# Cardiac MRI at 7-Tesla

**During conventional electro-cardiology, interference from electromagnetic fields (EMFs) tends to diminish image quality due to cardiac motion. To exclude that interference an acoustic cardiac triggering (ACT) approach, also called MR stethoscope, has been developed to trigger cardiac MRI at 7-Tesla. Developed by researchers at the Experimental and Clinical Research Centre (ECRC) in Berlin-Buch, Germany, the new technology will soon enable cardiac characterisation at tissue-level and promises to bring new insights into cardiac function and myocardial (patho-)physiology.**

Due to the heart's location in the middle of the thorax, surrounded by inhomogeneous tissue structures, and its on-going motion, up to now precise cardiac Magnetic Resonance Imaging (CMRI) has presented a technical challenge for researchers. However, some apparently invincible problems in cardiac imaging with 7-Tesla MRI seem to be almost solved. As reported in our Online-Edition (www.european-hospital.com 11/12/09) Professor Mark E Ladd and researchers at the Erwin-Hahn Institute for Magnetic Resonance Imaging, Essen, have developed applicable radio frequency (HF) antennae and coils that allow complete penetration of the deep-lying heart with HF, which avoids HF-inhomogeneities. This is seen as an important premise to receive complete and precise images of the heart.

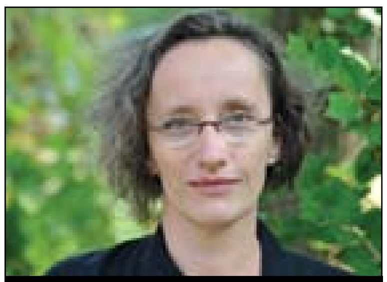
ECG triggering, one of the remaining most difficult challenges, has now been tackled by ECRC researchers in a cooperation run by the Max Delbrück Centre for Molecular Medicine and the Charité.

ECG triggering did not work reliably with the 7-T scanner and, to some extent with the 3-T, which led to an increase of artefacts. Consequently, the corrupted images were not suitable for diagnoses. 'To avoid artefacts due to cardiac motion and flow constraints, cardiac imaging requires high-speed, efficiency and precise synchronisation of data acquisition with the cardiac cycle,' explained **Professor Thoralf Niendorf**, physicist and head of the Berlin Ultrahigh Field Facility (B.U.F.F.) at ECRC. 'Up to now synchronisation was achieved by using ECG to trigger the MRI. Indeed, being an electrical measurement, ECG brings along the risks of interference with the MR-system, inter alia by electromagnetic and magneto-hydrodynamic effects. This interference increases with increasing magnetic field strength. The stronger the magnetic field, the

Thoralf Niendorf

higher the probability of artefacts in the ECG-trace; in other words instead of a precise ECG-recording, we receive a knitting pattern. Consequently, there will be an erroneous triggering and therefore a blurred image.'

Thus the research team developed an alternative method to trigger the MRI-scanner – Acoustic Cardiac Triggering (ACT). 'We were – in another, relatively new field of MR-application – phonetics – discussing how to scan the larynx and movement of vocal folds,' Prof. Niendorf continued. 'I came across the idea of using acoustic signals to detect motion.' The researchers transferred this concept to cardiac MRI and began a collaboration with cardiologist **Professor Jeanette Schulz-Menger**, at the HELIOS Hospital, in Berlin-Buch, to examine the applicability and clinical efficacy of MR-Stethoscopes to cardiac MR at 7-T.



Jeanette Schulz-Menger

The MR-Stethoscope consists of four elements: an acoustic sensor, acoustic waveguide, signal processor and a coupler linked to the MRI system. Like the chest piece of a common stethoscope, when located on a patient's chest the acoustic sensor registers cardiac sounds. In a specially developed procedure the acoustic signals are transformed into a trigger signal, mimicking the basic waveform of an ECG. The MR-Stethoscope is compatible with common MRI-scanners and does not need any hard- or software changes.

