Original article

Preoperative evaluation of the interface between tuberculum sellae meningioma and the optic nerves on fast imaging with steady-state acquisition for extended endoscopic endonasal transsphenoidal surgery

Yasuhiko Hayashi[1], M.D., Ph.D., Daisuke Kita[1], M.D., Ph.D., Issei Fukui[1], M.D., Yasuo Sasagawa[1], M.D., Ph.D., Masahiro Oishi[1], M.D., Osamu Tachibana[2], M.D., Ph.D., Fumiaki Ueda[3], M.D., Ph.D., Mitsutoshi Nakada[1], M.D., Ph.D.

Department of Neurosurgery[1] and Radiology[3], Graduate School of Medical Science, Kanazawa University, Kanazawa, Japan

Department of Neurosurgery[2], Kanazawa Medical University, Kanazawa, Japan

A running head; interface between tuberculum sellae meningioma and optic nerves

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Corresponding author; Yasuhiko Hayashi, M.D., Ph.D

13-1 Takara-machi, Kanazawa, Ishikawa, 920-8641, Japan

TEL; +81-76-265-2384, FAX; +81-76-234-4262

e-mail; yahayashi@med.kanazawa-u.ac.jp

Abstract

Introduction Endoscopic endonasal transsphenoidal surgery (EETS) is increasingly applied to treat tuberculum sellae meningiomas. However, if the tumor adheres firmly to the optic nerve, dissection of the interface between both structures should be prudent to preserve visual function. The purpose of this study was to investigate whether tumor adhesion to the optic nerve can be predicted preoperatively by fast imaging with steady-state acquisition (FIESTA).

Methods Twenty-two patients with tuberculum sellae meningioma treated with EETS were retrospectively identified. Clinical characteristics, radiological studies, intraoperative findings, and outcomes were reviewed from their clinical charts.

Results Patients' symptoms included visual function impairment in 18 patients and headaches in 4 patients. Symptoms were resolved in 19 patients after operation. Preoperative radiological evaluation was performed in 44 sides (22 patients) of the interface between tumors and the optic nerves, and revealed absence of peritumoral hyperintensity on FIESTA in 7 sides in 7 patients. In 5 out of the 7 sides, tumor dissection was complicated by firm adhesion to the optic nerves. Among these cases, visual functions were unchanged in 1 patient after complete removal of the adhesion, however, substantially improved in 3 patients after partial resection. In the remaining 37 sides with preoperative peritumoral hyperintensity, no adhesion was found between both structures intraoperatively.

Conclusion Absence of peritumoral hyperintensity between tuberculum sellae meningioma and the optic nerve on FIESTA may indicate firm adhesion at the interface, severely complicating complete removal. Preoperative recognition of this adhesion is important for safe tumor removal and preservation of visual functions.

Introduction

Endoscopic endonasal transsphenoidal surgery (EETS) is increasingly applied to treat tuberculum sellae meningiomas with the advancement and worldwide spread in the use of endoscopy [1,2]. EETS has the following advantages: low invasiveness for the surrounding brain parenchyma and compressed optic nerves, complete removal of dural attachment, and coagulation of dural feeding arteries before removal of tumor [1-3]. However, we occasionally encountered firm adhesion between tumor and the optic nerves. In these cases, the dissection of the adhered portion might induce severe damage to the optic nerve, leading to the deterioration of visual functions [4]. Therefore, it might be advisable to leave the adhered portion untouched to preserve visual functions postoperatively. As pituitary macroadenomas are usually removed with intracapsular dissections, the tumor capsule protects the optic nerves, the optic chiasm, and the supraclinoid portion of the internal carotid artery (ICA). Long-term compression of the tumor moves the arachnoid membrane between the tumor capsule and the optic nerves. Therefore, the adhesion becomes too strong to be easily detached.

The validity of detecting peritumoral hyperintensity on T2-weighted images (WIs) or fast imaging with steady-state acquisition (FIESTA) of magnetic resonance (MR) imaging of intracranial meningiomas in a preoperative evaluation of the interface between the tumor and the surrounding brain has been well established [4,5]. The key characteristic of FIESTA is the high discriminability between neural tissue and cerebrospinal fluid (CSF) [4-6]. A deterioration of this hyperintensity indicates that there is no CSF space between the tumor and the surrounding tissue, suggesting adhesion of the tumor capsule to the adjacent brain tissue.

Intraoperative recognition of the adhesion between the tumor and the optic nerve is one of the most important steps in the process of EETS. Dissection of the adhesion between the tumor and the optic nerves bears the risk of deteriorating visual functions [1-3]. Therefore, preoperative prediction of optic nerve adhesion enables us to devise a safer surgical strategy leading to postoperative preservation of visual functions [3,4]. In this study, we focused on detecting peritumoral hyperintensity in FIESTA to safely remove tuberculum sellae meningioma with consideration of incomplete removal of the adhered portions on the optic nerves.

