Visual Outcomes after Endoscopic Endonasal Approach for Craniopharyngioma: The Pittsburgh Experience

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Abstract

This series of patients has been published in the neurosurgical literature earlier this year, detailing multiple aspects of both the surgical technique and postoperative outcomes. Our aim in this series is not to revisit all the aspects of this publication, but rather to analyze more specifically the benefits of this procedure as it pertains to the preservation of neurological structures of vision—specifically the optic chiasm—and provide a more detailed analysis of visual outcomes in these patients.

Keywords
- craniopharyngioma
- vision
- expanded endonasal approach
- outcome

Introduction

Craniopharyngioma is an uncommon "benign" tumor of the skull base, representing 0.9% of intracranial tumors diagnosed in the United States. However, it is the most common nonglial intracranial tumor in children (4.1%).[1] A bimodal age distribution is observed with peak occurrences in childhood and the sixth decade of life.[2] The tumor exhibits solid and cystic components and is thought to originate from rests of cells arising from the lumen of the craniopharyngeal duct, the precursor of the adenohypophysis.[3] Of particular interest to ophthalmologist is the locally aggressive behavior of craniopharyngiomas, causing compression of visual structures, in addition to pituitary and hypothalamic dysfunction and hydrocephalus in as many as 58% of pediatric cases.[4]

While surgery often provides improvement in visual acuity and fields, iatrogenic injury secondary to damage of the optic nerves and the superior hypophyseal arteries supplying the chiasm and pituitary stalk and gland is possible, in addition to hypothalamic injury.[5] These arteries arise directly from the paraclinoid portion of the carotid artery and course superiorly (►**Fig. 1**) to supply the optic nerves, chiasm, and infundibulum.[6] Sparing of these delicate structures is balanced with the goal of gross total resection to attempt to decrease tumor recurrence.

Transsphenoidal surgical approaches, operating via a nasal speculum with an operating microscope, for lesions of the sella have long existed as an alternative to traditional transcranial approaches but extended transsphenoidal surgery had limited success at accessing suprasellar lesions.[7–9] Only recently have endoscopes and other surgical instrumentation been developed that allow precise visualization and manipulation of structures beyond the sella, extending farther into the coronal and sagittal planes.[10,11] These advances expand the indications for an approach to suprasellar lesions such as craniopharyngiomas from below to better visualize and preserve the vascular supply to the optic apparatus.

Here, we present a more in-depth analysis of visual outcomes on the same series of patients undergoing endoscopic endonasal approach (EEA) for craniopharyngioma previously analyzed with respect to extent of resection, tumor recurrence, associated complications, and patient survival in a related publication.[12]

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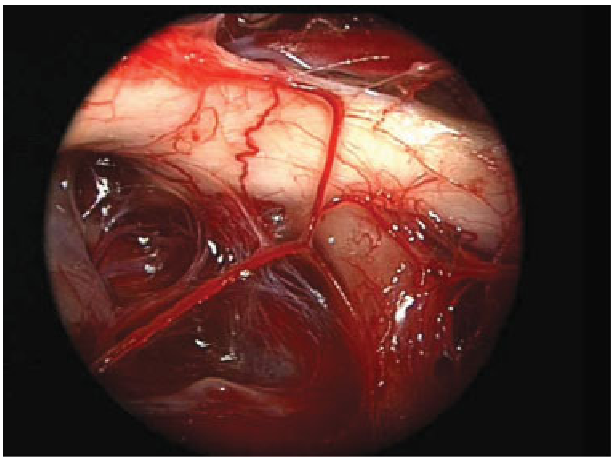


Fig. 1 Intraoperative photograph of right optic nerve, right carotid artery, optic chiasm (superiorly), and pituitary stalk being perfused by the superior hypophyseal arteries. The tumor is noted posterioinferiorly to the chiasm and arteries.

