Clinical Radiology xxx (2017) e1–e10

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

MRI of cystic fibrosis lung manifestations: sequence evaluation and clinical outcome analysis

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ARTICLE INFORMATION

Article history:
Received 12 October 2016
Received in revised form
19 January 2017
Accepted 20 March 2017

AIM: To evaluate different magnetic resonance imaging (MRI) sequences for diagnosis of pulmonary manifestations of cystic fibrosis (CF) in comparison to chest computed tomography (CT), including an extended outcome analysis.

MATERIALS AND METHODS: Twenty-eight patients with CF (15 male, 13 female, mean age 30.5±9.4 years) underwent CT and MRI of the lung. MRI (1.5 T) included different T2- and T1-weighted sequences: breath-hold HASTE (half Fourier acquisition single shot turbo spin echo) and VIBE (volumetric interpolated breath-hold examination, before and after contrast medium administration) sequences and respiratory-triggered PROPELLER (periodically rotated overlapping parallel lines with enhanced reconstruction) sequences with and without fat signal suppression, and perfusion imaging. CT and MRI images were evaluated by the modified Helbich and the Eichinger scoring systems. The clinical follow-up analysis assessed pulmonary exacerbations within 24 months.

RESULTS: The highest concordance to CT was achieved for the PROPELLER sequences without fat signal suppression (concordance correlation coefficient CCC of the overall modified Helbich score 0.93 and of the overall Eichinger score 0.93). The other sequences had the following concordance: PROPELLER with fat signal suppression (CCCs 0.91 and 0.92), HASTE (CCCs 0.87 and 0.89), VIBE (CCCs 0.84 and 0.85) sequences. In the outcome analysis, the combined MRI analysis of all five sequences and a specific MRI protocol (PROPELLER without fast signal suppression, VIBE sequences, perfusion imaging) reached similar correlations to the number of pulmonary exacerbations as the CT examinations.

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http://dx.doi.org/10.1016/j.crad.2017.03.017

CONCLUSION: An optimum lung MRI protocol in patients with CF consists of PROPELLER sequences without fat signal suppression, VIBE sequences, and lung perfusion analysis to enable high diagnostic efficacy and outcome prediction.

Introduction

Magnetic resonance imaging (MRI) of the lung is increasingly proposed as an adequate radiation-free alternative to chest computed tomography (CT).[1,2] Particularly in patients, in whom repeated detailed lung imaging is required, e.g., due to oncological diseases or chronic pulmonary disorders, such as cystic fibrosis (CF), cumulative life-long radiation doses can become relevant and increase the risk of developing radiation-induced carcinomas.[3–5]

The radiation-free lung MRI technique is challenging due to the low proton density and the high magnetic susceptibility effects of the pulmonary tissue as well as due to possible moving artefacts by heart pulsation or breathing.[6,7] The image quality, spatial and temporal resolution of lung MRI are continuously optimised because of improvements of MRI equipment and sequences.[7–10] One major advantage of lung MRI is the potential to image pulmonary disease by using differently weighted sequences and specific features, such as fat signal suppression. As T1-weighted sequences, gradient echo breath-hold sequences are mostly performed in clinical routine.[10,11] T2-weighted sequences can be acquired with breath-hold examinations or by respiratory navigator triggering.[10–12] Lung MRI sequences that can be used for specific indications are diffusion-weighted imaging for differentiation of lung lesions or perfusion imaging for diagnosis of pulmonary artery embolism and parenchymal perfusion deficits.[9,10] In 1999, the periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER) technique was introduced by Pipe[13] as a novel MRI sequence with a radial instead of a Cartesian acquisition of the k-space. The PROPELLER technique can reduce image artefacts and improve image quality in MRI examinations of different anatomical regions, e.g., of the head and neck.[13,14] Recently, the PROPELLER method has also been introduced in the MRI of the lung.[15–18]

Some studies have reported that lung MRI can image pulmonary CF manifestations with comparable findings to CT.[11,12,17] These investigations have either evaluated the MRI sequences as combined examinations or included singular clinical routine MRI sequences in their comparison analysis to CT.[11,12,17] To the authors' knowledge, no investigation has performed an evaluation of different MRI sequences in CF with 3 different T2-weighted sequences to obtain an optimum clinical MRI protocol. Thus, the main purpose of this prospective study was a distinct MRI sequence analysis in patients with CF, including T2-weighted PROPELLER images with and without fat signal suppression. To evaluate the prognostic impact of the MRI sequences versus CT, all CT and MRI parameters were correlated with the occurrence of pulmonary exacerbations in a clinical follow-up analysis over a period of 24 months.

Materials and methods

Study design and patients

This prospective clinical investigation was designed as an intra-individual comparison between lung MRI and low-dose multidetector CT at one single study centre. All MRI and CT examinations were performed within a maximum of 5 days to provide a reliable comparison. The study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki and was approved by the local ethics committee. All patients provided written informed consent before study participation. The clinical trial was initiated by the investigators; the results were independently obtained without any financial interest.

Patients ≥18 years with verified CF, who were referred to unenhanced low-dose CT for a clinical indication, such as acute pulmonary exacerbation, were included. The patients agreed to also receive a standardised MRI examination with the administration of intravenous MRI contrast medium after detailed information. Exclusion criteria were contraindications to MRI and/or MRI contrast media, chronic kidney disease ≥3 (estimated glomerular filtration rate, eGFR, <60 ml/min per 1.73 m^2), pregnancy or lactation in women, and administration of any contrast medium within 24 hours before the MRI examination. Patients who were clinically unstable, had physical and/or mental status, that interfered with the signing of the informed consent, were also excluded. Twenty-eight patients with CF (15 male, 13 female) fulfilled the inclusion criteria; their mean age was 30.5 years (standard deviation [SD] = 9.4 years) ranging from 19 to 52 years at the time of the CT and MR imaging.

Technical parameters of CT and MRI

Unenhanced, low-dose, chest CT was performed using a 64-section multidetector system (GE Lightspeed VCT 64; General Electric Healthcare, Milwaukee, WI, USA). Standardised technical CT parameters were used: axial section orientation, inspiratory breath-hold, 100 kV tube voltage, 35–80 mAs dose-modulated tube current, 1.375 pitch, 55 mm table speed per rotation, 0.625 mm reconstruction section thickness, 5 mm effective section thickness, no application of contrast medium. Lung MRI was acquired on

Please cite this article in press as: Scholz O, et al., MRI of cystic fibrosis lung manifestations: sequence evaluation and clinical outcome analysis, Clinical Radiology (2017), http://dx.doi.org/10.1016/j.crad.2017.03.017