Methods

Patient characteristics

This study was approved by Kanazawa University Institutional Review Board. In this retrospective clinical study, 22 consecutive patients who underwent EETS for tuberculum sellae meningioma between 2007 and 2016 at Kanazawa University Hospital were reviewed. Symptoms of the 22 patients in this study consisted of visual function disturbance in 18 patients and headaches in 4 patients. Tuberculum sellae meningioma in all patients had been detected and diagnosed by MR imaging preoperatively. All patients agreed to undergo surgery for the tumors with EETS. We compiled the following items from their clinical charts: sex, age, symptoms, finding of MR images, operative records, complications, and outcomes. Informed consent for reviewing their clinical data was obtained from all 22 patients presented in this study.

Neuroradiological evaluation

We utilized a 3.0-Tesla MR imaging (GE Health care Japan Corp., Tokyo) to obtain axial, coronal, and sagittal sections, before and after gadolinium administration. Neuroradiological evaluation was undertaken to obtain the following tumor characteristics, including maximum diameter, intensities of T1- and T2-WIs, and FIESTA. A three-dimensional FIESTA was performed in our institute according to the following protocol: repetition time, 430-460 ms; echo time, 2.0-2.2 ms; flip angle, 50°; field of view, 18 x 18 cm; matrix, 224 × 256; section thickness, 1.0 mm and section gap, 0.5 mm; number of excitations, 1. In both axial and coronal sections, the assessment of hyperintensity at the interface between the tumor margin and the optic nerve or the ICA was performed using FIESTA with contrast enhancement (CE). The absence of hyperintensity at the interface was presumed to indicate adhesion between the tumor and the optic nerve or the ICA (Figure1). And if the hyperintensity between the tuberculum sellae meningioma and the optic nerve/chiasm was not detected in at least one slice all the interface in both axial and coronal sections on FIESTA, we assessed the hyperintensity between both structure as “absence” (Table 2). In addition, to measure optic nerve characteristics, fluid attenuated inversion recovery (FLAIR) was evaluated to assess edema in the optic nerve. Based on this measurement, hyperintensity of the optic nerve was inferred, because edemas were likely caused by tumor compression.

Lateral extension of the tumors was evaluated on the basis of coronal section of FIESTA and classified as follows: group A, extension within the medial side of the ICA; group B, extension within the medial side of the anterior clinoid process (ACP); group C, extension within the lateral side of the ACP; group D, extension beyond the lateral side of the ACP. Calcification of tumors was evaluated based on bone images of computed tomography scan. The presence of the hyperintensity on FIESTA at the interface and the presence of postoperative residual tumors were evaluated by at least two neurosurgeons and a neuroradiologist. The final decision was made by consensus.

Operation

Basically, we select EETS as surgical procedure for all the tuberculum sellae meningiomas with maximum diameter less than 35mm. We believe the extended EETS provides us following advantages; coagulation of feeding arteries, removal of dural attachment at the tuberculum sellae before tumor resection, and possible avoidance of excess manipulation to the surrounding brain parenchyma and the optic nerve/chiasm.

The operation was performed under general anesthesia and tracheal intubation. The patients were placed in a supine position and heads were fixed in a Mayfield headrest. A rigid endoscope with a diameter of 4 mm and a length of 18 cm, and 0°, 30°, and 45° optics (Karl Storz Endoscope, Karl Storz, Tuttlingen, Germany) was used. Two surgeons performed the operation in close cooperation. Both nasal cavities were used as surgical corridors and the middle turbinate was removed if necessary. Nasal mucosa and the perpendicular plate at the nasal septum were preserved for the reconstruction of the skull base. Both sides of the sphenoid ostiums were enlarged, and the anterior wall of the sphenoid sinus was widely removed. The anterior surface of the sella, tuberculum sellae and the posterior part of the planum sphenoidale were removed with a high-speed drill and Kerrison Rongeur to expose the tumor and the suprasellar cistern. The dura was incised longitudinally at the midline and horizontally at the level of the optic canal. The intercavernous sinus was well coagulated with a bipolar coagulator. The dura mater at the attachment of the meningioma was removed as much as possible. After internal debulking of the tumor using an ultrasonic surgical aspirator, dissection between the tumor capsule and the optic nerve or the ICA was performed with possible preservation of the surrounding arachnoid membrane. If tumors invaded the optic canal, the anterior wall of the canal and the dura behind it were opened, and the tumor was removed by dissection from the optic nerve.

After tumor removal, grafts of fat and fascia at the abdomen were placed into the tumor cavity, and autologous bone from the nasal septum was inserted at the epidural space. The surface of the bone was sealed with fibrin glue and then covered with a pedicled mucosal flap. Lumber drainage was placed for 3-4 days after the operation.

Pathological examination of the surgical specimen was routinely performed using hematoxylin and eosin staining, immunohistochemical staining for the diagnosis of meningioma, and Ki-67 for the assessment of malignancy grade.

