

Dynamic cardiac phantom for magnetic resonance imaging and ultrasonography

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Purpose

The purpose of this project was to create a dynamic cardiac phantom which can be imaged using ultrasonography and magnetic resonance (MRI) methods, with the following requirements:

- shape, size and volume change rates are similar to left ventricle of the human heart, with the ability to simulate different rhythm and rate values,
- acoustic properties of the phantom and its surroundings are similar to properties of living tissue,
- T1 and T2 relaxation times are 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:

- validation of cardiac MRI pulse sequences,
- comparison of deformation analysis methods: between ultrasonography and magnetic resonance acquisitions,
- use in training of medical imaging staff and for presentation purposes.

Methods

1. The phantom

The phantom was manufactured in the form of a truncated thick-walled ellipsoid (Fig. 1.) with a fixing collar. It was made out of a polyvinyl alcohol (PVA) cryogel. This material has been proven to be appropriate as a phantom material for both magnetic resonance tomography and ultrasound imaging [4]. A water solution of 10 % of PVA and 10 % of glycerin was used in the process as described in [1].

2. Controlling the phantom's deformation

In the experimental setup (Fig. 2.), the phantom was deformed by a pump for hemodynamic simulations (SuperPump, Vivitro, Canada). The phantom was fixed in a container filled with distilled water. The pump and the phantom setup were connected by tubing of sufficient length (5m) to place the pump outside the MRI room.

The Vivitro pump controller together with Vivigen software allows for a wide range of pumping cycle shapes with “heart rate” values ranging from 2 to 220 beats per minute and stroke volume up to 150 ml. Test experiments were carried out using a sinusoidally shaped volume curve for HR 40, 48 and 60 per minute and stroke volumes of 100, 80 and 50 ml respectively.

After MRI test, pressures inside the phantom cavity were registered using a catheter (Sentron, Holland). The phantom was tested on a 1.5T Avanto scanner (Siemens Healthcare, Erlangen, Germany).

Results

To calculate T1 and T2 of the phantom, T1/T2 relaxation curves were fitted to a series of points with different TE/TI acquired from a series of static magnetic resonance images [3].

	T1 [ms]	T2 [ms]
Myocardium [2]	1130 ± 91,7	35.3 ± 3.85
Phantom	1045	180

Discussion

A cardiac phantom applicable for MRI and ultrasonography studies was constructed and validated. Majority of the requirements listed above were satisfied.

Conclusions

The dynamic cardiac phantom is a tool that allows error analysis of deformation calculation methods both in ultrasonography and magnetic resonance imaging. The phantom is also a valuable training tool for medical imaging staff, because it helps to visualize such issues as motion artifacts and ECG gating problems.

The deformation of the heart can be decomposed into expansion/compression, rotation and torque. In this phantom only expansion/compression was simulated. One of possible focuses of future work would be to create a phantom capable of rotating and twisting.

References

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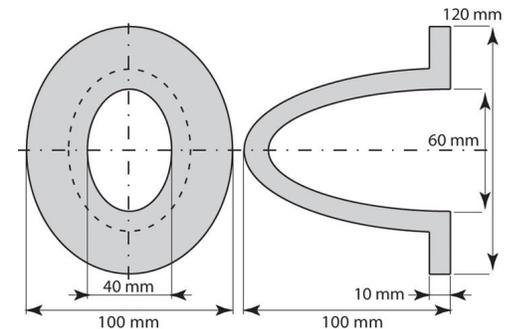


Figure 1: Stress-free geometry of the LV phantom with general dimensions.

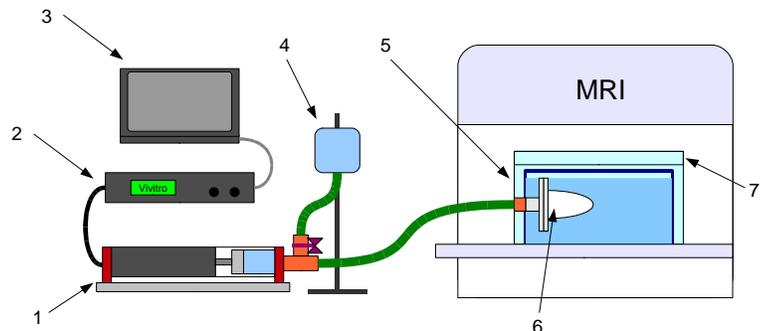


Figure 2: Experimental setup with the LV phantom as used in MRI examinations. 1 – Vivitro SuperPump, 2 – Vivitro controller, 3 – PC, 4 – constant pressure container, 5 – phantom tank, 6 – LV phantom, 7 – MRI coil