Original Article

MR pulmonary angiography: Can it be used as an alternative for CT angiography in diagnosis of major pulmonary thrombosis?

Ahmed M. Osman\textsuperscript{a,}\textsuperscript{*}, Emad H. Abdeldayem\textsuperscript{a}, Nehad M. Osman\textsuperscript{b}

\textsuperscript{a}Radiology Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt
\textsuperscript{b}Chest Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt

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Abstract

Objective: A comparative study between the non-contrast Magnetic Resonance pulmonary Angiography (MR-PA) and the Computed Tomography Angiography (CTA) in diagnosis of pulmonary embolism (PE).

Patients and methods: Fifty patients were included in our study. All patients were admitted and/or referred to Chest Department with moderate to high clinical suspicious of PE. All patients underwent CTA and non-contrast MR-PA in the same day or within two consecutive days. The radiological examinations were interpreted by two different radiologists. The results were compared and statistically analyzed.

Results: The mean age of the selected patients was about 55 years old. Thirty-one cases showed positive PE in both MR-PA and CTA. Four cases showed positive PE only in CTA with 2 cases showing positive PE only in MR-PA. The rest cases showed negative results in both. The sensitivity of MR-PA was 88.5\% with 86.6\% specificity. The sensitivity and specificity were also calculated per vessel and were 87.2\% and 99.3\% respectively.

Conclusion: The non-contrast MR-PA has a reasonable sensitivity and specificity in the diagnosis of PE especially in major branches. So, it can be used as an alternative to the CTA especially when the CTA and the use of gadolinium are contraindicated.

\textsuperscript{*} Corresponding author. Mobile: +20 1003689856.
E-mail address: Dr_osman80@yahoo.com (A.M. Osman).

1. Introduction

Acute pulmonary embolism (PE) is a life-threatening condition and considered one of the most important emergencies (1,2). The diagnosis of acute PE is considered a clinical dilemma due to its wide spectrum of multiple nonspecific signs and symptoms (3).
The D-dimer results are of bad positive laboratory test being positive in other situations rather than PE such as cancer and inflammation (4).

The rapid progress in cross-sectional imaging techniques offers a great help in the development of a reliable, accurate, and readily available technique for diagnosing pulmonary embolism (5,6). CT angiography (CTA) is considered the gold standard in diagnosis of PE (7). The multislice CT offered high spatial and temporal resolution imaging in a short time scan. CTA has the ability to assess the pulmonary tree down to the fifth to eighth order branches in less than 15 s due to high speed (8). Also, CTA allows direct visualization of the thrombus and can diagnose other alternative or associated chest causes of patient’s symptoms with high sensitivity and specificity (9–11).

The complications of CTA include the requirement of iodinated contrast media injection with its known renal complications and allergic reaction, and the exposure to ionizing radiation with its risk of cancer induction. Therefore, many patients with suspected PE, such as pregnant women, patients with impaired renal function and patient with known allergy to iodinated contrast media are contraindicated to do CTA (12,13).

Magnetic resonance-pulmonary angiography (MR-PA) is an attractive new method with the advantage of radiation avoidance without the use of nephrotoxic contrast agents or using much less complicated gadolinium contrast agent which has less nephrogenic effect and less allergic risk (14).

The aim of this work was to assess the sensitivity and the specificity of the non-contrast MR-PA in diagnosis of acute pulmonary embolism in comparison with CTA.

2. Patients & methods

2.1. Patients

The study was conducted over 50 patients who were admitted and/or referred to the Chest Department – Ain Shams University with moderate to high clinical suspicious of pulmonary embolism depending on simplified Well’s score (15,16) (Table 1). All patients were subjected to clinical examination. Written consents were taken from all the patients to participate in this study according to the rules of ethical committee. Each patient underwent CTA followed by non-contrast MR-PA within two consecutive days inside the Radiology Department – Ain Shams University. The study was conducted over the period from September 2014 to January 2016.

2.2. Exclusion criteria

- Patients with low Well’s score.
- Contraindication to CTA such as pregnant females, elevated kidney functions and known allergy to contrast media.
- Contraindications to MR-PA such as patients with implanted magnetic device “pacemaker” as well as patients with claustrophobia.

2.3. Patient preparation

Fasting for 4–6 h as well as available normal kidney function (serum creatinine). A 18–20 gauge cannula was inserted into the antecubital vein. There was no specific preparation for the MR-PA.

2.4. CTA technique

- Patient position: Supine with the arms is elevated.
- CT machine: High speed 16 slice CT machine – GE (general electric).
- Technique: Timing bolus technique with the region of interest (ROI) placed at the main pulmonary trunk. Scan direction was caudocranial in all patients. Scout was taken starting from 1 cm below the lowest costo-phrenic angle to 1 cm above the lung apices.
- CT parameter: (Table 2)
- Contrast media: we used 60–80 ml non-ionic contrast media injected via injector (MED TRONAG) at a rate of 4–5 ml/s.
- Image processing: The images were transferred to the work station where multi-planar reformatted images (MPR) were done as well as Maximum intensity projection (MIP) images were also processed. All images were displayed with three different windows for interpretation (lung window “1500 width/600 level”, mediastinal window “400/40” and pulmonary embolism specific window “700/100”).

