Usefulness of Preoperative Simulation in Skull Base Approach: A Case Report

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Abstract

Keywords

- preoperative simulation
- skull base
- 3D-CTA
- FIESTA
- clinoid meningioma
- feeding artery

Skull base approach is a neurosurgical challenge requiring dexterity of the operating surgeon for good postoperative outcome. In addition to the experience of the operating surgeon, adequate preoperative information of the tumor is necessary to ensure better outcome. In clinoid meningioma, it is sometimes difficult to determine its relationship with the surrounding structure and the feeding artery. Previously, preoperative simulation has been utilized to determine the intracranial course of the compressed nerves in relation to the petroclival meningioma. We report a case of clinoid meningioma where preoperative fusion of three dimensional computed tomography angiography (3D-CTA) and 3T-fast imaging employing steady-state acquisition (FIESTA) images was useful in determining the exact location of the feeding artery to devascularize the tumor and aid in surgery. Preoperative simulation with three-dimensional digital subtraction angiography (3D-DSA) and 3T-FIESTA fusion images can be a useful adjunct tool to supplement surgery and to train neurosurgical trainees.

Introduction

Skull base approach has always been a challenge in neurosurgery. The difficulty in approaching the skull base, complexity of the anatomy, location of the vital neurovascular structures, narrow surgical corridor, and longer operative time all render the skull base approach as a neurosurgical challenge.^{1–5} The outcome of the skull base approach also depends upon the dexterity and the experience of the operating surgeon, and the learning curve for this approach is steep. Furthermore, the technical difficulty, stronger brain retraction required, and the distortion of the complex skull base anatomy by the tumor also impede the good postoperative outcome.⁶

In such a condition, assuring a good postoperative outcome is of prime importance. Advances in the neuroimaging in addition to astounding improvement of microsurgical technique have contributed in the armamentarium of a skull base neurosurgeon. Previous studies have reported advan-

tage of preoperative simulation using advanced neuroimaging modalities in precise determination of the intracranial course of the nerves even in large skull base tumors with distorted anatomy.^{7–9} Here, we report a case of huge clinoid meningioma where preoperative simulation of the tumor with a combination of three-dimensional multidetector computed tomography (3D-MDCT), three dimensional digital subtraction angiography (3D-DSA) and 3T-fast imaging employing steady-state acquisition (FIESTA) proved to be a useful adjunct tool to determine the exact location of the feeding artery and to facilitate surgical resection.

Case Report

A routine brain dock examination in an asymptomatic 62-year-old female revealed an incidental mass in the left frontal lobe (► **Fig. 1A and B**). Magnetic resonance imaging (MRI) revealed iso- to hypointense 48-mm mass on T1 weighted image

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Fig. 1 Preoperative images of the patient with left clinoid meningioma. Computed tomography scan (A and B) showing a mass arising from the left side of clinoid and mild left cerebral edema. MRI, FLAIR (C), and post-contrast images (D–F) showing homogeneous enhancement and dural-tail sign. FLAIR, fluid-attenuated inversion recovery; MRI, magnetic resonance imaging.

(T1WI), which was homogeneously enhanced on post-contrast images (► **Fig. 1D–F**). FIESTA images showed the mass to be in close proximity to the left optic nerve and left internal carotid artery (ICA) (► **Fig. 2A and B**). Further investigation showed

that the mass had the base on the left side of anterior clinoid process with dural-tail sign. The mass was finally diagnosed as left clinoid meningioma. Cerebral angiogram showed the feeding artery arising from the ophthalmic branch of left

Fig. 2 FIESTA images (A and B) showing close relationship of the tumor with the left optic nerve and the left internal carotid artery. FIESTA, fast imaging employing steady-state acquisition.

ICA; however, the exact site of the origin of feeding vessel could not be identified.

