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) as the most important parameter for the severity of the disease is usually measured invasively by catheter-based angiography. This method is invasive introducing a catheter into the body through the right heart which can cause several complications. Furthermore, for correct placement of the catheter correctly in the MPA, fluoroscopic guidance is necessary exposing the patient and the examiner to ionizing radiation. Recently, magnetic resonance imaging using phase contrast flow measurements with high temporal resolution has shown feasibility 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 catherization for determination of mPAP and pulmonary vascular resistencies (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 simultaneously 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 10msec/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 multiple correlation analysis of these parameters, a linear combination was performed like in [4] resulting in the following equation to calculate the mPAP: $mPAP = 45.310 - (0.462 * Ata) - (0.436 * MV) + (0.704 * AV) + (0.00581 * dQ/dt)$.

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.

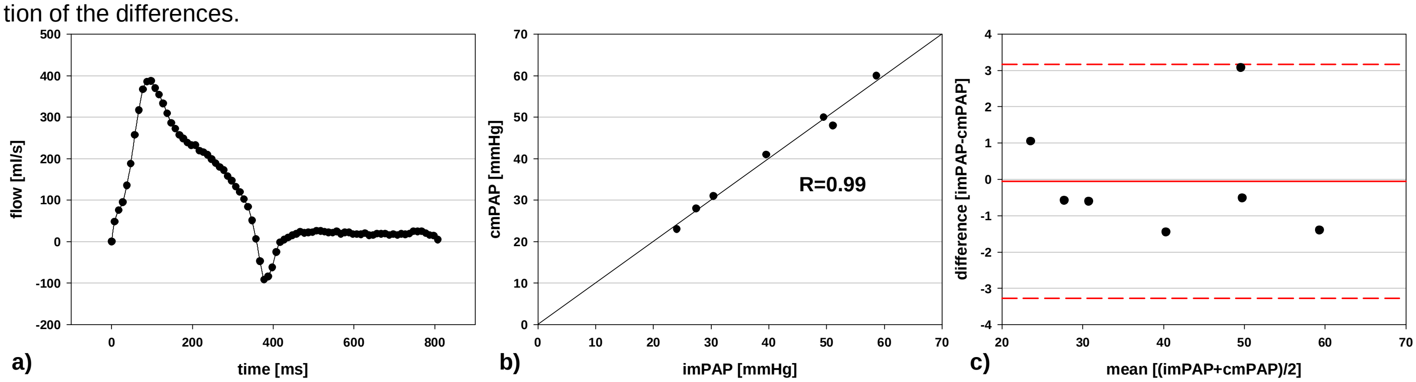

Figure 1: Typical flow-time-curve of one of the seven patients Figure 1a;, correlation analysis of the invasively measured mPAP (imPAP) with calculated mPAP (cmPAP) from magnetic resonance flow measurements Figure 1b); Bland-Altman-Plot of the comparison of imPAP and cmPAP (Figure 1c). The dashed lines represent 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 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 enables non-invasive assessment 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 informations for the diagnosis and therapy of CTEPH non-invasively and without the exposure to ionizing radiation.

References

[1] Kreitner et al., Eur Radiol 2007;17:11–21
[2] Wacker et al., MRI 1994;12:25–31
[3] Tardivon et al., Am J Respir Crit Care Med 1994;150:1075-1080
[4] Abolmaali et al., JMRI 2007:26:646–653,
[5] Kreitner et al., Radiology 2004;232:535-543