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TECHNICAL NOTE

3D-FIESTA MR images are useful in the evaluation of the endoscopic expanded endonasal approach for midline skull-base lesions

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Abstract The endoscopic expanded endonasal approach (EEA) has been reported in literature as a useful tool to treat sellar, parasellar, suprasellar, and clival lesions. The endoscope permits a panoramic view rather than a narrow microscopic view, and this approach can reach the lesion without brain retraction and with minimal neurovascular manipulation. However, because of the narrow corridor, the preoperative evaluation of the lesions should be of high priority. 3D fast-imaging employing steady-state acquisition (3D-FIESTA) or constructive interference in steady state (CISS) MR imaging provides high spatial resolution in the small structures within the cisterns. Therefore, this technique may be useful for better preoperative planning in detecting optic nerve, oculomotor nerve, chiasma, infundibulum, pituitary stalk, and small vessels in sellar region. Here we used the 3D-FIESTA MR images to evaluate EEA for seven midline skull-base lesions. Our report showed that, when EEA was used to treat midline skull-base lesions, 3D-FIESTA MR images were valuable in the assessment of vital structures in and around the tumor-involved midline skull-base region. 3D-FIESTA MR images can help in making a better preoperative planning, locating the intra-operative structures, and reducing the surgical risks. Otherwise, this approach is helpful for the craniopharyngioma classification based on EEA.

Keywords Fast-imaging employing steady-state acquisition · Sellar region · Tumor · Expanded endonasal approach

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Introduction

Due to the complicated neurovascular structures, it is always challenging to surgically treat tumors in the sellar, parasellar, suprasellar, and clival area. Recently, endoscopic endonasal surgery has been increasingly accepted by neurosurgeons. The application of this technique is improved with the increasing use of the endoscope with its improved illumination and wider field of view along with current sophisticated neuronavigation systems [6, 8, 13]. During the last several years, endoscopic expanded endonasal approach (EEA), which is used to access the entire midline ventral skull base, has been frequently reported [5, 9, 14–16]. The anatomical location of these lesions plays a critical role in surgical planning. Therefore, the detection of vital structures in and around the sellar region is useful for better preoperative planning, especially in the surgical approach. However, the conventional MR imaging protocol alone does not provide adequate information on the visualization of optic nerve, oculomotor nerve, chiasma, infundibulum, pituitary stalk, and small vessels. A 3D fast-imaging employing steady-state acquisition (3D-FIESTA) imaging provides a high spatial resolution in the small structures within the cisterns [23]. This technique has been used to evaluate cranial

nerves in the cavernous sinuses or in the cerebellopontine angle [19, 3], but to our knowledge, there has been no report on the identification of cranial nerves and pituitary stalk involved by the sellar region of tumors. In addition, 3D-FIESTA may be helpful for the classification of craniopharyngioma based on EEA.

Imaging procedures

Examinations were performed with a clinical 3.0-T whole-body MR system (SIGNA HDx; GE Healthcare) with an eight-channel head coil. Initially, multiplane localizations were performed to ensure the scan range. Imaging with the FIESTA protocol (TR/TE, 6.0/2.1; FOV, 160 mm; flip angle, 160; matrix, 384×384; slice thickness, 0.75 mm) was subsequently performed in sagittal views. All images were transferred to a post-processing workstation (Advantage Workstation, ADW 4.3, GE. Medical Systems), and then they were reconstructed in sagittal, coronal, and axial views for the evaluation of vital structures in and around the tumor-involved sellar region.

Illustrative cases

Case 1

Suprasellar craniopharyngioma

A 37-year-old male patient presented with headache and vision loss. Preoperative conventional MR images revealed that a 40-mm suprasellar tumor was extending into the third ventricle. Intravenous CE caused heterogeneous hyperintensity in the compact part of the tumor. The cystic components were in the posterior part of the tumor (Fig. 1a).

