

Three-Dimensional Contrast-Enhanced Magnetic Resonance Pulmonary Angiography in the Study of Pulmonary Vascular Pathology [114]

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ABSTRACT

Objectives: To assess the feasibility of performing pulmonary angiography using MRI with contrast enhancement in patients with pulmonary vascular disease.

Methods: We present our experience in ten individuals, two controls and eight patients who underwent the exam after injection of a gadolinium-based contrast agent on a 1 Tesla MR scanner using a time-of-flight sequence and breath-holding during injection of contrast.

Results: Pathology in the main pulmonary artery and its major branches was detected easily while resolution at the segmental and subsegmental levels was inadequate.

Conclusion: Contrast-enhanced magnetic resonance pulmonary angiography is feasible on a 1 Tesla MR scanner for the study of pathology of the main pulmonary artery and its major branches, like massive pulmonary embolism. However its ability to detect and define distal vessel pathology as found in chronic thromboembolic pulmonary hypertension and small pulmonary emboli is limited.

Key words

Pulmonary angiography; MRI;
Thromboembolism

RESUMO

Angiografia Pulmonar por Ressonância Magnética Tridimensional otimizada por Contraste, no Estudo da patologia Vascular pulmonar

Objectivos: Avaliar a possibilidade de realização de angiografia pulmonar utilizando imagem por ressonância magnética otimizada por contraste, em doentes com patologia vascular pulmonar.

Métodos: É apresentada a nossa experiência em dez indivíduos, dois controlos e oito doentes que foram submetidos ao exame após injeção de um agente de contraste baseado em Gadolinium com recurso a um equipamento de ressonância magnética de 1 Tesla, utilizando uma sequência com *time-of-flight* e interrupção da respiração durante a injeção de contraste.

Resultados: A patologia do tronco da artéria pulmonar e dos seus ramos principais foi facilmente detectada enquanto que os níveis de resolução segmentar e subsegmentar foram inadequadas.

Conclusão: A angiografia pulmonar por ressonância magnética de 1 Tesla otimizada por contraste, é possível para o estudo da patologia do tronco da artéria pulmonar e dos seus ramos principais, nomeadamente embolismo pulmonar. No entanto, a sua capacidade de detectar e definir patologia dos vasos distais como a habitualmente encontrada na hipertensão pulmonar associada a tromboembolismo crónico, é limitada.

Palavras-Chave

Angiografia pulmonar; Imagem por ressonância magnética;
Tromboembolismo

INTRODUCTION

The high incidence of pulmonary embolism has led to the development of a plethora of diagnostic techniques and algorithms, each with its own advantages, disadvantages, advocates and dissidents. Among the various imaging techniques, pulmonary angiography using MRI is relatively new and not widely used⁽¹⁾. However, MRI is the only technique that detects lower-limb deep venous thrombosis and pelvic vein thrombosis by direct thrombus imaging (DTI) without contrast^(2, 3). The ability to assess cardiac function in the same exam motivated some investigators to use MRI to study pulmonary emboli^(4, 5). Initially, MRI used time-of-flight (TOF) sequences without contrast. Because these techniques were inadequate, gadolinium-based contrast agents, which decreased imaging times and improved resolution, were developed⁽⁶⁻⁹⁾. However, imaging the pulmonary vasculature using MRI with contrast presents unique challenges. We investigated the possibility of using this technique in the imaging of pulmonary embolism.

METHODS

MRI used three-dimensional angiography techniques that we have described in the study of aortic pathology⁽¹⁰⁾. Briefly, a three-dimensional time-of-flight related sequence was used on a 1.0 Tesla GE Signa scanner with a pre-scan preparation time of 29 msec, time to repetition (TR) of 8.7 msec and a time-to-echo (TE) of 2.9 msec with a slice thickness of approximately three millimeters, a field of view of 48 x 48 cm, a flip angle of 45 degrees, a matrix of 256 x 160 and a bandwidth of 31.2 kHz, using a standard body coil applied to the thorax with no flow compensation. The imaging slab was placed coronally on a previously acquired sagittal localizing scan. Image acquisition was done in the anterior to posterior direction. Forty milliliters of a commercially available gadolinium-based contrast agent (Magnevist®, Schering Lusitana) was injected during the scan to maintain opacification for the entire duration of the scan, which usually lasted between 18 and 24 seconds with breath-holding. Injection of the contrast agent commenced during the initiation of the breath-holding maneuver, which lasted about five seconds before the initiation of the sequence. Reconstruction in a three-dimensional format was completed after

all the individual slices were acquired with the number of excitations (NEX) kept constant at one. Image interpretation was performed by post-processing of the 3D data with multi-planar reformatting (MPR), providing tomographic images in virtually any plane and maximum intensity projection (MIP) providing images analogous to conventional contrast angiography along with 3D reconstruction images that can be rotated. Inspection of the lumen for filling defects was performed in reconstructions in the axial, coronal and sagittal planes.

