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CASE REPORT

Simultaneous Visualization of Vessels and Brain Tumor with Contrast-enhanced Three-dimensional Phase-contrast MR Imaging

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The sequence for concurrently depicting engulfed vessels and a well-enhanced tumor in once-off scanning has never been reported for preoperative magnetic resonance imaging for brain tumor resection. Multimodal fusion techniques have been recently developed, but the risks of misregistration still remain. Here a case is reported where contrast-enhanced three-dimensional phase contrast sequence concurrently depicted an engulfed vessel and metastatic brain tumor in once-off scanning and related technical aspects are discussed.

Keywords: *preoperative simulation, magnetic resonance imaging, brain tumor, phase contrast, vessel*

Introduction

There are some methods for preoperative simulation prior to brain tumor resection, such as CT and MRI.[1–6] Contrast-enhanced (CE), 3D, T_1-weighted (T_1W), fast spoiled gradient-echo sequence (FSPGR) has traditionally been utilized for simulation with MRI.[2,3] Volume rendering (VR) with CE 3D T_1W FSPGR provides important information regarding the relationship between brain tumors and surrounding structures. However, this method cannot simultaneously depict engulfed vessels and a well-enhanced tumor because both are depicted as high-intensity objects due to the effect of T_1 shortening by gadolinium contrast medium. In addition, the process of vessel segmentation from the brain parenchyma requires a long time. Here, a case is reported in which Inhance 3D Velocity (dedicated software developed by GE Healthcare, Milwaukee, WI, USA), which could concurrently depict an engulfed vessel and a metastatic brain tumor in once-off scanning, was used and its diagnostic value was discussed.

Inhance 3D Velocity

Inhance 3D Velocity is an improved 3D phase contrast (PC) sequence technique. With a combination of parallel imaging and efficient k-space sampling, Inhance 3D Velocity is capable of obtaining the neurovascular anatomy in a shorter time than is the conventional PC sequence. Furthermore, to enhance contrast-to-noise ratio transverse magnetization is spoiled using phase cycling excitation radiofrequency pulses prior to each excitation mostly removing signal from the tissue with long T_2.[7] The pulse sequence diagram of Inhance 3D Velocity is shown in Fig. 1. PC sequence provides concurrent flow and magnitude images as two different datasets in once-off scanning. In conventional PC sequence, magnitude images show contrast-like proton-density-weighted images, whereas in Inhance 3D Velocity, magnitude images show T_1W contrast due to the above-mentioned reasons, which is advantageous to depict an enhancing tumor after contrast administration.

Case Report

A 74-year-old man was referred to our institution because of progressive left hemiparesis and was diagnosed with lung cancer and metastatic brain tumor. To visualize the metastatic brain tumor, CE-MRI was performed using the Inhance 3D Velocity technique in addition to T_2-weighted (T_2W) and T_1W spin echo sequences using a 1.5-tesla MR system (Signa HDxt; GE Healthcare). The scan parameters of the Inhance 3D Velocity technique are summarized in Table 1. Velocity encoding at a rate of 25 cm/s was chosen to depict the brain surface veins and distal arteries. Contrast administration was manually performed with a single intravenous injection of gadobutrol at 0.01 mmol/kg body weight (Gadvist 1.0; Beyer, Berlin, Germany). A tumor with a diameter of approximately 2.5 cm and extensive peritumoral edema was found in the right frontal lobe on MRI (Fig. 2). Emergent surgery was performed to decompress

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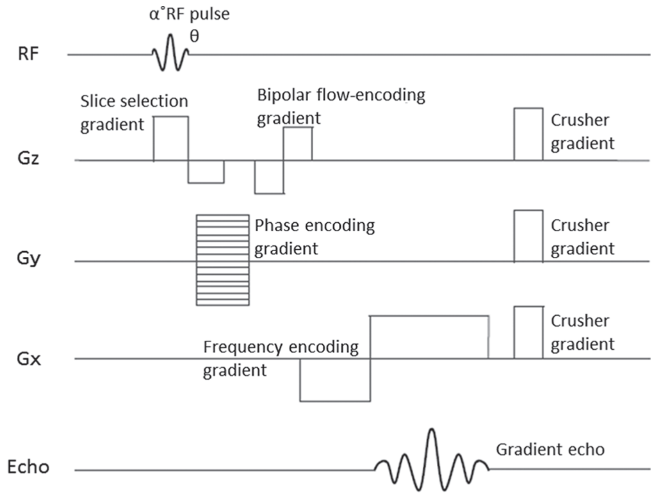

Fig. 1 Pulse sequence diagram of Inhance 3D Velocity. Residual transverse magnetization is canceled out by changing the phase (θ) of the excitation radiofrequency (RF) pulses for each TR. The gradient pulses of each axis are actually synthesized for TE shortening, but they were described separately for clarity.