Findings on the 3D-FIESTA image

The optic nerve, chiasma, infundibulum, pituitary stalk, internal carotid artery, anterior communicating artery complex, and basilar artery were depicted on the images (Fig. 1b, c). The pituitary gland could be found within the sella, and the tumor lied in the retroinfundibular space while the stalk was thinned and attenuated. This tumor entered the retroinfundibular retrochiasmatic space and extended into the floor of the third ventricle. The optic chiasma, infundibulum, and pituitary stalk were barely visible on conventional T1-with-contrast- and T2-weighted MR images (Fig. 1a). However, with EEA, the pituitary stalk and its relationship with the tumor are of equal importance, especially if preservation of the pituitary function is a goal of surgery [17]. Therefore, 3D-FIESTA images are more beneficial for the new classification of Kassam AB [17] about craniopharyngioma based on EEA.

Operative findings

We applied EEA to the above-mentioned patient. After the nasal and sphenoidal step, we obtained a good landmark, and image guidance could be very valuable for this part. Bone removal was extended to the medial opticocarotid recess and sphenoidal planum. After we opened the dura and arachnoid matter, the tumor was guarded anteriorly by the thinned and attenuated stalk (Fig. 1e). The anterior communicating artery complex located over the optic chiasma. After the suprachiasmatic space was opened, the bulged lamina terminalis was elevated by the tumor. This was consistent with those depicted in the preoperative 3D-FIESTA images. The reconstruction techniques used in this case were a nasal septal flap, a fat graft, and a Foley catheter balloon.

Case 2

Tuberculum sella meningioma

A female patient suffered from headache and felt uncomfortable on her left eye. A 28-mm typical tuberculum sella meningioma was found in the preoperative T1-with-contrast-weighted MR images. Peritumoral edema was not visible on T2-weighted MRI (Fig. 2a).

Findings on the 3D-FIESTA image

The anterior cerebral arteries, optic nerves, chiasma, infundibulum, pituitary stalk, and carotid artery could be much easier to find on the 3D-FIESTA images than on conventional MR images. The spatial relationships around the tumor were easily recognized on these images (Fig. 2b).

Operative findings

We applied the endoscopic expanded transplanum approach to this patient. With this approach, we removed the planum sphenoidale and tuberculum sellae. Dural incision was horizontally performed, and then it was enlarged. Subsequently, we meticulously removed the tumor from the surrounding structures. As shown in the operation picture, the optic nerves, chiasm, and pituitary stalk were oppressed, and the anterior communicating artery complex was elevated by the tumor (Fig. 2c, d). This was indicated by 3D-FIESTA images.

