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Three-dimensional Time-of-Flight MR Angiography: Applications in the Pulmonary Vessels

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Abstract Magnetic resonance angiography (MRA) is a new method for the noninvasive assessment. The goals of this study were to, 1) compare the usefulness of three-dimentional (3D) with two-dimensional (2D) time of flight (TOF) MRA in the imaging of pulmonary vessels, and 2) evaluate the clinical application of 3D-TOF MRA.

MRA studies were done by 3D-FLASH and 2D-FLASH in thirteen healthy male volunteers, and New 3D-FIASH in seven volunteers. 3D-FLASH and 3D-FLASH with gadolinium diethylenetriamine-pentraacetic acid (Gd-DPTA) was applied to nineteen clinical patients.

Compared with 2D-FLASH and 3D-FLASH or New 3D-FLASH, the difference is not statistically significant. However, images of 3D-FLASH or New 3D-FLASH was more excellent than 2D-FLASH at the branches of the superior pulmonary vein on the left side. Our results suggest that MRA by 3D-FLASH or New 3D-FLASH may be useful to equal or surpass 2D-FLASH in screening the pulmonary vessels. It is essential to use Gd-DTPA to obtain better information in patients.

Key Words : MR Angiography, 3D Time-of-Flight, Pulmonary Vessels, 2D Time-of-Flight

Introduction

Despite the very marked advances in MRA of the neck, brain, and peripheral vessels, MRA of the pulmonary arteries and veins is only beginning to be reported. 3D-TOF MRA in the pulmonary vessels was first reported by P. A. Wielopolski et al. in 1992.[1)]

This reflects some formidable technical obstacles in MRA of the lung vasculature.

These include motion (cardiac, respiratory, vascular), magnetic susceptible artifacts caused by air-tissue interfaces in the lung, the complex overlap between pulmonary arteries and veins, and their compound oblique orientation.[2),3)]

However, if these can be overcome, MR pulmonary angiography could represent a clinical advance. The two common approaches to MRA are phase contrast (PC) and time-of-flight (TOF) techniques.

The TOF information can be obtained as a series of 2D-images or a 3D data set. Such MR parameters as repetition time (TR), field of view (FOV), number of excitations (NEX), and flip angle naturally play important roles.[4)]

MRA by 3D-FLASH (fast low angle shot) could be done with spatial resolution and short scan times during a breath-hold.

Materials and Methods

MR angiographic studies were done by a 1.5 Tesla whole body imaging system (Siemens). In thirteen healthy male volunteers, scan parameters were 40msec/8msec/40° (TR/TE/flip angle), 256×256 acquisition matrix, 40 cm FOV, 4 mm slice thickness with a 1 mm overlap between each slices, and 13 sec image times for each breath-hold acquisition in 2D-FLASH and were 10/4/16°, 128×256, 35cm, 2mm slab thickness and 22 sec in 3D-FLASH. In seven heelthy volunteers. new scan parameters were 9/3/16°, 256×256, 35 cm, 2 mm and 20 sec in New 3D-FLASH.

Total imaging time was 20 min in 2D-FLASH, and 5 min in 3D-FLASH and new 3D-FLASH.

Each image was postprocessed by means of the maximum intensity projection (MIP) algorithm, calculated on a 256×256 grid. Images were view at rotational angle from +140° to +220° from the coronal plane at fixed 10° intervals (Fig. 1).

In nineteen clinical patients (bronchopulmonary sequestration, lung abscess, metastasis, 15 lung cancers, leiomyosarcoma of pulmonary artery), above-mentioned 2D-and 3D-FLASH were applied and 3D-FLASH with gadolinium diethylenetriamine pentraacetic acid (Gd-DTPA) were performed.

Results

Pulmonary vessels were visualized and graded as follows;