Statistical analysis

A Mann-Whitney U-test was applied for comparison in sizes of tuberculum sellae meningioma between the tumors with the hyperintensity at the interface and those without it, and between the tumors with intraoperative firm adhesion at the interface and those without it. These statistical analyses were performed using Microsoft Statview (ver.5, SAS institute Inc., Chicago, Illinois, USA). A P value of < 0.05 was considered as statistically significant.

Results

Patient characteristics

Of the 22 patients reviewed, 7 were men and 15 were women. The mean age of the patients was 58.2 (32-87) years. Their symptoms consisted of visual function disturbance in 18 patients and headaches in 4 patients. Symptoms were completely or substantially resolved in 19 out of these 22 patients. During the observation period, all patients with tuberculum sellae meningioma who intended to undergo operation were treated with extended EETS. None of the four patients with headaches used painkillers daily, but their activities of daily living were mildly disturbed. Their postoperative states were excellent and painkiller free. The remaining 18 patients with visual function disturbance presented with impairment of both visual acuity and field defects. Postoperatively, symptoms were resolved in 13, improved in 6, and unchanged in 3 patients. Pathological examination of the surgical specimen resulted in the diagnosis of meningioma in all the patients included in this study.

Neuroradiological evaluation

Intensities of tumor contents were as follows: In T1- WI, hypointensity was found in 3 patients and isointensity was found in 19 patients. In contrast, in T2-WI, isointensity was observed in 3 patients and hyperintensity was observed in 19 patients. Most tumor intensities were isointensity in T1-WI and hyperintensity in T2-WI, similar to previously reported intensities in typical meningiomas. Patients with hypointensity in T1-WI and isointensity in T2-WI harbored calcification inside the tumors. Calcification might influence the assessment of the tumor intensities. The average maximum diameter of the tumors was 24.3 mm (range, 15-34 mm; Table 1).

In 44 sides of the 22 patients, lateral extension grades of tumors were divided into 4 groups as described in the Methods section. We obtained the following results: 12 sides in group A, 18 sides in group B, 12 sides in group C, and 2 sides in group D. Involvement of the optic canal was found in 7 sides in 7 patients; all of these cases belonged to group C (Table 1). Optic nerve hyperintensity on FLAIR images was detected in 2 patients whose visual functions were more severely impaired. In these patients, adhesion of the interface between the tumor capsule and the optic nerve was found (Table 2).

Preoperatively, all parts of both the optic nerve and the optic chiasm were imaged in all the patients. Peritumoral hyperintensity on FIESTA-CE was identified at the interfaces in 37 out of 44 sides (84.1%) in 22 patients in FIESTA-CE (Figure 1). Absence of peritumoral hyperintensity between tuberculum sellae meningioma and the optic nerve was detected in the remaining 7 out of 44 sides (15.9%, Figure 2-4). The average size of tumors with hyperintensity at the interface (24.1 mm) was not statistical different from that without hyperintensity (24.6 mm, p = 0.83). Among the 5 cases of adhered portions between tumor and the optic nerve that had been confirmed intraoperatively (Figure 2, 3), 1 and 4 cases belonged to group B and C, respectively. The average size of tumors with firm adhesion at the interface (23.6 mm) was not statistically different from those without it intraoperatively, either (26.8 mm, p = 0.22). The second important intraoperative focus was the interface between tumor and the ICA. Our results from FIESTA-CE showed that the hyperintensity between tumor and the ICA was detected in 44 sides in 22 patients, and no adhesion between these two structures was identified intraoperatively (Table 2).

Results of extended EETS for tuberculum sellae meningioma

Tumor removal was complete in 15 patients, incomplete in 3 patients, and partial in 4 patients. Extended EETS was performed in all the patients without major neurological deterioration. Postoperative complications were transient oculomotor palsy in 1 patient and transient diabetes insipidus in 2 patients.

Areas with absent peritumoral hyperintensity between tuberculum sellae meningioma and the optic nerves on FIESTA-CE were observed in 7 sides in the 7 patients, as mentioned previously. In 5 out of the 7 sides, firm adhesion, which introduced difficulties in dissecting tumors from the optic nerves, was found intraoperatively at the interface between both structures. And, in other 39 sides, no adhesion was recognized. Among them, 2 sides in 2 patients had absence of the peritumoral hyperintensity, and the remaining 37 sides in 22 patients had presence of the hyperintensity at the interface between tumor and the optic nerves on FIESTA-CE. The sensitivity and the specificity of the absence of peritumoral hyperintensity on the intraoperative detection of adhesion between tumors and optic nerves was 71.4% and 100%, respectively. Although the number was limited to only 2 cases about the hyperintensity of the optic nerve on FLAIR images, we propose to combine the assessment of the peritumoral hyperintensity and the intrinsic changes of the optic nerve/chiasma as predictors of the adhesiveness. The absence of peritumoral hyperintesity at the interface was sensitive but less specific. On the other hand, the intrinsic change of the optic nerve/chiasma was less sensitive but more specific. No vascular injury related to the ICA emerged intraoperatively and no postoperative hemorrhage or infarction occurred (Table 2).

