

Comparative study of multi-slice CT angiography with digital subtraction angiography in the blood supply of meningiomas

XIANGJUN HAN, YUEFU ZHAN and JIANQIANG CHEN

Department of Radiology, Haikou People's Hospital, Haikou, Hainan 570208, P.R. China

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Abstract. Evaluation of multi-slice CT angiography (MSCTA) and digital subtraction angiography (DSA) was made through the comparison of the two methods in detecting the blood supply of meningiomas, providing further clues for the improved application of MSCTA and DSA in the blood supply of meningiomas. In this study, 20 patients with meningiomas underwent CT angiography by 16-slice spiral CT and inspection 1 week later using DSA. The blood supply of the meningiomas (including the tumor feeding arteries, draining veins, venous sinuses, vessels around the tumor and skull-shaped images, such as comparative evaluation) was compared. The results showed that MSCTA and DSA inspection clearly depicted tumor feeding arteries, draining veins and venous sinuses in all 20 patients. DSA was slightly more effective than MSCTA in displaying fine branches, and DSA had obvious advantages over MSCTA in displaying vessels near the skull. In the display of the tumor's compression and pushing over its peripheral vasculature, MSCTA had the three-dimensional advantage, although in displaying parasagittal sinus meningiomas, it may overestimate the presence of venous sinus invasion due to the impact of bone structure. This does not affect DSA. MSCTA accurately assesses the relationship between the tumor and the bone, and provides three-dimensional images for the pre-operative simulation of surgical approaches. Taken together, MSCTA and DSA are both able to provide important information, such as accurate visualization of tumor-feeding arteries, draining veins and venous sinuses, with high consistency. MSCTA is more advantageous in the depiction of three-dimensional relationships between the tumor and peripheral vessels and skull. Compared to DSA, MSCTA is non-invasive, faster and less costly.

Introduction

Meningiomas are abundant in the blood supply. Manelfe *et al* (1) divided meningiomas (based mainly on the external or

internal carotid artery) into four types according to the arterial blood supply. Several scholars (2-4) have performed studies on the blood supply of meningiomas through digital subtraction angiography (DSA). In meningiomas fed by a single internal or external carotid artery, DSA imaging clearly reveals the staining and arteriovenous branches of the tumor, but those fed by both an internal and external carotid artery cannot be displayed well as the image does not show both sides simultaneously. Multi-slice spiral CT vascular imaging involves a contrast injection to the full arterial and venous phases to fully stain the tumor and display dual feeding arteries and reflux veins, and has received attention from a number of researchers (3,5,6). To understand the advantages and disadvantages of multi-slice CT angiography (MSCTA) and DSA in the angiography of meningiomas, a comparative study of the two methods in the detection of meningioma blood supply was performed.

Materials and methods

General materials. Twenty inpatients in our hospital diagnosed with meningioma by CT or MR underwent MSCTA and DSA at the same time. The inspection interval was 1 week. Among 20 patients, 11 tumors were convex, 3 in the midline falx and 6 in the infratentorial (including the saddle, anterior and posterior cranial fossa and cerebellopontine angle area), including 3 cases in the near side of venous sinuses. Patients included 8 men and 12 women, aging from 17 to 74 years. The size of the largest tumor was 120x110x800 mm, while that of the smallest was 35x32x27 mm.

Equipment and contrast agent. The CT machine used was the Somatom Sensation 16-slice spiral CT machine. DSA was performed using the Advantx Lc/Lp DLX Dual C-arm DSA machine (GE, USA). The contrast agent used was iopamidol (370 mg/ml).

Examination methods. Multi-slice spiral CT examination and three-dimensional reconstruction: Informed consent was obtained from all patients prior to the study. We then successfully eliminated their emotional tension. Patients were placed in the supine position on the check-bed and initially plain-scanned to determine the scan range. The scan field generally ranged from the skull base to the calvaria. Patients underwent a contrast-enhanced scan. Scan parameters were 120 kv, 200 mAs, slice thickness 2 mm and collimation

Correspondence to: Dr Xiangjun Han, Department of Radiology, Haikou People's Hospital, Haikou, Hainan 570208, P.R. China
E-mail: jilinhxj@163.com

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16x0.75 mm. Contrast agent automatic tracking technology was used. A high pressure injector was applied to inject 80-100 ml (370 mg/ml) iopamidol through the elbow vein at the rate of 3 ml/sec. Reconstruction slice was 0.75 mm, with a spacing of 0.75 mm. Reconstruct multiplanar reformations (MPR), maximum intensity projection (MP), shaded surface display (SSD) and volume rendering technique (VRT) were conducted on the Wizard workstation.