Table 1. Inhance 3D Velocity scan parameters

FOV	220 mm
Slice thickness	1.4 mm
Reconstruction slice thickness	0.7 mm
Scan matrix (voxel or pixel size)	288 × 224 (0.76 × 0.98 × 1.4 mm)
Reconstruction matrix (voxel or pixel size)	512 × 512 (0.43 × 0.43 × 0.7 mm)
Slices	60
FA	20°
TE	5.1 ms
TR	11.1 ms
Band width	25 kHz
ASSET reduction factor	1.5
NEX	1
Fat suppression	non
Velocity encoding	25 cm/sec
Imaging option	ZIP2, ZIP512
Scan time	3:20

FA, flip angle; NEX, number of excitations; ASSET, array spatial sensitivity encoding technique; ZIP, zero-fill interpolation.

the intracranial pressure and to improve venous perfusion for tumor resection before initiating lung cancer therapy. The preoperative simulation procedure was conducted as follows: 1) a 2D-based fusion image was calculated with a weighting coefficient (flow:magnitude = 7:3) using an addition tool included with the MR system; 2) flow and

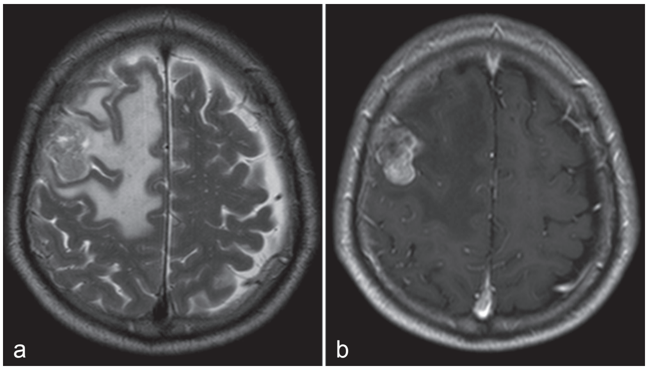

Fig. 2 Preoperative MR images. (**a**) T_2-weighted image. (**b**) Contrast-enhanced T_1-weighted image. A tumor with a diameter of approximately 2.5 cm and extensive peritumoral edema is found in the right frontal lobe.

magnitude datasets of Inhance 3D Velocity were transferred to a workstation (SYNAPSE VINCENT; Fujifilm Co., Tokyo, Japan); 3) in the magnitude dataset, the extracerebral structures, brain, and tumor were manually segmented using the object extraction function and cut tool; 4) in the flow dataset, noise was cut by adjusting the threshold; 5) a VR fusion image was produced automatically using the multi 3D tool; and 6) the opacities of the segmented structures were adjusted as needed for optimal observation. The reconstruction time was approximately 20 min. Figure 3 shows the relationship between the tumor and surrounding structures. Furthermore, an engulfed vessel in the metastatic brain tumor was identified, which was inferred as the terminal branch of the right middle cerebral artery by tracing backward from the distal to the proximal direction. Use of the preoperative VR fusion image detected not only the surface vascular structures that corresponded to the actual operation field but also the engulfed vessels embedded in the tumor tissue (Fig. 4). In practice, an engulfed vessel is considered as an involved artery, rather than a blood vessel that nourishes the tumor because it did not have any branches on the tumor. The engulfed vessel was removed concurrently with the tumor after adequate hemostasis, judging to be safe after resection. The postoperative condition of this patient was uneventful. Left hemiparesis improved within a few days, and cerebral edema rapidly disappeared on MRI.

Discussion

Preoperative VR flow/magnitude fusion images from Inhance 3D Velocity concurrently depicted an engulfed vessel and metastatic brain tumor. For preoperative simulation, identification of the vascular distribution is crucially important to plan the surgery. Use of this novel technique facilitated acquisition of much useful information for planning surgical procedures and to prevent potential intraoperative bleeding and venous infarction to facilitate safe tumor resection.