Conventional pulmonary angiography (CPA) was also performed in some patients with a low osmolar contrast (Ultravist, Schering Lusitana) using a power injector and 25 ml of contrast (at 10 ml/sec) in each major branch of the main pulmonary artery. Scanning was performed in the AP and oblique (right and left at 30 degrees) directions, using either a 7F multi-purpose catheter or an 8F pulmonary artery flotation catheter with side-holes for injection.

Patients: Two controls and eight patients with the following pulmonary artery pathology underwent MR studies: one with an aorto-pulmonary window, one with stenosis of the pulmonary valve with post-stenotic aneurysm of the pulmonary artery, three with massive pulmonary embolism (two of whom underwent thrombolytic therapy and one embolectomy), one with a pulmonary artery sarcoma, and two with chronic thromboembolic pulmonary hypertension (CTEPH) considered ineligible for thromboendarterectomy. Six of the eight patients also underwent CPA.

RESULTS

In the three patients with massive pulmonary embolism (two of whom had hemodynamic compromise) the embolus was clearly visible in the right branch of the main pulmonary artery (MPA) and disappeared after thrombolysis in two patients (*Figs. 1-2*), and the third patient underwent surgical embolectomy after CPA (*Figs. 3-4*). The patient with pulmonary artery tumor underwent both exams and the tumor was clearly visible in the left branch of the main pulmonary artery along with extension to the lobar artery of the left lower lobe (*Figs. 5-6*). This space-filling lesion was diagnosed as a large thrombus initially but did not resolve with anticoagulant therapy and was not associated with right ventricular dysfunction or

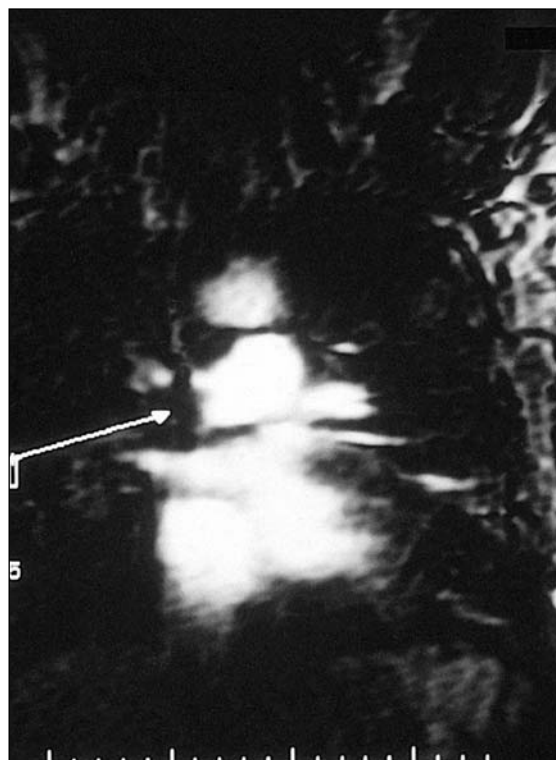


Fig. 1 A single slice showing a massive embolus in the right branch of the main pulmonary artery.



Fig. 2 After thrombolytic therapy, the right branch of the MPA is free of thrombus. Opacification in the left atrium is seen immediately below the MPA branches showing that this slice has captured images of both the arterial and venous phases of contrast injection.

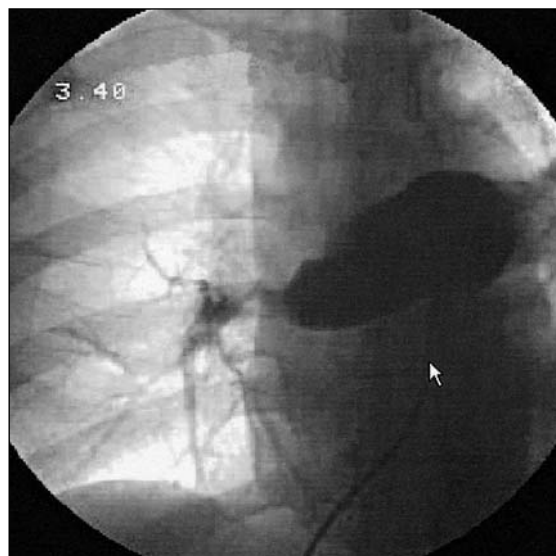


Fig. 3 Conventional pulmonary angiography showing truncation of the major branch to the right upper lobe.