DSA inspection. Informed consent was obtained from all patients prior to the study. We then successfully eliminated their emotional tension. Tranquilizers were used in agitated patients prior to the examination. Using the Seldinger technique, a 4F VER angiography catheter was inserted via the right femoral arterial approach, and placed in a 5F arterial sheath. The left and right carotid arteries and the left and right vertebral arteries were selected to perform contrast radiography. The high-pressure injection method was used and we selected iopamidol (370 mg/ml) as the contrast agent. Contrast agent dosage was as follows: carotid angiography flow rate of 5 ml/sec, with a total of 7 ml each time; vertebral angiography flow rate of 4 ml/sec, with a total volume of 6 ml each time. The orthophoric and lateral images were taken.

Data analysis. Two veteran radiologists analyzed two types of imaging data. One radiologist knew the medical history, but did not know the DSA results. The other took DSA as the 'gold standard' to evaluate the diagnostic sensitivity and specificity of CTA, and assessed the differences between the two imaging methods in the meningiomas' feeding arteries, draining veins and the adjacent sinus invasion or extent of invasion, as well as the spatial relationship between the tumor and great intracranial blood vessels. The specific observation methods were: i) the performance of the two techniques in displaying the feeding arteries of the tumor and the main branches of the brain arteries adjacent to the tumor, including the clarity of display of the arteries (comparison between tumor body and arteries in density and signal differences), the displayed number of arteries, artery embedding, compression and erosion and the existence of dissimilar observation results due to different pathogenic sites. ii) Comparative evaluation of draining veins, including the number of displayed draining veins, displaying clarity, characteristics of the joint between the draining veins and the tumor body, flow direction of the draining veins and the richness of the peripheral compensatory perforator veins. iii) Comparative evaluation of venous sinuses, including the clarity of the display of the relationship between parasagittal sinus meningiomas and venous sinuses, sinus damage, indicating violation of the integrity of the sinus. iv) Comparative evaluation of surrounding tissues, including the contrast of the degree of enhancement of the tumor body, the degree of the tumor compression and invasion of the surrounding brain tissues, and the effect of the tumor on the adjacent bones.

Results

Arterial blood supply of tumors. In 20 cases of meningiomas, MSCTA and DSA images were both clear in displaying the feeding arteries of the tumor. The feeding arteries around the tumor were connected to the body in clusters or arcuses, and

then branched into the tumor body (Fig. 1). MSCTA achieved the DSA imaging effects by adjusting displaying angles, clearly displaying intracranial branches of class IV or above. DSA displayed more peritumoral minor arteries than MSCTA. Both examination methods revealed that the intracranial arteries were involved in blood supply in 12 cases.

Relationship between tumor and its peripheral vessels. In this study, tumor body in 16 cases was closely related to its adjacent intracranial arteries (including the oppression and embedding of the tumor on the main arterial branches). The first-class branches of Willis' arteries were compressed and shifted in 7 cases. The middle cerebral artery was shifted and distorted by temporal meningiomas in 4 cases, and certain branches turned into significant distortion (Fig. 2). The anterior cerebral artery was shifted to the opposite side by arched compression in 2 cases. The anterior cerebral artery was shifted under the pressure in 1 case and some branches were involved in feeding the tumor. The MPR reconstruction technology of MSCTA was good at displaying the three-dimensional relationship between the tumor and other blood vessels.

Draining veins of the tumor. DSA provided information regarding venous drainage, especially small reflux veins. The MSCTA examination of 20 cases was also able to clearly display the morphology, abundance, drainage of the reflux veins of the tumor and the relationship between veins and venous sinuses. Veins surrounded the tumor or connected it in clusters, and therefore provided important clinical information, such as venous drainage into the adjacent sagittal sinus or the superficial and deep cranial veins (Fig. 3).

