MRI of Pregnant Patients for Suspected Pulmonary Embolism: Steady-State Free Precession vs Postgadolinium 3D-GRE

Ressonância Magnética em Doentes Grávidas com Suspeita de Embolia Pulmonar: Steady-State Free Precession vs 3D-GRE Após Gadolínio

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ABSTRACT

Introduction: Pulmonary embolism is a leading cause of maternal mortality in the developed world. Ventilation-perfusion scintigraphy and Computer tomography cause ionizing radiation exposure. Gadolinium-enhanced magnetic resonance imaging is generally not indicated in pregnant patients. MRI using motion resistant techniques that do not use intravenous contrast material, such as balanced steady-state free precession may be a better approach in pregnant patients.

Purpose: To describe the preliminary findings of the use of SSFP for the evaluation of pregnant patients with suspected PE, and to compare with a young women population evaluated with postgadolinium 3D-gradient echo sequences for the same intention.

Materials and Methods: Radiology database was searched for two groups of subjects who underwent chest MRI at 1.5T for suspected PE, between January, 2007 and June, 2010: pregnant patients with MRI including balanced SSFP (group A) and females younger than 45 years old including a T1-weighted postgadolinium 3D-GRE (group B) sequence. The final study population consisted of 21 subjects. Blind and independent evaluation of MR images was performed for image quality of the pulmonary arterial system, PE and other chest findings. Data was subject to statistical analysis.

Results: Good image quality was observed in all central and lobar arteries on both groups and in 90% (group A) and at least 83.3% (group B) of the segmental arteries. There was no significant difference between groups A and B for image quality of central and lobar pulmonary arteries ($P > 0.05$).

Conclusion: SSFP can visualize central, lobar and segmental pulmonary arteries with sufficient image quality in pregnant patients, comparable to 3D-GRE.

RESUMO

Introdução: A embolia pulmonar é uma importante causa de mortalidade materna no mundo desenvolvido. A cintigrafia de ventilação-perfusão e a tomografia computorizada causam exposição à radiação ionizante. A ressonância magnética com contraste-gadolínio endovenoso não é geralmente indicada em doentes grávidas. A RM utilizando técnicas resistentes aos artefactos de movimento, que não usam contraste endovenoso, como a balanced steady-state free precession (SSFP) poderá ser uma abordagem preferível em doentes grávidas.

Objectivo: Descrever os achados preliminares do uso de SSFP na avaliação de doentes grávidas com suspeita de EP, comparando com uma população de jovens mulheres avaliadas com RM 3D-gradiente eco após contraste-gadolínio pela mesma suspeita clínica.

Materiais e Métodos: O arquivo radiológico foi retrospectivamente analisado para dois grupos de doentes submetidos a RM do tórax em 1.5T por suspeita de EP, entre Janeiro de 2007 e Junho de 2010: grávidas com RM incluindo SSFP (grupo A) e mulheres com idade inferior a 45 anos com RM incluindo sequência ponderada em T1, 3D-GRE, após contraste-gadolínio (grupo B). A população final incluiu 21 doentes. As imagens de RM foram avaliadas com leitura independente e cega, para qualidade de imagem do sistema arterial pulmonar, EP e outros achados torácicos. Os dados foram submetidos a análise estatística.

Resultados: A qualidade de imagem foi considerada boa em todas as artérias centrais e lobares de ambos os grupos e em pelo menos 90% (grupo A) e 83,3% (grupo B) das artérias segmentares. Não ocorreram diferenças significativas na qualidade de imagem das artérias pulmonares centrais e lobares entre os grupos A e B ($P > 0,05$).

Conclusão: A RM com SSFP pode visualizar as artérias pulmonares centrais, lobares e segmentares em doentes grávidas, com qualidade de imagem adequada e comparável a 3D-GRE.

INTRODUCTION

Pulmonary embolism (PE) is a leading cause of maternal mortality in the developed world.[1-4] The incidence of pulmonary embolism during pregnancy is five times greater than that for non-pregnant women of the same age.[3] The ability to accurately diagnose PE is essential in order to treat this life-threatening condition or to prevent unnecessary treatment, as the treatment is associated with side effects for both mother and fetus.[2-4] Clinical manifestation of PE is often nonspecific and variable, and the assignment of a clinical pretest probability for PE has not been proven effective in pregnancy leading to under- or misdiagnosis.[1,5-7] Because of this, imaging has assumed a central role in the diagnosis of PE.[1]