Participants and Methods

With institutional review board approval a database of patients undergoing EEA at the University of Pittsburgh Medical Center from April 2002 to June 2011 was reviewed for patients being operated for craniopharyngioma. A total of 67 patients were identified. Of these patients, 52 had complete preoperative and postoperative data for visual acuity and visual fields (►**Table 1**), and 3 other patients had documentation of normal acuity and fields after surgery without preoperative data, for 55 total patients with 52 available for comparison to preoperative baselines. Total 10 were pediatric patients with a mean age of 9 years (5 males, 5 females). Of the 45 adult patients, the mean age was 51 years old (28 males, 17 females). Patient charts were analyzed for preoperative evaluations, operative notes, and all subsequent visits, with a mean follow-up of 4.8 years.

The best-corrected visual acuity of each eye was used to report vision and formal visual fields were obtained whenever possible. Patients were reported, rather than individual eyes, as this seems to more accurately reflect the effect of surgical outcome on daily life.[13] If any parameter of either eye was changed due to surgery, it was reported as a change in the status of the patient. "Normal" visual acuity was defined as 20/30 or better, and "improvement" or "deterioration" required a two-Snellen-line change in acuity.

Because visual acuity was measured for both the eyes of each subject on a discrete 16 point ordinal scale (►**Table S1**, ►**Supplementary Material** available in the online version only), had many tied values, and had missing values, classical parametric statistical procedures such as the *t*-test or analysis of variance, or their nonparametric equivalents, were not appropriate. Instead, the discrete ordinal visual acuities were assumed to come from an underlying, not directly observed, latent scale. On this continuous scale, the latent values are assumed to be normally distributed. An individual discrete ordinal scale was categorized depending upon whether the latent value fell above or below the 15 ordered thresholds (or cutoffs) delineating each of the 16 ordinal categories. In this threshold model, there were two latent variables—one for each eye—and they were allowed to be correlated. The preoperative latent values were assumed to be normally distributed with mean zero and standard deviation of 1. The postoperative latent values were assumed to be normally distributed with an unknown mean and unknown standard deviation. A structural equation model was constructed using the R statistical language and environment and the R OpenMx structural equation modeling package. Full information maximum likelihood (which accommodated the few missing values) was used to estimate the model parameters which consisted of the mean and standard deviation of the latent postoperative values, the 15 thresholds, and the correlation between eyes. This model can be thought of as a simple paired *t*-test for the latent (postoperative vs. preoperative) continuous values if one ignores the complication of having both eyes nested within each subject.[14,15]

Intervention

General endotracheal anesthesia was used for all patients. The head is fixed in a Mayfield apparatus, and image guidance is registered using a mask that is subsequently removed. Fused magnetic resonance/computed tomographic images are used intraoperatively as well as neurophysiological monitoring of any likely involved cranial nerves (e.g., III, VI). The otolaryngologist provides a binaural window, elevating and preserving a vascularized, pedicled flap of nasal mucosa/mucoperichondrium based on one of the posterior nasoseptal arteries.[16] After opening the sphenoid sinus and removal of additional bone in the necessary module (e.g., tuberculum sellae, planum sphenoidale, clivus, etc.), the neurosurgeon and otolaryngologist work together. The dura is opened and any cystic portion of tumor is internally debulked while care is taken to prevent drainage of the cyst contents into the cerebrospinal fluid (CSF). The capsule of the tumor is gently dissected from the surrounding tissue, while the perforating vessels coursing over its surface are preserved. In many cases, this proceeds until gross total resection is achieved, using angled endoscopes as necessary to visualize any residual mass. In other cases, particularly reoperations, the goal of surgery is to decompress a particular part of the optic apparatus (►**Fig. 2**). After establishment of hemostasis with warm-water irrigation and hemostatic agents, and repair of any dural defects, the nasal septal flap is tucked in place and supported with either a Foley catheter balloon or with cellulose sponges. A lumbar drain is placed if necessary, and the patient is transferred to a neurosurgical intensive care unit overnight for monitoring of blood pressure, volume status, and neurological status.