Displaying situation of venous sinus in parasagittal sinus meningiomas. Of the 20 cases, 8 were parasagittal sinus meningiomas. Both DSA and MSCTA showed the relationship between tumor body and venous sinus, as well as clinical information, such as the violation, stenosis and truncation of the venous sinus, including 5 cases near the superior sagittal sinus (3 cases of invasion), and 1 sigmoid sinus. However, in 4 cases of invasion, the invasion of the sinus cavity of 1 case was overestimated by MSCTA due to the impact of bone structure (Fig. 4).

Relationship between the tumor and its adjacent bone. In 20 cases, MSCTA completely displayed the anatomical relationship between the tumor and its adjacent skull, as well as the impact of the tumor on the bone structure. Eight cases showed thickening of bone structure, while 3 cases displayed thinning. Both thinning and thickening of bone structure existed in 2 cases, while 7 cases were not affected. In contrast to MSCTA, DSA provided little useful information on the relationship between the tumor and its adjacent bone.

Imaging of MSCTA compared to DSA. Tumor staining, arterial display, venous sinus invasion and the relationship between the tumor and its peripheral vessels are shown in Table I. A good display of arteries was one which revealed arteries of class IV or above. Venous display involved showing the superior veins above the reflux veins, the good clarity of venous sinuses and the depiction of the changes of peritumoral vessels involved in the tumor's compression, pushing and violation.

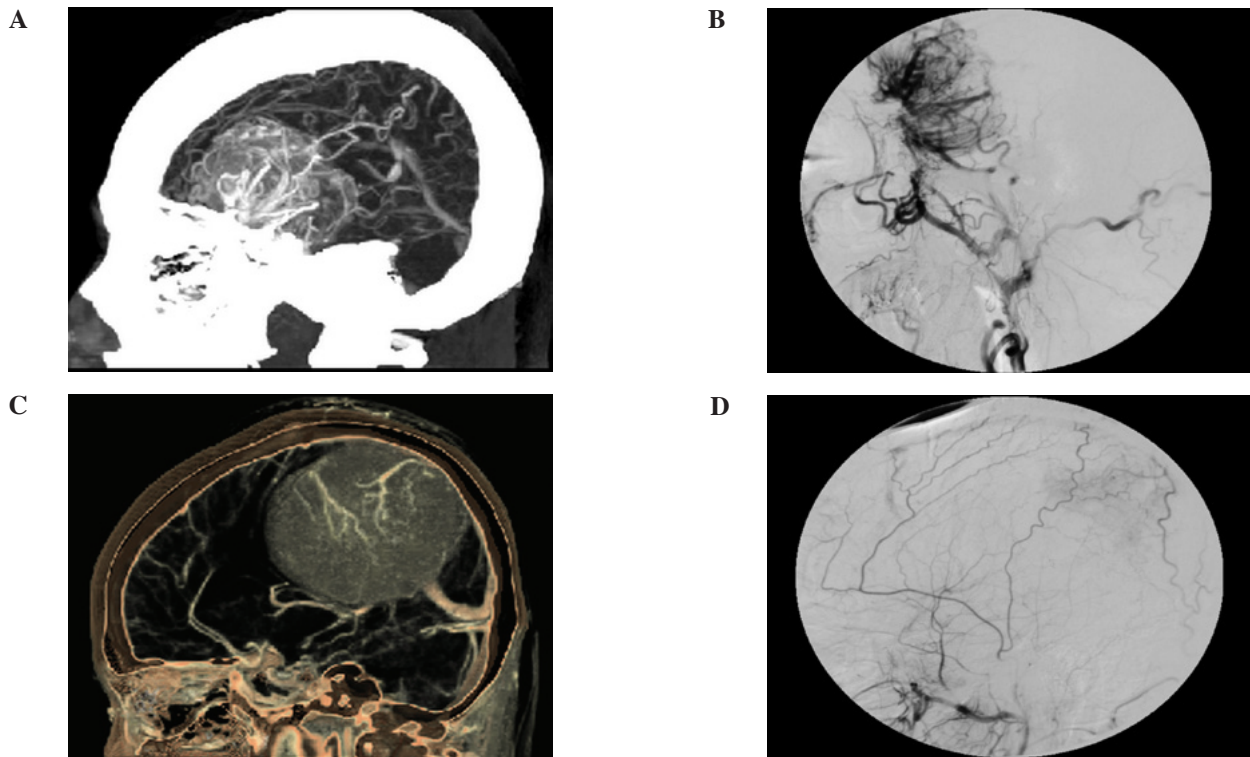


Figure 1. (A) CT angiography showing a cluster of arteries. (B) DSA showing the same image as (A) (the same case). (C) CTA showed the feeding artery. (D) DSA image [the same case as (C)].

