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Three-dimensional Helical CT Angiography of Skull Base Meningiomas

Kazuhiro Tsuchiya, Junichi Hachiya, Yoshiyuki Mizutani, and Ayako Yoshino

PURPOSE: To describe the findings of skull base meningiomas on three-dimensional CT angiograms obtained with helical scanning and to evaluate the usefulness of this method. **METHODS:** Fifteen patients who had a meningioma near the skull base were examined with helical CT after receiving an intravenous bolus injection of contrast material. **RESULTS:** All meningiomas had either a honeycomb (12 patients) or solid (3 patients) pattern of enhancement. Bony structures of the skull base and adjacent major arteries that were displaced or surrounded by tumor were also evident. **CONCLUSION:** Three-dimensional CT angiography depicts the relationship between skull base meningiomas and neighboring bony and vascular structures clearly, quickly, and with minimal risk to the patient.

Index terms: Computed tomography, three-dimensional; Meninges, neoplasms; Skull, base

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Magnetic resonance (MR) angiography is a noninvasive technique that is widely used in the examination of patients with intracranial and cervical vascular disorders. Three-dimensional computed tomographic (CT) angiography is another method for evaluating these vessels with minimal risk (1–3). Its usefulness and limitations have been discussed in connection with cerebral aneurysms, vascular malformations, and moyamoya disease (4–6). Helical, or spiral, scanning is a recently developed CT technique that has several advantages over conventional scanning methods. One is the ability to provide a continuous volume of data that can be reconstructed to produce 3-D images of high quality (7). This article describes our experience in using 3-D helical CT angiography to examine patients with meningiomas of the skull base.

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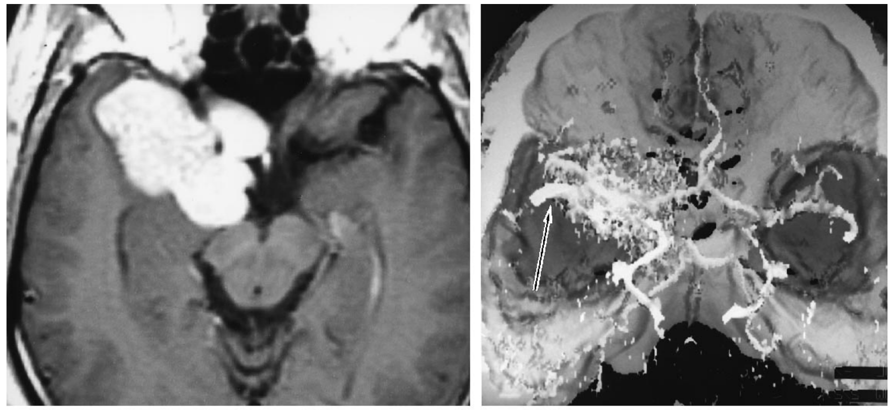
Subjects and Methods

Our study group consisted of 15 patients with meningioma near the skull base (7 men and 8 women; mean age, 53 years; age range, 19 to 78 years). Thirteen of the 15 meningiomas were proved surgically and the remaining 2 were diagnosed on the basis of results of MR imaging and conventional angiography. The meningiomas arose from the sphenoid ridge (6 patients), the tuberculum sellae (3 patients), the planum sphenoidale (3 patients), the cerebellopontine angle (2 patients), and the falx near the skull base (1 patient). Three patients were imaged postoperatively, 2 for recurrent tumor and 1 for residual tumor.

Helical CT was performed by using a TCT-900S (7 patients) or an Xforce (8 patients) scanner (Toshiba Medical, Tokyo, Japan). In 12 patients, we used a SPARCstation 10 (Sun Microsystems, Mountain View, Calif) system with a volume-rendering technique provided in the Cemax VIP software program (Cemax Inc, Fremont, Calif) to reconstruct 3-D images. In the remaining 3 patients, reconstruction was performed with the software provided in the scanner. The scanning parameters used were as follows: scanning cycle, 1 cycle per second; table feed speed, 2 mm/s; scanning time, 30 to 37 seconds; section thickness, 2 mm; and reconstruction interval, 1 mm. We injected 85 mL of iopamidol 300 (300 mg iodine per milliliter, 8 patients), iopamidol 370 (370 mg iodine per milliliter, 3 patients), or iotrolan 280 (280 mg iodine per milliliter, 4 patients) (Schering, Berlin, Germany) at a rate of 2 mL/s into the antecubital vein using a power injector. The injection was started 25 seconds before the initiation of scanning. When scanning was completed, we reconstructed multidirectional 3-D CT angiograms above a single thresh-