A first clinical study (published: *European Radiology* online. 12/09) showed proof of concept by comparing left ventricular function assessment using ECG and ACT triggered MR-Imaging at 1.5-T and 3-T. Meanwhile, Prof. Niendorf's and Prof. Schulz-Menger's team studied the feasibility of acoustic triggering at 7-T, using a whole-body human MR scanner with an 8-channel transmit-system at the Berlin Ultrahigh Field Facility (B.U.F.F.). They received exciting results: 'We achieved reliable and accurate CINE images of the beating heart with sharp contours. We can ensure, at 7-T, the standard we know from MR-Imaging at lower magnet fields. Testing the different methods the failure rate with ECG-triggering at 1.5-T came to a negligible 5% but, at 7.0-T, the rate was 40%. However, the MR-Stethoscope eliminated those failure rates,' said Prof. Niendorf.

Prof. Schulz-Menger added: 'With appropriate radio frequency coils and triggering devices in place we hope to achieve a kind of *in vivo* microscopy. In other words, we will examine and characterise the myocardial tissue with, up to now, unmatched precision. We can already achieve an in-plane spatial resolution of $1mm^2$, together with slices as thin as 2.5 mm with the 7-T scanner. You can even see subtle anatomical features, such as trabeculae and the right ventricle, in great detail, all in a non-invasive way, excluding harmful radiation exposure.'

Cardiac MRI at 7-T is expected to advance the ability to differentiate myocardial diseases, e.g. inflammation, or fibrosis, and to monitor disease processes. Considering the challenges and opportunities, Prof. Niendorf pointed out: 'By reminding us that previous limits on resolution, speed, and contrast are not fundamental, our efforts and results encourage us to connect basic research to clinical applications – and vice versa. Whilst today's (ultra)high Field CMR techniques remain in a state of creative flux, productive engagement in this area continues to lead us into the heart of the matter.'

Worldwide, 7-T scanners are still confined to research; they are not licensed for clinical routine. Besides – these scanners, with the strength of about 1,500,000 times that of the earth's magnetic field (between 30 to 60 micro-tesla) are currently too expensive for clinical use: the 7-T scanner at B.U.F.F., for example, costs around €8 million. Despite these constraints, Prof. Niendorf and Prof. Schulz-Menger are convinced that their research will bring important knowledge of heart disease risks factors and disease processes – all of which could help to develop new diagnostic strategies and therapies.

*Report: Bettina Döbereiner*

# MRI of the lung

## Ready for broad clinical application

Hans-Ulrich Kauczor

The lungs had to be regarded as the black hole for MRI for a long time. However, since the introduction of substantial improvements in hardware and scanner technology, there is certainly light at the end of the tunnel.

MRI offers two main advantages for the diagnostic pathways for pulmonary diseases applied today.

First, MRI provides comprehensive structural and functional assessment of the lungs in a single thirty-minute-examination, and has the potential to yield quantitative measurements. Using a standard protocol, pathologies of the lung parenchyma can be easily characterised by T1-weighted, T2-weighted, inversion-recovery, fat suppression, contrast enhancement and diffusion-weighted imaging. Functional assessment might encompass MR angiography of the pulmonary arteries, perfusion of lung and/or tumours, blood flow, (right) heart function, and ventilation.

MRI might even simplify the current diagnostic work-up for patients presenting with suspected pulmonary disease, because a lot of the results traditionally obtained from pulmonary function test, lab test, chest X-ray, echocardiography, CT, scintigraphy might become available from a single imaging technique, namely MRI.

Second is the lack of ionising radiation. Certainly, no dose is better than high dose, but no dose is also better than low dose. This holds especially true for children, women, and repeated follow-up examinations for disease surveillance or therapy monitoring.

