The purpose of this study was to create a dynamic phantom which can be imaged using ultrasonography and magnetic resonance methods, with the following requirements: shape, size and volume change rate similar to left ventricle of the human heart; acoustic properties of the phantom and its surroundings similar to properties of living tissue; $T_1$ (spin-lattice relaxation time) and $T_2$ (spin-spin relaxation time) similar to the myocardium; full compatibility with static and dynamic magnetic field present during MRI studies in high-field scanners.

Motivation for creating this phantom was mainly the comparison of deformation analysis methods between ultrasonography and magnetic resonance acquisitions. We also consider using such setup in training of medical imaging staff and for presentation purposes.

The phantom was manufactured in a form of a truncated thick-walled ellipsoid with a fixing collar. It was formed out of a polyvinyl alcohol (PVA) cryogel. This material has been proven to be appropriate as an phantom material for both magnetic resonance tomography and ultrasound imaging [3]. A water solution of 10% of PVA and 10% of glycerin was used in the process as described in [1]. In the setup (Fig. 1.) the LV phantom was deformed by a pump for hemodynamic simulations (SuperPump, Vivitro, Canada). The phantom was fixed in a container filled with pure water. During test experiments setup required a 5 m long tubing between the pump and the phantom so the pump could be placed outside the MRI room. The Vivitro controller and Vivigen software allows a wide range of pumping cycle shapes with HR values ranging from 2 to 220 beats per minute and maximum stroke volume of 150ml.

Figure 1. Experimental setup with the LV phantom as used in MRI examinations.
1 – Vivitro SuperPump, 2 – Vivitro controller, 3 – PC, 4 – constant pressure container, 5 – a phantom tank, 6 – the LV phantom, 7 – the MR coil

To calculate $T_1$ and $T_2$, corresponding model curves were fitted to a series of points with different $T_E/T_1$ (echo time and inversion time respectively) acquired from a series of static magnetic resonance images [2]. Obtained results ($T_1$ of phantom = 1045 ms; $T_2$ of...
phantom 180 ms) fulfilled all of the requirements listed above (in human heart: 1130 ± 91.7 ms and 35.3 ± 3.85 ms respectively).

The phantom is a tool that allows error analysis of deformation calculation methods both in ultrasonography and magnetic resonance imaging. Its known geometry and other properties are a sufficient input for simulations of the deformation process using Finite Element Method and thus allow obtaining “ground truth” for strain imaging techniques. What is more it is a valuable training tool for medical imaging stuff, it helps to visualize such issues as motion artifacts and ECG gating techniques. Also, the contrast between the phantom and its surroundings in magnetic resonance modality can be improved by using liquids with T1 and T2 that are more different from phantom than water.

References: