Characteristics and clinical value of 3D MR imaging in the diagnosis of pulmonary embolism

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Received April 28, 2016; Accepted July 22, 2016

DOI: 10.3892/etm.2016.3539

Abstract. The aim of the present study was to investigate the characteristics and value of 3D dynamic contrast-enhanced magnetic resonance pulmonary angiography (3D-DCE-MRPA) for the diagnosis of pulmonary embolism (PE). Among patients suspected with PE, 30 cases were scheduled for 3D-DCE-MRPA [magnetic resonance imaging (MRI) group], and 30 cases were examined using multislice computed tomographic pulmonary angiography (msCTPA) [computed tomography (CT) group]. Direct signs including location, number, morphology of emboli, and indirect signs such as pulmonary infarction, pneumonia and pleural effusion, were analyzed. Pulmonary artery enhancement was observed. Image quality was contrasted, branches of the pulmonary artery revealed, and differences in sensitivity, specificity and signal-to-noise ratio (SNR) were compared. The number and morphology of emboli in the two groups were compared, and there were no significant differences (P>0.05). In the MRI group, significantly more emboli were located in segmental and subsegmental bronchi (P<0.05). The indirect signs in the two groups were compared and the differences were not statistically significant (P>0.05). Levels 5 and 6 of the pulmonary artery branch were more evident in the MRI group compared to the CT group. The SNR and carrier-to-noise ratio in the MRI group were significantly higher than those in the CT group (P<0.05). Twenty-six cases of PE were diagnosed in the CT group, with a sensitivity of 90.5% and specificity of 86.7%. Twenty-five cases were diagnosed in the MRI group, with a sensitivity of 92.3% and specificity of 84.2%. In conclusion, 3D-DCE-MRPA surpassed msCTPA in revealing segmental and subsegmental pulmonary artery PE.

Introduction

Pulmonary embolism (PE) is widely acknowledged as an emergency vascular disease (1) that is frequently neglected and misdiagnosed, and can result in mortality. Early symptoms are atypical, while 30-65% of patients may be asymptomatic. Dyspnea, pectoralgia and hemoptysis are the triad of symptoms of the disease, although they only occur in 3-20% of patients (2). Acute PE can occur in patients with acute myocardial infarction and aortic dissection (3). Although therapy, including anticoagulation, thrombolysis and thrombectomy, is available, its efficacy are not satisfactory (4).

Lack of awareness in the early diagnosis is an important risk factor (5). The development of diagnostic technologies such as multislice computed tomographic pulmonary angiography (msCTPA) and MRPA have led to improvement in the diagnosis of PE, reaching up to 80-95% (6). 3D dynamic contrast-enhanced magnetic resonance pulmonary angiography (3D-DCE-MRPA) surpasses msCTPA in screening for PE.

Patients and methods

Patients. Sixty patients suspected highly of having acute PE were selected between January, 2013 and January, 2016 in the People's Liberation Army 107th Hospital. The exclusion criteria for the study were: Severe cases; <72 h of expected survival; complications including acute myocardial infarction, aortic dissection or sudden death; chronic PE; primary lung diseases such as chronic obstructive pulmonary disease, lung cancer or bronchiectasia; failure to end emergent computed tomography (CT) or magnetic resonance imaging (MRI);
### Table I. MRI sequence scanning parameter settings.

| Sequence | TR (msec) | TE (msec) | TI (msec) | FA (degree) | FOV (cm) | Matrix | Collection time |
|----------|-----------|-----------|-----------|-------------|----------|--------|-----------------|
| T1WI     | 583       | 15        | 90/180    | 224x256     | 42x42    | 1      |                 |
| FSE, T2WI| 3,000     | 100       | 90/160    | 192x256     | 18x18    | 2      |                 |
| 3D FFE   | 9         | 3         | 100       | 128x256     | 40x40    | 1      |                 |

MRI, magnetic resonance imaging; FSE, fast spin echo; FFE, fast field echo.

### Results

#### Statistical analysis. Data were analyzed using SPSS. Quantitative data are presented as mean ± standard deviation. Differences among the groups were assessed by t-test and χ² test. Countable data were expressed as case or percentage (%). Ranked data were evaluated by Kruskal-Wallis. P<0.05 was considered to indicate a statistically significant difference.

#### Comparison of direct signs. The average number and different formations of emboli in the two groups were compared, and there were no significant differences (P>0.05). There were more emboli appearing in segmental or subsegmental arteries in the MRI group, and the difference was significant (P<0.05) (Table II).
Comparison of indirect signs. We compared the indirect signs between the two groups, but there were no significant differences (P>0.05) (Table III).

