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Cranial nerve assessment in cavernous sinus tumors with contrast-enhanced 3D fast-imaging employing steady-state acquisition MR imaging

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Abstract
Introduction The purpose of this study is to apply contrast-enhanced 3D fast-imaging employing steady-state acquisition (3D-FIESTA) imaging to the evaluation of cranial nerves (CN) in patients with cavernous sinus tumors.
Methods Contrast-enhanced 3D-FIESTA images were acquired from ten patients with cavernous sinus tumors with a 3-T unit.
Results In all cases, the trigeminal nerve with tumor involvement was easily identified in the cavernous portions. Although oculomotor and abducens nerves were clearly visualized against the tumor area with intense contrast enhancement, they were hardly identifiable within the area lacking contrast enhancement. The trochlear nerve was visualized in part, but not delineated as a linear structure outside of the lesion.
Conclusions Contrast-enhanced 3D-FIESTA can be useful in the assessment of cranial nerves in and around the cavernous sinus with tumor involvement.

Keywords Cranial nerves · Fast-imaging employing steady-state acquisition · FIESTA · Cavernous sinus

Introduction

Treatment for tumors occupying the cavernous sinuses is difficult, and major complications such as occlusion of the internal carotid artery (ICA) and creation or aggravation of cranial nerve deficits are almost always associated with radical removal. Radiation therapy may also damage the neighboring neurovascular structures [1, 2]. Therefore, detection of individual cranial nerves may be useful for better treatment planning. However, visualization of nerves by conventional MR imaging protocols alone does not provide adequate information [3, 4].

Contrast-enhanced (CE) 3D fast-imaging employing steady-state acquisition (3D-FIESTA) or constructive interference in steady state (CISS) MR imaging providing high spatial resolution have successfully delineated individual normal cranial nerves [3–7]. In addition, it has been shown that gadolinium-based contrast agent increases relative contrast between the background structures and the cranial nerves within the cisterns or in the sinuses on FIESTA [5, 6], resulting in high detectability of the cranial nerves. Application of this technique in the evaluation of facial and cochlear nerves displacement by vestibular schwannomas has been demonstrated [7, 8], but there is no report, to our knowledge, on the identification of the cranial nerves involved by the cavernous sinus tumors. We report herein ten cases with cavernous sinus tumors evaluated with CE 3D-FIESTA.

Materials and methods

Eight women and two men (27–78 years old, five meningioma, two hemangioma, one lymphoma, one pituitary adenoma, and one metastasis) underwent MR imaging for the evaluation of cavernous sinus lesions.

Examinations were performed with a 3-T unit (SIGNA HDx; GE Healthcare). Following routine non-enhanced imaging, gadolinium-based contrast agent was manually injected (0.1 mmol/kg body weight), and T1-weighted images with 3D SPGR (TR/TE, 5.0/1.7; FOV, 240 mm; ST, 1 mm; SS, 1 mm; matrix, 256×256) were first obtained.

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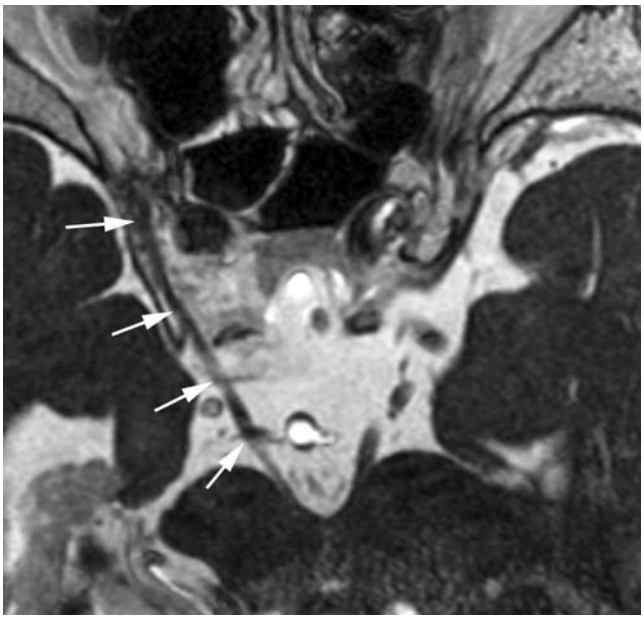

