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Case Report

Detection of suprasellar subarachnoid hemorrhage using intraoperative magnetic resonance imaging during endoscopic transsphenoidal resection of pituitary neuroendocrine tumors

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ABSTRACT

Background: Endoscopic transsphenoidal surgery (ETSS) is considered safe for the treatment of pituitary neuroendocrine tumors (PitNETs). Postoperative subarachnoid hemorrhage (SAH) is extremely rare in patients with PitNET, and information regarding the source of hemorrhage in such cases is limited.

Case Description: Herein, we report the cases of a 59-year-old man and a 49-year-old woman who underwent ETSS for nonfunctioning PitNETs. Gentle subcapsular removal was performed, and no cerebrospinal fluid leakage was observed during the procedure. We routinely perform intraoperative magnetic resonance imaging (iMRI) to confirm the presence of residual tumors. In the former case, conservative treatment was selected because minimal bleeding was observed in iMRI. In the latter case, obvious arterial bleeding was observed beyond the diaphragmatic sellae before iMRI, prompting the selection of an extended transsphenoidal approach to identify the bleeding site. In both cases, iMRI revealed an SAH localized between the optic chiasm and diaphragmatic sellae adjacent to the pituitary stalk. Combined with intraoperative findings, the superior hypophyseal artery was considered the bleeding source in both cases. Hemostasis was achieved in both cases without the need for hemostatic procedures.

Conclusion: SAH associated with ETSS is rare, and the source of the hemorrhage is sometimes undetectable on postoperative imaging. Herein, iMRI was useful for identifying the source and extent of the hemorrhages, allowing observation of the patients without additional intervention.

Keywords: Magnetic resonance imaging, Subarachnoid hemorrhage, Transsphenoidal surgery

INTRODUCTION

Subarachnoid hemorrhage (SAH), a rare but severe complication of endoscopic transsphenoidal surgery (ETSS) for pituitary neuroendocrine tumors (PitNETs), can occur intra- or postoperatively, even without exposure of the subarachnoid space. The causes include residual tumor bleeding,[8,17] preoperatively undetected aneurysms,[4,12] or small arteries adjacent to the tumor capsule.[5-7,13,14]

Intraoperative magnetic resonance imaging (iMRI)[2] or early postoperative MRI[1] has shown significant benefits in ETSS for PitNETs. Multiple studies have demonstrated that iMRI increases the rate of gross total resection, with improvements ranging from 20% to 40%,[10,15,16] and the benefits are particularly enhanced for suprasellar lesions.[9] In addition, a previous study demonstrated the usefulness of detecting postoperative hemorrhage from residual tumors in the resection cavity using iMRI.[16]

However, to our knowledge, no study has reported intraoperative SAH associated with ETSS detected using iMRI. Since the installation of a 3T-iMRI system (Magnetom Verio, SIEMENS, Munich, Germany), 156 patients with PitNETs underwent resection exclusively using ETSS in our department between May 2016 and October 2024. Among them, iMRI was performed in 126 (80.8%) patients to check for the presence of residual tumors after the surgery. The acquired MRI sequences included whole-brain diffusion-weighted, axial T2-weighted, and 3D T1-weighted images (1–3-mm slice thickness), which were obtained before and approximately 5 min after the injection of the gadolinium contrast agent. Among these cases, we encountered two (1.6% of 126 cases) cases of SAH localized to the suprasellar region despite gentle subcapsular resection of the tumor and no intraoperative exposure of the arachnoid. We believe that these two cases are highly informative, considering the source of SAH that occurred after the resection of macro-PitNETs.