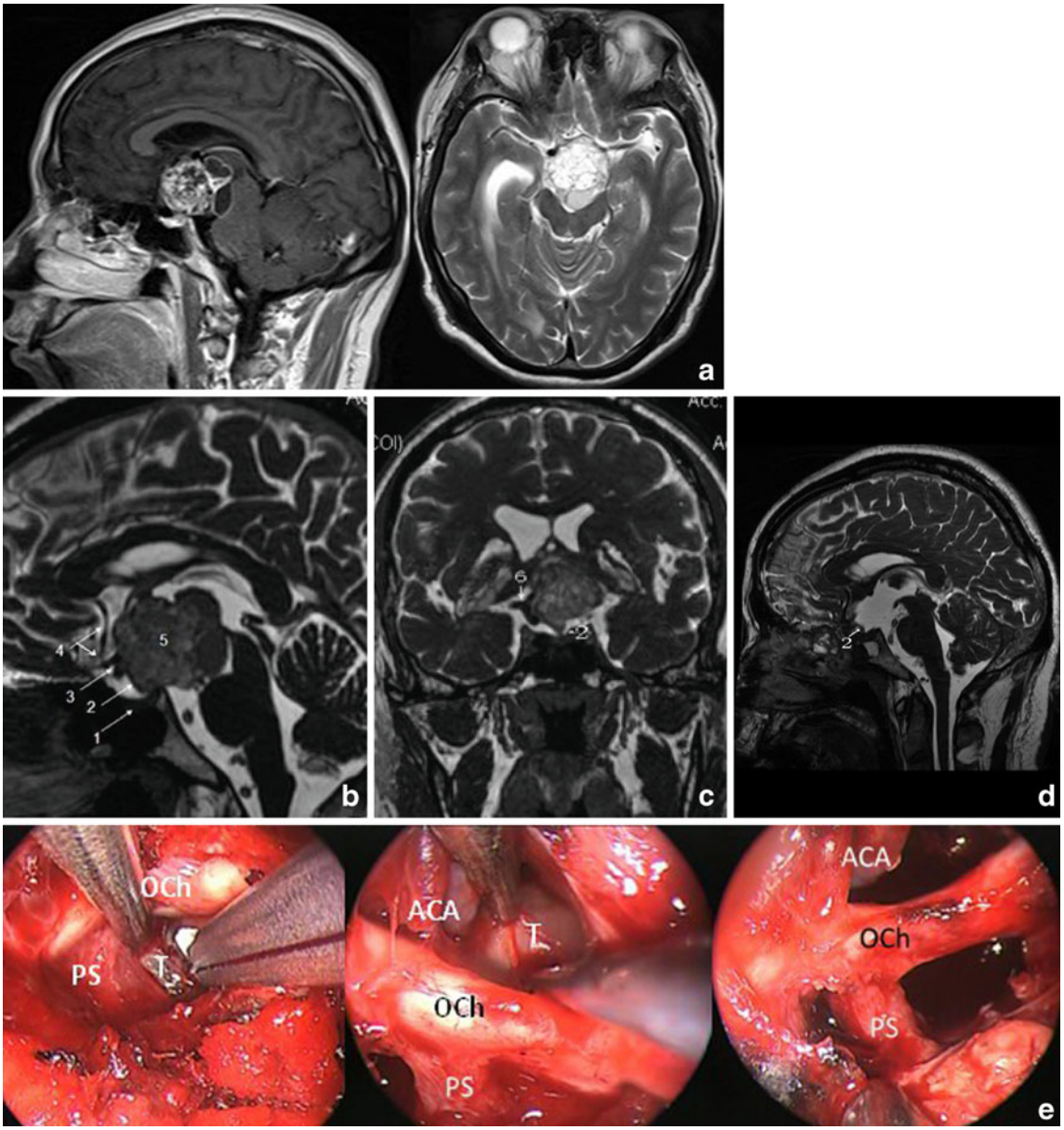

Fig. 1 **a** Sagittal preoperative contrast-enhanced T1-weighted and axial T2-weighted MR image demonstrates a craniopharyngioma extending into the third ventricle. The cystic components were in the posterior of the tumor. **b**, **c** 3D-FIESTA sagittal and coronal images clearly show these vital structures. The pituitary gland could be found within the sella, and the tumor lies in the retroinfundibular space while the stalk was thinned and attenuated. This tumor entered the retroinfundibular retrochiasmatic space and extended into the floor of the third ventricle. *1*, pituitary gland; *2*, pituitary stalk; *3*, optic chiasma; *4*, anterior communicating artery complex; *5*, tumor; *6*, the bifurcation of the ICA. **d** The postoperative 3D-FIESTA MR shows that the tumor was totally removed and the pituitary stalk was in the front side. **e** After the dura of the sella floor and sphenoidal planum was opened, the tumor was dissected from the infrachiasmatic and suprachiasmatic space. *OCH*, chiasma; *T*, tumor; *PS*, pituitary stalk; *PG*, pituitary gland; *ICA*, internal carotid artery; *ACA*, anterior cerebral artery

Case 3

Clival chordoma

A 40-year-old man complained of horizontal diplopia for 3 months. The CT images revealed a large lobulated lesion with bone destruction and marginal ossification. Figure 3a shows a 50-mm lesion with no enhancement, which was obtained by the preoperative conventional MR images. In the diffusion sequence, the signal was bright. The tumor extended into the sphenoid sinus and compressed the brainstem.