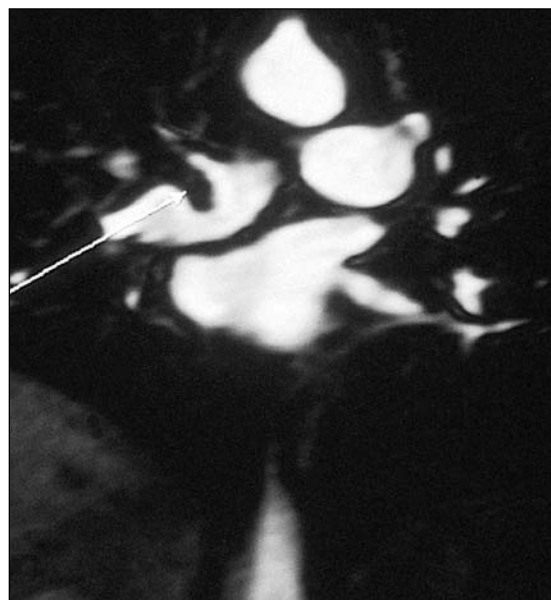


Fig. 4 A single slice of CMRPA shows the obstructing thrombus.

pulmonary hypertension. The MR angiography also confirmed the presence of the aorto-pulmonary window (and aneurysm of the MPA) detected during right heart catheterization and CPA. The distal obliterative disease in the patients with CTEPH was visible in CPA but resolution on contrast-enhanced magnetic reso-

nance pulmonary angiography (CMRPA) was inadequate at the segmental and subsegmental levels. In some individual slices it was easy to mistake a branch of the PA for a tributary of the pulmonary vein, which could confound interpretation.

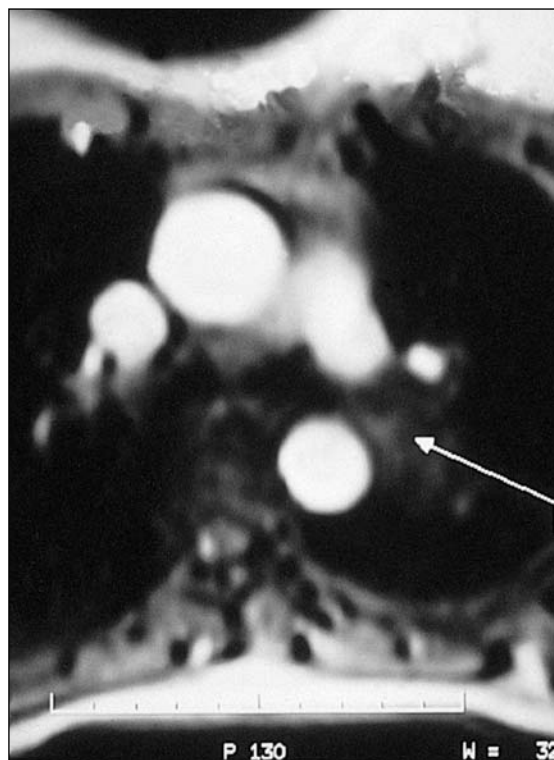


Fig. 5 Gradient echo sequence showing a mass in the left branch of the main pulmonary artery.

DISCUSSION

We used MRI to image space-occupying lesions (presumed to be emboli) in the MPA and its major branches up to the lobar level on a 1 Tesla machine. Resolution was inadequate to interpret images at the segmental and subsegmental levels, even in the controls. Some authorities have discounted the importance of emboli at the subsegmental levels. However, the subsegmental vasculature is important in those with marginal cardiopulmonary reserve, and therefore a vascular imaging technique should preferably have adequate resolution at this level. Imaging on scanners with higher gradient rise times (slew rates) provides higher resolution and image quality and shorter durations, permitting a better evaluation at the segmental level, while subsegmental images may still be inadequate. In patients with CTEPH with laminated organized thrombus at the segmental level, thromboendarterectomy performed by experienced surgeons has resulted in considerable clinical improvement⁽¹⁰⁾. Prior to this procedure, it is important to delineate the extent of thrombus clearly to define the surgical approach. In our patients only CPA could demonstrate this.