CASE DESCRIPTION

Case 1

A 59-year-old man underwent ETSS for a nonfunctional PitNET that caused bitemporal hemianopia. The tumor was soft, measured 25 mm × 23 mm × 17 mm, and extended into the suprasellar region; the diaphragm sellae was intact. There was no obvious aneurysm around the circle of Willis [Figures 1a-c]. Total removal of the tumor was achieved within the tumor capsule, which was confirmed using iMRI, and downward ballooning of the diaphragmatic sellae was observed. No cerebrospinal fluid (CSF) leakage was observed during the procedure. A localized SAH measuring 18 mm × 18 mm × 16 mm was observed between the diaphragmatic sellae and the optic chiasm, with the hemorrhage source identified at the inferior surface of the chiasm [Figures 1d and e]. However, because decompression of the optic nerves compared with the preoperative status was achieved and the hemorrhagic source was distant from the major intracranial vessels and the tumor capsule, no additional intervention was performed, and the patient was thoroughly monitored thereafter. We usually perform the Valsalva maneuver before concluding the surgery to confirm the absence of ` leakage. However, considering the risks of blood pressure fluctuations and rebleeding, this was not performed in this case. Early postoperative computed tomography (CT) [Figure 1f] obtained 1 h after iMRI showed no hemorrhage expansion, and magnetic resonance angiography (MRA) revealed no new aneurysms. The location of the hemorrhage suggested that the bleeding occurred from the branches of the superior hypophyseal artery (SHA), presumably the descending or infundibular branch, owing to the downward retraction of the tumor capsule. Visual impairment rapidly improved postoperatively, and the hemorrhage gradually resolved over time. Although the patient did not develop any new symptoms, he was discharged after 12 days of observation, considering the potential risks of postoperative rebleeding.

Case 2

A 49-year-old woman underwent ETSS for a nonfunctional PitNET that caused bitemporal hemianopia. The tumor measured 31 mm × 24 mm × 27 mm and extended into the suprasellar region; the diaphragm sellae was intact, and no obvious aneurysm was observed on MRA [Figures 2a-c]. During maximal resection within the tumor capsule, downward ballooning of the diaphragmatic sellae was observed. After arterial bleeding beyond the thinned diaphragmatic sellae [Video 1] was observed, the diaphragmatic sellae was incised, and the suprasellar region was directly inspected endoscopically. Careful suction of the blood clot revealed that although the bleeding had already ceased, a firm hematoma remained just beneath the optic chiasm, indicating this to be the bleeding point. iMRI was performed after hemostasis, and no residual blood was observed, except in the areas where the clots were intentionally left behind. Based on these findings, the descending or infundibular branch of the SHA was considered the source of bleeding [Figures 2d and e]. Postoperative CT revealed no expansion of the hemorrhage [Figure 2f]; no new neurological deficits were observed, and the preoperative bitemporal hemianopia rapidly improved. The patient was discharged on day 8 without any additional symptoms.

DISCUSSION

ETSS has substantially improved the surgical management of PitNETs, offering enhanced safety and efficacy compared with traditional transcranial and microscopic transsphenoidal approaches. However, intra- and postoperative hemorrhagic complications remain a significant concern, with injury to the internal carotid artery (ICA) being the most critical complication to be avoided. Particular caution is required in the management of chondrosarcoma and chordoma, which require extensive exposure and dissection of the skull base, with an incidence rate as high as 2%. In cases of PitNETs, the risk is relatively low at approximately 0.3%. However, caution is required in cases of tumor infiltration into the cavernous

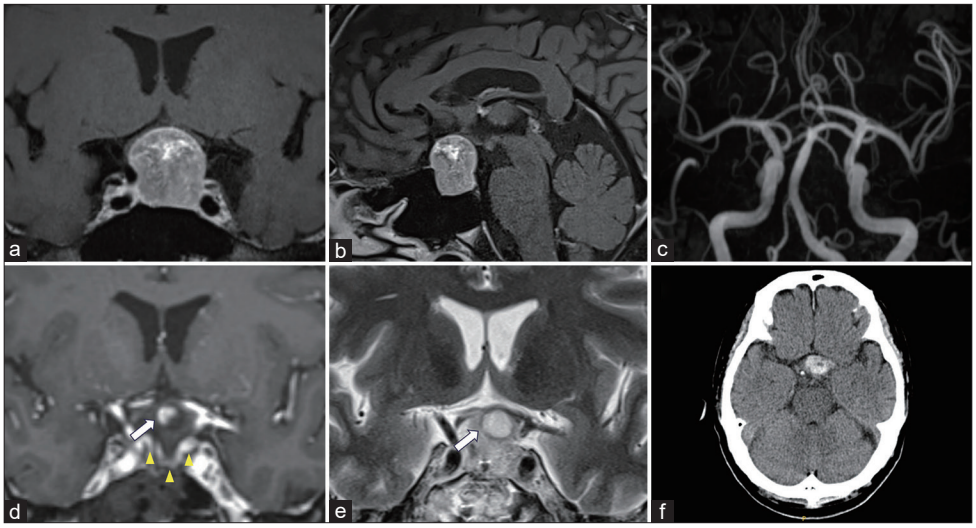


Figure 1: (a and b) Preoperative MRI showing a sellar mass with upper extension. (c) Preoperative MRA showed no aneurysm or vascular abnormalities around the tumor. (d) Intraoperative contrast-enhanced T1WI shows a small spot sign (white arrow), indicating acute hemorrhage between the optic chiasm and diaphragm sellae (arrowhead), and (e) T2WI showing the extent of hemorrhage (white arrow) around the spot indicated in (d). (f) Postoperative CT scan showed no expansion of hemorrhage. MRI: Magnetic resonance imaging, MRA: Magnetic resonance angiography, CT: Computed tomography, T1WI: T1-weighted imaging, T2WI: T2-weighted imaging.

