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Original Article

Inferior temporal quadrantanopia associated with pituitary adenomas and a potential mechanism of excessive optic nerve bending

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ABSTRACT

Background: Pituitary adenomas show typical visual field defects that begin superiorly and progress inferiorly. The cause of atypical visual field defects that start inferiorly remains unclear. This study aimed to understand this phenomenon using magnetic resonance imaging (MRI).

Methods: A total of 220 patients with pituitary adenomas underwent a visual field assessment of both eyes. Preoperative visual fields were assessed and classified into two types: superior quadrantanopia (typical) and inferior quadrantanopia (atypical). Several parameters related to tumor characteristics and optic nerve compression were evaluated using MRI.

Results: Of the 440 eyes examined, 174 (39.5%) had visual field defects. Of these, 28 (16.1%) had typical and 11 (6.3%) had atypical visual field defects. Patient age, tumor size, degree of cavernous sinus invasion, tumor pathology, and intratumor bleeding were similar between the two groups. The angle formed by the optic nerve in the optic canal and in the intracranial subarachnoid space at the exit of the optic canal (degree of optic nerve bending) was significantly larger in the atypical group than in the typical group (42.6° vs. 23.9°, $P = 0.046$).

Conclusion: In some pituitary adenomas, visual field defects begin inferiorly. This may be caused by optic nerve compression on the superior surface by the bony margin of the optic canal exit. Therefore, pituitary adenomas should be considered in patients with atypical visual field defects.

Keywords: Magnetic resonance image, Optic nerve, Pituitary adenoma, Visual field defects

INTRODUCTION

Visual field defects with pituitary adenomas typically present as bilateral hemianopia and are thought to be caused by upward compression of the optic chiasm by the tumor, resulting in the progression of the visual field defects from the superior to anterior position.[7,18,19,24,26] Surgical removal of the tumor and decompression of the optic nerve may improve the defects. Therefore, assessing visual field defects is important for surgical treatment.[7,24,26] However, in atypical cases, inferior visual field defects arise even though compression of the optic chiasm by the pituitary tumor. An upward compression of the optic chiasm does not explain such findings. Therefore, surgical treatment should be considered after other causes, such as ocular diseases, are ruled out. A previous report has suggested that the cause of inferior dominant visual field defects due to suprasellar meningiomas is compression of the superior aspect of the optic nerve by the falciform ligament.[21] The falciform ligament is a ligamentous structure that forms a roof at the entrance of the optic canal. For this reason, the mass of tumors and aneurysms resting on the inferior aspect of the optic nerve can easily compress the nerve against the falciform ligament, causing inferior quadrantanopia.[1] This study aimed to review cases of pituitary adenomas with atypical visual field defects and to analyze the anatomical cause based on preoperative magnetic resonance imaging (MRI) findings. We also reviewed improvements in visual field defects after surgery and verified whether atypical visual field defects could be cured by surgery for pituitary tumors.

MATERIALS AND METHODS

Study population

This study is a retrospective review of 220 patients who underwent transnasal transsphenoidal surgery for pituitary adenomas between 2001 and 2019 at Kanazawa University Hospital. The Institutional Review Board has approved the study protocol (No. 2014032) and waived the need for informed consent. Patients who had a history of pituitary surgery or radiation therapy, ophthalmic diseases such as glaucoma, or previous craniotomy were excluded from our study. Patient history, including age, sex, tumor histology, radiologic findings, medical history, and visual function impairment, were obtained from medical records. A flowchart depicting inclusion or exclusion criteria is shown in Figure 1.

Ophthalmologic evaluation

Ophthalmologic examinations were performed by experienced ophthalmologists who evaluated the preoperative and postoperative visual fields. Radiologic findings of the patients were not disclosed to the ophthalmologists. Postoperative evaluations were performed within a week after surgery. Visual fields were assessed using a Humphrey field analyzer and kinetic Goldmann perimetry. For qualitative assessment, visual field defects were classified into two types based on the pattern of loss in each eye. Typical types of defects included only the superior quadrant, while the atypical type of defects included the inferior quadrant.

