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TECHNICAL NOTE - BRAIN TUMORS

Extended endoscopic endonasal resection of craniopharyngioma using intraoperative visual evoked potential monitoring: technical note

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Abstract

Background To avoid deterioration of visual function, extended endoscopic endonasal transsphenoidal surgery (TSS) for craniopharyngioma was performed with visual evoked potential (VEP) monitoring using light-emitting diodes (LEDs).

Methods The position of the optic chiasm was carefully evaluated on the preoperative midsagittal magnetic resonance (MR) images. Intraoperatively, direct and sharp dissection of the tumor from the optic chiasm was performed under VEP monitoring with LEDs through extended endoscopic endonasal TSS. If the VEP finding changed and became unstable, the operator were informed and stopped the surgical manipulation for the optic chiasm to recover. After 5–10 min, recovery of VEP findings was checked and the procedure resumed.

Results Extended endoscopic endonasal TSS with VEP monitoring was performed in consecutive 7 adult patients with newly diagnosed suprasellar craniopharyngiomas with maximum diameters of 25–41 mm (mean 33.7 mm). VEPs were stable throughout the surgery in 5 cases, but showed temporary instability and amplitude decrease in 2 cases, although the VEPs had recovered at the end of the surgery. Visual function, evaluated using visual impairment score, was improved after surgery in all patients. Gross total removal was achieved in 5 cases, and subtotal removal (90%) in 2 cases.

Conclusions Intraoperative VEP monitoring is the only way to test visual function during surgery, and may be important and helpful in extended endoscopic endonasal TSS, which requires direct dissection between the optic nerve and craniopharyngioma under the endoscope.

Keywords Visual evoked potential · Intraoperative monitoring · Endoscopy · Extended endonasal approach · Craniopharyngioma · Resection

Abbreviations

TSS	Transsphenoidal surgery
VEP	Visual evoked potential
LEDs	Light-emitting diodes
VISs	Visual impairment scores
MR	Magnetic resonance
SHA	Superior hypophyseal artery

This article is part of the Topical Collection on *Brain Tumors*

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Introduction

Supradiaphragmatic craniopharyngioma is conventionally treated through craniotomy. Recently, extended endoscopic endonasal transsphenoidal resection of craniopharyngioma has been established [1, 2, 5, 11, 20, 26]. Direct dissection between the tumor and the optic chiasm under the endoscope is one of the most important manipulations during extended endoscopic endonasal transsphenoidal surgery (TSS). Visual dysfunction is one of the risks for extended endonasal TSS, even if performed by an experienced surgeon [5, 11–13, 21, 26].

Intraoperative visual evoked potential (VEP) monitoring is the only way to obtain information on visual function during general anesthesia and has been studied with the expectation of its usefulness in neurosurgical settings since 1973 [9, 25]. VEP has been adopted during resection of brain tumors located near or in contact with the optic pathway and structures such as the optic nerve, optic radiation, and occipital lobe, and during internal carotid artery aneurysm clipping, which involves the risk of impeding blood flow to the ophthalmic artery [7, 9, 22]. However, intraoperative VEP suffered from the problems of instability and poor reproducibility [1, 3, 9]. Recently, VEP detectability has been greatly improved by new high-luminosity stimulation devices with light-emitting diodes (LEDs), resulting in improved reproducibility and usefulness of recent intraoperative VEP methods [7, 9, 10, 14–16, 18, 19, 22, 23, 27]. Consequently, reproducible VEP recording using LEDs has become possible in 93.5% or 97.2% of cases [10, 22].

We report our experience with extended endoscopic endonasal transsphenoidal resection of craniopharyngioma using intraoperative VEP monitoring with new high-luminosity stimulation devices with LEDs, and describe the surgical and VEP neuromonitoring techniques, the intraoperative VEP findings, extent of resection, and results of postoperative visual function.

Methods

Preoperative evaluation of optic chiasm

The position of the optic nerve was difficult to identify on the preoperative images, whereas the position of the optic chiasm could be determined with reference to the anterior communicating artery complex on the preoperative midsagittal magnetic resonance (MR) images [12]. Forward or upward displacement of the optic chiasm by the tumor was carefully assessed (Figs. 1, 2, 3, 4, and 5) [21]. In a typical extended endoscopic endonasal TSS, the operational vertical range of tumor removal extends from the lower end of the chiasm to the upper end of the pituitary (or the sellar floor). Consequently, in the presence of forward displacement of optic chiasm, the operation range was suspected to be narrow for dissection between the optic chiasm and tumor.