Ventilation-perfusion (V/Q) scintigraphy and CT pulmo-

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nary angiography (CTPA) have been used as the first line imaging tests for the diagnosis of pulmonary embolism in pregnant patients, when compression US of the lower extremities does not result in a positive finding for deep vein thrombosis.[1-6,8,9] Although with comparable results,[10] the use of CTPA and/or V/Q scintigraphy have not been universally accepted as justifiable imaging strategies for the diagnosis of PE in pregnant patients because both modalities result in maternal and fetal radiation exposure.[2-6,8,9] It has been reported that any amount of radiation exposure from these diagnostic examinations during pregnancy increases the lifetime risk of developing malignancy in the fetus and proliferating breast tissue of the mother.[2-4,8,11,12] Also, in the case of V/Q scans, up to 21% of pregnant women may have non-diagnostic tests,[13] and additional imaging might be needed, potentially exposing them to further radiation.[1] In general, ionizing radiation techniques have been increasingly used during pregnancy for several conditions, with CT use increasing by 25% per year.[14] This concern with the potential deleterious effects associated with CT and iodinated contrast agents, and the fact that similar information may be obtained without the use of ionizing radiation or iodinated contrast media suggest the need to consider the benefits of the use of magnetic resonance imaging (MRI) for suspected PE in pregnant patients.[15,16]

Gadolinium-enhanced MR angiography (MRA) has been shown to have high accuracy for the diagnosis of pulmonary embolism in the general population, its major potential limitation associated with image degradation due to motion artifacts.[7,17-20] Other techniques, such as three dimensional gradient echo (3D-GRE) /volumetric interpolated breathhold examination (VIBE; Siemens, Erlangen, Germany) sequences, which are able to evaluate the pulmonary vasculature as well as other structures and organs in the chest, may be used in patients suspected to have PE.[18,21-25] Recently, complementary benefits to combining different contrast enhanced and non contrast enhanced MRI approaches for evaluation of PE has been shown.[26] However, gadolinium-enhanced MRI is generally not indicated in pregnant patients, because of safety concerns for the fetus.[9,14] In the absence of gadolinium, pregnant patients can undergo MRI, without reported cases of deleterious effect of MRI on the developing fetus.[27] MRI protocols using motion resistant bright blood techniques that do not use intravenous contrast material, such as balanced steady-state free precession techniques (SSFP) may be a better approach in this specific category of patients.[18,22] Also, the difficulties of having pregnant patients in the magnet bore can be overcome, given that these sequences have already shown success in studying fetus' cardiac anatomy without sedation.[28]

Thus, the purpose of our study is to describe the preliminary findings of the use of MRI including SSFP for the evaluation of pregnant patients with suspected pulmonary embolism, and to compare with a non-pregnant young women population evaluated with postgadolinium 3D-GRE sequences for the same intention.

MATERIALS AND METHODS

Patient Selection

Institutional review board approval with waiver of informed consent was obtained for our HIPAA compliant retrospective study. The Radiology Department database was searched for consecutive subjects who were pregnant and underwent chest MRI at 1.5 T including a balanced SSFP sequence (group A) and for female subjects younger than 45 years old who underwent chest MRI at 1.5 T including a T1-weighted postgadolinium 3D-GRE sequence (group B), both for suspected pulmonary embolism, between January, 2007 and June, 2010. The final study population consisted of 21 subjects. Group A included 6 subjects (mean age ± standard deviation, 26 ± 7.1) who were pregnant (mean gestational age ± standard deviation, 17 ± 2.5 weeks). None of the patients of group A had previous history of PE and/or deep vein thrombosis. Group B included 15 subjects (mean age ± standard deviation, 27 ± 6.8). Of these 15, three were pregnant, one did not have an appropriate intravenous access for computed tomography pulmonary angiogram (CTPA) and one could not tolerate ventilation/perfusion (V/Q) scintigraphy. Additionally; 3 subjects had a past history of PE and/or deep vein thrombosis (DVT), 2 subjects had factor V Leiden deficiency and 2 had sickle cell disease. The pregnancies were in the second trimester in all three subjects. All subjects from both groups were referred from the Emergency Department and had chief complaints including chest pain, dyspnea, syncope and extremity swelling, and underwent chest MRI for the evaluation of suspected PE. MRI examinations were performed for suspected pulmonary embolism at admission. The decisions to examine the subjects with MRI for suspected pulmonary embolism, including gadolinium administration, were made purely for clinical reasons and following discussion of its risks and benefits with the referring physicians and subjects. Written informed consents about the risks and benefits of MRI examinations and gadolinium administration to the health of fetus and mother were obtained from all pregnant subjects. Pregnant subjects that underwent an MRI protocol with gadolinium administration did so in 2007, when our institution's protocol included this approach in selected cases.[18,29,30]

