A broad freer for initial nasal dissection does little mucosal damage and reduces nasal bleeding. Upcut and downcut punches are used to open the sphenoid, taking bites of mucosa with the bone and a 1 mm upcut to open the pituitary fossa. For complex intracranial endoscopic procedures, the full set of long dissecting instruments should be available. Image guidance is invaluable for the extended and intracranial cases. Given the number of metal instruments required for the procedure, accuracy is better maintained with infrared-based navigation rather than electromagnetic tracking. A long-tipped CUSA and a small disposable Doppler probe are also very useful.

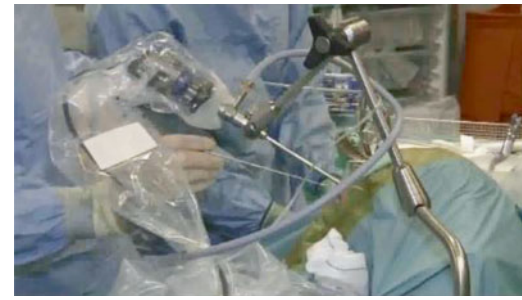

Fig. 7.1 The holding arm with endoscope. The arm is positioned arched out of the way from the surgical field, in order not to interfere with the surgeon's movement

2 ml of 10 % Cocaine HCL solution

2.2 ml of 1 % Sodium Bicarbonate solution

1 ml of 1:1000 Adrenaline solution (1 mg/ml)

Made up to 10 ml with 0.9 % NaCl

Fig. 7.2 Recipe for Moffat's solution

7.7 Surgical Technique

Here we will describe the surgical approach to suprasellar cystic CPs. Those occurring purely within the pituitary fossa are approached precisely as for adenomas and therefore require no further description [4, 6].

After induction of anesthesia, the patient is positioned with neck extended (nose-to-ceiling position) and the nasal mucosa sprayed with Moffat's solution (Fig. 7.2) [1]. A lumbar drain is inserted (as long as the ventricles are not