Surgical procedures

All extended endoscopic endonasal TSS procedures were performed by the senior author (M.T.) under the endoscope without using the operating microscope. The EndoArm with a 4-mm rigid high-definition endoscope (Olympus Corporation, Tokyo, Japan) was used with a 0°, 30°, or 70° angled lens and a fixation system. A navigation system (StealthStation; Medtronic Sofamor Danek, Memphis, TN, USA) was used for image-guided surgery. The endoscope was mainly introduced through the right nostril, but instruments were introduced through the bilateral nostrils without using a nasal speculum [24]. The bone of the tuberculum sellae and the posterior part of the planum sphenoidale were removed using a high-speed drill and a Kerrison bone punch. The dura mater was opened, the arachnoid membrane was sharply dissected, and the tumor was exposed between the upper surface of the pituitary gland and the optic chiasm. If the operational vertical range for tumor removal from the lower end of the chiasm to the upper end of the pituitary or the sellar floor was considered narrow, the antero-superior tip of the pituitary gland was partly cut to extend the operation range. After assessment of the pituitary stalk, the tumor was debulked adequately. Sharp dissection of the tumor or tumor capsule from the optic chiasm was performed carefully under VEP monitoring. The tumor was also carefully dissected off the small perforating arteries from the posterior communicating artery, superior hypophyseal arteries, and hypothalamus under the endoscope. After removal of the tumor, the dural defect was patched with fascia lata and sutured with 5–0 polypropylene suture in watertight manner (Fig. 2), and covered with the nasoseptal flap. In some recent cases, a nasoseptal flap was not needed. Lumbar cerebrospinal fluid drainage was not used during or after the operation.

VEP monitoring

Anesthesia was induced with bolus injection of propofol and remifentanil, then maintained with inhalation general anesthesia. However, if the VEP waves were unstable, intravenous general anesthesia was maintained with continuous infusion of propofol (6–10 mg/kg/min) and remifentanil (1–2 μg/kg/min). Intraoperative VEP monitoring was performed by the first author (T.M.). High-power light stimulation devices were used consisting of 16 red high-luminosity (100 mcd) light-emitting diodes covered in a 2-cm-diameter soft silicone disk (Unique Medical Co., Ltd., Komae, Tokyo, Japan) [9, 10, 15, 16, 19, 22]. After induction of general anesthesia, both eyelids were closed with transparent eyepatches. The duration of light stimulus was 20 msec, and frequency was 1 Hz with usually 2000–5000 lx (up to 20,000 lx). Needle electrodes were inserted subcutaneously at a point 4 cm above and 4 cm lateral from the external occipital protuberance (inion), reference electrodes were placed on the bilateral mastoid process point (A1, A2), and bilateral canthus for electroretinography. The impedance of the needle electrodes was adjusted to below 10 kΩ [22]. The electroretinography and VEP waveforms were analyzed with a high-end signal processor device (Neuromaster MEE-1000; Nihon Kohden Corp., Tokyo, Japan) and low (20 Hz) and high (500 Hz) band-pass filters. The analysis time was 200 msec. A total of 100 responses