MRI Technique

MR imaging of the chest was performed on 1.5-T MR system (Avanto MRI System, Siemens Medical Systems, Malvern, PA) using a phased-array torso coil, according to our institution's Chest MRI protocol for suspected pulmonary embolism, which included a T1-weighted fat saturated pre and postgadolinium 3D-GRE (VIBE) sequence, as was the case of subjects included in group B. If contrast administration has deemed contraindicated, a balanced SSFP sequence, multi-slice 2D true fast imaging with steady-state precession (TrueFISP), was performed instead of the 3D-GRE sequence, as was the case with subjects included in group A. All sequences were acquired in both coronal and axial planes. Intravenous gadobenate dimeglumine (Multi-

Hance, Bracco Diagnostics, Princeton, NJ, USA) was administered as a power-injected (Medrad, Pittsburgh, PA, USA) bolus of 0.1 mmol/kg at 2 ml/second in all subjects that underwent 3D-GRE. Postgadolinium 3D-GRE sequences were acquired at 5 seconds after the administration of gadolinium. Details of MRI protocol and sequences used for subjects with suspected pulmonary embolism are displayed in Table 1.

TrueFISP, or true fast imaging steady-state free precession, is a gradient-echo technique with fully refocused transverse magnetization, its signal intensity characterized by the square root of T2/T1. Thus, it provides intensive blood signal (long T1 and T2). With short TE and short TR approaches, all tissues with a reasonably long T2-relaxation time will demonstrate additional signal due to the various refocused echo paths. These characteristics allow inherent discrimination of embolic material and patent pulmonary vessels/blood. This bright blood technique is able to visualize the pulmonary vasculature as well as the lungs and other structures of the chest and may also be acquired as a single-shot technique in subjects who are not able to hold their breath due to respiratory distress.[18,22,26]

MRI Interpretation

Chest MRI studies of all subjects were independently and retrospectively evaluated by 2 experienced body radiologists separately (R1 and R2 with 6 years and 5 years of experience, respectively) who were blinded to the clinical information and diagnosis of the subjects but were aware that pulmonary embolism was suspected.

Reviewers evaluated all images of the pulmonary arterial system for diagnostic image quality and the findings of pulmonary embolism to the level of segmental branches on SSFP or postgadolinium 3D-GRE sequences in all subjects, according to previously published methods.[18,20,22] Additionally, the reviewers examined for other findings in other structures of the chest including lung parenchyma, heart, mediastinum, chest wall and diaphragm on all sequences.

Table 1 – Sequences and parameters of chest MRI protocol used for pregnant patients with suspected pulmonary embolism

Sequences	**TrueFISP***		**3D-GRE†**	
Planes	**Coronal**	**Axial**	**Coronal**	**Axial**
TR (ms)‡	2.91	2.97	4.3	4.3
TE (ms)§	1.44	1.48	1.68	1.68
Flip Angle (°)	60	60	10	10
Matrix	256x256	256x192	320x320	320x224
FOV (mm)‖	380	300	400	400
Number of Sections	50	50	72	72
Slice Thickness (mm)	5	5	3	3
Fat Suppression	No	No	Yes	Yes
Parallel Imaging (GRAPPA)¶	2	2	2	2
Respiratory Control	Breath hold	Breath hold	Breath hold	Breath hold
Acquisition Time (s)**	13	13	21	21

* True fast imaging with steady-state precession; † Three dimensional gradient echo; ‡ Repetition time (milliseconds); § Echo time (milliseconds); ‖ Field of view (millimeters); ¶ Generalized autocalibrating partially parallel acquisitions; ** seconds.

Table 2 – Definitions of scores for the evaluation of image quality of pulmonary arteries

Image Quality Scores	**Definitions**
1	Poor image quality and blurring of the arterial segment
2	Fair image quality but inadequate blood signal intensity/arterial enhancement for confident diagnosis
3	Good image quality and blood signal intensity/arterial enhancement, and adequate definition for confident diagnosis
4	Excellent image quality and blood signal intensity/arterial enhancement for highly confident diagnosis

The reviewers employed both coronal and axial datasets for SSFP and postgadolinium 3D-GRE sequences to evaluate the pulmonary arterial system.

The parts of the pulmonary arterial system which were evaluated by the reviewers were as follows: main, right and left pulmonary arteries (central pulmonary arteries), five lobar arteries (right upper, right middle, right lower, left upper, left lower), and 20 segmental arteries for a total of 28 parts. For each patient, 28 vessel parts were separately assessed for diagnostic image quality with regard to how clearly the vessel was defined by using a four point scale (1 - 4): poor image quality and blurring of the arterial segment (rated 1); fair image quality but inadequate blood signal intensity/arterial enhancement for confident diagnosis (rated 2); good image quality and blood signal intensity/arterial enhancement with adequate definition for confident diagnosis (rated 3); and excellent image quality and blood signal intensity/arterial enhancement for highly confident diagnosis (rated 4). Image quality of an arterial segment was rated to have probable sufficient diagnostic quality (score of ≥ 3) if the reviewers were confident that clinically relevant diagnostic information was visible with clear discrimination between the blood vessel and background tissue.[20] Image quality was considered nondiagnostic (score of ≤ 2) if the vessel was blurred or there was inadequate vessel signal intensity/enhancement.[20] Artifacts rendering the arterial parts nondiagnostic were also determined by the reviewers independently.

