

# A new PVA-based dynamic cardiac phantom for evaluation of functional MR imaging methods at 3T

R. Manzke<sup>1</sup>, A. Lutz<sup>2</sup>, M. Schenderlein<sup>3</sup>, A. Bornstedt<sup>2</sup>, R. C. Chan<sup>4</sup>, K. Dietmeyer<sup>3</sup>, and V. Rasche<sup>2</sup>

<sup>1</sup>Tomographic Imaging, Philips Research Europe, Hamburg, Germany, <sup>2</sup>Dept. of Internal Medicine II, University Hospital Ulm, Germany, <sup>3</sup>Inst. Measurement, Control, and Microtechnology, University Ulm, Germany, <sup>4</sup>Philips Research North America, Briarcliff Manor, NY, United States

## Introduction

Cine MR imaging for determination of cardiac functional parameters has become standard clinical practice in centers with cardiac MR facilities. More advanced techniques such as tagged and phase contrast MR, however, are still not established clinical methods for myocardial deformation analysis, but bear the potential for more thorough functional assessment and determination of e.g. cardiac torsion and strains [1]. In this work, we introduce a new dynamic cardiac MR phantom, aiming to enable cross validation of novel tagged and phase contrast MR methods at 3T, aiding the development of clinically relevant functional MR techniques.

## Methods

Different materials are known for MR phantom design, mimicking a variety of organs [2]. For our phantom, we have chosen to use polyvinyl alcohol (PVA, Lenticats, GeniaLab, Braunschweig, Germany) [3,4] since it offers desirable properties such as mechanical durability, variable stiffness and good MR imaging properties with sufficiently long T1. A cylindrical PVA mold with an inner radius of 6.6cm, an outer radius of 8.2cm and a length of about 9cm, providing an initial wall thickness about 1.6cm was generated using one freeze / thaw cycle at  $-35^{\circ}\text{C}/+20^{\circ}\text{C}$ . The phantom mold was placed in an MR-compatible air-pressured actuator [5] (see Fig. 1) which compresses and rotates the PVA according to a preset heart rate (in our experiments 60bpm). The phantom actuator is synchronized with the MR scanner by sending a 10mVpp ECG waveform to the optically decoupled standard ECG monitoring unit, placed outside the MR room. If desired, the actuator can swivel the mold up and down to simulate breathing motion.

MR imaging took place using a 3T system (Achieva, Philips Healthcare, Best, The Netherlands) with a 6 element cardiac coil in transverse slice orientation. Tagged MR was performed using a segmented gradient echo (sGRE) sequence with  $\text{TR}=5.5\text{ms}$ ,  $\text{TE}=3.2\text{ms}$ ,  $10^{\circ}$  flip angle and 7mm grid spacing. CSPAMM imaging was performed using a multishot EPI sequence with  $\text{TR}=30\text{ms}$ ,  $\text{TE}=6\text{ms}$  and 8mm line spacing. Phase contrast imaging was performed using a sGRE sequence with  $\text{TR}=12\text{ms}$ ,  $\text{TE}=3.8\text{ms}$ ,  $10^{\circ}$  flip angle and  $\text{venc}=15\text{cm/s}$  in throughplane direction.

## Results

Fig. 2 shows temporal tag fading of grid pattern in a transverse slice through the dynamic phantom at different phases of the RR-cycle. Tags are still visible towards the end of the RR-cycle, allowing for imaging at a motion frequency of down to 60bpm. Fig. 3 shows CSPAMM images with no apparent tag fading. Fig. 4 shows phase contrast images. Highest throughplane velocities are reached at about 20% RR and 50% RR simulating rapid motion phases in early systole and diastole and accounting for a shorter systolic and longer diastolic interval.

## Conclusions

A new cardiac MR phantom platform has been created which enables to test and cross validate novel dynamic imaging methods at 3T. Initial testing revealed useful phantom properties for dynamic imaging specifically at 3T. The properties of the PVA can be further modified to adjust relaxation times, i.e. for imaging at 1.5T, or to allow for multi-modality imaging. Rotational motion is clearly visible in tagged images as well as through plane deformation with phase contrast. Wall thickening can be simulated to a limited extend.

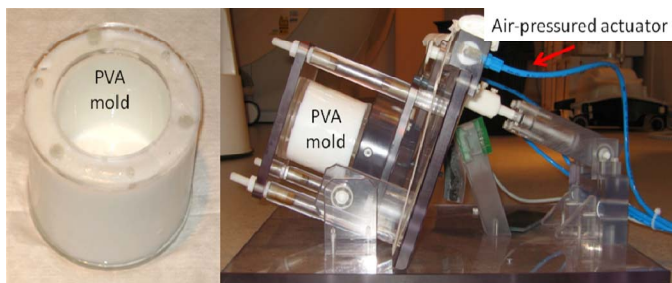


Figure 1: Left PVA cylinder mold, right PVA mold mounted in air-pressured actuator unit.

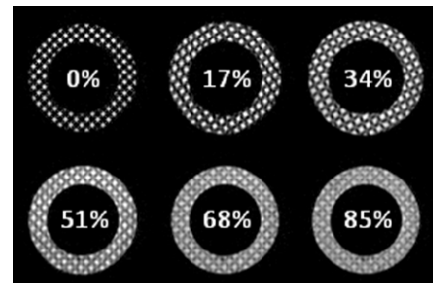


Figure 2: Tagged MR images of dynamic phantom showing deformation and tag fading over time.

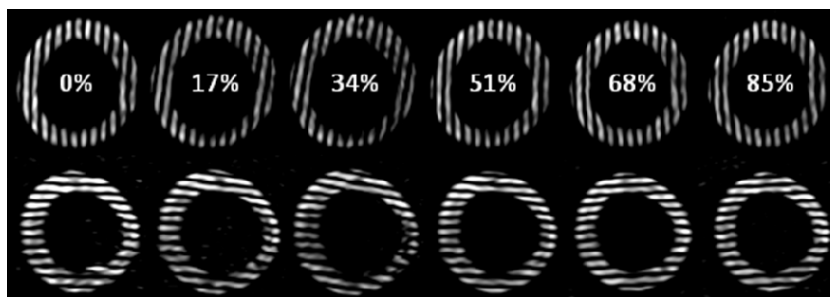


Figure 3: CSPAMM MR images.

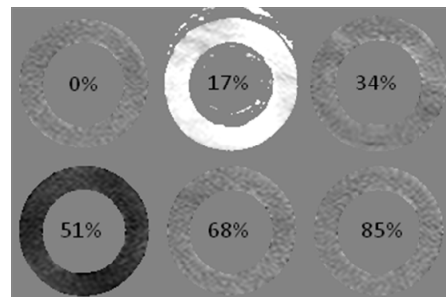


Figure 4: Phase contrast MR images  $\text{venc}=15\text{cm/s}$  throughplane.

## References

- [1] S. Masood et al., *MRM*, vol. 12, 2000, pp. 873–883.
- [2] H. Kato et al., *Medical Physics*, vol. 32, 2005, p. 3199.
- [3] I. Mano et al., *MRM*, vol. 3, 1986, pp. 921-926.
- [4] K.C. Chu et al., *MRM*, vol. 37, 1997, pp. 314-319.
- [5] H. Timinger et al., *Physics in Medicine and Biology*, vol. 49, 2004, pp. 719–732.