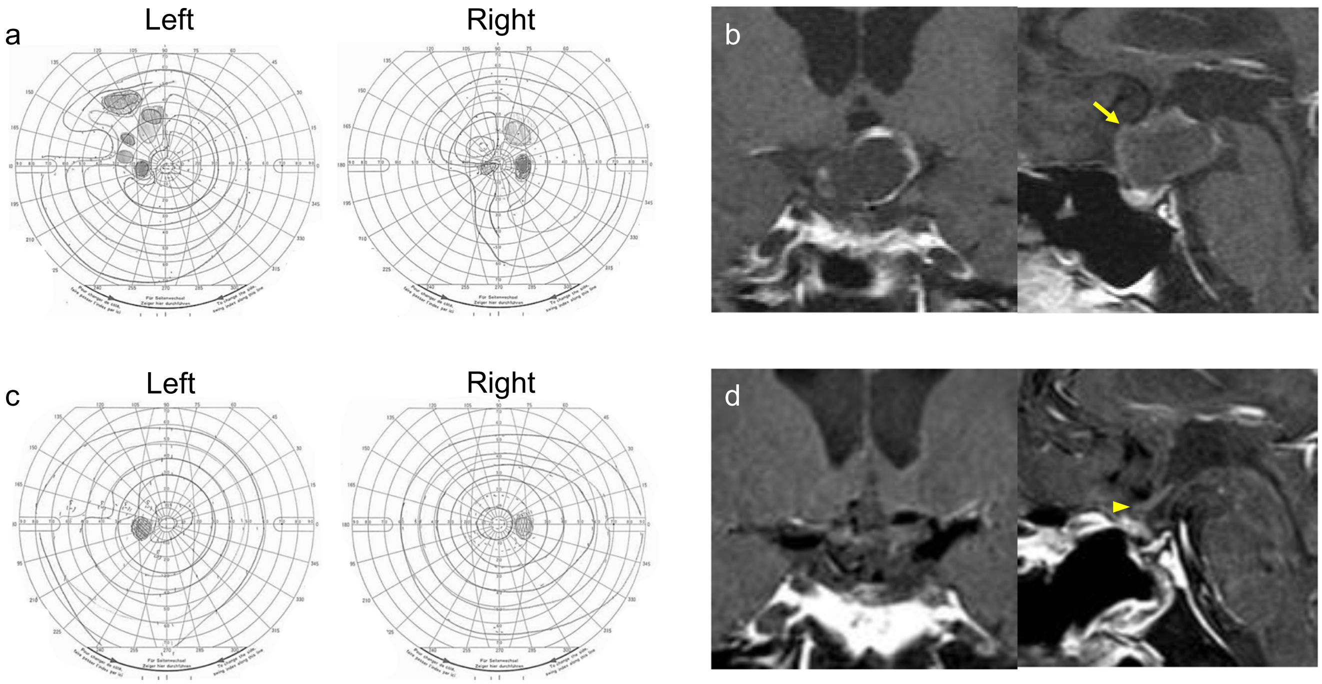

Fig. 1 Case 1. Preoperative Goldmann kinetic perimetry shows irregular visual field defect (**a**). Preoperative coronal and sagittal T1-weighted MR images after injection of gadolinium. The yellow arrow indicates the optic chiasm, which was identified with reference to the anterior communicating artery complex (**b**). Postoperative visual fields (**c**) show recovery. Postoperative MR images showing complete removal of the tumor. The yellow arrowhead indicates the optic chiasm (**d**)

were summed. The analysis focused on the large negative peak around 100 msec (N75) and followed by a large positive peak (P100). Before the surgical procedures, a minimum of two recording sessions of bilateral and unilateral left and right light stimulations to the eyes were obtained to confirm the reproducibility of the data. Light stimulation to both eyes was routinely performed at each step of the surgical procedures [10, 15]. During intradural procedures, stimulation was performed at the operator's instruction and the judgment of the VEP observer when the optic nerve was displaced or suspected to be compressed. In particular, light stimulation and monitoring was frequently performed during direct dissection between the optic nerve and tumor. Amplitude change was defined as a 50% decrease or increase in amplitude

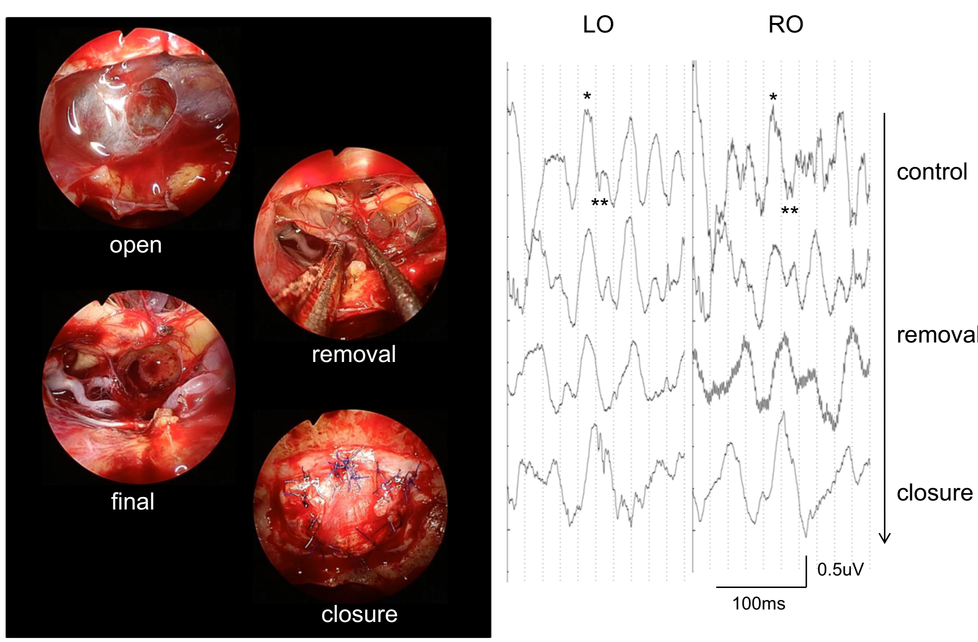

Fig. 2 Case 1. Left: Intraoperative photographs showing exposure of the sellar floor, removal of the tumor, the final view of tumor resection, and closure of the dura. Right: VEP findings showing amplitude preserved to the control level at the final stage of the surgery. In the control, the negative peak around 100 msec (N75) followed by a large positive peak (P100) are indicated by the asterisk and double asterisk, respectively