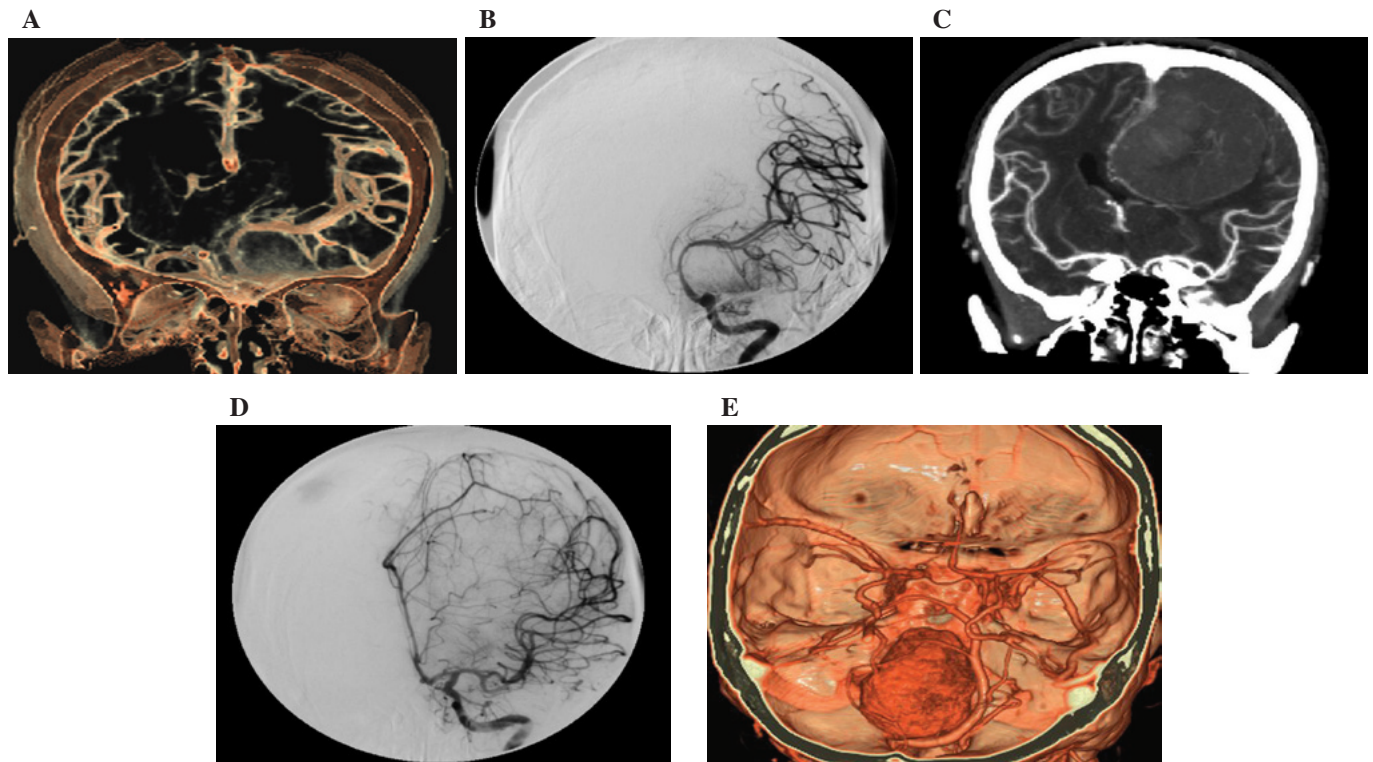


Figure 2. (A) Meningiomas pushing the middle cerebral artery to shift (CTA). (B) DSA displaying the same case. (C) Meningiomas pushing the anterior cerebral artery to shift. (D) DSA displaying the same case. (E) Cranial base meningiomas pushing the basilar artery to shift.