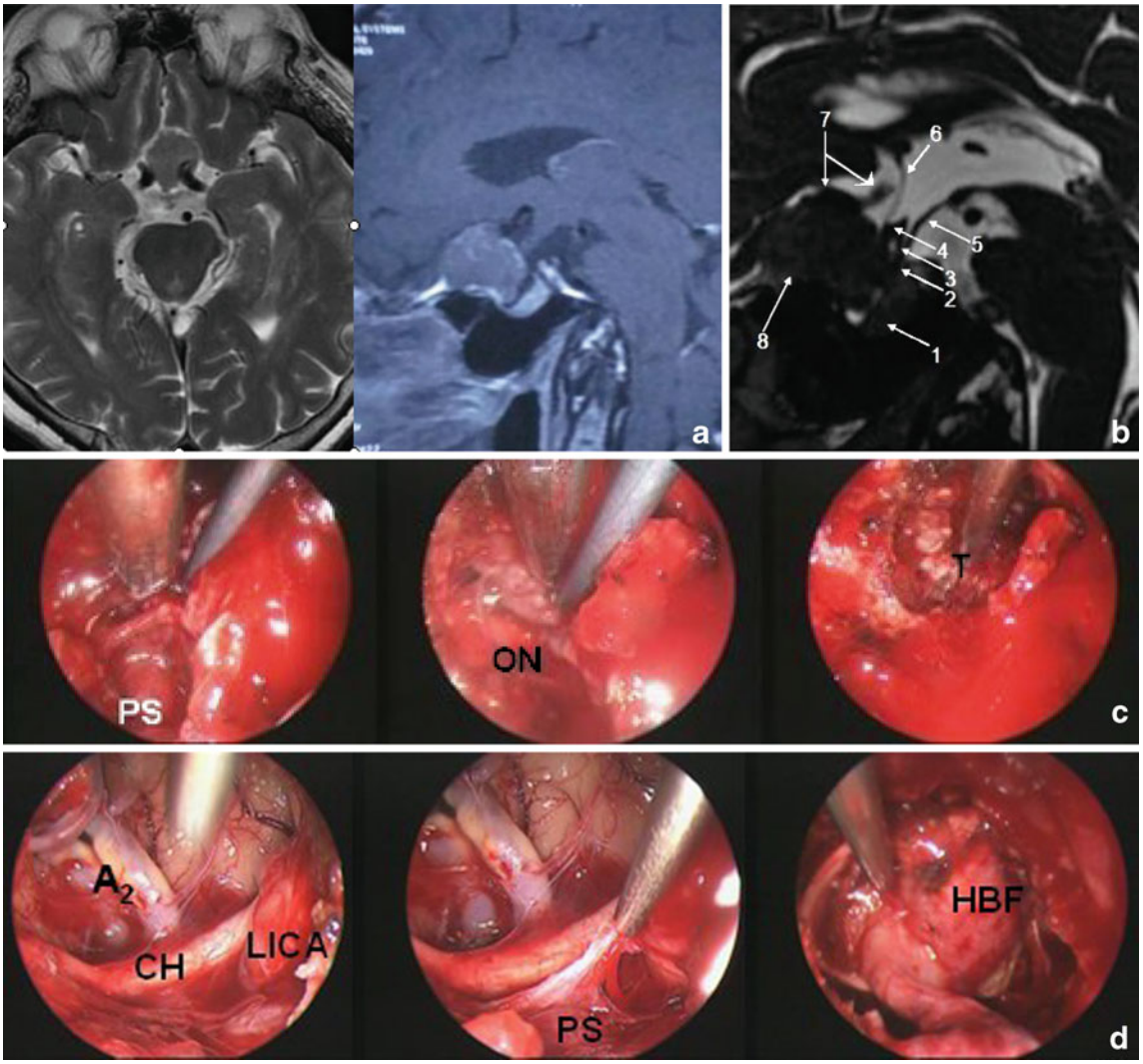

Fig. 2 **a** A 28-mm typical tuberculum sella meningioma was found by the preoperative axial T2-weighted and sagittal T1-weighted with contrast MR images. **b** In the 3D-FIESTA images, the spatial relationships around the tumor were easily recognized on these images. *1*, pituitary gland; *2*, pituitary stalk; *3*, infundibular recess; *4*, optic chiasma; *5*, tuber cinereum; *6*, lamina terminalis; *7*, anterior communicating artery complex; *8*, tumor. **c**, **d** An intraoperative view of the endoscopic expanded transplanum approach. *PS*, pituitary stalk; *ON*, optic nerve; *T*, tumor; *A2*, A2 segment of the anterior cerebral artery; *LICA*, left internal carotid artery; *CH*, chiasma; *HBF*, Hadad–Bassagasteguy pedicled nasoseptal flap

Findings on the 3D-FIESTA image

We could find the pituitary and stalk in front of the tumor, and the basilar artery was posteriorly pushed. The oculomotor nerve was laterally shifted by this tumor. The floor of the third ventricle was superiorly pushed, and the midbrain was posteriorly crushed. The dural matter of the upper clivus was eroded (Fig. 3b).