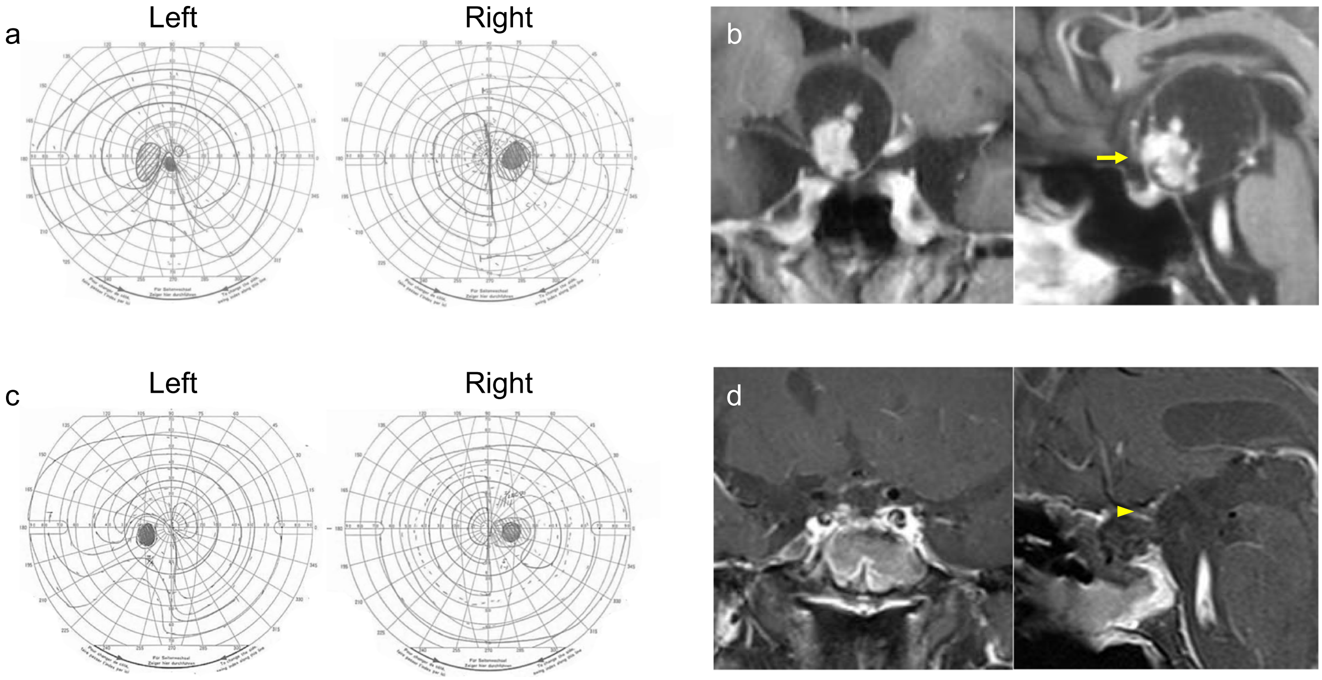

Fig. 3 Case 2. Preoperative Goldmann kinetic perimetry shows irregular temporal hemianopsia (**a**). Preoperative coronal and sagittal T1-weighted MR images after injection of gadolinium. The yellow arrow indicates the optic chiasm, which was identified with reference to the anterior communicating artery complex (**b**). Postoperative visual fields (**c**) show preservation. Postoperative MR images showing complete removal of the tumor. The yellow arrowhead indicates the optic chiasm (**d**)

compared with the control level [9, 10, 15, 16, 22]. However, destabilization of the more fundamental wave shape was also considered a VEP change [16]. The same observer monitored the waveform change over time and judged the change. Extended endoscopic endonasal TSS was performed under VEP monitoring and the optic nerve and tumor were sharply