Radiologic evaluation

Preoperative MRI images of the pituitary region were obtained for all patients using a 3-T scanner (MAGNETOM Trio; Siemens, Munich, Germany; or Signa Excite HDx; GE Healthcare, Tokyo, Japan). Pre-enhanced T1- and T2-weighted images and post-enhanced T1-weighted images were obtained for all patients in the sagittal and coronal planes with a 1.5 mm slice thickness. Tumor measurements were defined as follows: maximum craniocaudal diameter was defined as the tumor height; vertical length from the anterior skull base to the top of the tumor was defined as the tumor's top-anterior skull base distance; and cavernous sinus invasion of the tumor was evaluated based on the Knosp grade on coronal images.[17] The angle formed by the optic nerve in the optic canal and the intracranial subarachnoid space at the exit of the optic canal was defined as the sagittal optic nerve canal bending angle (ONCBA). This angle was measured at the entrance of the optic canal on T2-weighted sagittal images [Figure 2].[26] Two independent observers (M.D. and Y.S.) measured the above using customizable MRI image software (Digital Imaging and Communication in Medicine viewer EV Insite R (PSP Corporation, Tokyo, Japan) and assessed the average.

Surgical techniques

All patients underwent transnasal transsphenoidal surgery using microscopic or endoscopic techniques. Subcapsular removal was performed. When possible, the tumors were dissected using the pseudocapsular technique. In cases of intraoperative cerebrospinal fluid leakage, small pieces of abdominal fat and/or fascia were packed into the tumor cavity. Lumbar cerebrospinal fluid drainage was performed after surgery at the operator's discretion, according to the grading system reported by Esposito *et al*.[9] Cases in which surgically removed tumors were pathologically diagnosed as pituitary adenomas were included in this study.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences software (IBM, Armonk, NY, USA). The Mann–Whitney *U*-test was used to compare continuous data (tumor height), and the Chi-square test was used to compare categorical data (Knosp grade) between two groups. Statistical significance was set at $P < 0.05$.

RESULTS

Patient and clinical characteristics

Data from 266 of the 440 evaluated eyes were excluded due to the absence of visual field defects. Out of 174 eyes with visual field defects, 135 (77.6%) were excluded because temporal hemianopia had already occurred. Temporal quadrantanopia was observed in 39 eyes (22.4%), of which 28 (16.1%) and 11 (6.3%) had typical and atypical defects, respectively. The clinical characteristics of the patients in these groups are shown in Table 1.

The mean ages of the patients in the typical and atypical groups were 53.6 years (range 26–79 years) and 70.1 years (range 27–90 years), respectively ($P = 0.004$). There was no significant

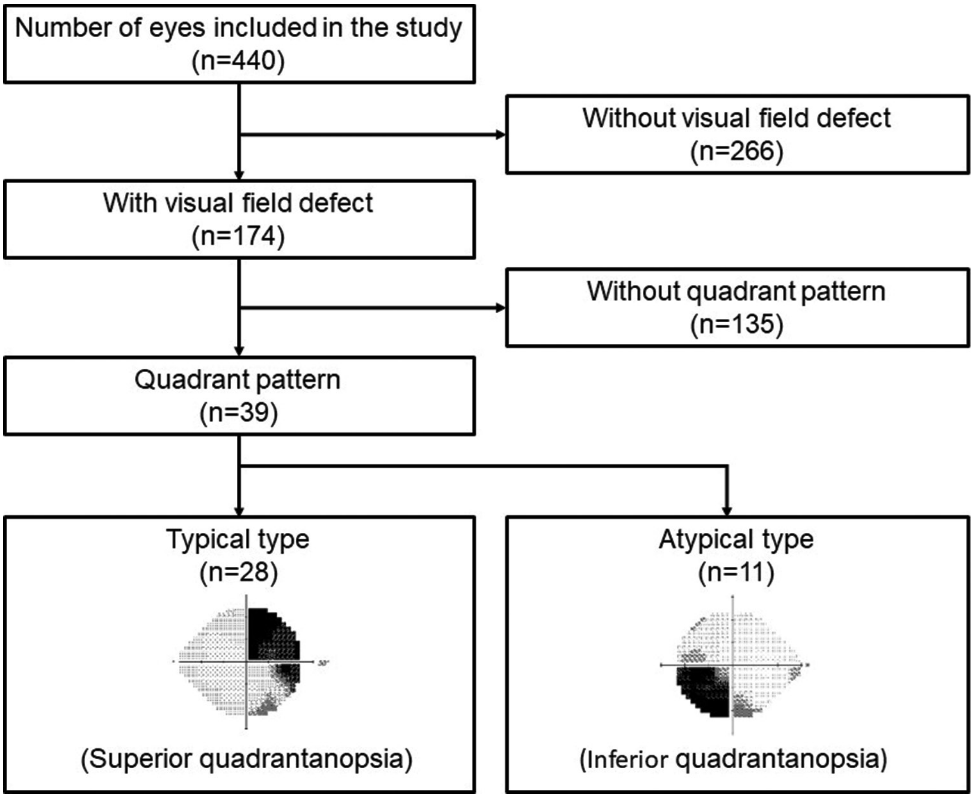

Figure 1: Flowchart showing the inclusion and exclusion criterion of the patient cohort in the study.