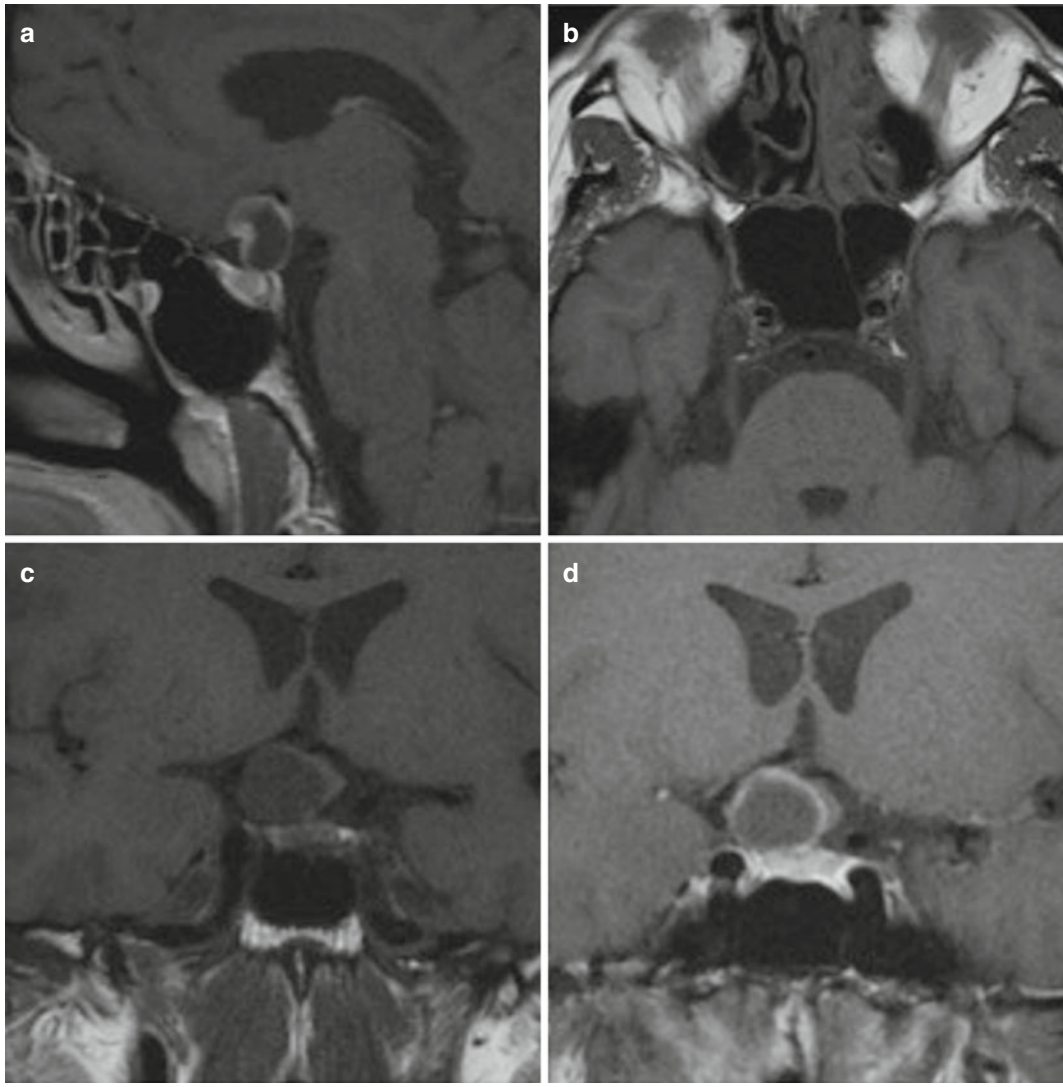

Fig. 7.3 (**a**) Sagittal post-contrast T1-weighted images showing a very well-pneumatized sphenoid sinus, (**b**) axial T1-weighted images showing the sphenoid septum that deviates to the left leading straight to the internal carotid artery, (**c**, **d**) coronal with and without contrast T1-weighted images showing the superiorly displaced chiasm and deviated stalk

obstructed) and intravenous antibiotics and hydrocortisone administered.

The images are assessed for degree of sphenoid pneumatization; the pattern of sphenoid septations; the position of optic nerves, chiasm, and pituitary stalk; and vessel position and encasement (Fig. 7.3).

A semi-sitting position is used to keep the operative field clear, but excessive head elevation is avoided. The head is turned to the right so that surgeon and patient face each other in a "conversational" attitude. The video monitor is positioned squarely over the patient's head with the navigation on the right of the patient (Fig. 7.4).

The septal flap is harvested first, based on the nasal septal branch of the sphenopalatine artery that crosses just above the choana. The septal mucosa is incised vertically just beyond the colu-