Results

Out of 52 patients, 42 patients (80.8%) with complete preoperative data had evidence of mass effect on the optic apparatus before surgery: either decreased visual acuity or decreased visual field was present in either eye. Out of these

Table 1 Preoperative and postoperative visual acuity of 52 patients with complete pre- and postoperative visual acuity data

Patient	Preoperative vision (OD, OS)	Postoperative vision (OD, OS)
1	20/30 OU	20/16, 20/20
2	NLP, 20/400	LP, 20/400
3	20/20 OU	20/20 OU
4	20/25, 20/125	20/20 OU
5	20/200, 20/60	20/60 OU
6	20/25, 20/40	20/30 + , 20/25
7	20/20, 20/60	20/20 OU
8	20/25, 20/40	20/20 OU
9	20/20 OU	20/20 OU
10	20/40, 20/50	20/30, 20/25
11	20/25 OU	20/25 OU
12	20/30, 20/25	20/30, 20/30 after VPS
13	20/25, 20/30	20/20 OU
14	20/40, no OS	20/20
15	HM, 20/20	same
16	CF, 20/20	20/15 OU
17	20/30, 20/40	20/25 OU
18	20/60, 20/16	20/25, 20/20
19	20/25, 20/60	20/20, 20/25
20	20/20 OU	20/20 OU
21	CF 5′, 20/25	20/25 OU
22	20/30 OU	20/25, 20/30
23	20/50, 20/60	20/20 OU
24	20/25, 20/30	20/20, 20/30
25	20/40, 20/25	20/20 OU
26	20/30 OU	20/30, 20/20
27	20/40, CF 2’	20/25, same
28	20/20, 20/25	20/25, 20/30
29	20/25 OU	20/20, 20/30
30	20/400, 20/30	20/20 OU
31	20/40, CF 2’	20/40, 20/100
32	20/30 scanning	20/20 OU
33	20/25, 20/60	20/30, 20/20
34	20/50, 20/200	20/25 OU
35	20/20 OU	20/20 OU
36	20/20 OU	20/25 OU
37	20/30, 20/40	20/16 OU
38	20/20 OU	20/20 OU
39	20/25, 20/20	20/20, 20/25
40	20/40, 20/50	20/25, 20/20
41	20/20, 20.25	20/25
42	20/30 OU	20/25 OU
43	20/200, 20/50	20/200, 20/40

Table 1 (*Continued*)

Patient	Preoperative vision (OD, OS)	Postoperative vision (OD, OS)
44	20/30, CF	20/20 OU
45	HM, CF 3′	HM, 20/400
46	20/20 OU	20/20 OU
47	20/20, 20/70	20/20 OU
48	20/25 OU	20/25 OU
49	20/25, 20/30	20/40, 20/25
50	20/25, 20/20	20/20 OU
51	20/20 OU	20/20 OU
52	20/60, 20/200	HM, 20/200

Abbreviations: CF, counting fingers; HM, hand motions; LP, light perception; NLP, no light perception; OD, oculus dexter; OS, oculus sinister; OU, oculus unitas; VPS, ventriculoperitoneal shunt.

37 (88.1%) patients had improvement in their visual function, 18 (42.8%) normalized completely. Two patients (3.8%) had decreases in their vision; three patients of the cohort (8.1%) with a preoperative decrease in vision maintained their preoperative function. Overall, over 96% of our patients with complete preoperative and postoperative data either maintained their preoperative visual function or improved after surgery.

Of the 42 patients with preoperative visual deficits 30 patients (71.4%) had both visual acuity and visual field abnormalities attributable to the tumor. Eleven patients (26.2%) had only visual field changes, and one patient (2.4%) had only a decrease in his visual acuity.

Out of 52, 10 patients (19.2%) with complete preoperative data were children. This is comparable to the 22.9% of our total 67 cases who were 14 or younger at the time of surgery. Their results did not differ from those of the group as a whole; 90% maintained or improved over their preoperative visual function and one patient had a postoperative optic neuropathy that improved over the course of observation.