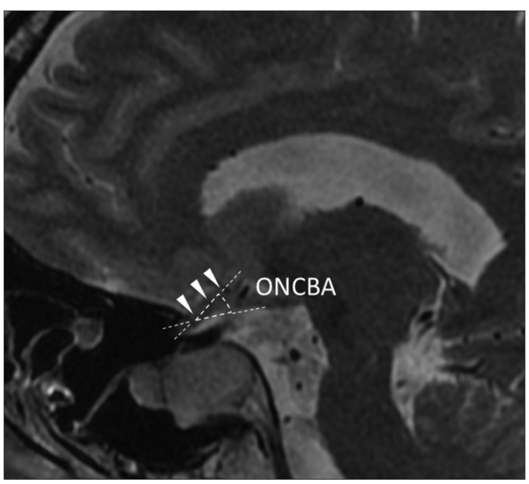

Figure 2: The sagittal T2-weighted image demonstrates the sagittal optic nerve-canal bending angle (ONCBA) formed by the optic nerve in the optic canal and the intracranial subarachnoid space at the junction (arrowheads). The two dotted lines represent extensions of the optic nerve in the optic canal and subarachnoid space whose intersection determines the ONCBA.

difference in the male-to-female ratios between the two groups ($P = 0.243$). Tumor heights were also not significantly different between the two groups (27.7 ± 5.6 mm vs. 32.9 ± 9.6 mm, $P = 0.078$). Moreover, there were no statistically significant differences between the groups in terms of cavernous invasion ($P = 0.198$), histology ($P = 0.981$), and Ki-67 labeling index (1.6% ± 1.3% vs 1.1% ± 1.4%, $P = 0.363$).

Table 1: Baseline demographic characteristics of pituitary adenomas in groups with typical and atypical visual field defects.

	Typical type	Atypical type	*P*-value
Number of eyes	28	11	
Age (year)	53.6 (±13.1)	70.1 (±20.0)	0.004*
Sex (male)	16 (57.1%)	4 (36.7%)	0.243
Tumor size (height), (mm)	27.7 (±5.6)	32.9 (±9.6)	0.078
Cavernous sinus invasion (Knosp grade: 3–4)	14 (50.0%)	3 (27.3%)	0.198
Histology (non-functioning adenoma)	23 (82.1%)	9 (81.8%)	0.981
Ki-67 labeling index (%)	1.6 (±1.3)	1.1 (±1.4)	0.363

*$P<0.01$

Radiological evaluation

All the acquired images provided acceptable diagnostic image quality. A summary of the radiological evaluations of the tumor and its relationship with the surrounding tissues on MRI is shown Table 2.

Tumor top-anterior skull base vertical distance (9.9 ± 2.6 mm vs. 12.9 ± 7.0 mm, *P* = 0.656) and intratumoral bleeding (*P* = 0.711) were not significantly related to the type of visual defects. ONCBA in the atypical group was significantly larger than that in the typical group (42.6° ± 29.5° vs. 23.9° ± 15.6°, *P* = 0.046) [Figure 3].

Visual outcome

The postoperative visual outcomes are reported [Table 2]. The majority of the typical visual field defects (85.7% [24/28 eyes]) improved postoperatively. Both eyes in one patient showed worsening visual field defects due to postoperative hemorrhage. In contrast, the improvement rate in the visual field was only 54.5% (6/11 eyes) in the atypical group, which was less than that in the typical group (*P* = 0.037). Among the atypical group, the characteristics were compared according to visual outcomes [Table 3]. No significant differences were found in demographic characteristics; however, tumor top-anterior skull base vertical distances were predominantly smaller in the improvement group (8.9 ± 3.6 mm vs 17.7 ± 6.3 mm, *P* = 0.048).

Table 2: Comparisons of radiological assessment and visual outcomes of pituitary adenomas in groups with typical and atypical visual field defects.