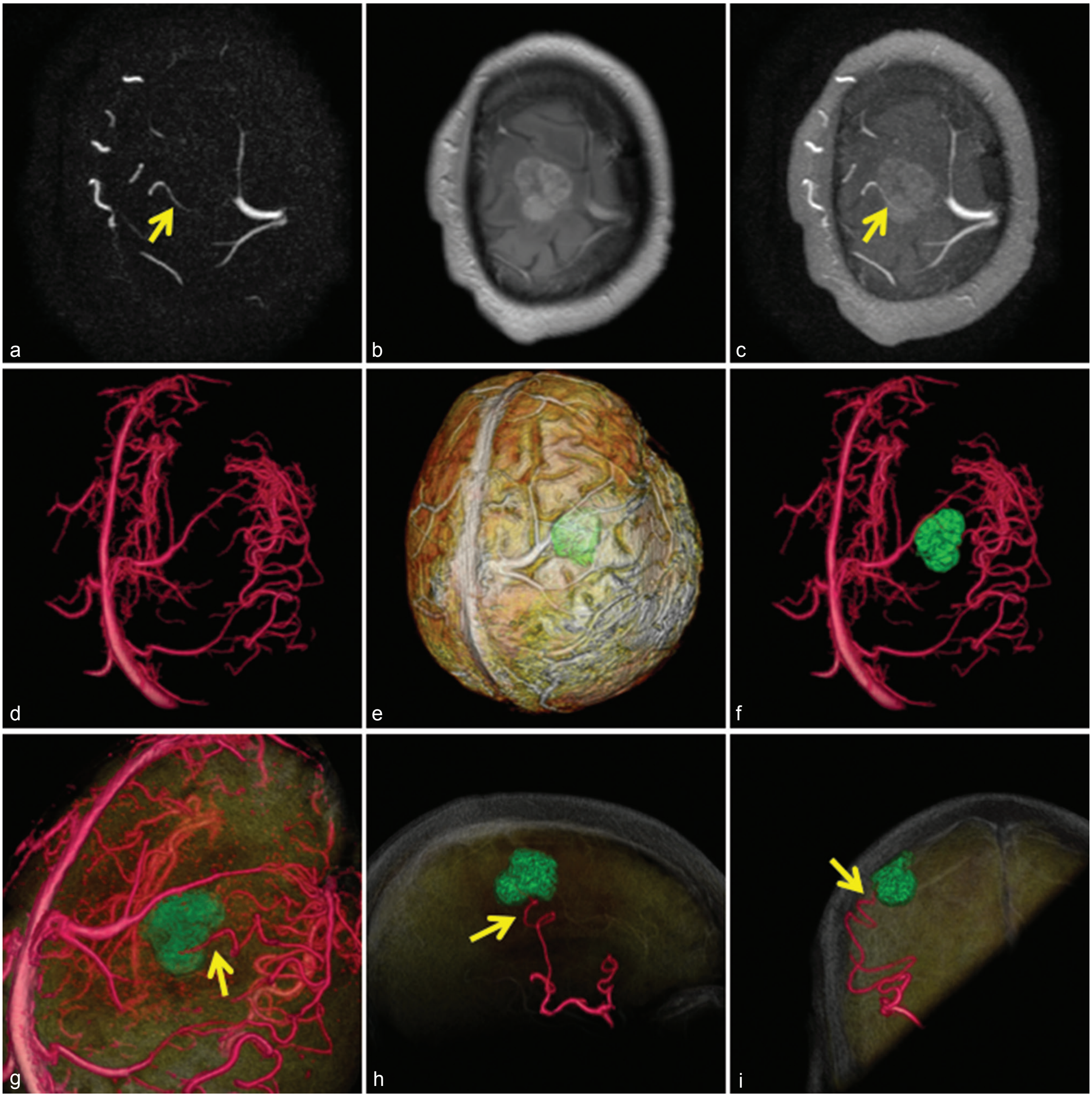

Fig. 3 Preoperative simulation using Inhance 3D Velocity. (**a** and **b**) Source images (flow and magnitude, respectively) are concurrently acquired in once-off scanning. (**c**) An engulfed vessel is depicted on a two dimensional (2D)-based fusion image. (**d**) A flow volume rendering (VR) image showing the distribution of surface and deeper vessels. (**e**) A magnitude VR image showing the relationship between the tumor, brain surface, and other structures. (**f**) Fused VR images showing the relationship between the tumor and surrounding vessels. Furthermore, an engulfed vessel in the tumor is identified on a fused VR image (**g**). Sagittal (**h**) and coronal (**i**) fused VR images provide information that the engulfed vessel is the terminal branch of the right middle cerebral artery. Yellow arrows indicate same engulfed vessel.

As mentioned above, Inhance 3D Velocity is known to improve 3D PC sequence technique. The focus of this technique was to spoil transverse magnetization. Magnitude images are generally treated as unimportant in non-contrast MR angiography. Hence, it was speculated that magnitude images can be utilized as T_1W images to detect enhancing effects by contrast medium. In fact, in this case, magnitude images were used to detect a metastatic tumor enhanced by contrast medium. The vessels on magnitude images were suppressed by bipolar flow-encoding gradient. Therefore, tumor-enhancing effects can be evaluated without being affected by the vessels.