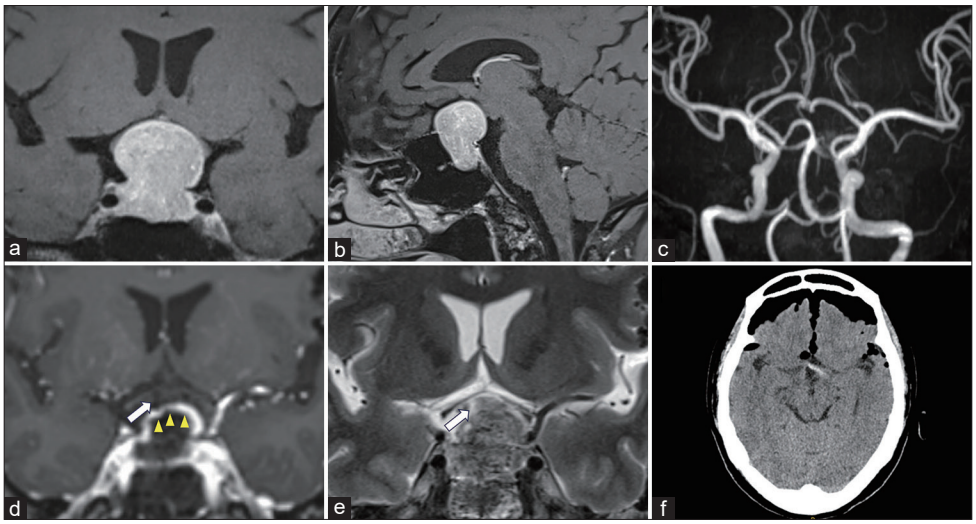
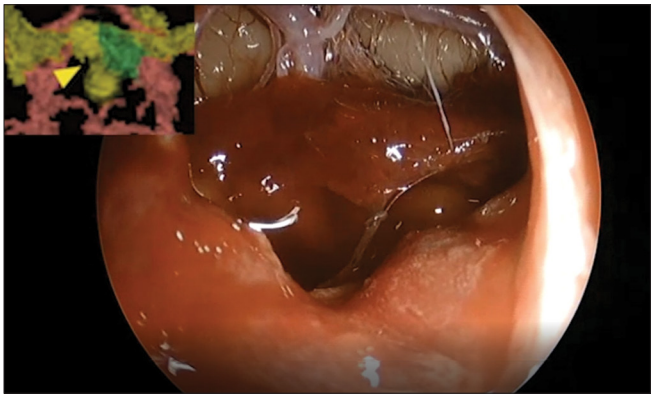


Figure 2: (a and b) Preoperative MRI showing a sellar mass with upper extension. (c) Preoperative MRA showed no aneurysm or vascular abnormalities around the tumor. (d) Intraoperative contrast-enhanced T1WI shows a small hemorrhage (white arrow) between the optic chiasm and diaphragm sellae (arrowhead), and (e) T2WI shows the extent of hemorrhage (white arrow). (f) The SAH observed on iMRI showed a decreasing trend on the postoperative CT scan. iMRI: Intraoperative magnetic resonance imaging, MRA: Magnetic resonance angiography, CT: Computed tomography, T1WI: T1-weighted imaging, T2WI: T2-weighted imaging, SAH: Subarachnoid hemorrhage.

sinus.[3] Injury to the ICA is life-threatening and requires urgent intervention, such as endovascular treatment, vessel occlusion with clips, or the use of flow-diverting stents.

