A 30-year-old woman presented to the emergency department with acute shortness of breath, dizziness, and left-sided thoracic pain. The patient had been diagnosed with adenocarcinoma of the lung and metastases in central nervous system, liver, and bones 2 years earlier. After initial radiation and chemotherapeutic treatment, the patient showed a mixed response and was subsequently treated with the tyrosine-kinase inhibitor crizotinib, as well as further radiation of the progressive and symptomatic cerebral metastases.

On admission, the patient was afebrile, displayed unimpaired oxygen saturation in room air, and presented with mild pitting edema of the calves. The ECG was without pathological findings and d-dimers were slightly elevated. Because of her clinical presentation and the increased pretest probability (clinical presentation and cancer diagnosis), a contrast-enhanced multidetector computed tomography was conducted to test for pulmonary embolism (PE). Multidetector computed tomography, however, showed no thrombotic mass in the main and segmental pulmonary arteries but a subpleural wedge-shaped consolidation, rated suspicious for beginning ischemic pneumonia, for example, because of subsegmental embolism, which is commonly missed by conventional multidetector computed tomography (Figure 1). The patient consecutively underwent ventilation and perfusion single-photon emission computed tomography (SPECT), which revealed a mismatch of a perfusion defect in segments 8 and 9 of the lower lobe but unimpaired ventilation corresponding to the findings with this new technique. FD allows for separation of the periodic MR signal changes induced by respiration and pulsatile blood flow in the lungs. Thereby, ventilation and perfusion maps can be generated in free breathing and without application of ionizing radiation or contrast agents. FD-MRI was performed using the SElf-gated Non–Contrast-Enhanced FUncational Lung (SENCEFUL) MRI approach, providing maps in sufficient spatial resolution and reconstruction of complete cardiac/respiratory cycles. The acquisition of a slice with 1-cm thickness in the coronal plane takes ≈2 minutes. Data acquisition of the entire lung amounts to 15 to 20 slices, resulting in an acquisition time of 25 to 40 minutes. Including image postprocessing, the overall examination time amounts to ≈90 minutes, which is comparable with ventilation and perfusion SPECT. SENCEFUL FD-MRI can be implemented in any commercially available MRI system as technical details of the sequence have been published. Limitations of FD-MRI refer to the common MRI contraindications. Evaluation and development of SENCEFUL-MRI is part of a research protocol on functional lung MRI in the reporting department.

The MRI ventilation maps of the reported patient displayed a physiological distribution of the ventilation without regional impairment matching the scintigraphy results (Figure 3A and 3B). Mapping of the lung perfusion showed a regional defect in the left lower lobe corresponding to the previous ventilation and perfusion SPECT findings (Figure 3C and 3D).

The reported case demonstrates the potential of functional FD-MRI for diagnosis of PE. FD-MRI results matched the findings of SPECT, which is currently the established reference standard in functional lung imaging. Concerning diagnostic imaging of PE, SPECT is commonly used to assess thromboembolic events in subsegmental arteries. Using multidetector computed tomography, these small subsegmental arteries cannot be safely evaluated about PE as the limited spatial resolution is insufficient for differentiation between thrombotic material and intraluminal partial volume effects. In addition to the promising diagnostic potential as illustrated within this initial report, no ionizing radiation is required for FD-MRI data acquisition in contrast to established imaging modalities for PE diagnosis. Therefore, its application in clinical routine is desirable especially for patients requiring particular radiation protection, such as young individuals or pregnant women. As the latter are known to feature increased risks for thromboembolism and should not be exposed to radiation, detection of PE in pregnant women might be a clinical scenario in which...
FD-MRI application would be preferable. In this context, the omission of gadolinium contrast is another benefit favoring noncontrast FD-MRI, compared with contrast-enhanced lung MRI techniques. Equivalent diagnostic information of FD-MRI and contrast-enhanced pulmonary MRI has already been reported. With no contrast agent needed, FD-MRI could be used for pulmonary diagnostics in patients with renal insufficiency as well.

About the general diagnostic accuracy of FD-MRI, good correlation with ventilation/perfusion scintigraphy in porcine experiments has been previously published. The present case initially confirms this correlation in human application. FD-MRI has the potential to play a future role in functional lung MRI for perfusion and ventilation assessment especially in certain subgroups with contraindications for other types of imaging or when particular radiation protection is mandatory. This initial report with promising results of FD-MRI in patient application underlines the necessity for further research in the field. Serial trials on representative patient populations will be subject to future work to specifically evaluate the diagnostic performance of SENCEFUL-MRI in clinical application and to validate it against established reference techniques.

Disclosures

The project underlying this report was funded by the Interdisciplinary Center of Clinical Science of the University of Würzburg. Responsibility for the content of this publication lies with us.

References


Key Words: magnetic resonance imaging • perfusion • pulmonary embolism • ventilation

Figure 1. A, Transversal multidetector computed tomographic scan and (B) coronary maximum intensity projection reconstruction showing a subpleural wedge-shaped consolidation in the left lower lobe suspicious for beginning ischemic pneumonia (arrows). In addition, multiple osteoblastic metastases in the spine are visible. The linear fibrosis in the left lower lobe was caused by the previous radiotherapy and showed constant appearance when compared with previous scans.
Figure 2. A, The ventilation map acquired by ventilation single-photon emission computed tomography displays no pathological findings. B, The corresponding perfusion map reveals a perfusion defect in the segments 8 and 9 of the left lower lobe indicating a peripheral pulmonary embolism.
Figure 3. A and B, Ventilation maps acquired by noncontrast Fourier decomposition magnetic resonance imaging (FD-MRI). Ventilation is visualized by quantitative color coding in mL gas per mL lung tissue. No ventilation impairment is seen in the FD-MRI data. Linear darker lines correspond to pulmonary vessels. D and E, FD-MRI perfusion maps. Both maps represent 2 adjacent slices at a slice thickness of 10 mm. Color coding of the perfusion data is semiquantitative and normalized to the maximum signal. In accordance with the single-photon emission computed tomography findings shown in Figure 2B, a perfusion defect in the left lower lobe is clearly identifiable.
Acute Pulmonary Artery Embolism Detected by Noncontrast Functional Lung Magnetic Resonance Imaging

Christian Kestler, Andreas Max Weng, Andreas Steven Kunz, Mona Laubmeier, Clemens Wirth, Herbert Köstler, Thorsten Alexander Bley and Simon Veldhoen

_Circ Cardiovasc Imaging_. 2016;9:e004141
doi: 10.1161/CIRCIMAGING.115.004141

_Circulation: Cardiovascular Imaging_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2016 American Heart Association, Inc. All rights reserved.
Print ISSN: 1941-9651. Online ISSN: 1942-0080

The online version of this article, along with updated information and services, is located on the World Wide Web at:

http://circimaging.ahajournals.org/content/9/2/e004141

**Permissions:** Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation: Cardiovascular Imaging_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

**Reprints:** Information about reprints can be found online at:
http://www.lww.com/reprints

**Subscriptions:** Information about subscribing to _Circulation: Cardiovascular Imaging_ is online at:
http://circimaging.ahajournals.org//subscriptions/