Module: Elective Advanced Lectures: Applied Physics

Module No.: physics70b

Course: Physics in Medicine: Cardiovascular Magnetic Resonance Imaging (CMRI) (A)

Course No.: physics777

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

Requirements for Participation:

Preparation:
Lectures Experimental Physics I-III (physik111-physik311) respectively

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Understanding the principles of physics of Cardiovascular Magnetic Resonance Imaging (CMRI)

Contents of the Course:
1. Basic principles of MRI I (Bloch equation, spatial encoding)
2. Basic principles of MRI II (extended Bloch equation)
3. k-space trajectories and reconstruction techniques (Cartesian data: Fast Fourier transform (FFT); Non Cartesian: Nonuniform fast Fourier transform (NUFFT), REGRIDDING, BACK PROJECTION)
4. Basic principles of CMRI (physiology, motion correction, gating strategies)
5. Preclinical MRI systems at high magnetic fields (7T and above) – hardware, advantages and limitations

6. Magnetic resonance contrast agents (from a biophysical point of view, hands-on at MRI)
7. Myocardial relaxometry (T1, T2, T2* mapping, Extracellular Volume mapping, hands-on at MRI)
8. Magnetic resonance angiography (contrast enhanced MR angiography, navigator-based MR angiography)
9. CMRI of moving spins (blood flow velocity: phase contrast MRI, 4D velocity vector fields, velocity-time curves, vorticity, helicity, streamlining, pathfinding, hands-on at MRI)
10. Myocardial perfusion imaging (contrast-enhanced imaging techniques, Arterial Spin Labeling)
11. Myocardial architecture imaging (Diffusion-weighted magnetic resonance imaging (DWI), Diffusion tensor imaging (DTI), quantitative analysis, hands-on at MRI)
12. Myocardial MR Spectroscopy (Point Resolved Spectroscopy (PRESS), Stimulated Echo Acquisition Mode (STEAM), Chemical Shift Imaging (CSI), 31P-Image-Selected In vivo Spectroscopy (ISIS))
13. Novel approaches in metabolic MRI of the heart (Chemical exchange saturation transfer (CEST), Magnetization transfer contrast (MTC), comparison to 1H-MR Spectroscopy, quantitative analysis)
14. Concepts of acceleration in cardiac MRI at preclinical systems (Compressed Sensing (CS), Total Variation (TV), Parallel Imaging)

Recommended Literature:
1. V. Hörr: Scriptum zur Vorlesung

2. MRI: The Basics, Ray H. Hashemi, William G. Bradley, Christopher J. Lisanti, Lippincott Williams & Wilkins.
3. In Vivo NMR Spectroscopy, Robin de Graaf, John Wiley & Sons.
4. Compressed Sensing Magnetic Resonance Image Reconstruction Algorithms, Bhabesh Deka, Sumit Datta, Springer.
5. Magnetic Resonance Imaging: Physical Principles and Sequence Design, Robert W. Brown, Yu-Chung N. Cheng, E. Mark Haacke, Michael R. Thompson, Ramesh Venkatesan, John Wiley & Sons.
6. Cardiovascular Magnetic Resonance, Warren J. Manning, Dudley J. Pennell, Elsevier.