(2+): clear and consecutively

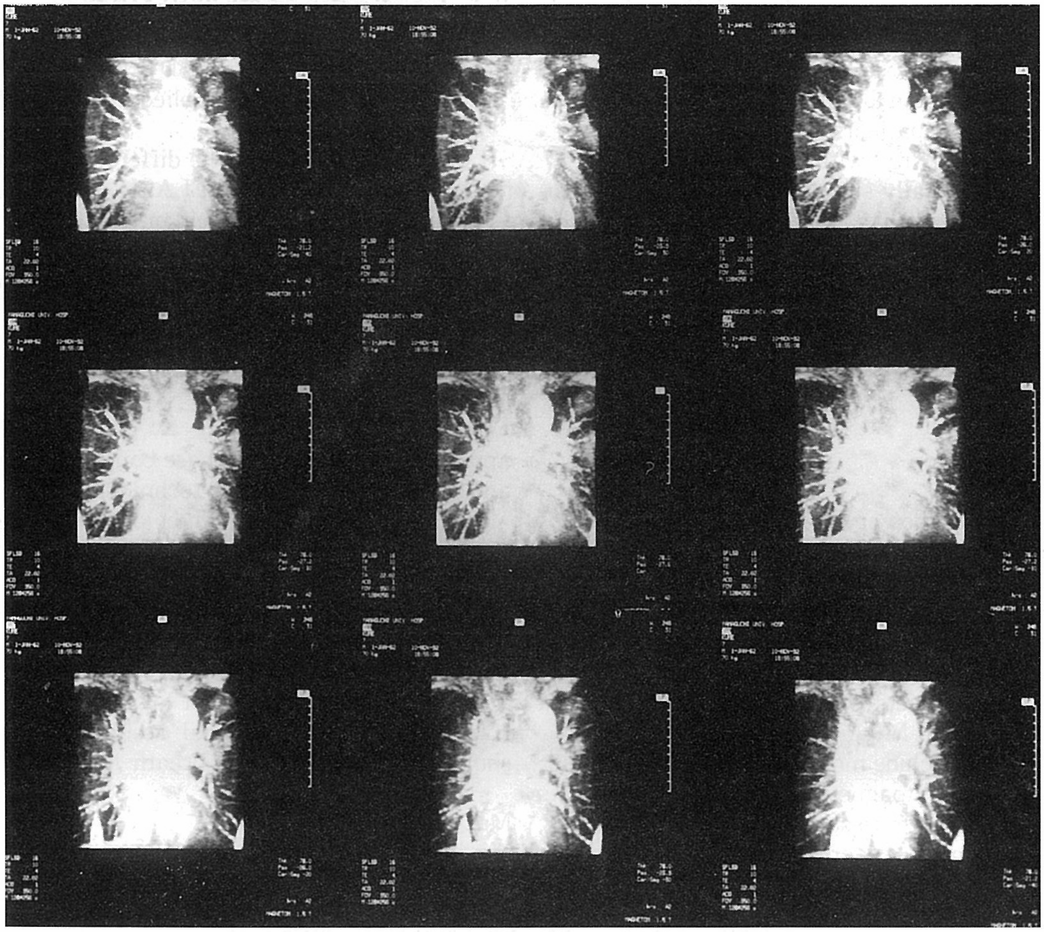


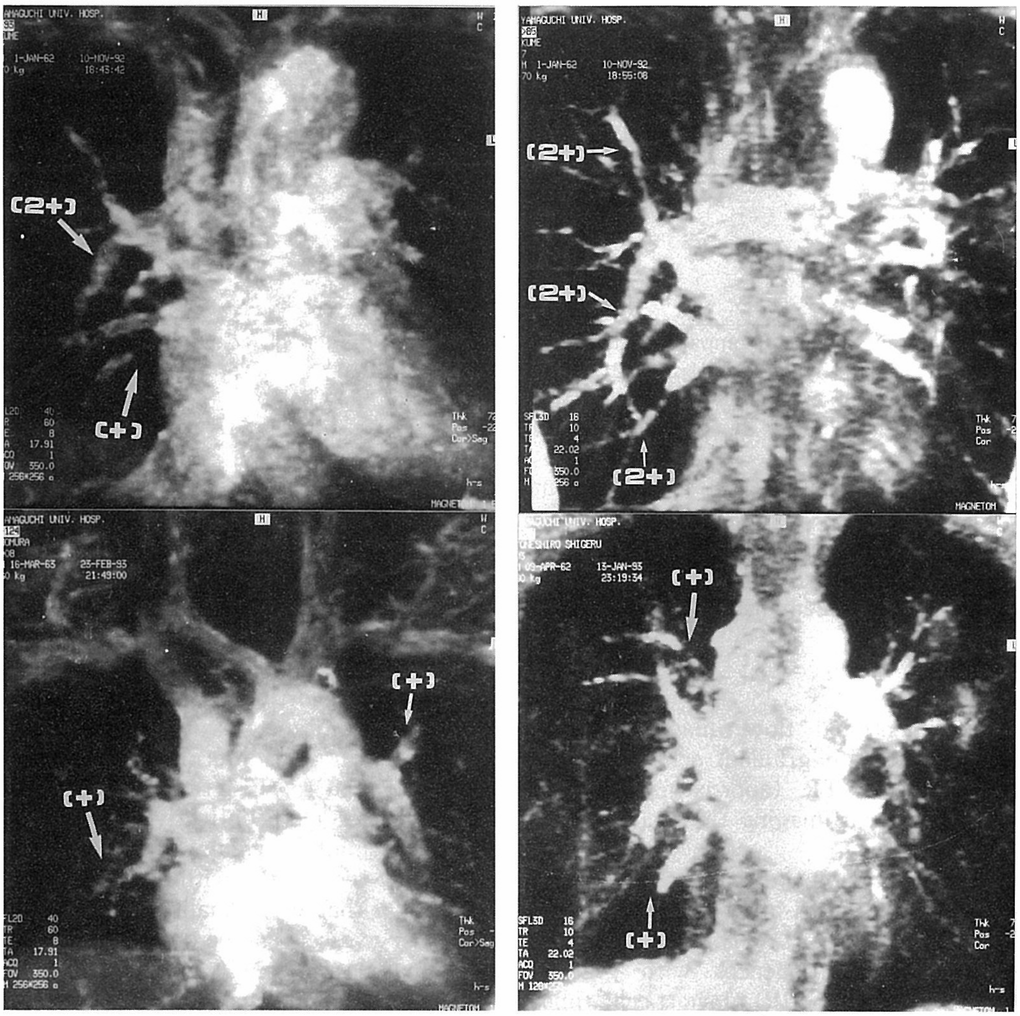
Fig. 1. 3D-FLASH.
MR pulmonary angiogram from normal volunteer after MIP processing by rotational angle from +140° to +220° at fixed 10° intervals.