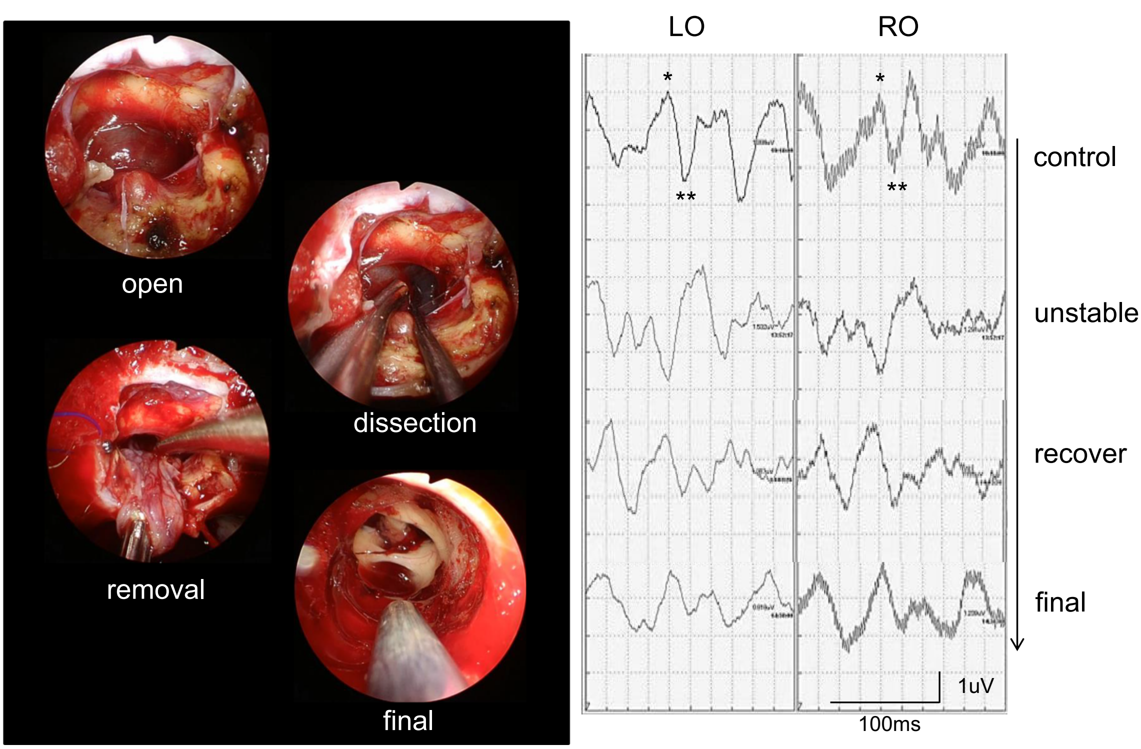

Fig. 4 Case 2. Left: Intraoperative photographs showing exposure of the sellar floor, removal of the tumor, and the final view. Right: VEP findings showing wave changes during tumor resection (unstable). In the control, N75 and P100 are indicated by the asterisk and double asterisk, respectively