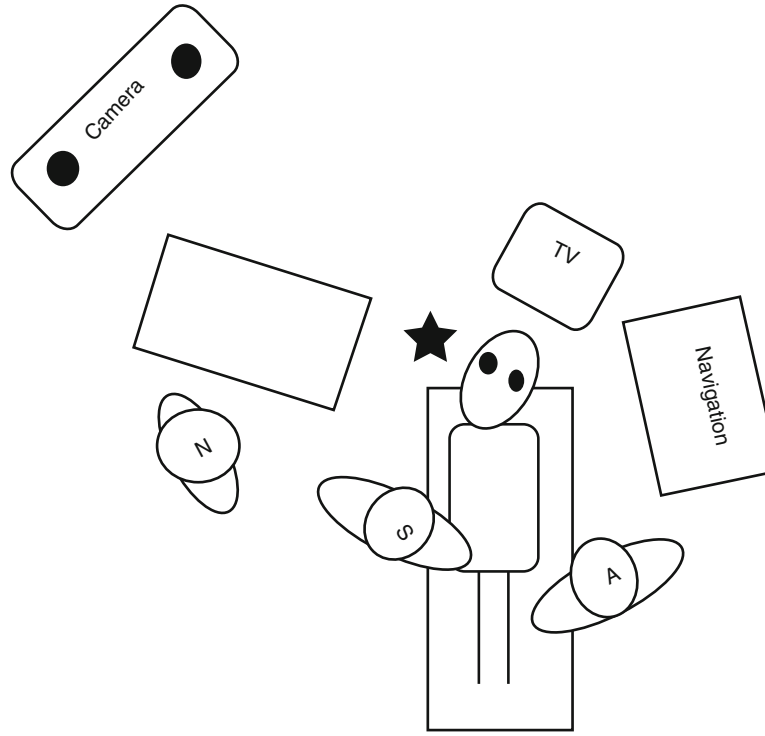

Fig. 7.4 Theater setup: surgeon (*S*) on the patient's right with endoscope monitor (*TV*) above the patient's head and navigation reference frame (*star*) and camera to the right; nurse (*N*); assistant (*A*)

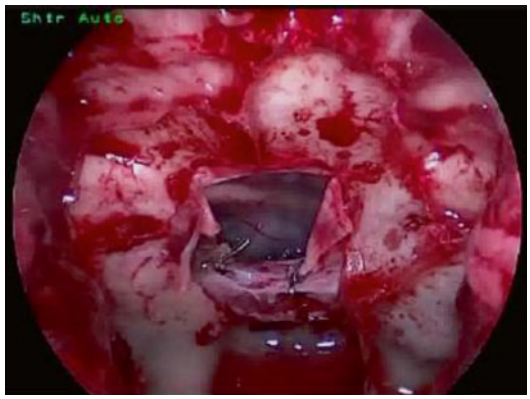

Fig. 7.5 Intraoperative image showing "I" shape of the dural opening; ligaclips are positioned at the level of the intercavernous sinus in order to control the venous bleeding. The two "doors" of dura are folded out opening the access to the suprasellar area

mellar strut and a "lollipop"-shaped flap harvested and turned down into the pharynx [16, 19, 24]. A binasal approach is used, compressing rather than removing the middle turbinate. The whole anterior wall of the sphenoid is removed, with posterior ethmoids as necessary and all septa. The mucosa of the posterior 1/3 of the nasal septum is also resected [4, 14, 13, 32]. The extent of bone removal from fossa and skull base is tailored to the individual pathology with the navigation system. The dura is opened in a capital "I" incision, across the diaphragma sellae and intercavernous sinus. The dura is thereby loose enough to control the sinus with ligaclips. The two "doors" of dura may then be folded out and the arachnoid opened (Figs. 7.5 and 7.6).

On dividing the arachnoid, the position of the optic nerves is established, by deflating the cyst if necessary. The capsule is cleared of crossing vessels and dissected from the diaphragma sellae and stalk. The inferior part of the capsule is mobilized and grasped with cup forceps. Gentle traction is used and the further attachments divided. The central capsule is then truncated and any solid component reduced with the ultrasonic aspirator. Dissection of the deeper component can then be attempted. The main determinant of whether the tumor can be completely removed or not is the degree of adhesion