(1+): clear but partly
(−): not shown (Fig. 2).

In 3D-FLASH, (2+) and (1+) were 13 (100%) at pulmonary artery, 12 (92.3%) at the branches of the superior pulmonary vein (SPV) and 13 (100%) at the branches of the inferior pulmonary vein (IPV) on the right side. 12 (92.3%), 10 (76.9%) and 11 (84.6%) on the left side, respectively. In 2D-FLASH, (2+) and (1+) were 13 (100%), 11 (84.6%) and 12 (92.3%), respectively on the right side and 13 (100%), 2 (15.4%) and 12 (92.3%), respectively on the left side. In New 3D-FLASH, (2+) and (1+) were 100% except for 6/7 (85.7%) at the branches of the IPV on the left side (Table 1).

Compared with 2D-FLASH and 3D-FLASH or New 3D-FLASH, the difference is not statistically significant.

However, the differences between the visualization by 2D-FLASH and by 3D-FLASH or New 3D-FLASH were significant refer to a p value of 0.004 or less at the branches of the SPV on the left side. Images of 3D-FLASH and New 3D-FLASH were more excellent than 2D-FLASH at the branches of the SPV on the left side. Further studies are required to evaluate the visualization of New



a b

Fig. 2. Grading of the visualization. a) 2D-FLASH. b) 3D-FLASH. (2+) was graded if pulmonary vessels were visualized clear and consecutively, (1+) if cleer but partly or (-) if not shown.

Table 1. Comparison of visualization

a) 3D-FLASH in 13 volunteers

	(right side) 2+	1+	−	(left side) 2+	1+	−
pulmonary artery	7	6	0	10	2	1
	(100%)*			(92.3%)^{*2}		
branches of the SPV	6	6	1	4	6	3
	(92.3%)^{*2}			(76.9%)^{*4}		
branches of the IPV	13	0	0	6	5	2
	(100%)*			(84.6%)^{*3}		

b) 2D-FLASH in 13 volunteers

	(right side) 2+	1+	−	(left side) 2+	1+	−
pulmonary artery	10	3	0	8	5	0
	(100%)*			(100%)*		
branches of the SPV	8	3	2	0	2	11
	(84.6%)^{*3}			(15.4%)		
branches of the IPV	8	4	1	3	9	1
	(92.3%)^{*2}			(92.3%)^{*2}		

c) New 3D-FLASH in 7 volunteers

	(right side) 2+	1+	−	(left side) 2+	1+	−
pulmonary artery	5	2	0	3	4	0
	(100%)^{*5}			(100%)^{*5}		
branches of the SPV	1	6	0	1	6	0
	(100%)^{*5}			(100%)^{*5}		
branches of the IPV	6	1	0	0	6	1
	(100%)^{*5}			(85.7%)^{*6}		

Statistical significance as compared with the visualization of the left branches of the SPV by 2D-FLASH are shown by symbols($^{*}p=0.001$; $^{*2}p=0.001$; $^{*3}p=0.001$; $^{*4}p=0.002$; $^{*5}p=0.001$; $^{*6}p<0.004$). SVP: superior pulmonary vein, IPV: inferior pulmonary vein.

3D-FLASH. In clinical cases, pulmonary vessels related to the focus were not so visualized. It is essential to use Gd-DTPA to obtain better information.

Some cases are demonstrated (Fig 3, 4, 5).