Fig. 1 Contrast-enhanced 3D-FIESTA in oblique axial view shows the right oculomotor nerve emerging from the midbrain, piercing the dura mater, running along the lateral wall of the cavernous sinus involved by hemangioma, then enter the orbit through the superior orbital fissure (*arrows*)

Imaging with FIESTA protocol (TR/TE, 6.0/2.1; FOV, 160 mm; ST, 0.4/0.6 mm; SS, 0.2/0.3 mm; matrix, 384× 384, axial view) was subsequently performed. Images were reconstructed in sagittal and coronal views for the evaluation of the cranial nerves.

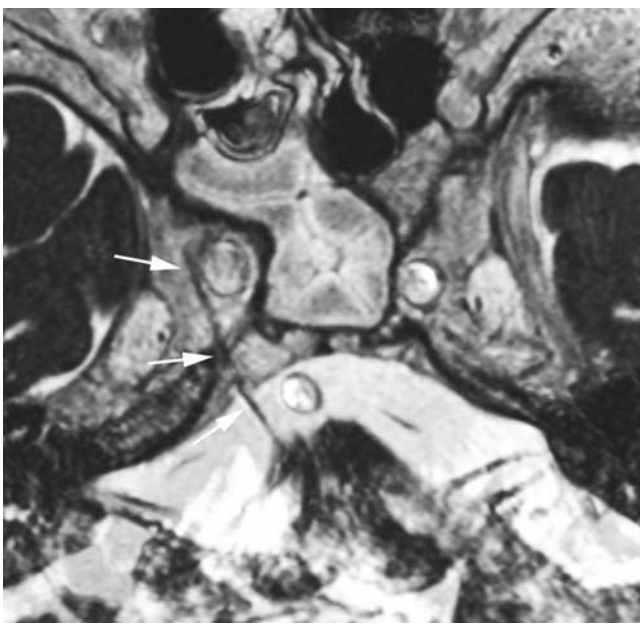

Fig. 2 Contrast-enhanced 3D-FIESTA in oblique axial view shows the right abducens nerve emerging from the brainstem, piercing the dura mater, entering the cavernous sinus to run in the middle of the tumor and then entering into the orbit through the superior orbital fissure (*arrows*)

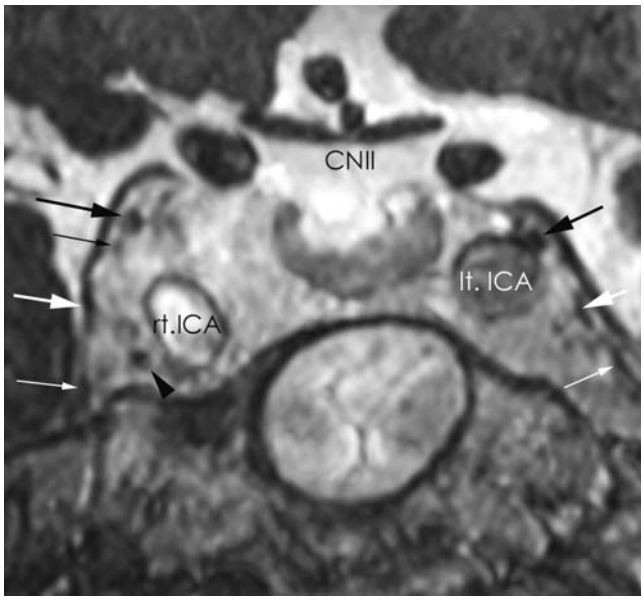

Fig. 3 Contrast-enhanced 3D-FIESTA in coronal view shows the right cavernous sinus involved by hemangioma, the oculomotor nerve (*large black arrows*), the trochlear nerve (*small black arrow*), the trigeminal nerves; V1 (*large white arrows*), V2 (*small white arrows*), and the abducens nerve (*black arrowhead*)

Results

In all ten cases, the oculomotor, trigeminal, and abducens nerves were clearly visualized outside of the tumors on CE 3D-FIESTA. The trochlear nerves were intermittently observed outside of the tumor.