Operative findings

This patient underwent an EEA. In the sinus phase, we found the tumor with bone destruction. After we drilled the bone, two suctions were used. Figure 3c shows that the upper part of the basilar artery, the posterior cerebral artery, the superior cerebellar artery, and the cranial nerve III could be visualized when the tumor was removed just as indicated in the 3D-FIESTA images.

Discussion

Endoscopy for expanded endonasal surgery has several advantages, including a more direct midline exposure from below, no need of any brain retraction or neurovascular manipulation, and the early devascularization of the lesion [7]. However, the neurovascular structures in the sellar region are always complicated. Limitations and contraindications

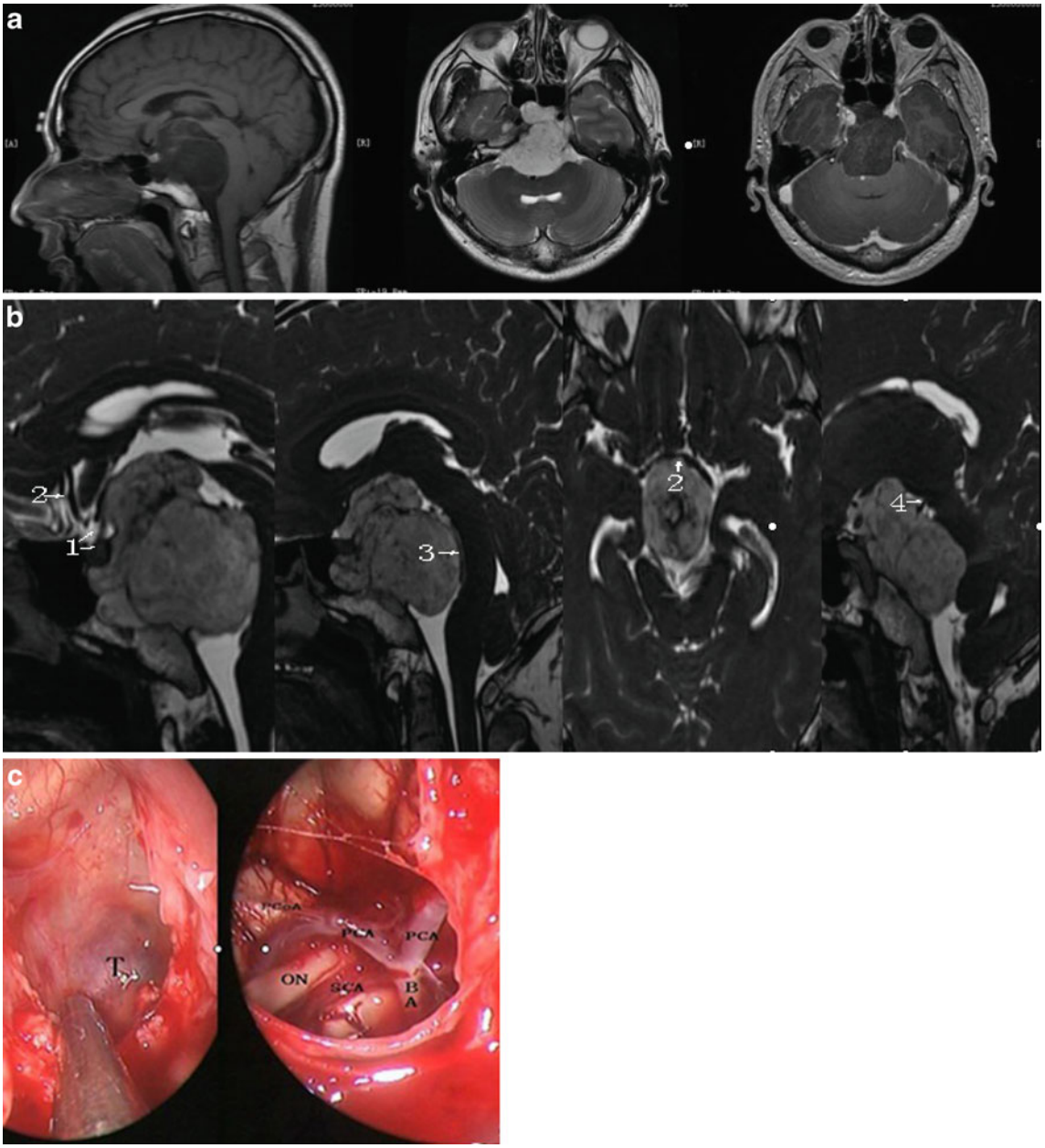

Fig. 3 **a** Preoperative conventional MR images revealed a 50-mm lesion with no enhancement. The signal of T1 weight is high but the T2 signal is low. **b** In the 3D-FIESTA images, we could find the pituitary and stalk in front of the tumor, and the basilar artery was posteriorly pushed. The oculomotor nerve was shifted by this tumor, and the dura matter of the upper clivus was eroded. This was important in this atypical radiology case. *1*, pituitary gland and stalk; *2*, anterior communicating artery complex; *3*, basilar artery; *4*, oculomotor nerve. **c** In the operation, we found that the tumor extended into the sphenoidal sinus. After the tumor was totally resected, many vital structures indicated by the 3D-FIESTA images were visualized. *BA*, basilar artery; *PCA*, posterior cerebral artery; *PCoA*, posterior communicating artery; *ON*, oculomotor nerve; *SCA*, superior cerebellar artery; *DM*, dura mater

should also be carefully assessed before a decision is made. Furthermore, preoperatively interpreting the MR images should be of high priority.

Generally speaking, 3D-FIESTA or constructive interference in steady state (CISS) MR imaging is a high-spatial-resolution and refocused gradient-echo MR imaging sequence that is flow-compensated. It generates a steady-state contribution of the transverse magnetization for tissues with long T2. Therefore, it is called T2-weighted. Moreover, the 3D-FIESTA sequence not only provides a better contrast between the parenchyma of the central nervous system and the cerebrospinal fluid (CSF) but also yields delineation of fine anatomic structures in CSF. The margin between the CSF and neural structures, vessels, and the dura mater is displayed with more details.