Regarding visual functions in this study, visual function impairments were postoperatively resolved in 9 patients, improved in 7 patients, and unchanged in 2 patients. However, we had difficulties in tumor removal because of severe adhesion of the tumor to the optic nerve in 5 cases, as described earlier. Resection of the adhered portion yielded the following results in these 5 patients: complete removal led to unchanged visual function in 1 patient, and incomplete resection led to substantially improved visual function in the remaining 4 patients (Table 3).

Discussion

Dissection of firm adhesion of tumors to the optic nerve and the ICA should be performed carefully to preserve visual function and avoid vascular injury leading to the life-threatening deterioration of the patient's condition [3,4]. Our results clearly show that the presence of adhesion between tumors and optic nerves can be predicted by absence of hyperintensity at the interface between both structures on FIESTA-CE. In addition, no adhesion between tumors and ICAs were observed intraoperatively, and hyperintensity between both structures on FIESTA-CE was found in all the patients.

FIESTA can provide strong T2 contrast, emphasizing CSF signals. In addition, FIESTA offers a high signal-to-noise ratio and inherent flow compensation, which is suitable for direct three-dimensional imaging [5-7]. Therefore, FIESTA can show even small structures surrounded by CSF [8]. Gadolinium-based contrast material can increase the relative contrast between background structures and the cranial nerves within the cisterns or in the cavernous sinus when using FIESTA [9]. However, conventional MR imaging often fails to show optic nerves and tracts because of their marked thinning caused by long-term compression by a tumor. Watanabe et al. showed the usefulness of FIESTA-CE, which can identify the anterior optic pathway including the optic nerve and the optic chiasm, in patients with large suprasellar tumors [4,10]. Yamamoto et al. showed that dural attachment of intracranial meningioma could be clearly delineated using FIESTA-CE at 3 T [11].

Cautious dissection of the tumor from the inferior surface of the optic nerve (under a close view using the endoscope) is performed to avoid damaging the arachnoid sheet covering the arterial vascular supply to the optic pathway [1]. However, if the arachnoid sheet is absent from the interface between the tumor capsule and the optic nerve, adhesion has likely occurred and sharp dissection is required. Therefore, if adhesion can be predicted at the preoperative assessment, the adhesive portion can be left in place to preserve the function of the optic pathway.

Our results showed that in 5 out of 7 cases with absence of hyperintensity at the interface between tumor and the optic nerves on preoperative FIESTA images, firm adhesion at the interface was found intraoperatively. In addition, in the other 37 sides from 22 patients with hyperintensity at the interface, no firm adhesion at the interface was observed intraoperatively. Our results show that postoperative visual functions including visual acuity and visual field remained unchanged in 1 patient who had undergone complete removal, and improved in 3 patients who had undergone incomplete removal. Complete removal of the tumor including the severely adhered portion might have damaged the optic nerves, which might have canceled the effect of decompression. In contrast, incomplete removal of the tumor, leaving the adhered portion, might improve visual function without damaging the optic nerve.

Margalit et al. reported a surgical technique for resection of meningiomas involving the optic nerves using a frontotemporal approach [12]. These investigators emphasize the importance of identification and separation of the tumor from the nerve with minimal manipulation of the optic nerve. Regarding treatment of tuberculum sellae meningioma, Ohta et al. emphasizes the importance of the surgical technique used to separate the optic nerve from the tumor and to preserve the feeding arteries of the optic nerve, especially in cases with long-standing and severe visual disturbance [13]. However, neither of these studies commented on preoperative radiological evaluation and dissection procedures for the adhered potion of the tumor to the optic nerves.

In our series, 3 out of 5 cases with firm adhesion at the interface between the tumor and the optic nerve showed lateral extensions of the tumors reaching the lateral side of the ACP. The dissection of the adhered portion could be performed under the endoscopic view regardless of the lateral extensions of the tumors. Therefore, if the preoperative evaluation of the adhesion at the interface between the tumor and the optic nerves were accurate, this surgical procedure of tumor removal would be effective and safe [14-16]. The importance of preoperative detection of the presence or absence of peritumoral hyperintensity at the interface in FIESTA-CE should be emphasized to preserve the postoperative visual functions [17,18].

There are some limitations to our study. First, this study included its retrospective. Second, total number of patients (22 patients) was too small to obtain significant statistical power. Third, the decision on the presence or absence of hyperintensity at the interface was made by inspection by neurosurgeons and a neuroradiologist. Nevertheless, the decision was subjective. Forth, the information about preoperative and postoperative visual function impairment was not enough, and the assessment was not scored on a visual impairment scale.