Discussion

Importance of angiography in meningiomas. The primary treatment method for meningioma is surgery, although inadequate

preparation often causes massive hemorrhage, leading to unnecessary risks. Angiography of meningiomas provides clinical information, such as the tumor's feeding arteries, the fate of venous drainage, changes of venous sinuses and its adjacent

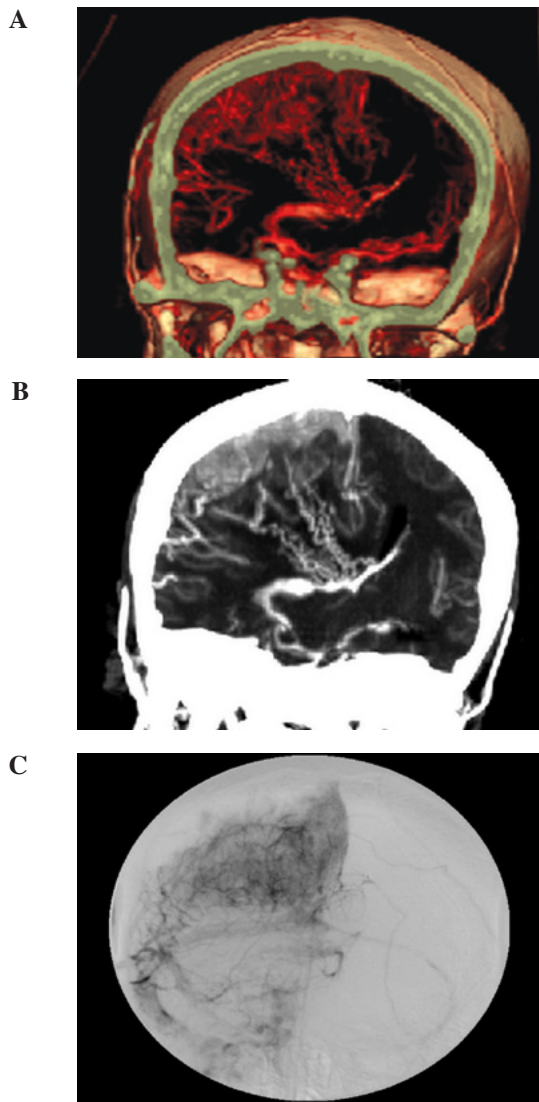


Figure 3. (A and B) Meningiomas' venous reflux. (C) DSA.

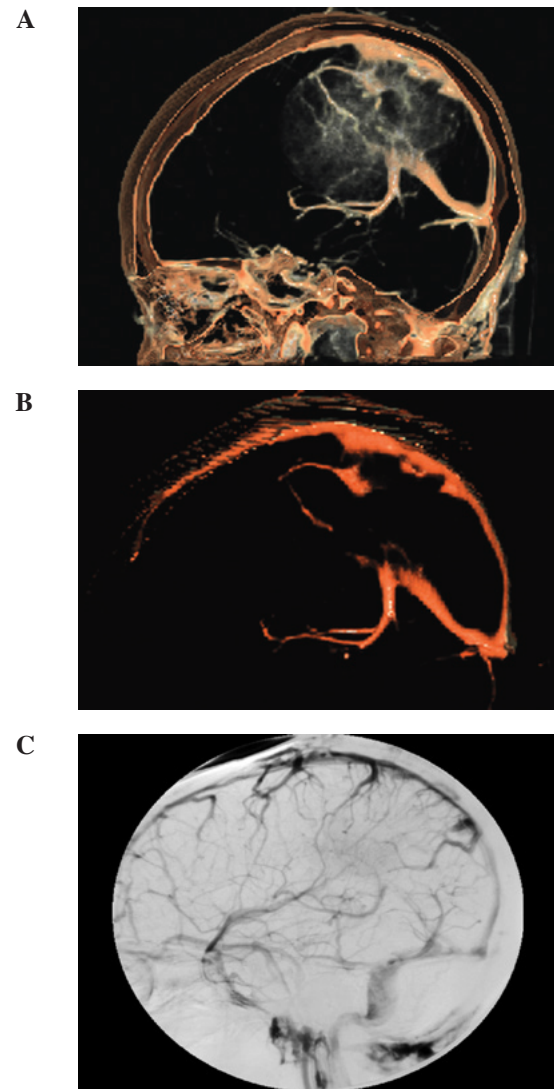


Figure 4. (A and B) MSCTA showing violation in the superior sagittal sinus. (C) DSA showing normal results in the same case.