Fig. 6 CMRPA shows the mass in a coronal slice.

A few anatomical and technical details deserve comment. The pulmonary vasculature divides in three directions – from medial to lateral, anterior to posterior and superior to inferior – within the lung. Hence some slices will image some branches that may be coursing the lung in the superior-to-inferior direction while others may be doing so in the anterior-to-posterior direction. This means that some vessels will be cut along their short axis while others along their long axis. This anatomical feature of the pulmonary vasculature can compromise resolution with some vessels in a slice being clearly visible while others are blurred.

The data acquired in MRI (called the individual k-lines that add to what is technically called the k-space which eventually forms the image) has to coincide with maximal contrast presence in the MPA and its branches⁽¹¹⁾. However, the time between the arterial phase enhancement and the initiation of the venous phase in the pulmonary vasculature is extremely short. If image acquisition is commenced too late contrast may not be present in the MPA or branches, while imaging too early may show the contrast in the superior vena cava and the right heart chambers with very little enhancement of the MPA. Some commercially

available programs (SMARTPREP) are available that claim better coordination of contrast injection and image acquisition. Our experience with this program, though limited, has not been encouraging. Recent improvements with software resulting in fluoro-triggered MRA sequences provide better coordination between bolus arrival and image acquisition and may improve the quality of images. Image analysis by MPR and MIP is also time-consuming, tedious and unreliable due to the overlap of vessels mentioned above. Therefore even many experts do not recommend MRI to rule out PE in an acute situation.

The ability to image the leg veins and the pelvic veins is unique to MR (although spiral CT can perform leg venography, albeit with contrast). If further technical improvements can be made in sequences with better bolus-image acquisition coordination, this technique may provide a comprehensive approach to imaging the venous and pulmonary vasculature in embolic disease. In venous thromboembolic disease vascular imaging confirms the clinical consequence of a thrombophilic state that is treated by anticoagulation. Therefore imaging techniques have their inherent limitations in this clinical context and do not stand alone. Optimal management of PE should involve an optimal clinical assessment for hemodynamic instability, laboratory measurement of D-dimer levels using a sensitive assay, echocardiography to assess RV dysfunction and an imaging modality that can detect thrombi, as shown in a recent study⁽¹²⁾. One study even provided evidence for the safety of managing patients for suspected PE based on the pretest probability and the D-dimer result alone, avoiding any type of diagnostic imaging⁽¹³⁾.

The emergence of spiral CT, which is also available in our institution, as a robust technique has further diminished the interest of some groups in MRI. Single-detector helical CT performed extremely well as the primary diagnostic test to rule out PE, with a total mortality of 4.1% in patients with a normal helical CT, none dying of fatal PE, only one among 246 patients developing a nonfatal PE and another patient developing venous thromboembolism⁽¹⁴⁾. Multi-detector CT can provide higher sensitivity for small subsegmental emboli, thinner imaging sections (up to 1 mm), shorter imaging times and more extensive coverage of the thorax⁽¹⁵⁾. However at this time and to the best of our knowledge, although spiral CT

techniques do exist for the venous system in the lower extremity⁽¹⁶⁾, the pelvic veins and cardiac function cannot be assessed. Right ventricular dysfunction is a powerful predictor of outcome in patients with pulmonary embolism^(17,18). Although this information can be obtained by transthoracic echocardiography, not even transesophageal echocardiography can image the left branch of the MPA completely because of the interposed trachea. MRI with contrast provides information on the systemic venous and pulmonary vasculature and cardiac function, although significant limitations exist. The development of multidetector CT technology along with the limitations of MRI will probably relegate the latter technique to a secondary role in the diagnostic imaging of PE, unless further technical developments overcome the current limitations.

LIMITATIONS

It needs to be stated clearly that this study involved only MR, precluding us from launching into a discussion on any relative merits of the technique compared to spiral CT other than those mentioned in the preceding paragraphs. Scanner strengths up to 3 Tesla are currently being applied in MR angiography studies.

The number of patients is very small and we were unable to gather an adequate number of patients in each group due to logistical and financial constraints, in order to make conclusive statements on each pathological state. The diagnosis of pulmonary artery tumor was a serendipitous finding and we do not attempt to state that this technique is confirmatory in the diagnosis of these conditions, as only a space-filling defect will be seen and other sequences like spin echo with better definition of tissue characteristics based on T1 or T2 weighting is more useful.

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