Conclusion

Absence of peritumoral hyperintensity between tuberculum sellae meningioma and the optic nerve on FIESTA predicted the existence of severe adhesion at the interface with high specificity. In these cases, complete intraoperative dissection was considered to be difficult. Preoperative recognition of the adhesion at the interface between the two structures is important to perform tumor removal safely. If the adhesion was too firm to dissect the tumor from the optic nerve, we recommend leaving the adhered portion of the tumor to preserve postoperative visual functions. Therefore, a FIESTA sequence for positive or negative between tumor and the optic nerve could predict adhesion at the interface and potentially inform the surgical plan.

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Figure Legends

Figure 1; Pictures of representative cases showing the interfaces between tuberculum sellae meningioma and the optic nerve on coronal (a) and axial (b) sections of FIESTA with contrast enhancement (CE). The hyperintensity areas at the interface between the tumor (asterisk) and the optic nerve (arrows) of the both sides were clearly visible (arrowheads). (c) Intraoperative picture clearly depicted the tumor was totally removed without any adhesion to the optic nerve as expected preoperatively, resulting in excellent recovery of visual function.

Figure 2; The coronal (a) and axial section (b) of FIESTA with CE reveal the hyperintensity area at the interface between the tumor (asterisk) and the optic nerve (arrows) was absent (arrowheads). Intraoperative picture (c) displayed the tumor (black asterisk) severely adhered to the optic nerve (black arrows) on the left side. The tumor was partially removed, leaving the adhered portion. Remarkably, visual function impairment was resolved.

Figure 3; The coronal (a) and axial section (b) of FIESTA with CE reveal the hyperintensity area at the interface between the tumor (asterisk) and the optic nerve (arrows) was absent (arrowheads). Intraoperative picture (c) showed the tumor (black asterisk) severely adhered to the optic nerve (black arrows) on the left side. Although the tumor was totally removed, visual function impairment was unchanged.

Figure 4; The coronal (a) and axial section (b) of FIESTA with CE reveal the thin hyperintensity area at the interface between the tumor (asterisk) and the optic nerve (arrows) was faintly present (arrowheads) on the right side. Intraoperative picture (c) revealed the complete configuration of optic nerve on the right side was preserved without any severe dissection of tumor. Even if only thin and faint hyperintensity at the interface could be recognized on preoperative MRI, severe adhesion could not be found intraoperatively. The tumor was totally removed, and visual function impairment was remarkably improved.

Table Legends

Table 1

Clinical characteristics of the patients in this study

Table 2

Comparison between preoperative MR images and intraoperative findings

Table 3

Comparison of tumor removal of adhered portions and visual function outcomes

Figure 1

Yasuhiko Hayashi

(a) (b) (c)