The logistics employed for the preoperative simulation were as follows: software SYNAPSE VINCENT by Fujifilm, equipped in a workstation FN-7941, and No.: 22000BZX00238000 hardware with operating system of Microsoft Windows Server 2008 Standard 64 bit in a central processing unit with Quad Core Intel Xenon processor. Basically, we neurosurgeons simulate preoperatively with computed tomography angiography (CTA), MRI, or DSA. We fused the CTA together with DSA or other modality, from the base information arranged in advance, and the operators can easily simulate by using those fusion data within 15 minutes in each medical recording system by themselves (► **Fig. 3**). Preoperative simulation with fusion of 3D-MDCT, CTA, computed tomography venography (CTV), and 3T-FIESTA images (► **Video 1**) showed the tumor compressing the left optic nerve and in close proximity to the left ICA. The feeding artery, however, could not be visualized clearly. Further simulation with fusion of 3D-MDCT, 3T-FIESTA, and 3D-DSA images (► **Video 2**) clearly showed the feeding artery arising from the left ophthalmic artery and entering the cranial cavity at two sites.

Video 1

This video shows the preoperative simulation with 3D-MDCT, CTA, CTV, and 3T-FIESTA fusion images. The tumor which is shown in green is seen with its relationship with the surrounding structures and is based at the anterior clinoid. The left optic nerve marked with yellow in the video is derived from the FIESTA image and can be visualized as compressed by the tumor itself. The arteries and the veins around the tumor can be well visualized, but the feeding arteries and their origin cannot be precisely demarcated. 3D-CTA, three-dimensional computed tomography angiography; CTV, computed tomography venography; 3D-DSA, three-dimensional digital subtraction angiography; FIESTA, fast imaging employing steady-state acquisition; ICA, internal carotid artery; 3D-MDCT, three-dimensional multidetector computed tomography. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0038-1660843.

Video 2

This video shows the preoperative simulation with 3D-CTA and 3D-DSA fusion images. The tumor marked with green is seen with its relationship with the surrounding vessels. The feeding arteries can be

precisely visualized with 3D-CTA/3D-DSA fusion image. The feeding arteries are seen to arise from the ophthalmic branch of the left ICA and enter the cranial fossa at two points at the base of the tumor near the anterior clinoid process and finally supply the tumor. 3D-CTA, three-dimensional computed tomography angiography; 3D-DSA, three-dimensional digital subtraction angiography; ICA, internal carotid artery. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0038-1660843.

The patient was operated via combined left orbitozygomatic and Dolenc approach. After the dural incision and exposure of the tumor, further dissection was performed to expose the site of intracranial entry of the feeding vessels (► **Video 3**). The vessels were then coagulated and cut at the two sites of entry as determined on preoperative simulation. Following this, left anterior clinoidectomy was done, and the meningo-orbital band was cut exposing the left ICA and optic nerve. The tumor was gradually detached and dissected from the surrounding tissue. As the tumor was totally devascularized, there was hardly any bleeding from the tumor and was finally gross-totally removed achieving Simpson's grade II resection. The postoperative MR images showed no residual tumor (► **Fig. 4**). The post-operative course was uneventful, and there was no focal neurological deficit.

Video 3

This is a short clip from the intraoperative video. The patient was operated via the combined left orbitozygomatic and Dolenc approach. In this video, we can see how the preoperative simulation aided in achieving complete devascularization of the tumor with minimal blood loss during surgery. First, we can see the coagulation and cutting of the feeding arteries at the first entry point near the anterior-clinoid process followed by coagulation and cutting at the second entry point. After that, the left partial anterior clinoidectomy was done. The meningo-orbital band was cut to expose the left ICA and left optic nerve. The tumor was slowly detached from the surrounding brain surface by careful dissection of arachnoid. Debulking of the tumor with CUSA showed no blood loss at all as a result of complete devascularization of the tumor. The tumor was gradually dissected from its surrounding attachment. Finally, the tumor was gross totally resected and the dural attachment of the tumor was coagulated. This shows that the utilization of preoperative simulation with 3D-DSA and 3T-MR fusion images enabled determination of the exact site of entry of the feeding vessels into the intracranial compartment, which aided in their coagulation and

Fig. 3 Pre-operative DSA (A and B) and CTA (C) and fusion images (D and E) showing the feeding vessels to the clinoid meningioma and its relation to the tumor. CTA, computed tomography angiography; DSA, digital subtraction angiography.

enabled total devascularization of the tumor during surgery. CUSA, cavitron ultrasonic surgical aspirator; 3D-DSA, three-dimensional digital subtraction angiography; ICA, internal carotid artery; MR, magnetic resonance. Online content including video sequences viewable at: www.thieme-connect.com/products/ejournals/html/10.1055/s-0038-1660843.