Discussion

Two-dimentional flow images typically are obtained with gradient-echo sequences that use short TR (approximately 20-60 msec). Minimum imaging times are several seconds.

Images with good contrast can be obtained in less than 1 second by using fast gradient echo sequences like FLASH. 2D-FLASH and 3D-FLASH are sequences with gradient motion rephasing (GMR) at short echo times. Each images could be acquired during a breath-hold.[5]

The advantages of 2D-TOF include sensitivity to slow-flow rates, minimal saturation effects or normal flow velocities, and short acquisition times (5-7minutes). One of several disadvantages is the need for large gradient amplitudes in thin slice imaging, limiting the minimum echo time (TE).

On the other hand, the advantages of 3D-TOF include short scan times, high spatial resolution, ability to obtain very short TE, sensitivity to fast or intermediate flow rates, and high signal-to-noise ratio (SNR). One of disadvantages is the effectiveness only for relatively small 3D-volumes.[6,7]

The 3D-techniques with ultra-short TR has shown that good-quality images of the pulmonary vessels can be obtained in reasonable imaging times (10-13minutes), and it may prove useful in evaluation of a variety of pulmonary desorders, such as pulmonary embolism, veseel malformations, atelectasis, and others.

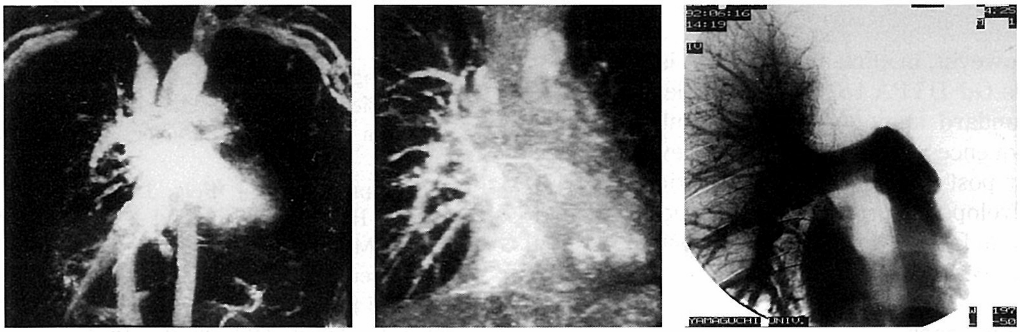
a b c

Fig.3. Patient with lung carcinoma.

a) A nodular mass adjacent to the right pulmonary artery was demonstrated, and MR angiogram (3D-FLASH) with Gd-DTPA shows obstraction of the right pulmonary artery.

b) Original image enhanced with Gd-DTPA demonstrated severe narrowing of the right pulmonary artery.

c) This was confirmed by DSA (intraarterial digital subtraction angiography).



a b c

Fig.4. Patient with malignant fibrous histiocytoma of the left pulmonary artery. a) 2D-FLASH with Gd-DTPA. b) 3D-FLASH with Gd-DTPA. c) DSA.

Both images by 2D-FLASH and 3D-FLASH show the obstraction of the left pulmonary trunk. Image of DSA shows severe narrowing. The MIP display of MRA may overestimate luminal narrowing at stenotic sites, with the signal loss resulting flow turbulence and the slower velocity.

P. Wielopolski, et al. used a FLASH gradient structure with a TR of 8.2 msec, a TE of 2.7 msec and the small FOV, down to 175 mm. In New 3D-FLASH, the parameter were similar to these structures. New 3D-FLASH could be done with high resolution and short scan times.[1)]

In clinical cases, pulmonary vessels were not so visualized. It is essential to use Gd-DTPA. This will be the subject of further study.

The technique of 3D-TOF MRA is noninvasive and relatively fast. The technique appears to have achieved a high degree of spatial resolution. This study represents our initial trials to evaluate the pulmonary vessels, which is still difficult to evaluate without the use of other modalities as PC technique. 3D-TOF MRA also have some limitations.

These include insensitivity to slow flow, inability to image the abnormality without the use of MR contrast agents and effectiveness only for relatively small 3D volumes.

3D-FLASH or New 3D-FLASH may be useful in screening the pulmonary vessels.

a

b

Fig. 5 Patient with bronchopulmonary sequestration.
a) The artery at the sequestration was not shown by MRA of 3D-FLASH without Gd-DTPA. b) MR angiogram by 2D-FLASH with Gd-DTPA demonstrated the branch (arrow) from the descending aorta.

However, in clinical patients, it is essential to use Gd-DTPA to obtain reliable images like standard angiogram. At present, new pulse sequences for evaluation and new techniques for post processing of information are being developed. Further detailed studies must be made for the noninvasive assessment without contrast agents.

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