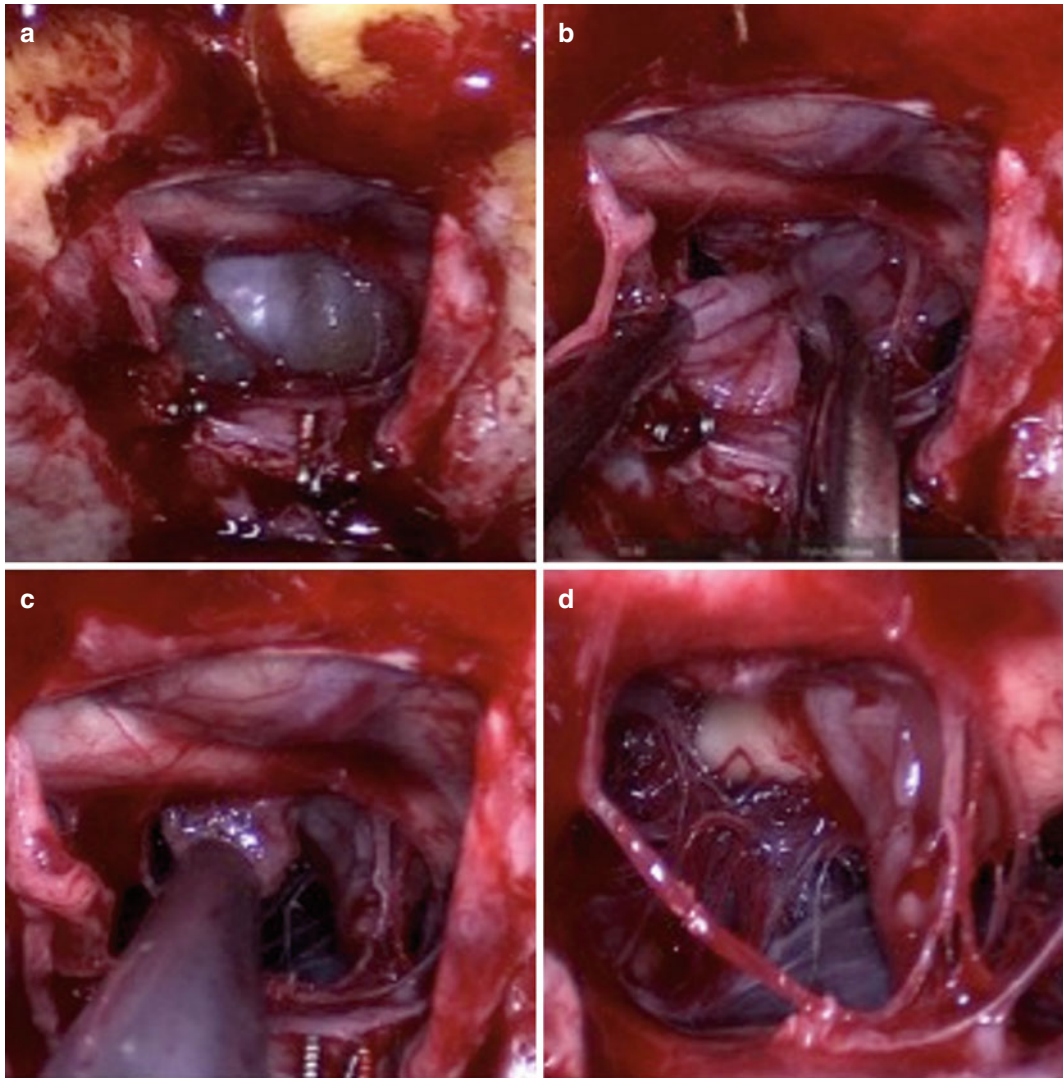

Fig. 7.6 Intraoperative image showing (**a**) the exposure of the tumor capsule, (**b**) truncating the capsule, (**c**) CUSA aspiration of the last fragment adherent to the chiasm, (**d**) final view after tumor removal

to the hypothalamus. If the capsule separates readily, then a complete removal should be possible without significant complications. If however the capsule is adherent, dissection is likely to cause neurologic deficit. Preservation of the pituitary stalk should always be attempted though in adults not at the expense of otherwise complete resection.

Regarding closure a pedicled mucosal flap is the most essential component. For best adhesion this flap should have direct contact with the bone and dural defect margins and is secured in place by spots of glue. Free fat grafts covering all edges are placed and held by sponge and ribbon gauze soaked in bismuth iodine paste.

7.8 Postoperative Management

The lumbar drain outlet height is adjusted to maintain flow at a maximum of 10 ml/h. Free drainage is continued for 5 days and the drain clamped for 24 h and removed after postural testing for a leak. The fluid balance, urine specific

gravity, and serum sodium are monitored 2 hourly and DI treated with DDAVP as required. Hydrocortisone 20 mg tds is always prescribed and a 9 a.m. cortisol performed on day 3. Other hormonal assays are performed in the outpatient setting at 3–4 weeks.