main cerebral arteries before surgery, enabling surgeons to fully understand the circumstances that may be encountered during surgery, thus making sure that they have a well thought-out plan, avoiding accidents due to a lack of preparedness. Therefore, increasing attention is being paid to angiography in clinical practice. Previously, DSA was mainly used for the angiography of meningiomas, but DSA had obvious disadvantages, such as iatrogenic vascular injury, radiation exposure, side-effects and complications of contrast agents, as well as high cost, and thus was not very easily accepted by patients. With the emergence and development of multi-slice spiral CT, this relatively non-invasive examination technology is being approved by more and more doctors and patients. The application of DSA for the vascular diagnosis of meningioma is decreasing (4), although in some respects, DSA continues to play an irreplaceable role. In this study, we applied multi-slice spiral CT to image the blood supply of meningiomas and compared MSCTA and DSA in various aspects, to explore the application value and advantages of the two methods in imaging the blood supply of meningiomas.

Application of DSA in meningiomas. As the 'gold standard' of angiography, DSA still plays an important role as it is able

to directly and faithfully observe the narrow, fine branches and the existence of invasion, stretch and embedding in blood vessels. According to the DSA imaging of meningiomas, we can analyze whether the blood supply is abundant, and whether there is risky intracranial-extracranial anastomosis in different parts of the tumor and its feeding arteries. Based on such observation, pre-operative embolization treatment can be implemented in selected suitable cases. Therefore, DSA enables us to better grasp the indications of selective external carotid artery embolization, improve efficacy and reduce complications. However, the shortcomings of DSA are also evident. Among the cases in our study, 12 out of 20 cases presented with dual arterial blood supply by the internal and external carotid artery. During DSA imaging, the catheter was first placed in the external carotid artery and then into the internal carotid artery for imaging. Such a time lag meant that we could not reveal the dual arterial blood supply simultaneously. Singly-displaying the infusion of contrast agent in the arteries while being unable to display the other set of arteries supplying the blood caused insufficient tumor staining (Fig. 1D). A similar problem occurred in the veins. DSA cannot display the full view of the tumor and its exact location or the relationship

Table I. Comparison of the tumor displaying between the two methods.

Methods	Complete tumor staining (N1=20) No. (%)	Arterial display (N1=20) No. (%)	Venous display (N1=20) No. (%)	Venous sinus display (N1=8) No. (%)	Changes of peritumoral vessels (N1=16) No. (%)
MSCTA	20 (100)	19 (95.5)	18 (90)	7 (87.5)	16 (100)
DSA	8 (25)	20 (100)	15 (75)	8 (100)	10 (62.5)

No., cases of clinical signs appearing; N1, no. of patients with tumor.

between the tumor and the skull. Invasion, radiation and high cost also affect the acceptance by the examinees.

Application of MSCTA in meningiomas. The multi-slice spiral CT is receiving more and more acceptance from doctors and patients. At present, MSCTA is being widely used in clinical practice. Vascular imaging applied to all parts of the body provides important information for clinicians, and vascular imaging of meningiomas has been widely used at home and abroad (5,7). MSCTA has certain advantages, such as its non-invasiveness, and has fewer complications. After one enhanced scan, an arbitrary point can be chosen to reconstruct the multi-dimensional image of the lesion, to determine the causes of vascular compression and the extent of compression. In particular, three-dimensional helical CT angiography (3D-CTA) applies a continuous, rapid, non-interval spatial data scanning technique to obtain high-quality three-dimensional images. Because of the faster scanning speed, the ion radiation and the contrast agent use is significantly reduced, while the application of the contrast agent tracking trigger technique renders the scan delay time more accurate, thus obtaining higher quality images. In this study, 20 cases of meningiomas underwent MSCTA examination. Contrast medium intelligent tracking technology was applied, ordering the scanning to be automatically triggered 5 sec after the threshold (set as the carotid artery, generally 100 Hu) was reached, starting from the extracranial parts of the common carotid artery, including the whole brain. This method has proven to be clinically feasible (8). MSCTA scans in the arterial phase and the venous phase and displays the tumor staining and blood supply in the different phases. It can also reveal the relationship between the tumor body and peripheral vessels and skull by adjusting different thresholds (Fig. 2E), providing comprehensive clinical information.