As previously reported, this technique is useful for the evaluation of the acoustic neurinomas, epidermoids, ventricular lesions, aqueductal stenosis, syringomyelia, rhinorrhoea, hemifacial spasm, and trigeminal neuralgia and the differentiation between paraclinoid and cavernous sinus aneurysms [1–4, 10–12, 18, 20, 22]. However, no study has been reported on the application of this technique in detecting optic nerve, oculomotor nerve, chiasma, infundibulum, pituitary stalk, and small vessels in the sellar region. We found that the 3D-FIESTA sequence provided a better delineation of the sellar region lesions and their surrounding structures than T1- and T2-weighted or 3D-MPRAGE images. This technique is more compatible to the operative field. It can help in making better preoperative planning, locating the intraoperative structures, and reducing the surgical risks.

The pituitary infundibulum and its relationship with the tumor are equally important, especially in the EEA. Consequently, Kassam et al. classified the suprasellar lesions using a new scheme as follows: type I, preinfundibular; type II, transinfundibular; type III, post- or retroinfundibular (this type can be further subdivided based on rostral or caudal extension, that is, anterior third ventricular (infundibular recess, hypothalamic) and interpeduncular fossa); and type IV, isolated third ventricular [17]. As a prerequisite of this new classification, the identification of infundibular or stalk should be very clear. In addition, 3D-FIESTA sequence may be used to better detect the small structures in the CSF. The pituitary stalk of type I and II is thinned and attenuated when the tumor is very large. Therefore, applying this approach would be challenging. We should pay extra attention to this structure before incising the dura and arachnoid matter.

Our findings were only based on seven patients. Therefore, a large population must be examined to determine the usefulness of this sequence in the EEA. Shiori et al. reported that the contrast-enhanced 3D-FIESTA is useful in the assessment of cranial nerves [3], and the acquired 3D image data allow high-quality planar images to be generated in any desired direction by means of MPR (multi-planar reconstruction) [21]. Cranial nerves are sometimes hard to distinguish from vascular structures. Therefore, it is necessary to distinguish the nerves from vascular structures either by their location and continuity or by enhancing the contrast.

Conclusions

Our newly developed method for producing images allows neurosurgeons to have a better understanding on the relationship between a lesion and its surrounding structures with minimal invasiveness to the patient. Moreover, our method is valuable in safely designing the surgical strategy, especially in the EEA. Finally, it may be helpful for the classification of craniopharyngioma based on EEA.

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Conflicts of interest None.

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