	Typical type	Atypical type	*P*-value
Number of eyes	28	11	
Tumor top-anterior skull base distance (mm)	9.9 (±2.6)	12.9 (±7.0)	0.656
Intratumor bleeding	12 (42.9%)	4 (36.4%)	0.711
ONCBA (degree)	23.9 (±15.6)	42.6 (±29.5)	0.046*
Postoperative visual improvement	24 (85.7%)	6 (54.5%)	0.037*

*$P<0.05$. ONCBA: Optic nerve-canal bending angle

DISCUSSION

We first analyzed the anatomical relationship around the optic nerve in cases of atypical visual field defects caused by pituitary adenoma. We found excessive bending of the optic nerve where it entered the optic tract to be common in patients with atypical visual field defects due to pituitary adenomas.

Visual field defects caused by pituitary tumors typically present as bilateral hemianopia, which is thought to arise superiorly and progress inferiorly.[16,19,21] Ogra *et al.* reported that out of 99 eyes with visual field defects due to pituitary adenomas, only three had inferior quadratic loss.[19] Schiefer *et al.* reported that out of 153 patients with visual field defects related to chiasmal lesions, only 1% had both temporal inferior quadrants affected.[20] An earlier study of 1000 patients with pituitary adenomas also reported that an atypical pattern was present in only three patients.[13] In our study, 11 out of 440 eyes with pituitary adenomas had inferior dominant visual field defects. However, this rate may be disproportionally high due to the small sample size (220 cases) compared to the number of cases reported in the previous studies; as such, the incidence would become even rarer as the number of cases increases. Therefore, we should still consider MRI images of the head for pituitary tumors, even if inferiorly dominated visual field defects are found on ophthalmological examination.

The underlying mechanism of pituitary adenoma-induced inferior dominant visual field defects may involve demyelination or ischemia. Excessive bending of the optic nerve, which is lifted upward by the tumor at the bony margin of the optic canal exit, results in a strong compression of the superior surface of the optic nerve. In animal studies, continuous compression of the optic nerve leads to demyelination. The remyelinated fibers observed after continuous nerve compression coexist with completely demyelinated fibers and do not appear to revert to their normal thickness and

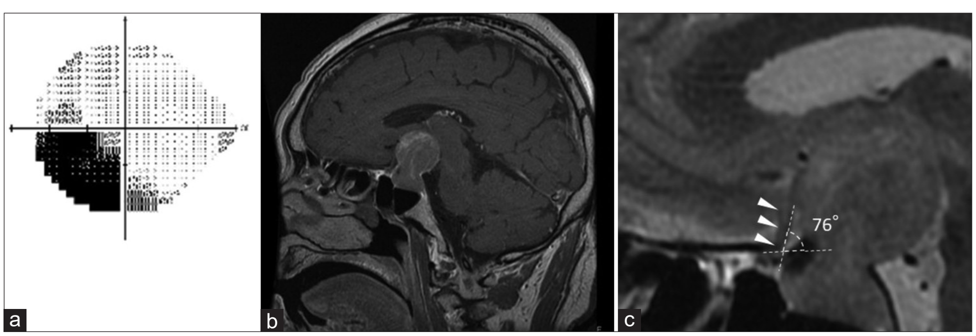

Figure 3: An illustrative case of atypical visual field defects due to a bent optic nerve. (a) The preoperative Humphrey visual field test shows lower quadrantanopia in the left eye. (b) The sagittal gadolinium-enhanced T1-weighted image shows a pituitary adenoma with suprasellar extension. (c) The sagittal T2- weighted image demonstrates that the left optic nerve is bent (optic nerve-canal bending angle: 76°) due to the tumor (arrowheads). At the exit of the optic canal, the upper surface of the nerve appears to be compressed by the bony structure.

Table 3: Comparisons of demographic and radiographic features in visual outcomes of pituitary adenomas with atypical visual field defects.

	No Improvement	Improvement	*P*-value
Number of eyes	5	6	
Age (year)	75.6 (±6.5)	65.5 (±24.2)	0.407
Sex (male)	3 (60.0%)	1 (16.7%)	0.137
Tumor top-anterior skull base distance (mm)	17.7 (±6.3)	8.9 (±3.6)	0.048*
Intratumor bleeding	2 (40.0%)	4 (66.7%)	0.819
ONCBA (degree)	50.2 (±23.9)	36.3 (±29.8)	0.459
Ki-67 labeling index (%)	1.3 (±0.7)	1.7 (±1.2)	0.555