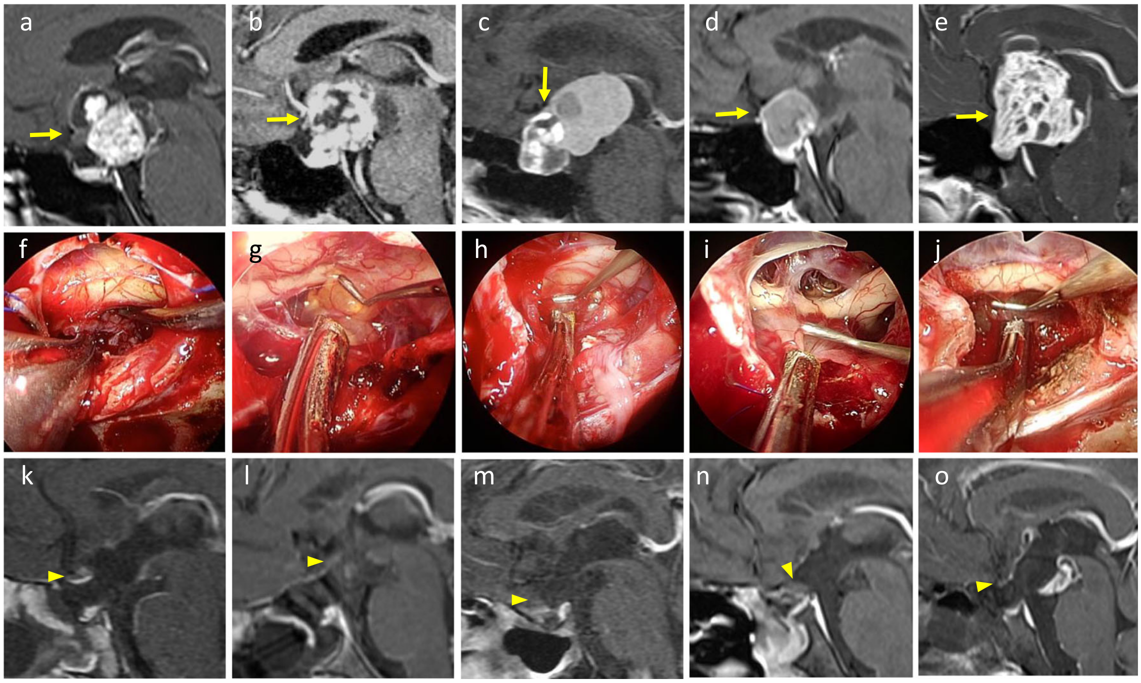

Fig. 5 Pre- and postoperative images, and intraoperative photographs in cases 3 (**a**, **f**, **k**), 4 (**b**, **g**, **l**), 5 (**c**, **h**, **m**), 6 (**d**, **i**, **n**), and 7 (**e**, **j**, **o**). The upper row (**a**–**e**) shows midsagittal T1-weighted MR images with gadolinium before surgery. The yellow arrow indicates the optic chiasm, which was identified with reference to the anterior communicating artery complex. The middle row (**f**–**j**) shows the intraoperative photograph of the intranasal endoscopic view of the dissection between the tumor and the optic chiasm. The lower row (**k**–**o**) shows midsagittal T1-weighted MR images with gadolinium after surgery. The yellow arrowhead indicates the optic chiasm

dissected. If the VEP finding changed and reached the warning criteria, the operator were informed and stopped the surgical manipulation for the optic chiasm to recover. After 5 min, VEP was performed again and the procedure was restarted if recovery was seen. Further 5-min pauses were made in the case of poor recovery. Recovery of VEP was obtained with rest after 5 to 10 min in many cases [10, 22].

Illustrative cases

Case 1

A 61-year-old man presented with visual dysfunction, predominantly in the right eye. Preoperative visual field examination showed severe defect on the right side and upper quadrantanopsia on the left side. Visual acuity with the best corrective lenses was 0.1 in the right eye and 1.2 in the left eye, and VIS was 36 (Fig. 1a). MR imaging showed a suprasellar cystic lesion. The tumor size was 25 × 17 × 26 mm (Fig. 1b). The optic chiasm showed upward displacement. During surgery, dissection between the optic chiasm and tumor was necessary, but fine manipulation was possible because the distance between the optic chiasm and the upper end of the pituitary gland was sufficiently wide. VEPs were stable throughout the surgery. The VEP amplitude was preserved at the end of the tumor resection (Fig. 2). At discharge, postoperative visual field had improved with bilateral visual acuity of 1.2 with the best corrective lenses, and VIS improved to 4 (Fig. 1c). MR imaging showed that the tumor was gross totally removed (Fig. 1d). He returned to his previous work.

Case 2

A 47-year-old female complained of temporal hemianopsia in the right visual field and quadrantanopsia in the left visual field. Visual acuity with the best corrective lenses was 0.7 in the right eye and 0.9 in the left eye, and the VIS was 22 (Fig. 3a). During the operation waiting period, the cyst of the craniopharyngioma underwent minor rupture, and chemical meningitis with severe headache and appetite loss was treated by medical support. MR imaging showed a suprasellar cystic lesion containing partially solid component. The tumor size was 37 × 32 × 36 mm (Fig. 3b). The optic chiasm showed forward displacement, and the distance between the optic nerve and the upper end of the pituitary body was narrow. During surgery, manipulation of dissection between the optic chiasm and tumor was relatively difficult. VEP amplitude temporarily became unstable, and prolonged latency was suspected compared with the control during tumor resection from the optic chiasm. The operator were informed immediately and surgical manipulation was stopped for over 5 min. The VEP amplitude then recovered, operative manipulation was restarted, and the VEP was preserved at the end of the surgery (Fig. 4). At discharge, the postoperative visual field was preserved, visual acuity improved to 1.0 in the right eye and 1.2 in the left eye with the best corrective lenses, and VIS improved to 10 (Fig. 3c). MR imaging showed that the tumor was gross totally removed (Fig. 3d). She returned to her occupation as housewife.