7.9 Results

In the neurosurgical literature contemporary series of transcranial craniopharyngioma surgery reveals a 10-year recurrence-free survival rate of 74–81 % for gross total resection, 41–42 % for partial removal, and 83–90 % after surgery and radiotherapy [22]. A meta-analysis of the complications in CP treatment revealed new neurologic deficits in 5.1 % of patients undergoing GTR and in 2.2 % of patients undergoing fractionated radiotherapy (fXRT) or SRS alone. On multivariate analysis, GTR conferred a significant increase in the risk of neurologic deficits compared to STR + XRT. The overall rate of new endocrinopathy for all patients undergoing surgical resection of their mass was 37 %. Patients receiving GTR had over 2.5 times the rate of developing at least one endocrinopathy compared to patients receiving STR alone or STR + XRT [31]. Vascular injury was an uncommon complication of CP surgery, occurring in just two cases. Visual decline was more frequent in patient undergoing fXRT or SRS than surgery (8.5 % vs. 3.7 %, respectively) [31]. Complication rates are significantly lower for surgical teams with larger volume series. The main determinant of quality of life was found to be hypothalamic dysfunction; therefore hypothalamic-pituitary and optic nerve function preservation should be the major aims in planning the best treatment strategy [26].

In a purely endoscopic series of 64 CPs treated by the Pittsburgh group, GTR was achieved in 37.5 % of the patients. Of the 40 patients who had presented with pituitary insufficiency, pituitary function remained unchanged in 50 %, worsened in 30 %, and improved in 20 %. Approximately half of the patients suffered from postop DI. With regard to visual outcome, out of the 44 patients who had preoperative visual deficit, this improved or normalized after surgery in 86 %, remained unchanged in 5, and was transiently worse in 1. No permanent visual deterioration occurred. CSF leak was described in 23 %. No operative mortality was reported [7, 24]. The Tokyo group achieved GTR in 77.8 % of patients, STR in 18.9 %, and partial removal in 3.3 %. Postoperative hormonal disturbances were the main reported complication: 66 % of patients with normal preoperative function or partial anterior pituitary loss developed some degree of hormonal deficiencies; new DI was reported in half of the patients. Visual symptoms improved in 90.2 %. The early postoperative mortality rate was 2.2 %. CSF leakage occurred in 11 patients (5 required surgical repair) [32].

An extensive review of the literature comparing the benefits and limitations of the various approaches showed that of 3470 patients, the endoscopic cohort had a significantly greater rate of GTR (66.9 % vs. 48.3 %; $P<0.003$) and improved visual outcome (56.2 % vs. 33.1 %; $P<0.003$) compared with the open transcranial cohort. The transcranial cases carried a significantly greater rate of permanent DI, but a lower rate of new hypopituitarism compared with the transsphenoidal. The rate of CSF leakage was greater in the endoscopic (18.4 %) than in the transcranial group (2.6 %; $P<0.003$), but the transcranial group had a greater rate of seizure (8.5 % vs. 0 % in the transsphenoidal group, $P<0.003$). Hemiparesis/stroke occurred in 2.9 % of the transcranial patient, and there was also a significantly greater rate of wound or bone flap infection, but no significant difference in the rate of meningitis between groups. There was a lower rate of recurrence in the transsphenoidal cohort compared with the open cohort ($P<0.003$) [23].

7.10 Adjuvant Therapies

Even with GTR, disease-free survival is increased with radiotherapy, but there are still complications associated with radiotherapy. For known STR and observed recurrence during follow-up, radiotherapy is mandated, given via IMRT or proton beam therapy for children. Gamma knife

radiotherapy may be useful but only for residual or recurrent tumor distant from the optic nerves and chiasm.

Several chemicals have been used for intracystic chemotherapy for recurrence. First reported by Leksell and Liden in 1952, beta-emitting sources, such as phosphorus-32 (32P), yttrium-90, and rhenium-186, have been tried with variable results. With 32P overall progression-free survival of 72 % and 45 % at 24 and 60 months, respectively, has been reported. 32P however does not halt the development of new cysts or the progression of solid parts [20]. Overall complete or partial cyst resolution is described in 71–88 % of cases [26]. One of the main concerns with intracystic chemotherapy is toxic effect due to subarachnoid leakage: visual and hearing loss, peritumoral edema, hypothalamic dysfunction, cerebral ischemia, hemiparesis, progressive panhypopituitarism, and death have been reported [12, 30]. The latest agent under assessment is interferon-α. This has established efficacy against squamous cell carcinoma (which shares the same embryological origin as CP) and is many times less neurotoxic than the other agents described [11, 28].

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