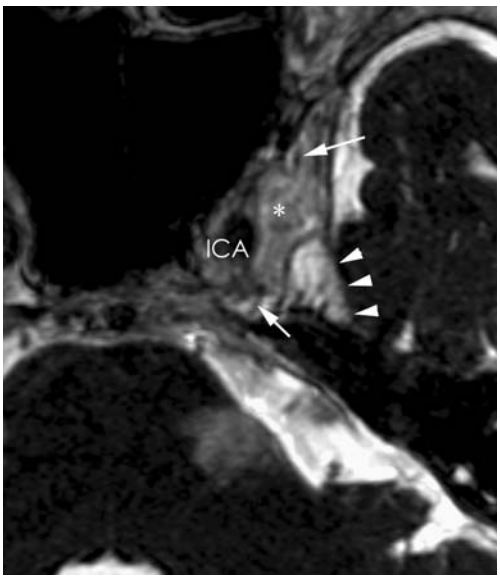

Fig. 4 Contrast-enhanced 3D-FIESTA in axial view of the left cavernous sinus meningioma irradiated 3 and 10 years ago. Some parts of the trochlear nerve are visible against the contrast-enhanced lesion (*arrows*), but not in the area without contrast enhancement (*asterisk*). The trigeminal nerve in the Meckel's cave is also shown (*arrowheads*)

The entire length of the oculomotor nerves involved in tumor was visible on CE 3D-FIESTA in all (Fig. 1). In five of ten cases, almost the entire length of the abducens nerves were identified running through the middle of the tumor (Fig. 2). Trochlear nerves were, again, only partly shown in all (Fig. 3). In one case of lymphoma, the abducens nerve was scarcely detected within the tumor with intense enhancement. In another case of hemangioma, the abducens nerve was minimally identified within the part of the tumor lacking contrast enhancement, which may correspond to degenerated or necrotic tissue (Fig. 4) Trigeminal nerves running lateral (V1) or inferolateral (V2) to the ICA were also clearly visualized in all but one case of lymphoma. Trochlear nerves were again only partly shown.

In one case of clinically suspected meningioma irradiated 10 and 3 years before, abnormal enhancement of the oculomotor nerve was visualized within and out of the tumor on T1-weighted images.

Discussion

Anatomy of the cavernous sinus has been well studied and explored [5, 9–16]. As previous studies have shown, CE 3D-FIESTA visualizes the CN III–VI in the cavernous portion against the contrast-enhanced normal structures with a delectability of 65–100% [5]. We tried to apply this technique to the evaluation of the cranial nerves running through the cavernous sinus with tumor involvement.

Oculomotor nerves running superolateral and lateral to the ICA, and trigeminal nerves running inferolateral to the ICA were easy to identify. Compared to the abducens and trochlear nerves, it seems that the oculomotor and trigeminal nerves are thick and thus less vulnerable, or that they are thick enough to be detected even when the contrast enhancement of surrounding structures is relatively faint.

Abducens nerves, the only nerve running inside of the cavernous sinus, were clearly shown in five cases. The nerves were easily identified when the enhancement of the surrounding tumor was intense, but not within the part showing mild or no enhancement. However, in one case of lymphoma, CN V and CN VI nerves were not visible despite the intense enhancement of the tumor; thus, visibility of the nerves is not only dependent on the contrast enhancement of the surrounding structures. The patient suffered from CN V palsy and it seems that the invisibility is attributable to the abnormal enhancement of the nerve itself or the disruption of the nerve.

One limitation of the CE 3D-FIESTA is that it is sometimes difficult to discriminate cranial nerves from vascular structures. Although it is reported that trochlear nerves are shown at least in three consecutive sections in 65% of the cases in a previous study [7], they were hardly identified as linear structures in the cavernous portion in our cases. It was therefore necessary to distinguish the trochlear nerves from vascular structures by their location and continuity or by contrast enhancement. Although not as high as FIESTA in spatial resolution, CE 3D SPGR images were useful to distinguish tiny nerves from vascular structures or in evaluating abnormal enhancement of the cranial nerves; when employed combined with FIESTA, it could compensate the limitation and add some qualitative information.