Results

Seven consecutive patients, 4 men and 3 women aged 36–61 years (mean 47.7 years), were treated with extended endoscopic endonasal TSS with VEP monitoring for newly diagnosed craniopharyngiomas with maximum diameters of 25–41 mm (mean 33.7 mm) from December 2015 to March 2018 at Gunma University Hospital (Table 1). The institutional review board of Gunma University Hospital approved the study and written informed consent for the study was obtained from all patients.

The optic chiasm was compressed forward in 5 cases, and upward in 2 cases [21]. Intraoperative direct dissection under the endoscope between the tumor and optic nerve was achieved using VEP in all cases (Figs. 1, 2, 3, 4, and 5). Intraoperative VEPs were stable during surgeries in two patients, but were unstable or the amplitude decreased to below 50% compared with control in two patients, although the VEPs had recovered at the end of the surgery (Table 1). The optic chiasm was decompressed in all cases (Figs. 1, 2, 3, 4, and 5). The N75–P100 components of VEP were preserved at the end of tumor resection in all patients. The mean latencies and amplitudes of N75 were 81.0 ± 11.1 msec and 0.97 ± 0.34 μV. The mean latencies and amplitudes of P100 were 103.3 ± 18.1 msec and 0.82 ± 0.50 μV.

Visual impairment score (VIS) was calculated according to the German Ophthalmological Society by adding the scores of the tables for assessing best corrected visual acuity and the visual field defects; each table combined the findings for both eyes. VIS shows the overall visual function as the sum of the scores of best corrected visual acuity and visual field defects (ranging from 0 to 100) [6, 8]. VIS was calculated based on the results of visual examinations before and soon after surgery (within 2 weeks except for one patient at 6 weeks after surgery). VIS was improved after surgery in all patients. VISs after surgery were significantly lower than that before surgery ($p = 0.018$, Wilcoxon signed-rank test). Subtotal removal (90%) was achieved of the largest, and the second largest tumor (cases 4 and 7), and gross total removal in the other 5 cases based on the intraoperative findings and postoperative MR imaging (Table 1). All patients were discharged without neurological deficits, and returned to their previous occupations. No complication associated with the VEP monitoring occurred.

Discussion

The optic nerve and tumor are directly dissected in the subarachnoid space during extended endonasal TSS for supradiaphragmatic craniopharyngioma [1, 2, 20, 26]. VEP monitoring during extended transsphenoidal removal of craniopharyngioma should be discussed separately from that during conventional, transsellar, and subdiaphragmatic pituitary tumor surgery. A total of 15 cases of surgical removal of craniopharyngioma under intraoperative VEP monitoring have been reported in 4 studies [4, 10, 16, 22]. Six [4] and 2 [10] cases were treated with non-extended TSS, and no direct surgical dissection was performed between the optic nerve and

Table 1 Patient characteristics

No.	Age (years)/sex	Maximum diameter (mm)	Results of resection	Position of the optic chiasm[a]	VEP changes during dissection	VIS[b]	
						Preop.	Postop.
1	61/M	26	GTR	Upward	Stable	36	4
2	47/F	37	GTR	Forward	Transient amp. decrease	22	10
3	57/M	27	GTR	Forward	Transient amp. decrease	25	4
4	36/F	41	Subtotal resection (90%)	Forward	Stable	22	10
5	47/M	40	GTR	Upward	Stable	10	6
6	44/F	25	GTR	Forward	Stable	8	0
7	42/M	40	Subtotal resection (90%)	Forward	Stable	18	10

amp., amplitude; *preop.*, preoperative; *postop.*, postoperative; *VEP*, visual evoked potential; *VIS*, visual impairment score; *GTR*, gross total removal based on the intraoperative findings and postoperative magnetic resonance imaging. [a] The position of the optic chiasm was identified with reference of anterior communicating artery complex in preoperative mid sagittal MR images. [b] VIS shows the overall visual function as the sum of the scores of best corrected visual acuity and visual field defects using a special formula combining left and right sides (ranging from 0 to 100) tumor. Two cases of craniopharyngioma were removed using VEP, similar to our VEP system, but with craniotomy [22]. Three cases without description about approach might have undergone craniotomy [16]. A study of the new generation of VEP in TSS mainly assessed the usefulness and results in pituitary adenoma surgery, included 2 cases of extended microscopic TSS for craniopharyngioma assisted by endoscope, but did not show the surgical and intraoperative technique and findings, pre- and postoperative imaging, and functional results for the two cases of craniopharyngioma [10].