**P*<0.05. ONCBA: Optic nerve-canal bending angle

tissue structure.[3,4,22] Thus, demyelination with partial remyelination due to nerve compression leads to progressive deterioration of optic nerve function. In addition, partial ischemia may occur due to bending and stretching of the optic nerve. The posterior part of the optic nerve, which includes intracranial and intracanalicular parts, has only a pial vascular plexus supplied by a variable number of fine branches originating from surrounding arteries.[2,12] This part may be more prone to ischemic neuropathy than the anterior part of the optic nerve, which is supplied by posterior ciliary artery circulation. Although inferior-dominant visual field defects most commonly present with anterior ischemic optic neuropathy,[23] they can also occur in posterior ischemic optic neuropathy due to partial ischemia caused by compression. In addition, ischemia in elderly patients may result in visual field impairment; reports have shown that visual field defects due to pituitary adenomas are seen in older patients.[19]

In our study, the superior surface of the optic nerve, which could be a finding supporting this study, could not be observed intraoperatively using transsphenoidal surgery; however, there have been reports of intraoperative visualization of the optic nerve during craniotomy for suprasellar meningiomas. Shapey *et al*. performed a craniotomy in a case of suprasellar meningioma with inferiorly dominated visual field defects and found a trace of compression on the superior surface of the optic nerve by the falciform ligament.[21] Moreover, there may have been cases of bilateral hemianopia in which visual field impairment started inferiorly and progressed superiorly. Although it may be difficult to detect the mechanism of visual field defects based on MRI findings alone, atypical cases may be present in patients whose condition does not immediately improve following surgery.

Visual field defects caused by pituitary tumors can be improved by decompression of the optic nerve with surgical removal of the tumor.[5,8] It has been reported that atypical visual field defects can also be improved by surgery;[16,21] However, the improvement rate is lower than that of the typical type, as per our study. The dural sheath of the optic nerve is tightly bound to the periosteum and is the most vulnerable to damage due to its close attachment to the optic nerve.[11,24] This leads to demyelination and ischemia, which may be related to poor postoperative recovery. It has been reported that visual field defects improve immediately after surgery[14] and continue to do so for several years.[10,15] In this study, ophthalmological examinations were only performed within the 1st postoperative week; therefore, even atypical types may show long-term improvement. In addition, optical coherence tomography can predict postoperative visual field improvement in patients with pituitary adenomas;[6,25] however, we did not have sufficient data to examine this.

The study's limitations are its retrospective design and inclusion of a small patient population. Another limitation is the lack of long-term follow-up. As mentioned above, it is possible that the atypical group with poor visual outcomes in this study may also have improved their visual field impairment in the long term. It is important to examine the long-term visual outcomes and compare them between the two groups, which can lead to different results from the current study. In addition, kinetic vision testing was only used in some patients. Although static vision testing is a well-established and commonly used quantitative method to evaluate visual field defects in clinical practice, future analyses using kinetic vision testing would strengthen our findings.

CONCLUSION

Excessive bending of the optic nerve at the edge of the optic canal observed using preoperative MRI is associated with inferior temporal quadrantanopia due to pituitary adenoma. Even if atypical visual field defects are found after visual field testing, pituitary tumors cannot be ruled out.

Ethical approval

The Institutional Review Board has approved the study protocol (No. 2014032) dated on June 19, 2019.

Declaration of patient consent

Patient's consent not required as patient's identity is not disclosed or compromised.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

