Mean pulmonary arterial pressure estimation by high temporal resolution phase-contrast MR imaging in patients with chronic thromboembolic pulmonary hypertension (CTEPH) and correlation with simultaneous invasive pressure recordings – first results

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Introduction
Chronic thromboembolic pulmonary hypertension (CTEPH) is a severe disease whose prevalence has been underestimated for a long time [1]. Cross-sectional imaging modalities like MR imaging or CT may establish the diagnosis. However, the mean pulmonary artery pressure (mPAP) in the main pulmonary artery (MPA) is the most important parameter for the severity of the disease. For the proper diagnosis, invasive mPAP with catheter-based pressure measurement is necessary as an gold standard [2]. Magnetic resonance imaging (MRI) has also been used for the estimation of mPAP [3]. The combination of these parameters allows for a reliable estimation of mPAP [4]. To the best of our knowledge, this study is the first where simultaneous invasive mPAP and phase contrast flow measurements with high temporal resolution have been shown feasible to measure and quantify the pressure in the MPA indirectly [2,3] or even directly [4]. The aim of this study was to validate the estimation of mPAP using phase contrast magnetic resonance flow measurements with invasive catheter-based pressure measurement simultaneously in the MRI scanner in patients with CTEPH.

Material and Methods
After approval of the local ethics committee, seven patients with CTEPH underwent right heart catheterization for determination of mPAP and pulmonary vascular resistances (PVR) and for intrarterial DSA of the pulmonary arteries. After angiography, a 4 F pigtail catheter was placed in the MPA, and the patients were carried to the MRI scanner to undergo simultaneous measurement of mPAP and phase contrast flow measurements. Magnetic resonance imaging was performed on a 1.5T system (Magnetom Sonata, Siemens Medical Solutions, Germany) using a six element cardiac phased array coil for signal detection (Siemens Medical Solution, Germany). Flow measurements were performed using an unsegmented phase-contrast 2D-FLASH pulse sequence with high temporal resolution (TR/TE 10/5msec/2.5msec) which was planned perpendicularly to the MPA. The measurements were performed with prospective triggering to the electrocardiogram and during free breathing of the patients. Velocity- and flow-time-curves were analyzed using the Argus software (Siemens Medical Solutions, Germany). Based on these curves, the absolute acceleration time (Ata), the maximum of mean velocities (MV), the volume of acceleration (AV), and the maximum flow acceleration (dQ/dt) were calculated. Using the linear combination of these parameters, a linear combination was performed like in [4] resulting in the following equation to calculate the mPAP:

\[
\text{mPAP} = 45.310 - (0.462 \times \text{Ata}) - (0.436 \times \text{MV}) + (0.704 \times \text{AV}) + (0.00581 \times \frac{dQ}{dt}).
\]

Results
In all seven patients flow and simultaneous invasive pressure measurements could be carried out successfully. A typical acquired flow-time-curve can be seen in figure 1a. From these curves the parameters Ata, MV, AV, and dQ/dt were calculated. Using the linear combination of these parameters the mPAP values were calculated from phase contrast MRI. The derived values correlated very well with the simultaneously measured invasive mPAP values (R=0.99, see figure 1b). Figure 1c shows the corresponding Bland-Altman-Plot for comparison of both methods. All variations of the cmPAP values fluctuate around zero and are smaller than the two-fold standard deviation of the differences.

Discussion
Previous studies showed very good correlation between invasive measured mPAP and phase contrast MRI flow measurements in pigs [1,4]. To the best of our knowledge, this study is the first where patients with CTEPH were investigated for simultaneous measurements of invasive mPAP and flow-based MRI. Very high correlation was found between both methods indicating that the mPAP can be reliably determined by flow-derived parameters from high temporal resolution phase contrast MRI. In conclusion, high temporal resolution phase contrast MRI enables reliable measurement of the mPAP. Thus, this method provides non-invasive measurement of the extent of pulmonary hypertension caused by CTEPH. Together with the possibilities of morphologic and functional imaging [5], MRI will play a central role in the diagnosis and severity of the disease. Therefore, with MRI it is possible to achieve the most relevant information for the diagnosis and therapy of CTEPH non-invasively and without the exposure to ionizing radiation.

References