Reports of SAH or intracerebral hemorrhage associated with ETSS are relatively rare, with only approximately 20 reported cases. Most of these cases describe intra- or postoperative bleeding from a residual tumor or surrounding soft tissues extending into the suprasellar subarachnoid space through tearing of the diaphragmatic sellae.[8,17] To our knowledge, only seven cases of SAH related to an

injury of the intracranial small artery adjacent to a PitNET have been reported, including the two cases presented here. Considering that the incidence of postoperative SAH confirmed by MRI at our institution was 1.6%, it is likely that minor bleeding may be underreported [Table 1]. In these cases, decompression of the macroadenoma resulted in the traction of a small adherent artery surrounding the tumor downward or medially. Except for our two cases, no abnormalities were observed intraoperatively within the visible range of the sella turcica, and bleeding due to vascular injury beyond the diaphragmatic sellae or arachnoid membrane was not observed during the procedure. In these cases, bleeding was first observed only after postoperative imaging or the onset of consciousness disturbance. By that stage, the hemorrhage had already spread throughout the basal cistern, and the source of bleeding could not be identified on plain CT alone. In a report by Yoshimoto *et al.*, a localized SAH was observed immediately after surgery, and 1 h later, the bleeding had expanded, with simultaneous progression of visual impairment. As a result, extended ETSS was performed to remove the hemorrhage, revealing that the source of the bleeding was the SHA.[14] Their report



Video 1: Arterial bleeding beyond the thinned diaphragma sellae was observed (arrow), and the diaphragma sellae was incised. By the time the suprasellar region was directly inspected, active bleeding had already ceased. Upon removal of the soft hematoma, a firm hematoma remained just beneath the anterior communicating artery and optic chiasm, as in Figure 3c, indicating the bleeding point was around there.

Table 1: Non-aneurysmal SAH due to injury of small arteries after subcapsular removal of PitNETs by transsphenoidal approach

Authors (year)	Age (sex)	Tumor size (mm)	Degree of tumor removal	Possible Bleeding source	Hunt-Hess grade	Distribution of SAH	Management of SAH	Postoperative New symptoms	mRS at discharge
Matsuno *et al.* (1993)	42 (M)	N.A.	GTR	Anterior choroidal artery	IV	Massive SAH in basal cistern and right thalamic hemorrhage	Conservative	Severe disturbance of consciousness, died on 21st postoperative day	6
Kuroyanagi *et al.* (1994)	59 (F)	20	STR	Posterior thalamoperforating artery	IV	Massive SAH in basal cistern and left midbrain hemorrhage	Conservative, Required ventriculoperitoneal shunt for hydrocephalus	Weber syndrome, right hemiparesis	3
Ito *et al.* (2009)	51 (M)	N.A.	STR	Perforator from anterior cerebral artery	IV	Massive SAH in basal cistern	Conservative, Required ventriculoperitoneal shunt for hydrocephalus	Severe disturbance of consciousness	3
Yamauchi *et al.* (2015)	55 (F)	45	GTR	Perforator from Posterior cerebral artery	I	Localized, interpeduncular cistern	Conservative	Oculomotor palsy	1
Yoshimoto *et al.* (2021)	49(M)	27	GTR	SHA	II	Massive SAH in basal cistern	Extended TSS	None	0
Present report									
Case1	59 (M)	25	GTR	SHA	I	Localized, suprasellar region	Conservative	None	0
Case2	49 (F)	31	GTR	SHA	I	Localized, suprasellar region	Conservative	None	0

SAH: Subarachnoid hemorrhage, mRS: Modified Rankin scale, N.A.: Not available, GTR: Gross total resection, STR: Subtotal resection, TSS: Transsphenoidal approach, SHA: Superior hypophyseal artery