2.5. Non-contrast MR-PA technique

- Patient position: supine position with the arms is elevated.
- MR machine: we used Philips superconductive magnet system at 1.5 Tesla using 8 channel dedicated phased array cardiac coil

<table>
<thead>
<tr>
<th>Variable</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical sign and symptoms of DVT (leg swelling and pain with palpation of the deep veins)</td>
<td>3.0</td>
</tr>
<tr>
<td>An alternative diagnosis is less likely than pulmonary embolism</td>
<td>3.0</td>
</tr>
<tr>
<td>Heart rate &gt;100 beats/min</td>
<td>1.5</td>
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<tr>
<td>Immobilization or surgery in the previous 4 weeks</td>
<td>1.5</td>
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<tr>
<td>Previous DVT/pulmonary embolism</td>
<td>1.5</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>1.0</td>
</tr>
<tr>
<td>Malignancy (treatment ongoing or within previous 6 months or palliative)</td>
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The probability calculated as follows:

<table>
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<th></th>
<th>Total points</th>
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<tr>
<td>High</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>Moderate</td>
<td>2–6</td>
</tr>
<tr>
<td>Low</td>
<td>&lt; 2</td>
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</tbody>
</table>

Table 1  Simplified Well’s score for patients with suspected PE.
2.6. Image interpretation

The diagnostic criteria for acute pulmonary embolism in either CTA or MR-PA are the same because of all provided morphological representations of the same pathological process (17,18). These findings include the following:

- **Total arterial occlusion:** CTA showed failure of enhancement of the entire lumen of the artery. In MR-PA-WB, the thrombus appeared to be hypointense in comparison with the white (bright) arterial tree.
- **Partial occlusion of the artery:** CTA showed partial defect surrounded with contrast material while in MR-PA-WB, the thrombus appeared hypointense surrounded with white blood causing “polo mint sign” in the images acquired perpendicular to the long axis of the vessel or “railway track sign” in the images acquired parallel to the long axis of the vessel.
- **Partial peripheral thrombus adherent to the wall:** appeared as hypodense material in CTA or hypointense in MR-PA-WB forming an acute angle with the wall.

2.7. Analysis of data

Two independent observers reviewed the CTA and MR-PA studies. The main, lobar and segmental branches were observed and recorded as positive and negative for pulmonary embolism using the CTA as a reference modality. The results were collected and compared together and the sensitivity and specificity of the MR-PA were calculated per patient and per vessel. The analysis data were done using IBM SPSS (Statistical Program for Social Science version 22.0, IBM Corp., USA, 2013). Diagnostic validity tests were used including diagnostic sensitivity and specificity.

3. Results

The study was conducted over 50 patients, and their ages ranged between 45 years old and 70 years old with a mean age 55 years. Thirty-five patients were female representing 70% of the cases. The main presenting symptom was dyspnea detected in 100% of cases followed by chest pain detected in 95% of cases. 60% of the patient’s were diagnosed to have moderate probability for pulmonary embolism using Well’s score while the rest 40% diagnosed to have high probability.

Thirty-one patients diagnosed to have positive pulmonary thrombosis in both the CTA and MR-PA (Figs. 1 and 2) with 7 of them showed unequal distribution of the thrombus being...
less in MR-PA in comparison with the CTA representing false—ve results in per vessel analysis (Figs. 3 and 4). Thirteen cases were diagnosed to be free in both studies. Two cases showed positive thrombosis in only MR-PA representing the false positive results while the rest 4 cases showed positive thrombosis in only the CTA study representing the false negative results (Fig. 5).

The sensitivity of MR-PA per patient was calculated to be 88.5% while the specificity was 86.6%.

The left main pulmonary artery was the commonest to be affected between the study population showing positive thrombosis in 15 cases (representing 30% of cases) followed by the right main and right lower lobe division with each was positive in 13 cases (26% of cases). The main pulmonary trunk was the least to be affected being positive in only 4 cases representing 8% of cases.

The vessels in each case were analyzed in both the CTA and MR-PA namely the main pulmonary trunk, right and left main divisions, Right upper, middle and lower lobar divisions and the left upper and lower lobar divisions as well as their segmental branches. No analysis was done for the sub-segmental branches. The results of analysis per vessel are demonstrated in Table 4.

The MR-PA detected thrombosis in 75 pulmonary arteries out of 86 arteries detected by CTA. The sensitivity of MRA per vessel was 87.2% while the specificity was 99.3%. The false—ve results (11 vessels) were noted at the level of the segmental branches except one seen at the level of the left upper lobar artery. The false +ve results were noted at the segmental branches of the lower lobar divisions bilaterally. The per vessel sensitivity of the MR-PA reached to about 98.6% with 100% specificity at the level of the major pulmonary arteries down to the lobar divisions (Fig. 6).