The latent threshold model described above was then fitted to the observed visual acuities, including the additional three patients that did not have complete preoperative data. The estimated thresholds are shown in ►**Table S2**, ►**Supplementary Material** available in the online version only. The estimated latent pre- and postoperative normal distributions along with the thresholds, is shown in ►**Fig. 3A, B**. Compared with the preoperative distribution (mean 0 and standard deviation 1), the postoperative distribution mean was shifted to 1.047 (95% confidence interval: 0.634–1.528) indicating postoperative improvement in visual acuity and this improvement was statistically significant. In addition, the

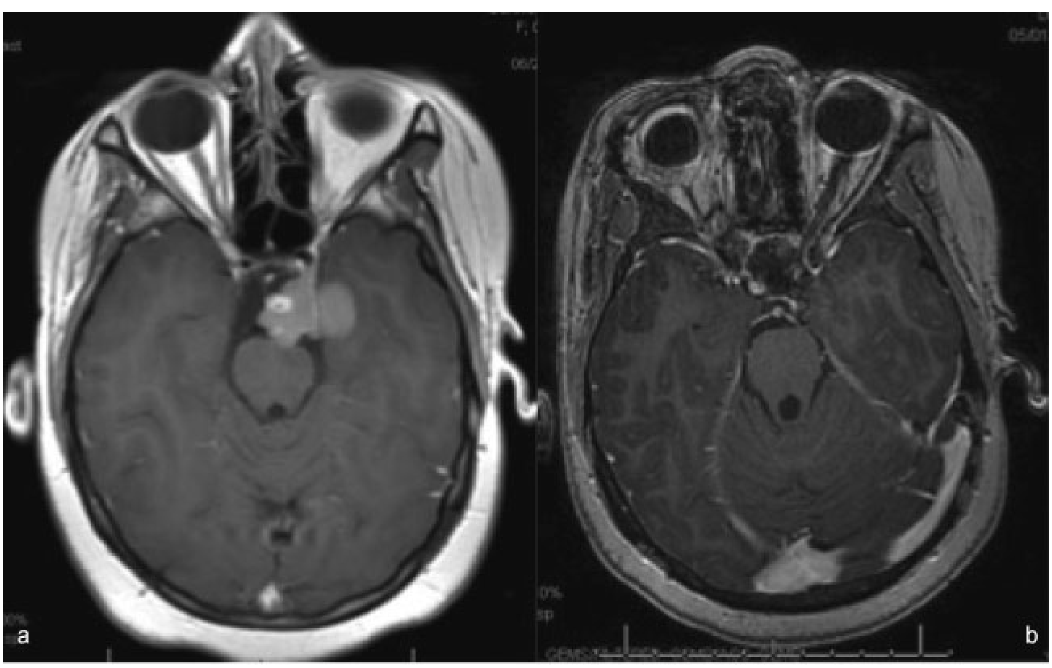
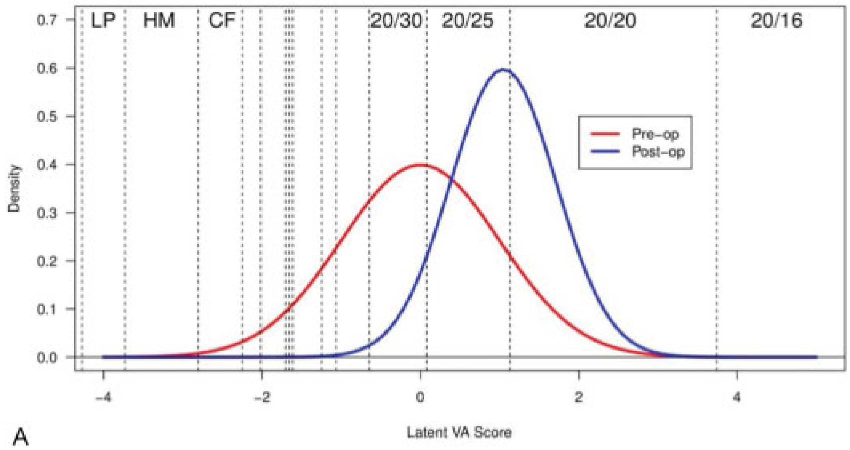


Fig. 2 Axial preoperative (a, [left]) and postoperative (b [right]) enhanced T1-weighted MRI demonstrating enhancing mixed solid and cystic suprasellar mass with postoperative gross total resection. MRI, magnetic resonance imaging.