REFERENCES

1. Altafulla JJ, Iwanaga J, Kikuta S, Prickett J, Ishak B, Uz A, *et al*. The falciform ligament: Anatomical study with microsurgical implications. Clin Neurol Neurosurg 2020;195:106049.
2. Biousse V, Newman NJ. Ischemic optic neuropathies. N Engl J Med 2015;372:2428-36.
3. Clifford-Jones RE, Landon DN, McDonald WI. Remyelination during optic nerve compression. J Neurol Sci 1980;46:239-43.
4. Clifford-Jones RE, McDonald WI, Landon DN. Chronic optic nerve compression. An experimental study. Brain 1985;108:241-62.
5. Comtois R, Beauregard H, Somma M, Serri O, Aris-Jilwan N, Hardy J. The clinical and endocrine outcome to trans-sphenoidal microsurgery of nonsecreting pituitary adenomas. Cancer 1991;68:860-6.
6. Danesh-Meyer HV, Wong A, Papchenko T, Matheos K, Stylli S, Nichols A, *et al*. Optical coherence tomography predicts visual outcome for pituitary tumors. J Clin Neurosci 2015;22:1098-104.
7. Dekkers OM, de Keizer RJ, Roelfsema F, Vd Klaauw AA, Honkoop PJ, van Dulken H, *et al*. Progressive improvement of impaired visual acuity during the first year after transsphenoidal surgery for non-functioning pituitary macroadenoma. Pituitary 2007;10:61-5.
8. Dekkers OM, Pereira AM, Roelfsema F, Voormolen JH, Neelis KJ, Schroijen MA, *et al*. Observation alone after transsphenoidal surgery for nonfunctioning pituitary macroadenoma. J Clin Endocrinol Metab 2006;91:1796-801.
9. Esposito F, Dusick JR, Fatemi N, Kelly DF. Graded repair of cranial base defects and cerebrospinal fluid leaks in transsphenoidal surgery. Oper Neurosurg (Hagerstown) 2007;60(4 Suppl 2):295-303; discussion 303-4.
10. Gnanalingham KK, Bhattacharjee S, Pennington R, Ng J, Mendoza N. The time course of visual field recovery following transphenoidal surgery for pituitary adenomas: Predictive factors for a good outcome. J Neurol Neurosurg Psychiatry 2005;76:415-9.
11. Guler TM, Yilmazlar S, Ozgun G. Anatomical aspects of optic nerve decompression in transcranial and transsphenoidal approach. J Craniomaxillofac Surg 2019;47:561-9.
12. Hayreh SS. Ischemic optic neuropathy. Prog Retin Eye Res 2009;28:34-62.
13. Hollenhorst R, Younge B. Ocular manifestations produced by adenomas of the pituitary gland analysis of 1000. In: Kohler PO, Ross GT, editors. New York: Elsevier; 1973.
14. Jakobsson KE, Petruson B, Lindblom B. Dynamics of visual improvement following chiasmal decompression. Quantitative pre- and postoperative observations. Acta Ophthalmol Scand 2002;80:512-6.
15. Kerrison JB, Lynn MJ, Baer CA, Newman SA, Biousse V, Newman NJ. Stages of improvement in visual fields after pituitary tumor resection. Am J Ophthalmol 2000;130:813-20.
16. Kim JH, Kim CY, Yang HK, Hwang JM. Unusual chiasmal visual field defects. Neurol Sci 2013;34:2057-60.
17. Knosp E, Steiner E, Kitz K, Matula C. Pituitary adenomas with invasion of the cavernous sinus space: A magnetic resonance imaging classification compared with surgical findings. Neurosurgery 1993;33:610-7; discussion 617-8.
18. Lee IH, Miller NR, Zan E, Tavares F, Blitz AM, Sung H, *et al*. Visual defects in patients with pituitary adenomas: The myth of bitemporal hemianopsia. AJR Am J Roentgenol 2015;205:W512-8.
19. Ogra S, Nichols AD, Stylli S, Kaye AH, Savino PJ, Danesh-Meyer HV. Visual acuity and pattern of visual field loss at presentation in pituitary adenoma. J Clin Neurosci 2014;21:735-40.
20. Schiefer U, Isbert M, Mikolaschek E, Mildenberger I, Krapp E, Schiller J, *et al*. Distribution of scotoma pattern related to chiasmal lesions with special reference to anterior junction syndrome. Graefes Arch Clin Exp Ophthalmol 2004;242:468-77.
21. Shapey J, Danesh-Meyer HV, Kaye AH. Suprasellar meningioma presenting with an altitudinal field defect. J Clin Neurosci 2012;19:155-8.
22. Smith KJ, Blakemore WF, McDonald WI. The restoration of conduction by central remyelination. Brain 1981;104:383-404.
23. Traustason OI, Feldon SE, Leemaster JE, Weiner JM. Anterior ischemic optic neuropathy: Classification of field defects by Octopus automated static perimetry. Graefes Arch Clin Exp Ophthalmol 1988;226:206-12.
24. Wang H, Sun W, Fu Z, Si Z, Zhu Y, Zhai G, *et al*. The pattern of visual impairment in patients with pituitary adenoma. J Int Med Res 2008;36:1064-9.
25. Wang MT, King J, Symons RC, Stylli SS, Meyer J, Daniell MD, *et al*. Prognostic utility of optical coherence tomography for long-term visual recovery following pituitary tumor surgery. Am J Ophthalmol 2020;218:247-54.
26. Yamaguchi R, Tosaka M, Miyagishima T, Osawa T, Horiguchi K, Honda F, *et al*. Sagittal bending of the optic nerve at the entrance from the intracranial to the optic canal and ipsilateral visual acuity in patients with sellar and suprasellar lesions. J Neurosurg 2019;134:180-8.

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