Contrast between MSCTA and DSA. MSCTA has a relatively high spatial resolution. It can reveal intracranial arterial circles of class IV and above, and can clearly display abnormal meningeal and intracranial feeding branches, which is sufficient to meet the clinical requirements for displaying vessels of interest. The results are consistent with the DSA imaging. MSCTA also has a high temporal resolution. Scanning time from the base of the skull to the calvaria was not more than 10 sec. Additionally, contrast medium intelligent tracking technology was adopted. Therefore, there were fewer opportunities for venous pollution: there were only 2 cases among 20 patients that had arteriovenous hybrid imaging. However,

this did not affect the clinical diagnosis. As the cerebral veins have high imaging speed, the venous phase can be obtained by scanning immediately after the arterial phase. MSCTA imaging in cerebral veins has been widely recognized by clinicians (5,7), which can clearly display the shape, abundance and drainage fate of draining veins (Fig. 4). In this study, 18 out of 20 cases showed a clear-cut venous system, while in the remaining 2 cases, the tumors' lack of blood supply proved to be a rare arteriovenous blood supply by later surgery.

In this study, when performing DSA with unilateral and one-leg angiography, we found that certain parts of the tumor were not stained, particularly when the branches of the internal and external carotid arteries were all involved in feeding the tumor. MSCTA scans with the contrast agent completely infiltrated into the interstitial tissue of the tumor by delayed scan. Therefore, the extent of tumor staining in MSCTA is stronger than in DSA. It reflects the blood abundance of the tumor body, thus providing a reference for the clinical understanding of the tumor blood supply, as well as judgments of pre-operative embolization. To obtain the complete staining of the tumor, dual angiography should be implemented by scanning the internal and external carotid artery at the same time, although this increases the damage and dosage of the contrast agent.

As there is no bone structure impact in parasagittal sinus meningiomas, DSA shows obvious superiority in displaying circumstances, such as the changes of sinus cavity and establishment and the improvement of the collateral venous circulation path, as well as the complete display of vessels adjacent to the skull. In this study, among 8 cases of parasagittal sinus meningiomas, 5 cases revealed sinus cavity invasion. DSA provided accurate and three-dimensional information about sinus cavity invasion. MSCTA only displays the general profile of the venous sinus. Due to the sinus bone structure, it is difficult to assess the narrow sinuses at the bone side, assaults and the tumor thrombus. The bone subtraction algorithm not only is time consuming, but also affects the venous sinuses, as enhanced vessels have similar density to bones, while other factors also exist. In this study, among 8 cases of venous sinus invasion, 1 case of meningioma that MSCTA had difficulties in diagnosing was due to the extent of the damage of the venous sinuses, the size of the tumor thrombus and stenosis of the sinus, as well as bone artifacts and partial volume effects. Meanwhile, DSA shows clear superiority in displaying vessels adjacent to the skull. In the same plane, it can provide a complete and three-dimensional image of the running characteristics of blood vessels near the skull side. In this study, DSA completely showed 26 blood vessels near the skull side

in the same plane, but MSCTA showed only 12 due to the bony interference. Therefore, when no surrounding tissues are interfering, DSA does better in displaying vascular change features near the skull side than MSCTA (including vascular courses, the extent of compression and three-dimensional information). With regard to the relationship between tumor body and its peripheral vessels, MSCTA shows better performance. It provides stereoscopic imaging of displacement and compression between the tumor and vessels by MPR, VRT and other three-dimensional reconstruction technology, so as to provide clear and visible data for clinicians.

Compared to DSA, MSCTA is more invasive, faster, less expensive and with relatively fewer contraindications. Additionally, MSCTA displays the three-dimensional relationship between the tumor, blood vessels and the skull. It also simulates surgical approaches for clinicians from multiple perspectives and avoids destroying the adjacent massive vessels and important tissues. However, CTA also has limitations, including: i) the spatial resolution of CTA is lower than DSA, but there was no diagnostic difference in the requirements of clinically interesting vessels in this group; ii) CTA cannot dynamically observe the blood flow, so that it cannot correctly judge the direction of blood flow; iii) there are relatively more influential factors in CTA imaging. Both examination methods have advantages in the evaluation of blood supply in menin-

giomas, and are to some extent complementary. We should select a reasonable method to measure the characteristics of tumors in clinical practice.

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