MRI findings diagnostic of PE were defined as a low signal intensity filling defect in an arterial part (seen in multiple projections) or abrupt cutoff of the main or lobar pulmonary arteries.[19]

Clinical and Imaging Follow-up

Clinical and imaging follow-up data for all subjects were obtained from the clinical information system and radiology database. Clinical follow-up included comorbid conditions (e.g. malignant disease, pulmonary infection) diagnosed at patient admission or during the subsequent hospitalization, clinical course during or following hospitalization, the administration of anticoagulant treatment, course of the pregnancies, incidence of new PE and/or mortality during follow-up. The results of additional imaging tests performed for suspected PE at admission and later during the follow-up were also obtained. The findings of the reviewers were compared to each other and the consensus data was also compared to the original MRI interpretation.

Statistical Analyses

The extent of agreement between the reviewers for the evaluation of diagnostic image quality of pulmonary arteries was calculated with Kappa statistics. Kappa values less than 0 were considered to represent no agreement; those between 0 and 0.40, poor agreement; those between 0.41 and 0.75, good agreement; and those between 0.76 and 1.00, excellent agreement. Mann-Whitney U test was used to test the null hypothesis that SSFP and postgadolinium 3D-GRE sequences were not different from each other for the demonstration of separate parts of the pulmonary arterial system based on the diagnostic image quality data. The significance of difference of the frequencies of diagnostic and nondiagnostic arterial parts between the two groups was calculated with Chi-square test for the comparison between proportions. Kruskal Wallis with post-hoc multiple comparisons were used to test the null hypothesis that diagnostic image quality of separate parts of the pulmonary arterial system was not different from each other on SSFP and postgadolinium 3D-GRE sequences separately. Associations were considered statistically significant if two-tailed $P < 0.05$. Analyses were performed by using MedCalc for Windows, version 11.3.0.0 (Medcalc Software, Mariakerke, Belgium).

RESULTS

Pulmonary Arterial System Findings

The rate of agreement between the reviewers for the evaluation of image quality of pulmonary arteries ranged from 0.66 to 1.0. All central (18/18) and lobar (30 / 30) pulmonary arteries (both reviewers), as well as 90.6% (110 / 120; reviewer 1) and 90.8% (109 / 120; reviewer 2) of the segmental arteries were visualized with sufficient image quality (≥ 3) on group A (Table 3) (Fig. 1). All central

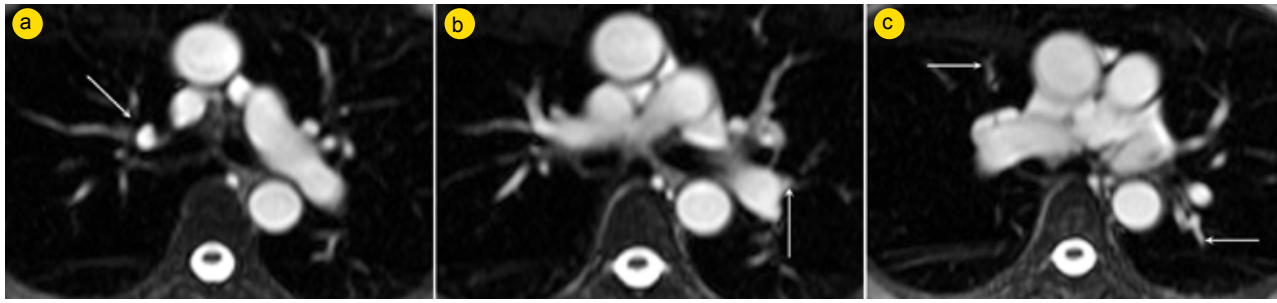

Fig. 1 – True Fast Imaging Steady-state free precession (TrueFISP) images (**a**,**b**,**c**) in the axial plane of a 30 year/old pregnant woman with suspected pulmonary embolism, showing different pulmonary vessel parts. Notice the good image quality, signal intensity and definition allowing for confident diagnosis of the main left pulmonary artery (**a**), emergence of the right superior lobar artery (arrow, **a**), the main right pulmonary artery (**b**) and segmental vessel parts including middle lobe and left lower lobe **(**arrows**, c)** pulmonary arteries . Notice the emergence of the left lower lobe segmental branches (arrow**, b**). No pulmonary embolism was found at chest MRI or suspected at clinical follow-up.