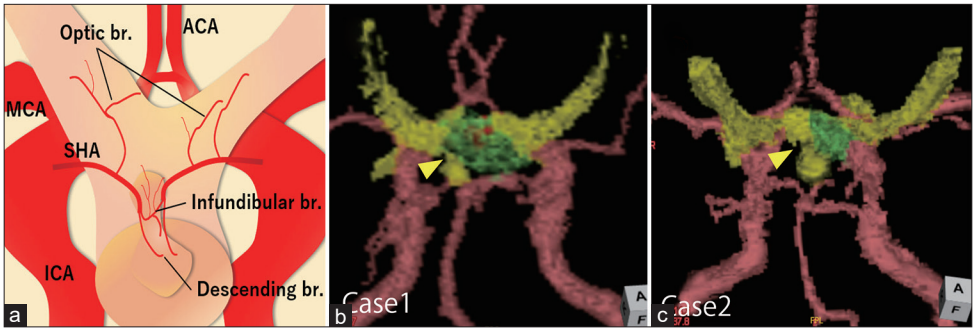


Figure 3: (a) Conceptual schema of the SHA and surrounding structures. In our cases, the hemorrhage occurred anterolaterally to the pituitary stalk due to traction of the infundibular or descending branch. (b) A 3D reconstruction of a fusion image created from contrast-enhanced T1-weighted and T2-weighted images illustrating the relationship between the hemorrhage in Case 1 and the surrounding structures. The green color represents the extent of the hematoma, the red color indicates the location of the spot sign, and the arrowhead indicates the pituitary stalk. (c) 3D reconstruction of a fusion image obtained from Case 2, following the method described in (b). Arrowhead indicates the pituitary stalk. The green color represents the extent of residual hematoma after removal, which is nearly identical to the spot sign observed in Case 1. SHA: Superior hypophyseal artery.

concluded that the early removal of the hemorrhage and hemostasis could achieve favorable outcomes. In other cases, conservative management was chosen for the bleeding, and in three cases with a massive hemorrhage, severe complications, including prolonged consciousness disturbance, hemiparesis, and hydrocephalus, occurred.[5-7] Conversely, in cases where the bleeding was localized, a favorable outcome was achieved without the need for additional treatment.[13] In cases with massive bleeding on initial postoperative imaging, identifying and controlling the bleeding endoscopically through the nasal route are anticipated to be extremely challenging. In this context, intraoperative MRI is highly valuable for identifying the source of bleeding before it spreads extensively and determining whether the removal of suprasellar hemorrhage using extended ETSS is necessary.

In the two cases presented herein, the descending or infundibular branch of the SHA was considered the bleeding source. Although SHA exhibits some anatomical variations, it usually arises from the ICA and, after branching the optic branch, almost always creates a preinfudibular anastomosis and sends some descending or infundibular branches around the pituitary stalk and the upper half of the pituitary.[11] Herein, based on the intraoperative findings and the results of the iMRI, bleeding was determined to be confined between the optic chiasm and diaphragm sellae adjacent to the pituitary stalk [Figures 3a-c]. If the main trunk of the SHA was severed, it could potentially result in visual field deficits or endocrine dysfunction. However, in the present two cases, only one descending branch on one side, distal to the preinfundibular anastomosis, was affected. This limited disruption likely explains why no new visual field deficits or endocrine abnormalities were observed. In both cases, we performed subcapsular removal of the tumors; the diaphragma sellae and arachnoid were intact, and no CSF leakage was observed. Therefore, the bleeding was attributed to the downward traction of the pituitary stalk from the optic chiasm due to tumor decompression. Risk factors for hemorrhage from SHA may include elevation of the stalk and chiasm by a macroadenoma. Similar characteristics were observed in a case reported by Yoshimoto *et al.*, in which hemorrhage from the SHA was observed.[14] However, considering that most macroadenomas eligible for surgical intervention share these features, this characteristic is unlikely to be helpful in preoperative prediction.

Intraoperative MRI is available only in limited facilities and is time-consuming. Considering the rarity of SAH after ETSS, its sole use for detecting bleeding is impractical. However, the routine use of iMRI during or immediately after surgery for PitNETs is reported to be beneficial for reducing residual tumors and detecting intratumoral hemorrhages.[10,15,16] Although it may be challenging to visualize the anatomical relationship due to the surrounding structures, intraoperative CT could be a viable alternative for detecting the extent of hemorrhage. In institutions where the extent of macroadenoma resection is routinely evaluated using iMRI, it is also possible to simultaneously check for suprasellar hemorrhage. If bleeding is detected on iMRI, hematoma removal or hemostasis can be electively performed through extended ETSS depending on the extent and volume of bleeding, potentially preventing serious complications.

CONCLUSION

SAH due to injury to the surrounding small vessels during PitNET resection is rare; however, it can result in severe complications. iMRI was useful in identifying the source of bleeding as SHA in the former case, while in the latter case, it reflected the distribution of the hematoma observed intraoperatively. After

assessing the extent of the hemorrhage, careful observation of the patients was adopted without additional intervention, which potentially prevented serious complications.

Ethical approval: This study was conducted in accordance with the principles of the Declaration of Helsinki, and approval was obtained from the Institutional Review Board of Kyoto University Hospital (approval number: R2088).

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent.