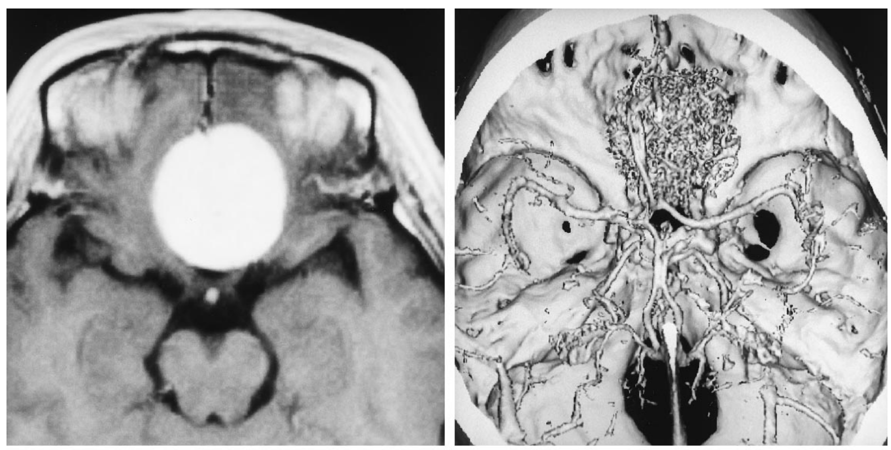


A B

Fig 1. Thirty-nine-year-old man with a meningioma of the right sphenoid ridge.

A, Postcontrast T1-weighted MR image (600/11/2 [repetition time/echo time/excitations]) shows an enhancing mass originating from the right sphenoid ridge.

B, Superior view of 3-D CT angiogram obtained using software provided in the CT scanner shows honeycomb enhancement pattern of the tumor. The distal internal carotid, proximal middle cerebral, and anterior cerebral arteries are surrounded by the tumor. A dilated vessel, probably a vein, is seen on the surface of the tumor (*arrow*).



A B

Fig 2. Forty-six-year-old woman with a meningioma of the planum sphenoidale.

A, Postcontrast T1-weighted MR image (470/15/2) shows an intensely enhancing mass in the anterior cranial fossa.

B, Superior view of 3-D CT angiogram obtained using a workstation for postprocessing shows honeycomb enhancement pattern of the tumor. Displacement of the anterior cerebral arteries is apparent.

old of 55 to 130 Hounsfield units. This threshold defined bone and significantly enhancing tissue and vessels.

Results

Each meningioma showed either a honeycomb (12 patients, Figs 1 and 2) or solid (3 patients, Fig 3) pattern of enhancement. Pathologic classification of the meningioma was available for 9 tumors: 7 were meningotheliomatous and 2 were transitional. The honeycomb enhancement pattern was noted in 5 meningotheliomatous tumors and in 1 transitional tumor, whereas solid enhancement was seen in 2 meningotheliomatous tumors and in 1 transitional tumor. It was also possible to observe the bony structures of the skull base. In addition, 3-D CT angiograms showed adjacent major arteries displaced or surrounded by a meningioma in every patient. These arterial changes were verified at the time of surgery in all patients who had surgery. The arteries involved included the anterior cerebral artery (12 patients, Figs 1 and 2), the middle cerebral artery (6 patients, Figs 1 and 3), the posterior cerebral artery (5 patients), the internal carotid artery (3 patients, Fig 1), the basilar artery (1 patient), and the posterior communicating artery (1 patient). In 7 patients, we detected abnormal vessels, probably veins, running on the surface of the tumor (Figs 1 and 3).

Image reconstruction after scanning usually took about 20 minutes using the software provided in the scanner and about an hour using the workstation.

Discussion

In the 1980s, several studies investigated the suitability of 3-D CT to the evaluation of intracranial vascular and neoplastic lesions (1, 2, 8, 9). However, this technique failed to gain wide acceptance because, at that time, 3-D reconstruction required highly specialized and expen-

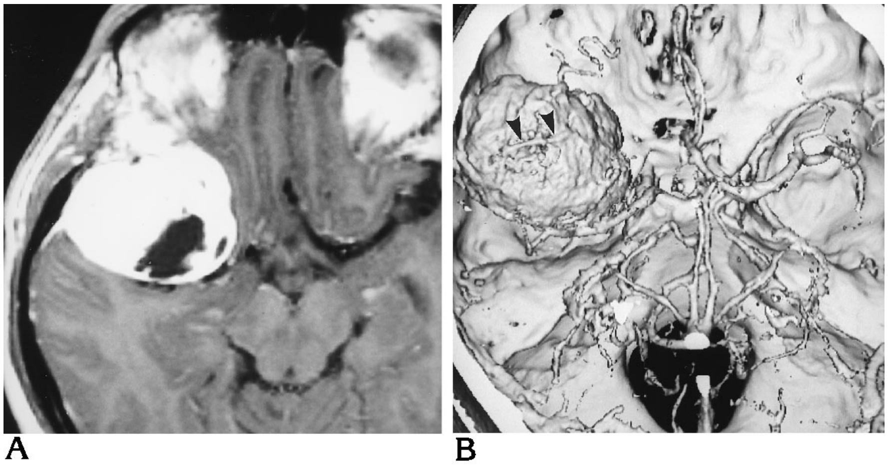


Fig 3. Thirty-year-old man with a meningioma of the right sphenoid ridge.