4. Discussion

This study demonstrates the ability of MR-PA in diagnosis of PE with sensitivity about 88.5% per patient and 87.2% per vessel reaching to about 98.6% at the level of the major vessels down to the lobar arteries. So, it can be used as an alternative to the CTA with avoidance of the radiation and the complications of contrast media.

CTA is the most widely used for diagnosis of PE with the sensitivity and the specificity ranging from 53% to 100% and 67% to 100% respectively with the variation depending on the extent of the thrombus, machine criteria and the radiologist experiences (19). With the advanced development in CT generations the sensitivity increased to be 94–96% and specificity reached about 94–100%. So, the CTA is considered the modality of choice in diagnosis of PE (20,21).
The main disadvantages of the CTA include the high radiation exposure, the contrast allergy and the complications of contrast induced nephropathy (2). Radiation exposure to the female breast during scanning of PE was calculated to be equal to 15–25 times two view mammogram and equal to 100–400 plain X-ray chest. The exposure dose reaches to about 10 mSv (22,15).

The previous disadvantages make the CTA is contraindicated in special cases such as pregnant and lactating patients as well as the patients with known allergy to contrast media and patients with high kidney function raising the need for an alternative radiological modality.

MR-PA is still an evolving technique with the advantages of radiation avoidance as well as more safe and even absent contrast agent (23). The first study using MR-PA was done by Loubeyre et al. (24) using the conventional angiography as the reference study with 70% sensitivity and 100% specificity. Other multiple studies were done trying to evaluate the

**Fig. 3**  A female patient 47 years old presented with dyspnea and chest pain with moderate probability of PE according to Well’s score. (A) and (C) Axial CT image demonstrates pulmonary embolism totally occluding the right main pulmonary artery. Also, a totally occluding one noted involving the segmental branch of the right upper lobe division (arrow). (B) and (D) Axial MR-PA-WB taken 48 h later reveals the right main pulmonary embolism appearing as a hypointense filling defect (arrow) yet partially occluding the lumen. The embolism involving the segmental branch of the right upper lobe division couldn’t be demonstrated in MR-PA as in CTA.

**Fig. 4**  A female patient 50 years old presented with dyspnea and chest pain with high probability of PE according to Well’s score. (A) and (C) Axial CT images demonstrate saddle pulmonary thrombus involving the major pulmonary trunk (black arrow) and pulmonary embolism involving the segmental branches of the right lower lobe division (white arrow) with subsequent peripheral pulmonary infarction (curved arrow). (B) and (D) Axial MR-PA-WB taken 48 h later reveals the presence of saddle thrombus yet much lesser in extent and size (black arrow) and failed to demonstrate the embolism involving the segmental branches of the right lobe division with still noted pulmonary infarction yet of much smaller in size (curved arrow).
The gadolinium based contrast agents are characterized by having much low adverse reaction compared to the iodinated contrast agent yet still with risk of systemic nephropathic
fibrosis in nephropathic patients (12, 17). Also, it is still not proven to be safe in pregnant patients (17).

In this study, we tried to evaluate the non-contrast MR-PA technique on 50 patients. This is similar to Mudge et al. (12) who used the same technique yet on only 11 patients. Also Kluge et al. (28) and Kalb et al. (29) tried to evaluate the non-contrast MRA in diagnosis of PE yet as a part of a larger MRI protocol including the use of gadolinium in other sequences with the CTA was also the reference tool.

Per patient results in this study are almost similar to Kluge et al’s (28) study who concluded 89% per patient sensitivity. Also, close to this, Mudge et al. (12) demonstrated about 82% per patient sensitivity.

The difference between the per patient and per vessel results in our study is referred to that, seven of the true positive patients had multiple scattered pulmonary thrombi involving multiple scattered arterial branches which are not totally identified by MR-PA in comparison with the CTA resulting in more false – ve results during the per vessel analysis. We failed to identify PE in 11 vessels. These 11 non-detectable thrombi were detected inside the segmental branches of the lobar divisions except one case failed to detect the thrombus inside the left upper lobar division itself raising the results at the level of the major branches. These results are close to Kluge et al. (28) who found 81% per vessels sensitivity. However, these results are higher than results obtained by Kalb et al. (29) and Mudge et al. (12) who found 67% and 69% per vessels sensitivity respectively.

The false –ve and +ve results occurred in our study are owing to the low MR-PA resolution due to thick image acquisition, breathing motion artifacts due to long exam time and the delay in MR-PA imaging after CTA.

The main limitations were mainly the timing of MR-PA study that was delayed up to 48 h in some cases after the CTA due to unavailability of the MR machine and during such period the patients were already starting their treatment against the PE which may alter the morphology and the extent of the PE in MR-PA. Also, the acutely ill patients couldn’t afford the long examination time of MR-PA causing a lot of breathing motion artifact as well as repetition of the sequences with more time consumption.

5. Conclusion

The MR-PA offers an alternative tool in diagnosis of PE mainly at the level of the major vessels without radiation exposure or facing the contrast media complications. So, it can be used in selected patients with contraindication to CTA and contrast media use as in pregnant, nephropathic patients and patients known allergic to the contrast agents.

Conflict of interest

The authors declare that there are no conflict of interests.

References