Table 3 – Distribution of number of arterial parts with diagnostic image quality at different levels on groups A and B

	Reviewer 1		Reviewer 2	
Vessel Parts	**Group A***	**Group B†**	**Group A**	**Group B**
Central‡	18/18 (100%)§	45/45 (100%)	18/18 (100%)	45/45 (100%)
Lobar	30/30 (100%)	75/75 (100%)	30/30 (100%)	75/75 (100%)
Segmental	110/120 (90.6%)	259/300 (83.3%)	109/120 (90.8%)	272/300 (90.7%)

* Group A includes patients who underwent chest MRI using TrueFISP (True fast imaging with steady-state precession) in coronal and axial planes; † Group B includes patients who underwent chest MRI using post gadolinium 3D-GRE (Three dimensional gradient echo) in coronal and axial planes; ‡ Main, right and left pulmonary arteries; § Number of arterial parts with diagnostic image quality/ total number of arterial parts (proportion of diagnostic arterial parts).

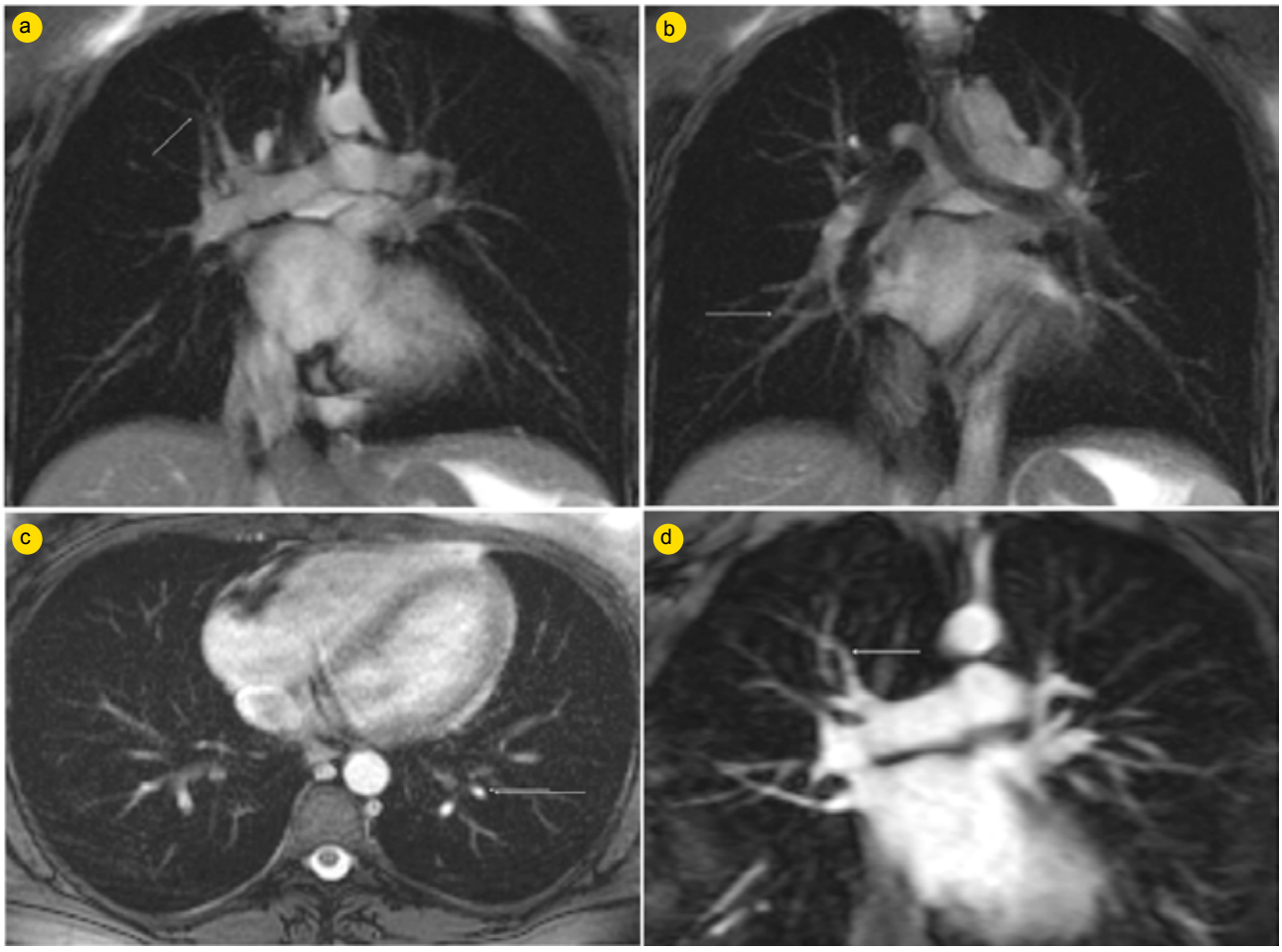

Fig. 2 – True Fast Imaging Steady-state free precession (TrueFISP) images in the coronal (**a**,**b**) and in the axial **(c)** planes of a 28 year/old pregnant woman and T1-weighted post-gadolinium three dimensional gradient-eco (3D-GRE) image in the coronal plane **(d)** of a 32 year/old woman that underwent MRI for suspected pulmonary embolism. Good image quality, signal intensity and definition for confident diagnosis were found at central, lobar and most segmental (arrow, c) pulmonary vessel parts both using TrueFISP and 3D-GRE in these two different patients.