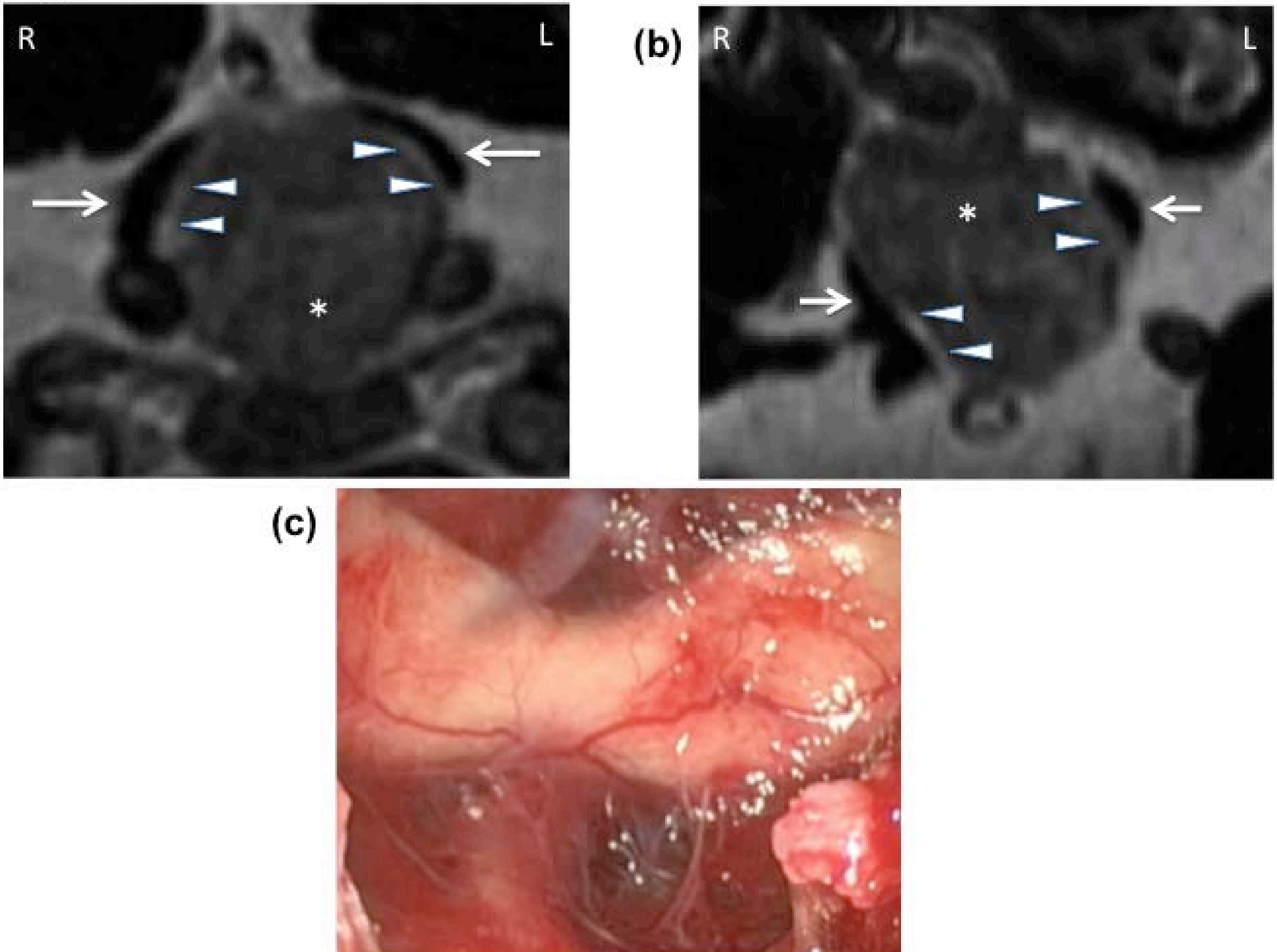

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Figure 2

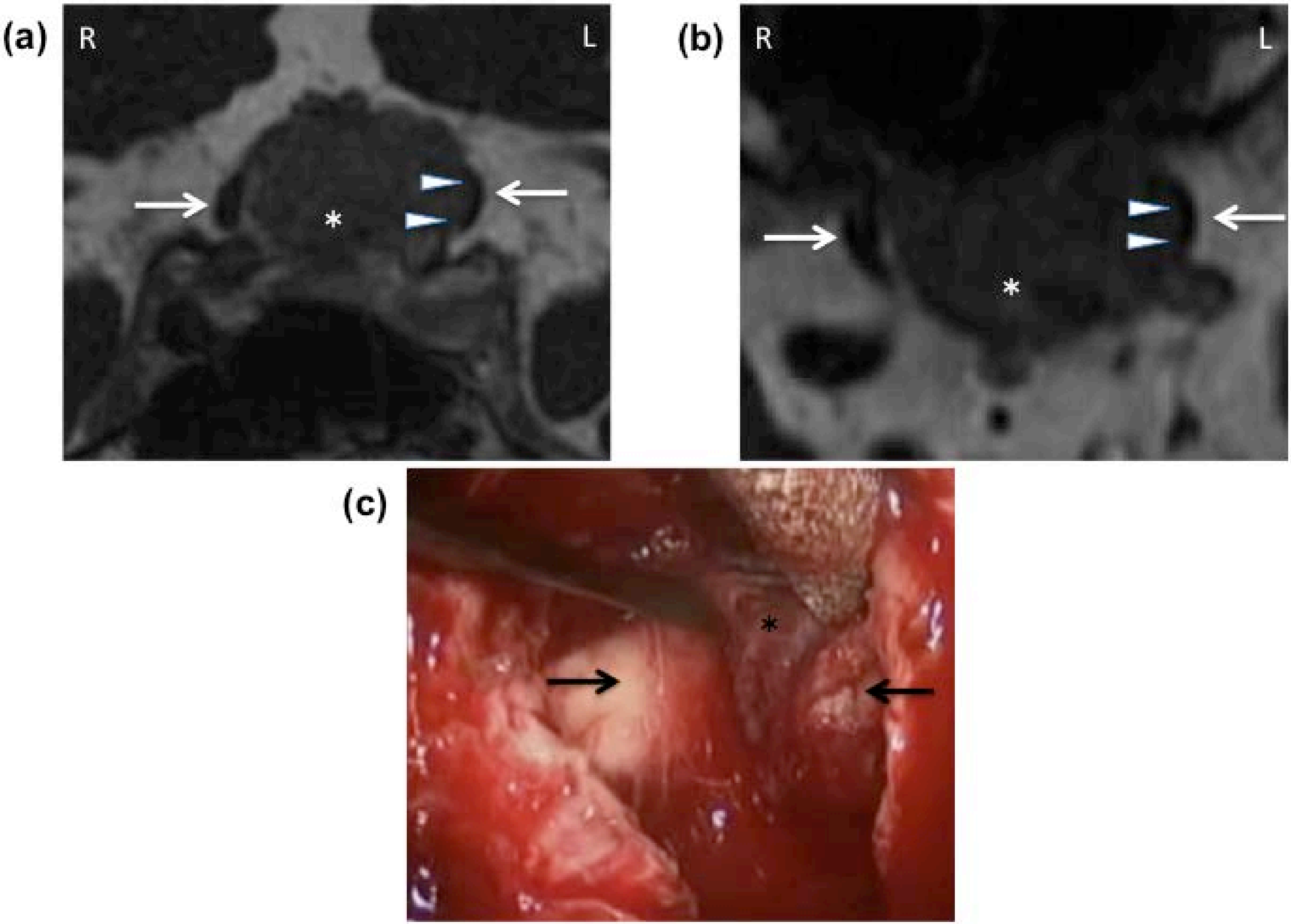