In this case, an engulfed vessel within the metastatic tumor was identified preoperatively. The preoperative VR

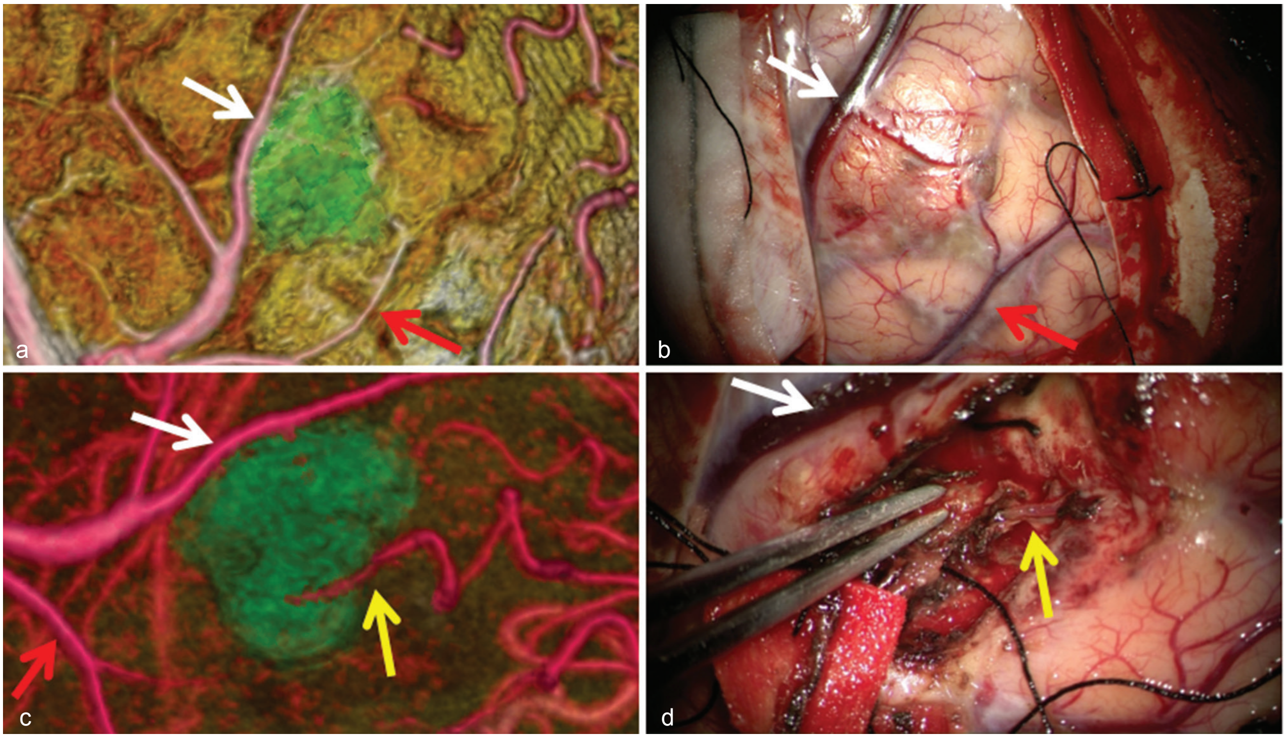

Fig. 4 Preoperative volume rendering (VR) flow/magnitude fusion images and intraoperative images. Zoomed preoperative VR flow/magnitude fusion image (**a**) corresponds to the operative field after opening the dura mater (**b**). An engulfed vessel that the VR image identified (**c**) is found on the operative field during tumor resection (**d**). The yellow, white, and red arrows indicate the same vessels.

flow/magnitude fusion images were reconstructed by fusing reconstructed flow and magnitude VR images from each dataset. Therefore, this method can depict engulfed vessels in well-enhanced tumors, as in the present case. Several multimodal fusion techniques have been recently developed, such as CT/MR, CT/digital subtraction angiography (DSA), and DSA/MR (4–6, 8–10). Although these techniques can depict engulfed vessels in well-enhanced tumors, there is an increased risk of misregistration and radiation exposure. On the other hand, these risks are not associated with the proposed method.

In addition, this method has the potential to reduce reconstruction processing time compared with conventional CE 3D T_1W FSPGR methods. Narita et al. described that vessel segmentation was difficult if brain parenchymal and vascular signal intensities were at the same level.[3] On the other hand, the proposed method does not require vessel segmentation because there is no signal other than flow in flow images.

This case highlights the benefits of CE Inhance 3D Velocity for concurrently depicting an engulfed vessel and well-enhanced tumor in once-off scanning. The CE Inhance 3D Velocity is useful for preoperative simulation prior to brain tumor resection.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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