(45 / 45), lobar (75 / 75), and 83.3% (259 / 300; reviewer 1) and 90.7% (272 / 300; reviewer 2) of the segmental arteries were visualized with sufficient image quality in group B (Table 3) (Fig. 2).

Ratings of the reviewers for the image quality of vessel parts of the pulmonary arterial system are displayed in Table 4. Image quality ratings of central pulmonary arteries were not significantly different from the ratings of lobar arteries on the SSFP sequence for both reviewers and on postgadolinium 3D-GRE sequence for one reviewer. Image quality of segmental arteries was significantly lower compared to the ratings of central and lobar arteries on SSFP and postgadolinium 3D-GRE sequences for both reviewers ($P < 0.0001$). There was no significant difference between SSFP and postgadolinium 3D-GRE sequences for image quality of central ($P = 0.23$ for both reviewers) and lobar ($P = 0.06$ for reviewer 1 and $P = 0.1$ for reviewer 2) pulmonary arteries. Only reviewer 2 (R2) found significant differences

Table 4 – Results of the pulmonary arterial vessel parts analysis for both reviewers

	Reviewer 1			Reviewer 2		
Vessel Parts	**Group A***	**Group B†**	***P*‡**	**Group A**	**Group B**	***P***
Central§	3.9 ± 0.2‖	3.8 ± 0.4	0.23	3.9 ± 0.2	3.8 ± 0.4	0.23
Lobar	3.8 ± 0.4	3.6 ± 0.5	0.06	3.7 ± 0.4	3.6 ± 0.5	0.1
Segmental	2.9 ± 0.3	3.0 ± 0.6	0.09	2.9 ± 0.3	3.1 ± 0.5	0.02

* Group A includes patients who underwent chest MRI using TrueFISP (True fast imaging with steady-state precession) in coronal and axial planes; † Group B includes patients who underwent chest MRI using post gadolinium 3D-GRE (Three dimensional gradient echo) in coronal and axial planes; ‡ Results of the Mann-Whitney U test. Associations were considered statistically significant if two-tailed P < 0.05; § Main , right and left pulmonary arteries; ‖ Results of the pulmonary arterial vessel parts analysis are expressed as average±standard deviation. Scores range from 1(poor) to 4 (excelent) image quality and blood signal intensity/arterial enhancement.

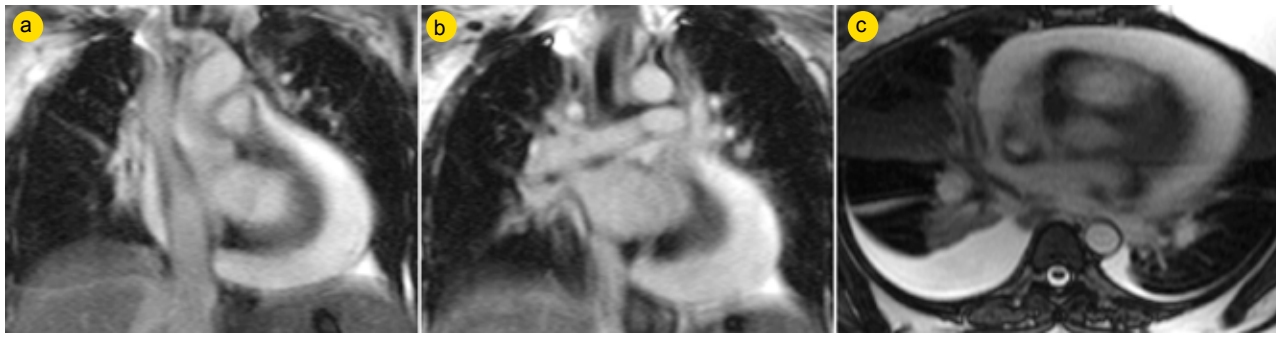

Fig. 3 – True Fast Imaging Steady-state free precession (TrueFISP) images in the coronal (**a**,**b**) and axial planes **(c)** of a 35 year/old pregnant woman with suspected pulmonary embolism and a history of metastatic breast carcinoma. Pericardial effusion causing right heart compromise which revealed an increase in size of the hepatic veins and inferior vena cava, was identified together with bilateral pleural effusions, bilateral atelectasis involving posterior regions of both lungs and perihilar parenchymal radiation changes.

between the scores of segmental pulmonary arteries with 3D-GRE and SSFP. R2 found slightly lower and nondiagnostic calculated mean for the SSFP sequence, but there was no statistical significance of the difference of the proportions of nondiagnostic studies between groups A (8.3%) and B (13.7%) (*P* = 0.1). Respiratory motion artifacts were determined as the cause of nondiagnostic image quality in all subjects in group B, and both poor blood signal intensity and motion artifacts in segmental arteries were considered the cause for nondiagnostic pulmonary artery parts depiction in group A, by both reviewers.