Figure 3

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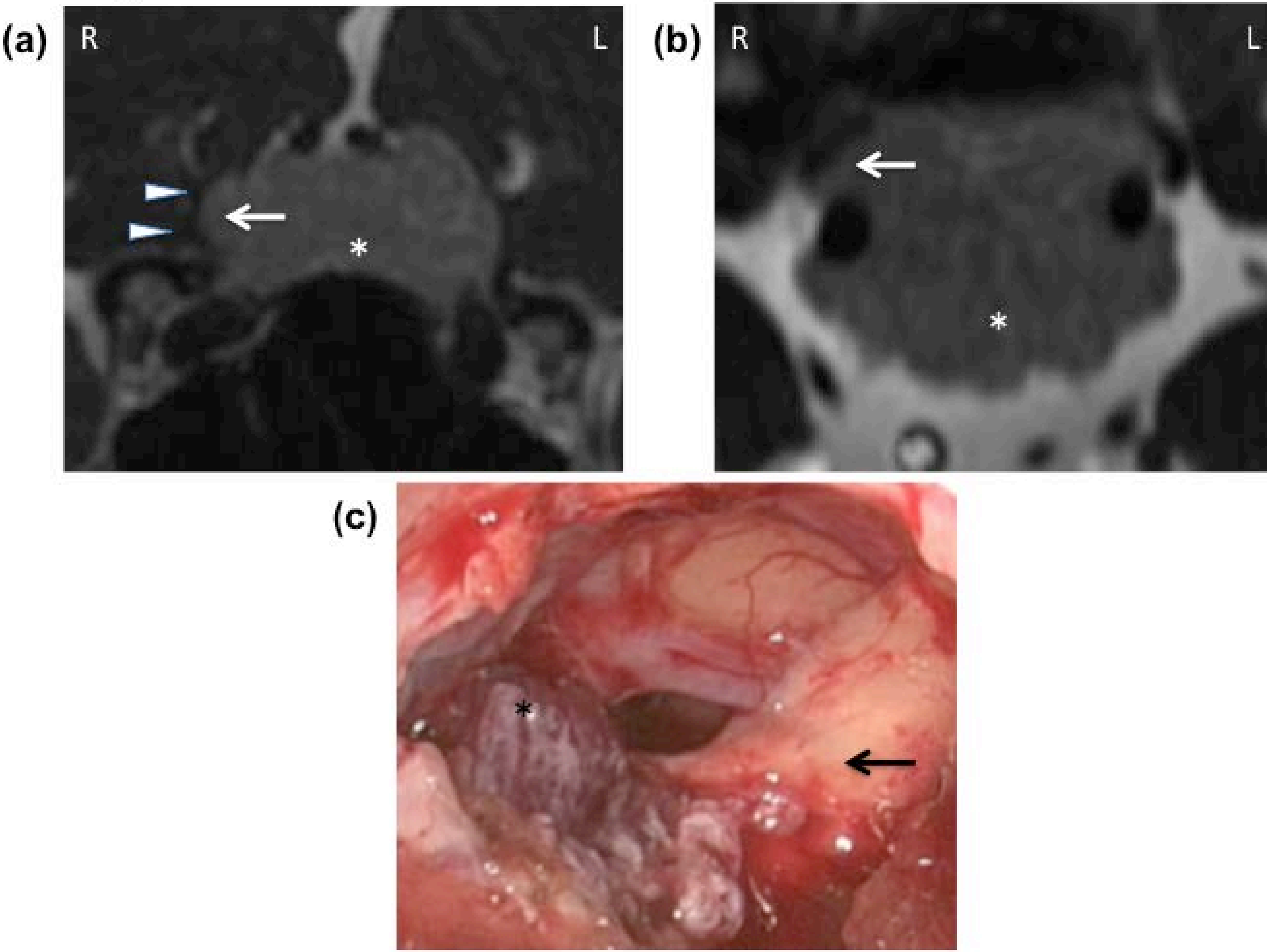

