Wednesday Educational Course
LV Function Assessment & Cardiac Chamber Quantification at 7.0 T
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Introduction
Recently, high-field 7T MR imaging was introduced. The higher field-strength has potential advantages, mainly related to increased signal-to-noise-ratio. One of the potentially exciting applications may be cardiovascular MR imaging. Cardiovascular MRI requires robust correction for heart motion, breathing motion and correction of field inhomogeneities. Therefore, cardiovascular imaging at high MR field strength has many challenges to be solved.

Purpose
To assess clinical feasibility of 7T cardiovascular MR imaging.

Methods
Regular clinical patient exams are scheduled weekly at a regular time slot in our 7T MR imaging centre, the Gorter centre. During the initial phase of protocol development the presence of a dedicated MR physicist and MR technician is required, as well as presence of a cardiovascular radiologist and non-invasive imaging expert cardiologist. Clinical cardiovascular MRI was performed using a commercially available human whole-body 7T MRI system (Philips Achieva, Best, The Netherlands), vector-ECG-gating and a custom-built 13-cm-diameter quadrature double-loop RF transmit/receive surface coil operating at 298.1 MHz. Standard clinical cardiovascular MR sequences were adapted from 1.5T and 3T protocols to a 7T MR scanprotocol. After imaging based shimming, breath-hold cine MR imaging was performed using TE 1.7 msec, TR 4 msec, flip angle 15, reconstructed pixel size 0.88x0.88 mm. Transmitral flow using velocity sensitivity of 150 cm/sec, TE 2.6 msec, TR 4.6 msec, flip angle 20, reconstructed pixel size 1.5x1.5 mm. Delayed enhancement acquisitions were performed approximately 15 minutes after intravenous administration of 0.1 mmol/kg Gadolinium using an inversion-recovery 3D turbo-field echo sequence, TE 1.06 msec, TR 3.7 msec, flip angle 15, reconstructed pixel size 1.5x1.5 mm. Inversion time was determined with real-time plan scan to null normal myocardial signal.
Results
Initial clinical results are presented as a pictorial essay below. Examples were acquired in a routine clinical setting. ECG-triggering was effective in about 80% of patients.

Healthy volunteer, cine MR imaging
Myocardial infarction, RCA, cine MR imaging
Prominent trabecularization, dysfunction, E<A
delayed enhancement MR imaging

Healthy volunteer, carotid vessel wall MR imaging

Discussion
Initial clinical results are presented as a pictorial essay (see Figure). Examples were acquired in a routine clinical setting. ECG-triggering was effective in about 80% of patients. Obviously, many technical issues have to be solved to obtain cardiovascular MR images of similar quality as can be acquired on a clinical 1.5T MRI system. The main purpose of the presented work is to show that 7T MRI can provide basic images of the heart, which form the basis for future developments. It is expected that the additional value of 7T MRI of the cardiovascular system will focus on exploiting the increased signal-to-noise and contrast-to-noise ratio of the higher field strength, in comparison to clinical MR systems. Most likely, inflow MR angiographic imaging techniques, vessel wall imaging and MR spectroscopy techniques will benefit most from the higher field strength. To be able to develop and use these more suitable applications of 7T cardiovascular MRI, it is necessary to have the basic imaging techniques available too. Thereby, a combined basic clinical exam and advanced 7T-specific MRI can be performed. The present results should be regarded as a first step towards that comprehensive exam. Currently presented results were obtained using a single transmit system. It is expected that addition of at least a second transmit channel will improve penetration depth and image homogeneity dramatically.

Conclusion
7T clinical cardiovascular MR imaging is feasible. Many basic problems still have to be resolved, such as improved ECG-triggering, improved penetration depth of the send-receive surface coil, multi-transmit setup, optimization of inversion pulses for delayed enhancement and vessel wall imaging. Clinical practice has to prove what the advantages are of high-field cardiovascular MR imaging.