No filling defect in central, lobar or segmental pulmonary arteries and/or no abrupt cutoff of central or lobar pulmonary arteries were detected by both reviewers in all subjects included in group A. In Group B, PE was identified in one subject and the reviewers identified the involved arterial segments in complete agreement in that subject. In this subject who had inadequate access for CTPA and a history of sickle cell disease, the diagnosis of PE was confirmed with V/Q scintigraphy performed within 24 h of chest MRI, which demonstrated high probability for PE. The involved arteries identified on MRI were concordant with the perfusion defects seen in the involved segments of the lungs on V/Q scintigraphy.

Other findings were detected in 2 / 6 subjects in group A and 3 / 15 subjects included in group B by both reviewers. There was no discordance between the reviewers for the detection of other findings. In group A, subsegmental atelectasis was detected in the right middle lobe in one patient. In another patient with a history of metastatic breast carcinoma, pericardial effusion causing right heart compromise which revealed an increase in size of the hepatic veins and inferior vena cava, was identified together with bilateral pleural effusions, bilateral atelectasis involving posterior regions of both lungs and perihilar parencyhmal radiation changes were detected (Fig. 3). In this patient, all segmental arteries were rated as nondiagnostic on SSFP sequences. In Group B, one patient was found to have three lung nodules ranging from 2 to 6 mm in size on a follow-up CT within 24h, but only the largest lesion was identified on MRI. This difference did not impact patient management. In another patient, multiple areas of consolidations involving different segments of both lungs were detected, which was confirmed with chest X-rays and diagnosed as pneumonia clinically. In another patient who had sickle cell disease, superior vena cava stenosis was detected and this was confirmed with venography and treated with venoplasty.

Clinical and Imaging Follow-Up

All subjects were followed up clinically for 4.7 ± 2.2 months (group A) and 6.6 ± 3 months (group B) after MRI examinations. No subjects had additional imaging tests for the diagnosis of PE at admission. No subjects had clinically suspected PE during the follow-up period. The patient who had the history of metastatic breast cancer was further hospitalized and treated for cardiac tamponade. Histopathologic proof was obtained that the pericardial effusion was malignant and secondary to breast cancer. Therapeutic abortion was also performed in this patient.

DISCUSSION

The results of our study have shown that all central and lobar arteries and 90% of segmental arteries were visualized with good image quality on SSFP sequences (group A). The success rate of SSFP sequences for the demonstration of lobar arteries in our study concurs with the reported success rate of SSFP for vessel demonstration, which has been described as 99% accurate in recent studies.[18,22] However, the success rate of SSFP sequences for the demonstration of segmental arteries was lower in our study compared to previous studies, which has been reported to be 97%.[18,22]

Our study has also shown that all central, lobar and at least 83% of the segmental pulmonary arteries were visualized successfully with sufficient diagnostic quality on postgadolinium 3D-GRE sequences. In our small population, results were comparable between the two approaches (groups A and B). The success rates of postgadolinium 3D-GRE sequences for the demonstration of lobar and segmental arteries concur with the success rates of MRA, which have been reported to vary in the range of 76-98% and 70-93%; respectively, in recent studies, with better results in the absence of motion artifacts.[7,18,19] The ability to evaluate other organs in the chest is a major advantage of gadolinium enhanced 3D-GRE compared to MRA, as shown in a prior study, at least 50% of young adult patients investigation for PE have some abnormal finding in the chest.[21]

Image quality ratings of segmental arteries were significantly lower than that of central and lobar arteries on SSFP and 3D-GRE sequences. This finding is in agreement with the results of other studies in the literature.[17-20,25]

One reported advantage of CTPA over MRI is the higher spatial resolution of CT which theoretically should result in better definition of small vessel, subsegmental pulmonary arterial emboli.[15] The severity of PE has been related with its location, with severity increasing with more proximal locations.[31] It is at present investigation whether treatment of isolated distal subsegmental PEs with heparin may result in greater patient morbidity than benefit.[32-36] Patients diagnosed with isolated subsegmental pulmonary emboli have favorable 3-month outcomes. Short-term prognosis for recurrent thromboembolism may be lower than the risk of adverse events with anticoagulation in patients at high risk of hemorrhage.[37]

Motion artifacts are the most important factor associated with potential degradation of image quality of T1-weighted contrast enhanced MRI for the evaluation of the pulmonary vessels,[7] which concurs with our results, as 13.7% of the arterial vessel parts of group B had nondiagnostic quality due to motion.