Figure 4

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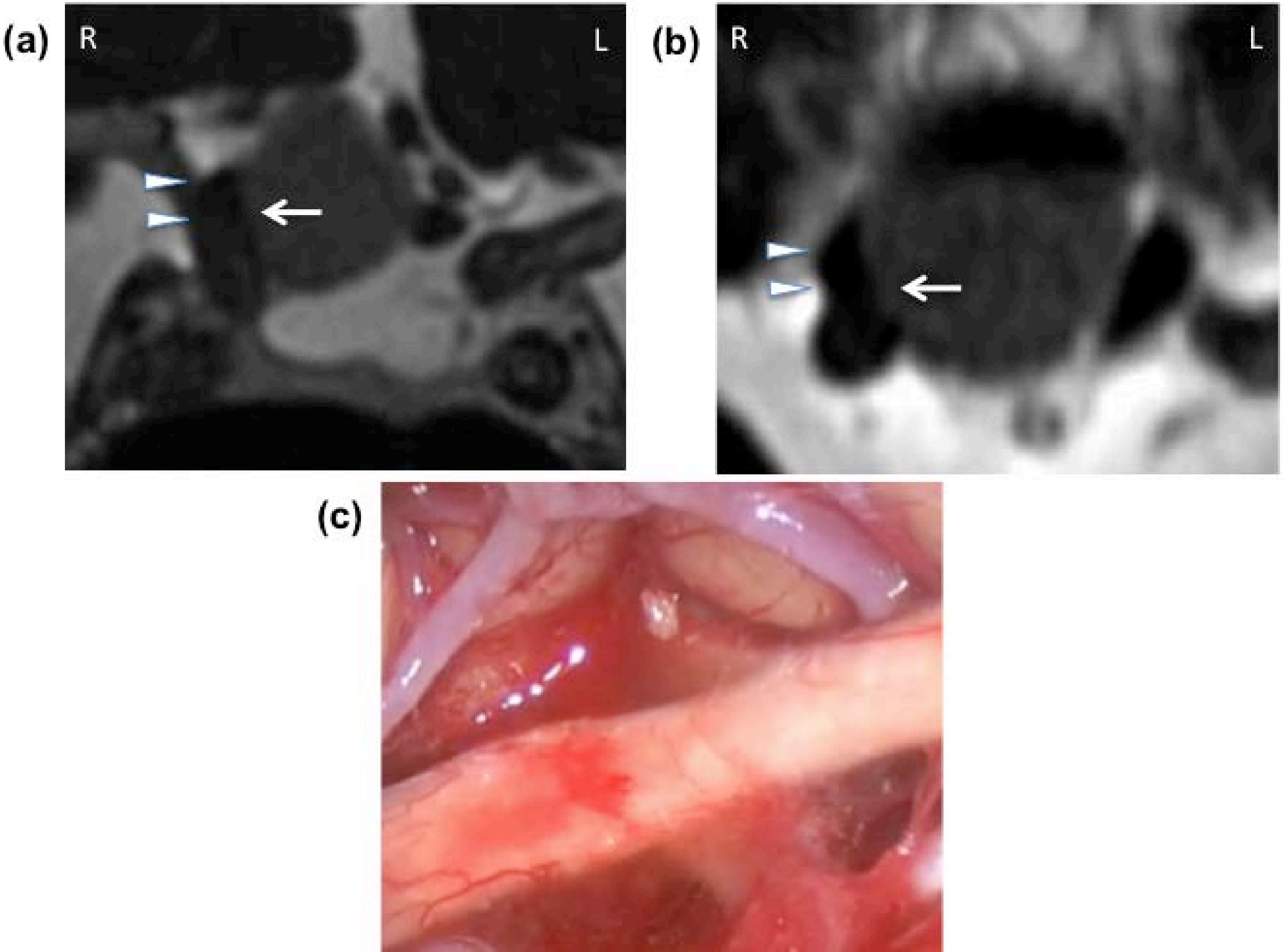

Table 1.

Clinical characteristics of the patients in this study

Variables		Numerical values	
Gender	male	7	
	female	15	
Age		58.3	(32-87)
Size	maximum diameter	24.3	(15-34)
Symptoms	visual disturbance	18	
	headache	4	
MRI T1	hypo	3	
	iso	19	
	hyper	0	
MRI T2	hypo	0	
	iso	3	
	hyper	19	
Calcification	with	3	
	without	19	
Optic canal involvement	with	7	
	without	37	
Lateral extension	A	12	
	B	18	
	C	12	
	D	2	

MRI: magnetic resonance images

Table 2.

Comparison between preoperative MRI and intraoperative findings

			Intraoperative findings		
			adhesion at the interface		
preoperative MRI	***tumor and optic nerve***		+	-	total
	hyperintensity	+	0	37	37
		-	5	2	7
		total	5	39	44
	tumor and ICA		+	-	total
	hyperintensity	+	0	44	44
		-	0	0	0
		total	0	44	44

ICA: internal carotid artery, MRI: magnetic resonance imaging

Table 3.

Comparison between tumor removal of adhered portions and visual function outcomes

Postoperative Results

Removal	number	with adhesion
total	15	1
subtotal	3	1
partial	4	3

Symptoms	Visual disturbance				Headache	total
outcomes	number	with adhesion	resection	Optic nerve hyperintensity	number	22
resolved	9	3	incomplete 3	1	4	13
improved	6	1	incomplete 1	1	0	6
unchanged	3	1	complete 1	0	0	3