A

	LB	estimate	UB
Pre-oper Mean		0	
Post-oper	0.634	1.047	1.528
Pre-oper SD		1	
Post-oper	0.100	0.668	1.342

B

Fig. 3 (A) Normal distributions of pre- and postoperative visual acuity. Preoperative visual acuity is set with mean zero and standard deviation 1, with z score mean and standard deviation of postoperative visual acuity reflecting the relative change in postoperative visual acuity. (B) Numerical values of distribution shown in (A). LB, lower bound of confidence interval; UB, upper bound of confidence interval.

postoperative distribution standard deviation decreased to 0.668 (range, 0.1–1.342) although this narrowing of the distribution was not statistically significant. The correlation between eyes was estimated as almost 1 (range, 0.682–1). The resulting improvement in the observed visual acuity values is shown in ►**Table S3**, ►**Supplementary Material** and ►**Fig. S1**, ►**Supplementary Material** (available in the online version only). It can be seen that the modeled percentages in each ordinal category are similar to the observed percentages, although the model tends to underestimate slightly the lower categories (especially preoperative counting fingers and postoperative hand motions) and tends to overstate the postoperative 20/25 category. Overall, the model adequately fits the observed data and reasonably predicts the observed improvement in the visual acuity from preoperative to postoperative. Thus, the statistical analysis strongly supports the hypothesis of postoperative improvement in visual acuity.

Of 52 patients, all but one had both preoperative and postoperative visual field data, so 51 patients were included in the visual field analysis. Nine patients (17.6%) had normal visual fields before surgery and all were unchanged postoperatively. Overall, 42 patients (82.4% of patients) had some type of visual field defect quantifiable either on Humphrey or Goldmann perimetry, or, when that was not possible, by counting fingers fields. The defects could be classified as bitemporal in 42.9% of patients, as homonymous in 28.6%, and as neither in the remaining 28.6%. Out of these, 37 patients (88.1% of those presenting with defects) had documented improvement in their visual fields, and in 17 people (40.5% of those with preoperative deficits), the visual field entirely normalized in both eyes (within what was possible given the extant intraocular pathology, e.g., age-related macular degeneration; AMD). The other five patients (11.9% of the patients with preoperative visual field loss) maintained their preoperative status, though one of these patients subsequently developed visual field loss and confusion due to increased intracranial pressure. Visual field data are summarized in ►**Fig. 4**.

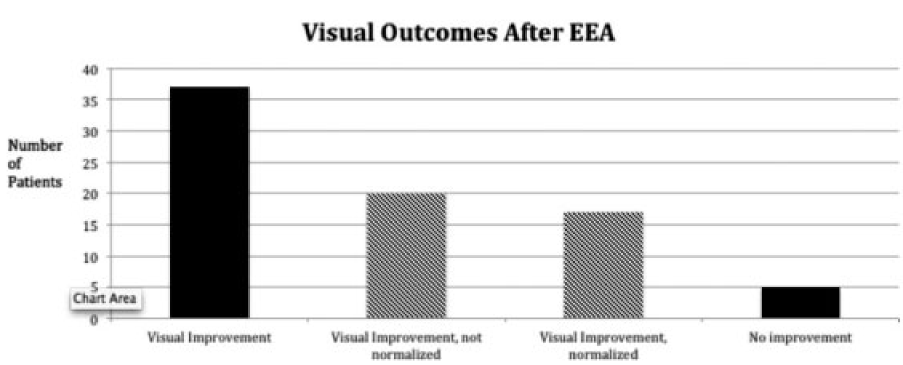


Fig. 4 Outcomes of 42 patients with preoperative visual field defects. Out of 42, 37 (88.1%) had improved visual fields after EEA, with 20 (47.6%) experiencing improvement without total normalization and 17 (40.5%) having normalized postoperative visual fields. EEA, endoscopic endonasal approach.

A previous publication of a nearly identical series of patients at our center (including nine additional patients excluded from this series due to incomplete visual data) described other nonvisual outcomes at length.[12] In short, it was found that EEA for craniopharyngiomas allowed gross total, near gross total (> 95%), and subtotal resection in 37.5, 34.4, and 21.9%, respectively. After a 38 month follow-up tumor recurrence was observed in 34.4% of patients. Complications included new-onset pituitary insufficiency (58.3% of the 24 patients with initially normal pituitary function), postoperative diabetes insipidus (29.7%), CSF leak (23.4%, decreased to 10.6% after introduction of vascularized nasoseptal flaps), meningitis (7.8%), postoperative hydrocephalus (12.7%), and transient cranial nerve palsies (7.8%).