A, Postcontrast T1-weighted MR image (500/14/2) shows a markedly enhancing mass with a necrotic component.

B, Superior view of 3-D CT angiogram obtained using the workstation shows solid enhancement of the tumor. Posterior displacement of the proximal right middle cerebral artery is apparent. A small vessel is noted on the surface of the tumor (*arrowheads*).

sive software and hardware. In addition, the postprocessing time was extremely long. Today, recent advances in computer technology are again drawing the attention of neuroradiologists to the 3-D display of intracranial lesions.

Helical, or spiral, scanning is a recently developed CT technique that can be applied to the 3-D reconstruction of images (3, 10–15). In this technique, continuous data are acquired while the patient passes through the CT gantry on a table moving at a constant speed. The volume data acquired in this manner can be used to generate source images for 3-D reconstruction with a fine pitch at any desired section position. Because the scanning time is short, vessels are well visualized with proper timing of a bolus injection of a small amount of contrast material (15). It is possible to generate CT scans in the axial plane as well as in other planes from the volume of data. Accordingly, we can perform 3-D CT angiography as part of the routine CT examination when helical scanning is used. Although the workstation used in this series produces 3-D images of better quality than those produced by the software provided in the CT scanner, the time required for postprocessing is a little problematic. However, with continued development, we anticipate that this problem will be solved in the near future.

Neuroradiologic examinations that are performed in the diagnosis of meningiomas generally include CT, MR imaging, and conventional angiography. We believe that 3-D CT angiography is a useful supplement to these examinations, especially in patients with skull base meningiomas. First, this technique provides images that clearly depict the anatomic relationship between the meningioma and the bony structures of the skull base. Although attachment of a meningioma to the dura is more precisely delineated on MR images, especially in the sagittal or coronal plane, 3-D CT angiograms directly show both the meningioma and the skull base. Second, this technique clearly demonstrates the relationship between a skull base meningioma and neighboring vessels, especially arteries. Unlike postcontrast CT, MR imaging, and angiography, this technique is able to depict in 3-D the relationship between the meningioma and the displaced or surrounded arteries. MR imaging can also portray meningiomas and neighboring vessels at the same time; however, its demonstrability is not 3-D but two-dimensional. MR angiography is able to show changes of vessels, but it is generally unable to picture the meningiomas themselves. Third, in our series, 3-D CT angiography frequently showed vessels on the tumor surface that are thought to be draining veins or dilated cortical veins. Thus, we believe that the information obtained by this technique is of value in surgical planning.

It is probable that the enhancement characteristics of meningiomas observed in this series reflect their rich vascularity. We made no change in scanning parameters except for the contrast agent used. In our experience with these fixed parameters, few tumors of other types have shown similar enhancement characteristics. Therefore, it may be possible to differentiate a meningioma from other kinds of tumor. In our limited number of patients, there was no apparent relationship between the histologic subtype of the meningiomas and the pattern of enhancement. We are planning to investigate this issue in a larger series.

There are several disadvantages to 3-D CT angiography. First, X-ray exposure and the use of a contrast agent are unavoidable. However, the X-ray exposure dose is lower in helical scanning than in rapid sequence scanning (eg, 39 mGy versus 50 mGy to the surface of the face in a previous study [6]). The amount of contrast agent used in this series was also rather small. Second, overlapping of the enhanced choroid plexus and the venous system is a problem, but it can be overcome by changing the view direction. In addition, although we do not use color imaging routinely, it is possible to display structures in separate colors. Third, the view is limited from certain directions owing to the bony structures of the skull base. When indicated, the computer can remove or make transparent the segment of the bone that obscures the tumor. We regard as noteworthy the technique reported by Napel et al (12) in which bones are suppressed and the maximum intensity projection technique is used. However, deleting the bony structures makes it impossible to evaluate their relationship to the meningioma. Finally, size and configuration of a meningioma may change depending on the threshold selected for 3-D reconstruction. Furthermore, although this did not occur in our patient group, we would be able to visualize the exocranial extent of a meningioma if we viewed the lesion from outside the skull. But the exact extent of a meningioma may be seen better on cross-sectional CT scans or MR images.

In summary, 3-D CT angiography depicts the relationship between skull base meningiomas and surrounding bony and vascular structures clearly, quickly, and with minimal risk to the patient. It is hoped that with the increasing availability of CT scanners with helical scanning capabilities, this technique will become part of routine CT examinations.

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