This study reflects our clinical experience with imaging pregnant patients for pulmonary embolism. No PE's were detected in any of the arterial segments on MRI in any patient included in group A. No PE was observed in the pregnant patients in group B as well. Additional imaging tests at admission and/or clinical and imaging follow-up confirmed this finding. This emphasizes that although the incidence of PE is higher in pregnancy than in other young patients, it is still a rare disease in this age group. The incidence of venous thromboembolism in pregnant women has been estimated to be 5 – 12 events per 10,000 (0.05 -0.12 %) pregnancies antenatally (from conception to delivery), pregnancy associated deep vein thrombosis (DVT) having an incidence about three times higher than that of pregnancy-associated PE.[1-3] On the other hand, many disease processes in the chest and the physiologic changes of pregnancy may mimic the symptoms and signs of PE.[1,3] Additionally, pulmonary emboli in pregnant patients may be associated with related or unrelated findings that may affect therapeutic approaches.[1,3] SSFP which is able to evaluate not only the pulmonary vasculature but also the lung parenchyma, heart, mediastinum, diaphragm and chest wall may render this method a useful technique for the examination of pregnant patients who have symptoms and signs suggesting PE, but may in fact have other chest diseases. The detection of other findings in 2 / 6 (33%) of subjects in group A provides additional evidence of the value of a technique that evaluates the entire contents of the thorax.

Postgadolinium 3D-GRE sequences have higher spatial and contrast resolution compared to the SSFP sequence; however, the latter has decided advantages, and should be preferred over postgadolinium 3D-GRE sequence in pregnant patients. SSFP does not require contrast administration, hence avoiding this risk, and can be acquired as a single shot technique in patients with respiratory distress, which renders it a motion resistant sequence.[18,22] Current treatment options for PE depend on the prognostic stratification of patients with PE. Mortality for PE is 2% in normotensive patients without evidence of right ventricular dysfunction (RVD), but rises up to 30% in patients with shock and up to 65% in patients with cardiac arrest at presentation.[38] It has been reported that delay and misdiagnosis of pulmonary embolism is frequent, but much of this data comes from studies on the elderly.[39] Imaging has been reported to correlate well with prognostic stratification in some studies,[40] but further validation is needed in larger population studies and in pregnant patients[6,40].

Based on our findings, it may reasonable to consider using SSFP either as a first line modality, reserving postcontrast CT or V/Q for patients who have equivocal findings on SSFP, or to use SSFP as a short-term follow-up technique, after the diagnosis of PE has been established by CTPA or V/Q.[41] Further validation of our findings is however needed before widespread implementation of our suggestion.

Limitations of our study include the small sample size with its corresponding implications in statistical power, and the lack of detected PE in subjects evaluated with SSFP. It is conceivable that future studies may show significant differences that were not found in this study for the same tested parameters, although our rating results suggest that SSFP may potentially be used to evaluate pregnant patients with suspected PE. It is universally accepted that clear demonstration of high signal in vessels is a definitive surrogate of the demonstration of patency of vessels and exclusion of PE. SSFP is an already established technique in which

flowing blood is high in signal intensity and clot is intermediate to low signal, hence we did not consider it a substantial set-back that no PE was present as we did not considered that SSFP required validation as an angiographic test.[18,22] The small population size may be also related with the retrospective nature of our study and partly to the more limited access to MRI comparing to CTPA, as the MRI unit at our institution is not as close to the emergency department as the CT scanner. The choice of tests likely depends in part on physician practice styles and availability of tests. In fact, it has been reported that only 0.1% of the patients undergo MRI or MRA of the chest when PE is clinically suspected.[42] The recognized diagnostic value and at the same time easy access of CTPA often mitigates against the emergency department clinician requesting an MRI for the evaluation of PE.[43] In a recent paper, 98% of emergency department physicians reported that CTPA was available at all hours and 30% reported MRI either not available for PE diagnosis or not available at all hours.[43] Another limitation is associated with the lack of a reference test in all subjects. The absence of a reference test in all subjects reflects the concern of radiation and contrast agents in pregnant patients at our institution. Notwithstanding its limitations, the study reflects our routine clinical practice and experience for pregnant patients with suspected PE.

CONCLUSION

Balanced SSFP imaging can visualize central, lobar and segmental arteries with sufficient image quality in pregnant patients, comparable to 3D-GRE, and thus may potentially be used to evaluate pregnant patients with suspected PE successfully. Further validation with prospective studies is necessary.

CONFLICT OF INTERESTS

None stated.

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