Comparison of image quality, pulmonary artery branches and SNR. Image quality in the two groups was not statistically different (P>0.05). There were more level 5 and 6 pulmonary arteries in the MRI group than in the CT group, which also had higher SNR and CNR. The differences were significant (P<0.05) (Table IV).

Comparison of sensitivity and specificity in diagnosis. Twenty-six cases of PE were confirmed in the CT group, in which sensitivity was 90.5% and specificity was 86.7%. Twenty-five cases were confirmed in the MRI group, in which sensitivity was 92.3% and specificity was 84.2%.

Discussion

The process of imaging by 3D-DCE-MRPA was performed as follows: Paramagnetic contrast agent was injected which shortened the T1 time to adjacent tissues, including adipose tissue. FFE was selected for scanning of the targeted vessels while patients held their breath. After reconstruction of MIP, well-defined and high-resolution vessel images were obtained. The images were observed at every angle and there was no need to apply spatial pre-saturation, which eliminated disadvantages such as unenhanced MRA, making it suitable for large vessels such as the pulmonary artery. Pulmonary emboli were revealed with filling defects in the pulmonary trunk or branch or with disconnection, blocking, narrowing or deficiency of pulmonary arterial branches (8). It has been shown that if emboli are located in the center of the lumen, a ‘track sign’ appears (9).
Compared to msCTPA, 3D-DCE-MRPA allowed for the acquisition of multidimensional images, and the pulmonary vessels in the macropinacoid, middle lobar and lingular artery were seen with precision (10). Therefore, 3D-DCE-MRPA is superior to msCTPA in revealing smaller pulmonary arterial branches. Similarly, examination of the deep vein in the pelvis and lower limbs is convenient and precise (11). PE and deep vein thrombosis are defined as different stages of venous thromboembolism (VTE), advancing the screening of potential PE. Sensitivity in diagnosing PE approached 100%, specificity was 95%, the positive predictive value was 86% and the negative predictive value was 100% (12).

Use of msCTPA in diagnosing emboli in the pulmonary trunk, interobar and segmental artery is highly accurate, with a sensitivity of 94-98%, and specificity of 96-99%. However, diagnosis in the subsegmental and peripheral vessels proved more difficult (13). In addition, more contrast agent was needed for enhanced scanning, which is toxic and can have adverse effects on patients with liver or kidney dysfunction (14). High resolution time leads to monoyclic reconstruction time being shortened to 83 msec. This avoids artifacts caused by the heartbeat and breathing and enhances image quality and efficiency of diagnosis. In addition, peripheral vessels, such as the pulmonary artery and aorta were clearly presented (15). Original images, with high spatial resolution provided a high guarantee for post-processing techniques. The value of isotropic projection reconstruction was obtained, without the misdiagnosis of vertical and subsegmental arteries (16). The requirements for diagnosis and treatment of acute chest pain were met. Standard diagnostic requirements, such as examining for the triad of symptoms of PE, obtaining images of the coronary artery, pulmonary artery and other large vessels in the thorax were unnecessary and were accomplished by a single, rapid scan in order for the diagnoses to be made rapidly and with precision (17). Various post-processing techniques of images guaranteed definite identification of emboli within the pulmonary artery. Intra-arterial filling-defects were shown in MPR. The subtypes were identified and pulmonary artery filling-defects were revealed in the multi-directional and multi-angle phase. Emboli in the horizontal segmental and subsegmental pulmonary arteries were precisely diagnosed (18). The pulmonary artery has been directly visualized with the assistance of MIP and VR technology. In particular, the location of the pulmonary segmental artery has been directly visualized (19), providing exact objective evidence for physicians.

In conclusion, the average number and formations of emboli in the two groups were compared, and no significant differences were observed. There were more emboli appearing in the segmental or subsegmental arteries in the MRI group, and the difference was statistically significant. A comparison of indirect signs between the two groups revealed no significant differences. The image quality in the two groups was not statistically different. Level 5 and 6 pulmonary arteries were observed more in the MRI group than in the CT group, with higher SNR and CNR. The differences were significant. Twenty-six cases of PE were confirmed in the CT group, with sensitivity of 90.5% and specificity of 86.7%. Twenty-five cases were confirmed in the MRI group, with a sensitivity of 92.3% and specificity of 84.2%. Compared with msCTPA, more segmental or subsegmental pulmonary arteries were observed using 3D-DCE-MRPA, with enhanced SNR.

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