The present study firstly describes purely endoscopic endonasal extended transsphenoidal removal of craniopharyngioma under intraoperative VEP with endoscopic findings, intraoperative VEP findings, and pre- and postoperative visual functions using VIS. We showed that sharp dissection of the optic nerve and tumor is important in the extended endoscopic endonasal TSS, especially in cases with forward displacement of the chiasm such as our case 2 [21]. The close-up endoscopic view itself is important to avoid injuries to the optic chiasm/nerve. Additionally, warnings provided by intraoperative VEP monitoring during extended endoscopic endonasal TSS may be useful in these cases.

Previous reports indicated that VEP was not monitored in patients with corrected visual acuity < 0.1 and visual field less than hemianopia [19, 22]. Our case 1 had visual acuity with the best corrective lenses of 0.1, and visual field was less than hemianopia in the right eye. Reproducible VEP recordings were obtained in his right eye just before the surgical procedure. Visual acuities with the best corrective lens in the other eyes of patients were at least 0.7, and visual fields did not exceed hemianopia. Intraoperative VEPs were detected in all 7 patients. VEPs were stable throughout the surgery in 5 cases, but showed temporary instability and amplitude decrease in 2 cases, although the VEPs had recovered at the end of the surgery. All patients suffered no severe postoperative deterioration in visual function, suggesting that intraoperative VEP monitoring can help prevent postoperative visual dysfunction. However, the intraoperative waveform change indicating warning to the surgeon remains controversial [4, 8, 14, 16, 22].

Sasaki et al. reported that all cases with intraoperative disappearance of VEP or decrease to 20–30% of the control amplitude (without subsequent recover to 50% of the control level) showed apparent deterioration of visual function after surgery [22]. In principle, if the amplitude decreases by more than 50% [9, 14–16, 22], the operator is warned, but instability of the wave is a more fundamental warning factor. Prolonged latencies have also been listed as a warning factor [16]. In the present series, unstable VEP findings were counteracted by temporarily ceasing surgical maneuvers for from 5 to 10 min, then repeating the VEP recording to evaluate the influence on the optic nerve (Fig. 4). The VEP wave disappeared in a case of transient optic nerve ischemia, but recovered 10 min after release of the blood flow [22]. VEP responses were obtained with high stability and reproducibility using the new-generation light stimulation device as shown in Fig. 1, and evaluation of destabilization and amplitude were also possible. Intraoperative continuous trend observation of VEP by the same observer to reliably detect changes may give useful reassurance to the operating surgeon.

Obvious decrease of the VEP occurred due to occlusion of the superior hypophysial artery (SHA) during craniotomy for an aneurysm at the internal carotid artery-SHA junction. Resolution of the occlusion resulted in immediate recovery of the VEP [22]. Occlusion of the SHA is a known cause of visual dysfunction after endonasal extended TSS for craniopharyngioma [7]. On the other hand, the SHA has bilateral anastomoses with the commissural artery and tuberoinfundibular arteries, and large anatomical variations [17].

In this study, transient occlusion of the SHA was not performed. Coagulation of small branches caused no change in the VEP. The applicability of the study is limited by the number of cases and experience with more cases will verify the usefulness of intraoperative VEP monitoring for extended endoscopic endonasal resection of craniopharyngioma.

Conclusion

Intraoperative VEP monitoring is the only way to test visual function during surgery, and may be especially important in extended endoscopic endonasal resection of craniopharyngioma, which requires direct dissection between the optic nerve and the tumor under the endoscope. Our VEP system and monitoring were safe and effective; these caused no complications during extended endoscopic endonasal TSS for craniopharyngiomas and were useful for preservation and improvement of postoperative visual function.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committees of the country of each participating member and with the 1964 Helsinki declaration and its later amendments or comparable standards.

Informed consent Informed consent was obtained from all participants included in the study.

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Comments The authors report on their experience with the use of VEP during endoscopic resection of suprasellar craniopharyngiomas. The series consists of 7 consecutive patients. The paper is well conceived, and the cases are well documented, probably with prospective inclusion and retrospective review of the data. The authors want to make two points: 1) novel techniques for VEP-monitoring are reliable, 2) VEP monitoring during resection of suprasellar craniopharyngiomas is helpful in preserving visual function. The authors advise to stop dissection of the optic chiasm when VEP becomes unstable and wait for more than 5 minutes, then repeating the VEP recording to evaluate the function of the optic structures. They state that continuous intraoperative trend observation of VEP to detect changes gives great reassurance to the surgeon concerning postoperative visual function. Using this technique, no deterioration of visual acuity and visual field occurred. Further studies and a larger experience with this technique are needed, but it seems promising for safer surgery in these patients.

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