In conclusion, we confirmed that CE 3D FIESTA imaging can be useful in the assessment of cranial nerves in and around the cavernous sinus with tumor involvement.

Conflict of interest statement We declare that we have no conflict of interest.

References

1. Sindou M, Wydh E, Jouanneau E et al (2007) Long-term follow-up of meningiomas of the cavernous sinus after surgical treatment alone. J Neurosurg 107:937–944. doi:10.3171/JNS-07/11/0937
2. Kuo JS, Chen JC, Yu C et al (2004) Gamma knife radiosurgery for benign cavernous sinus tumors: quantitative analysis of treatment outcomes. Neurosurgery 54:1385–1393. doi:10.1227/01.NEU.0000124750.13721.94
3. Yousry I, Camelio S, Schmid UD et al (2000) Visualization of cranial nerves I–XII: value of 3D CISS and T2-weighted FSE sequences. Eur Radiol 10:1061–1067. doi:10.1007/s003300000452
4. Seitz J, Held P, Fru¨nd R R et al (2001) Visualization of the IXth to XIIth cranial nerves using 3-dimensional constructive interference in steady state, 3-dimensional magnetization-prepared rapid gradient echo and T2-weighted 2-dimensional turbo spin echo magnetic resonance imaging sequences. J Neuroimaging 11:160–164
5. Yagi A, Sato N, Taketomi A et al (2005) Normal cranial nerves in the cavernous sinuses: contrast-enhanced three-dimensional constructive interference in the steady state MR imaging. AJNR Am J Neuroradiol 26:946–950
6. Yousry I, Moriggl B, Schmid UD et al (2005) Trigeminal ganglion and its divisions: detailed anatomic MR imaging with contrast-enhanced 3D constructive interference in the steady state sequences. AJNR Am J Neuroradiol 26:1128–1135
7. Shigematsu Y, Korogi Y, Hirai T et al (1999) Contrast-enhanced CISS MRI of vestibular schwannomas: phantom and clinical studies. J Comput Assist Tomogr 23:224–231. doi:10.1097/00004728-199903000-00010
8. Taoka T, Hirabayashi H, Nakagawa H et al (2006) Displacement of the facial nerve course by vestibular schwannoma: preoperative visualization using diffusion tensor tractography. J Magn Reson Imaging 24:1005–1010. doi:10.1002/jmri.20725
9. Harris FS, Rhoton AL Jr (1976) Anatomy of the cavernous sinus: a microsurgical study. J Neurosurg 1045:169–180
10. Umansky F, Nathan H (1982) The lateral wall of the cavernous sinus. J Neurosurg 56:228–234
11. Taptas JN (1982) The so-called cavernous sinus: a review of the controversy and its implications for neurosurgeons. Neurosurgery 11:712–717. doi:10.1097/00006123-198211000-00019
12. Ono M, Rhoton AL Jr, Barry M (1984) Microsurgical anatomy of the region of the tentorial incisura. J Neurosurg 60:365–399

13. Kehrli P, Ali M, Reis M Jr et al (1998) Anatomy and embryology of the lateral sellar compartment (cavernous sinus) medial wall. Neurol Res 20:585–592
14. Dietemann JL, Kehrli P, Maillot C et al (1998) Is there a dural wall between the cavernous sinus and the pituitary fossa? Anatomical and MRI findings. Neuroradiology 40:627–630. doi:10.1007/s002340050653
15. van Overbeeke JJ, Jansen JJ, Tulleken CA (1988) The cavernous sinus syndrome: an anatomical and clinical study. Clin Neurol Neurosurg 90:311–319. doi:10.1016/0303-8467(88) 90002-9
16. Tuccar E, Uz A, Tekdemir I et al (2000) Anatomical study of the lateral wall of the cavernous sinus, emphasizing dural construction and neural relations. Neurosurg Rev 23:45–48. doi:10.1007/s101430050031