Discussion

Skull base approach still remains a neurosurgical challenge even to an experienced neurosurgeon despite marked advancement in microsurgical techniques. The primary difficulty encountered is to protect the underlying neurovascular structures while achieving maximum safe resection. In skull base meningiomas, particularly petroclival and clinoid meningiomas, it is necessary to preserve the integrity of the intracranial nerves and the supplying vessels to preserve the neurological functional integrity of the neurons. Of particular importance is the preoperative determination of feeding vessels of the tumor to minimize blood loss during surgery and to ensure better outcome.

Previous study has reported the advantage of preoperative simulation using advanced 3D-imaging in skull base and deep tumors.¹⁰ Similarly, various studies have reported its usefulness in different surgeries, such as mastoid surgery and liver surgery, and even for personalizing patient-specific surgery.^{11–13} The visualization and determination of feeding vessels have pre-

viously been attempted using cerebral angiography and other techniques, particularly in large tumors where the normal anatomy is grossly distorted. Continuous efforts are made to improve the technique for better visualization and

Fig. 4 Postoperative MR images showing gross total removal of the tumor. MR, magnetic resonance.

determination of the feeder arteries. Recently, studies have reported use of diffusion tensor imaging (DTI), FIESTA, diffusion spectrum imaging (DSI), and 3D-fast spoiled gradient echo dual echo (3D-FSPGR) to reconstruct and determine the intracranial course of cranial nerves.^{7,8,14,15} Similarly, Yang et al have reported the use of preoperative simulation by fusing images of CTA and FIESTA for determining the intracranial course of abducens nerve compressed by petroclival meningioma.⁹ However, pre-operative simulation using fusion images to determine the feeding vessels in skull base meningioma has not been widely used. Oishi et al have reported the use of interactive pre-surgical simulation with advanced 3D imaging in skull base tumors.¹⁰ They have reported the advantage of presurgical simulation to determine the complex surgical anatomy of the skull base and to choose the optimum surgical strategy while efficiently educating the neurosurgical trainees.

To determine the exact site of the feeding vessels, we tried to simulate preoperatively first by fusing the 3D-MDCT, CTA, CTV, and 3T-FIESTA images and then by fusing the 3D-MDCT, FIESTA, and 3D-DSA images. MRA, CTA, and DSA are common and widely performed imaging modalities to visualize the feeding vessels in the tumor. However, there are no reports describing the utility of fusing these imaging modalities for clear visualization. In our case, fusion of 3D-MDCT and 3T-FIESTA images provided adequate information regarding the relationship of the tumor with the surrounding vessels and the left optic nerve, but the information about the feeding vessel could not be obtained. However, fusion of 3D-MDCT, 3D-DSA, and 3T-FIESTA images provided the precise anatomy of the feeding vessels and the point of entry into the intracranial compartment, which facilitated their coagulation and devascularization of tumor during surgery. Future large prospective studies are needed to determine the usefulness and limitations of this technique.

Preoperative simulation offered a few advantages. The position of the feeding artery could be precisely located in the bone near the anterior clinoid process and optic sheath, thus avoiding injury to the optic nerve even before actual visualization of the nerve and hence making the surgery safer. Furthermore, young neurosurgical trainees could be educated regarding the optimum surgical approach. Lastly, preoperative simulation can ensure better outcome by eliminating the experience of the surgeon as a determining factor in postoperative outcome.

Conclusion

We report a case of large clinoid meningioma where the preoperative determination of the feeding vessels was difficult, based solely on the conventional MR images and DSA. Utilization of preoperative simulation with 3D-DSA and 3T-MR fusion images enabled determination of the exact site of entry of the feeding vessels into the intracranial compartment, which aided in their coagulation and enabled total

devascularization of the tumor during surgery. Preoperative simulation with 3D-DSA and 3T-MR fusion images can be a useful adjunct tool to supplement surgery and to train neurosurgical trainees.

Conflict of Interest

None.

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