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REFERENCES

1. Alhilali LM, Little AS, Yuen KC, Lee J, Ho TK, Fakhran S, *et al*. Early postoperative MRI and detection of residual adenoma after transsphenoidal pituitary surgery. J Neurosurg 2021;134:761-70.
2. Fahlbusch R, Ganslandt O, Buchfelder M, Schott W, Nimsky C. Intraoperative magnetic resonance imaging during transsphenoidal surgery. J Neurosurg 2001;95:381-90.
3. Gardner PA, Tormenti MJ, Pant H, Fernandez-Miranda JC, Snyderman CH, Horowitz MB. Carotid artery injury during endoscopic endonasal skull base surgery: Incidence and outcomes. Neurosurgery 2013;73:ons261-9; discussion ons269-70.
4. Habibi Z, Mojtaba Miri S, Sheikhrezaei A. Pituitary macroadenoma coexistent with a posterior circulation aneurysm leading to subarachnoidal hemorrhage during transsphenoidal surgery. Turk Neurosurg 2015;25:469-74.
5. Ito Y, Takano S, Muroi A, Matsumura A. Massive subarachnoid hemorrhage and intraventricular hemorrhage after transsphenoidal surgery of pituitary adenoma: A case report. No Shinkei Geka 2009;37:887-92.
6. Kuroyanagi T, Kobayashi S, Takemae T, Kobayashi S. Subarachnoid hemorrhage, midbrain hemorrhage and thalamic infarction following transsphenoidal removal of a pituitary adenoma. A case report. Neurosurg Rev 1994;17:161-5.
7. Matsuno A, Yoshida S, Basugi N, Itoh S, Tanaka J. Severe subarachnoid hemorrhage during transsphenoidal surgery for pituitary adenoma. Surg Neurol 1993;39:276-8.
8. Shu H, Tian X, Wang H, Zhang H, Zhang Q, Guo L. Nonaneurysmal subarachnoid hemorrhage secondary to transsphenoidal surgery for pituitary adenomas. J Craniofac Surg 2015;26:e166-8.
9. Tanei T, Nagatani T, Nakahara N, Watanabe T, Nishihata T, Nielsen ML, *et al*. Use of high-field intraoperative magnetic resonance imaging during endoscopic transsphenoidal surgery for functioning pituitary microadenomas and small adenomas located in the intrasellar region. Neurol Med Chir (Tokyo) 2013;53:501-10.
10. Tanji M, Kataoka H, Kikuchi M, Sakamoto T, Kuwata F, Matsunaga M, *et al*. Impact of intraoperative 3-tesla mri on endonasal endoscopic pituitary adenoma resection and a proposed new scoring system for predicting the utility of intraoperative MRI. Neurol Med Chir (Tokyo) 2020;60:553-62.
11. Truong HQ, Najera E, Zanabria-Ortiz R, Celtikci E, Sun X, Borghei-Razavi H, *et al*. Surgical anatomy of the superior hypophyseal artery and its relevance for endoscopic endonasal surgery. J Neurosurg 2019;131:154-62.
12. Tsuchida T, Tanaka R, Yokoyama M, Sato H. Rupture of anterior communicating artery aneurysm during transsphenoidal surgery for pituitary adenoma. Surg Neurol 1983;20:67-70.
13. Yamauchi T, Kitai R, Kikuta K. Subarachnoid hemorrhage without direct vascular injury after transsphenoidal surgery: 2 cases report. No Shinkei Geka 2015;43:551-5.
14. Yoshimoto H, Yamada S, Shiramizu H, Kato M, Ishida A, Sato H, *et al*. Hemostasis through extended transsphenoidal route for subarachnoid hemorrhage after conventional transsphenoidal surgery for a pituitary adenoma. NMC Case Rep J 2021;8:545-9.
15. Zaidi HA, De Los Reyes K, Barkhoudarian G, Litvack ZN, Bi WL, Rincon-Torroella J, *et al*. The utility of high-resolution intraoperative MRI in endoscopic transsphenoidal surgery for pituitary macroadenomas: early experience in the Advanced Multimodality Image Guided Operating suite. Neurosurg Focus 2016;40:E18.
16. Zhang H, Wang F, Zhou T, Wang P, Chen X, Zhang J, *et al*. Analysis of 137 Patients who underwent endoscopic transsphenoidal pituitary adenoma resection under high-field intraoperative magnetic resonance imaging navigation. World Neurosurg 2017;104:802-15.
17. Zhou W, Yang Z. Complications of transsphenoidal surgery for sellar region: Intracranial vessel injury. Chin Med J (Engl) 2009;122:1154-6.

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