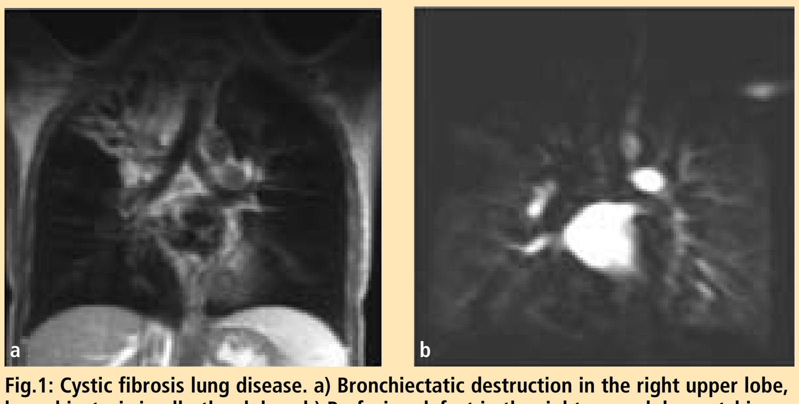


Fig.1: Cystic fibrosis lung disease. a) Bronchiectatic destruction in the right upper lobe, bronchiectasis in all other lobes. b) Perfusion defect in the right upper lobe matching bronchiectatic destruction.

The clinical indications for MRI of the lung are straightforward. All cross-sectional imaging in children with pulmonary disease or abnormalities should be MRI. The best example is cystic fibrosis. Patients suffering from this chronic inflammatory disease need regular, annual imaging for disease surveillance and/or therapy monitoring. Since life expectancy soon will rise above 40 years, repeated CT scans would simply lead to an unacceptable amount of radiation accumulated over the years.

Indications in adults include, but are not limited to, pulmonary hypertension; T-staging of lung cancer or whole body MRI for M-staging, as well as chronic obstructive airway disease such as COPD and asthma.

The latter is an extremely important application, because the incidence of COPD and asthma is increasing all over the world. It is a benign disease, which has a great social and economic impact and might benefit substantially from more in-depth understanding and imaging. This has led the German Federal Ministry of Education and Research (BMBF) to launch a network of scientific and medical competence in 2008. This competence Asthma and COPD network, called Asconet, consists of two major projects. One is Asthma-MRI. This focuses on establishing MRI as an imaging method for the diagnosis and monitoring of COPD and asthma without radiation exposure. 'The close collaboration of specialised scientists and medical doctors from three Universities (Heidelberg, Mainz, Würzburg) and the Fraunhofer Institute Mevis in Bremen gives us the chance to know more about the coherences of COPD and its related diseases,' said Professor Hans-Ulrich Kauczor MD (Heidelberg University), speaking for Asthma-MRI. 'We accepted the challenge to develop new diagnostic methods to advance therapy and prevention of chronic pulmonary diseases like asthma and COPD.'

Fig.2: Cystic fibrosis lung disease: Small cell lung cancer in the left upper lobe

Fig.3: Non-small cell lung cancer in the right lung with concomitant pleural effusion

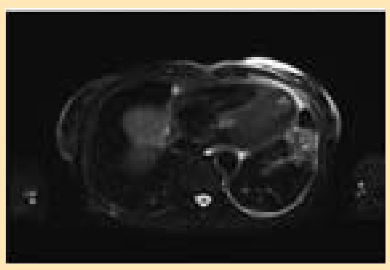


Fig.4: Bronchopneumonia in the left lower lobe

Two years down the line, MRI for COPD should be ready to be rolled out for broader application throughout Germany, starting within the second major project of the competence network COSYCONET. The core of COSYCONET is a cohort of 3,000 registered patients. 'To determine the frequency of co-morbidities, we are going to observe and examine regularly 3,000 patients, all suffering COPD of different severities', explained Professor Claus Vogelmeier (University of Marburg), who is chairman of Asconet. MRI will then be used to phenotype COPD lung disease and assess systemic, inflammatory co-morbidities.

However, the MRI protocol developed by Asthma-MRI is not only set up for use within the COSYCONET-Study but should also be established as a diagnostic clinical tool accompanied by recommendations for appraisal based on a software platform with dedicated tools for the individual parts of the protocol.

*Hans-Ulrich Kauczor*