Discussion

While craniopharyngiomas exhibit benign pathology, they exhibit a locally aggressive behavior with both endocrine and visual deficits being common. The presenting symptom of 47 to 53% of the patients in the two largest modern series was a change in vision, with 77% exhibiting a chiasmal syndrome on formal examination.[17] Usually, this reverses or improves after surgery, but a very real risk of both surgery and recurrence is worsening of visual function.

Since Cushing time, dogma has dictated gross total resection (GTR) as the only possibility of preventing recurrence.[18] While the transsphenoidal approach (with speculum and magnification) has existed since this era and has been life sustaining for many, it has often lead to unacceptable iatrogenic injuries including blindness, in addition to severe hypothalamic sequelae. Since the introduction of the operating microscope in the early 1970s approaches to sellar tumors were limited to transsphenoidal microscopic and transcranial.[19] Given the far superior exposure of the extrasellar areas afforded by a subfrontal or pterional approach, most surgeons believed the transcranial route was the most advantageous for a craniopharyngioma and gave them the best chance of GTR.[17] Contemporary surgery often follows attempted GTR with radiation to known residual tumor, either via confocal radiation (radiosurgery) or injected β-emitting substances into the cyst, or by close regular surveillance for recurrence.[20] Sacrifice of pituitary function is considered acceptable in the pursuit of GTR, as there are now good hormone replacement regimens, but sacrifice of visual function is not.

The EEA capitalizes on the transsphenoidal approach's elimination of brain retraction and the superior visualization of small perforating vessels arising from the ventral surface of the carotids. It then improves upon it by giving far wider and more dynamic views, as well as more room for manipulation. Thus, almost all craniopharyngiomas (other than the type IV which are completely contained within the third ventricle) can be operated on in this manner.[11] We present data in support of the excellent visual outcomes achieved by this surgery, including an 88.1% improvement in visual acuity (VA), with 42.8% having complete normalization of VA. In addition to statistically and clinically significant improvement in VA, our analysis also suggests a decrease in variability of VA postoperatively. We further showed an improvement in VF for 88.1% of patients with preoperative deficits and complete normalization of the visual fields of 40.5%.

Our series is the largest series to date of fully endoscopic resection of craniopharyngiomas.[12] There are historical data on the rate of visual recovery and preservation among patients undergoing transsphenoidal and transcranial approaches for their tumors. Among large modern series of patients undergoing transcranial surgery, some recovery of vision is evident in 35 to 54% and full recovery is realized in 34 to 36%. Deterioration is noted postoperatively in 6 to 15%.[2,17,18,20]

There is little in the way of prospectively collected objective data comparing preoperative and postoperative visual function for any form of surgery for this tumor. One of the most comprehensive series to date describes 30 patients (adults and children) in the pre- and postoperative periods after undergoing a transcranial approach.[21] They found that 42% of patients had decreased visual acuity preoperatively, which was decreased to 23% postoperatively. They observed 48% of patients with normal visual fields postoperatively compared with only 20% preoperatively. They also found that no patients observed over a longer period than 1 month improved any further than they did in that initial postoperative period. A later study of 31 of only their pediatric patients showed that postoperatively 71% of patients had "normal vision" in their better eye (20/40 or better) and 26% had acuity less than 20/200 in their best eye.[22] In an Australian review of 36 patients, 32 had surgery via a transcranial route (4 had no surgery).[23] In this series, long-term visual outcome of patients was examined. Approximately, one-third of their patients showed deterioration over several years, whereas only about a third improved.

Our series, with its 88% rate of visual improvement and 4% rate of visual deterioration, supports the ventral approach as a reasonable method and may be of low morbidity for the optic apparatus. Given that about half of these tumors occur in children, it is interesting to observe that in our pediatric cases (10 of 52), one experienced visual worsening whereas 50% improved their preoperative deficits.

Disclosures
C. S.: Consultant/ownership interest in SPIWay LLC. No other authors have any relevant disclosures.

Authorship

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Conflict of Interest

There are no conflicts of interest to report for any author.

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