Using PIV for left ventricular flow analysis

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Introduction
The flow in the left ventricle of the heart is of great interest to a number of research areas like embryonal development and congenital defects, diagnostics of abnormal muscle activity, influence of prosthetic valve orientation and geometry on its function and optimization of new valve designs.

Objectives
To analyse the flow in a left ventricle model by means of an experimentally validated 3D computational model.

Methods
Computational
A 3D computational model of the ventricle was developed using a finite element method to solve the in-stationary Navier-Stokel equations using an arbitrary Lagrange-Euler method. Mesh deformation is prescribed to mimic the wall movements in the experiments.

Experimental
A transparent EPDM rubber model of the ventricle based on MRI images was mounted in a plexiglass box (fig 1). The model was deformed by changing external pressure by motion of a piston. The flow is visualised using Particle Image Velocimetry. A Carbomedics prosthetic valve (fig 2) was tested in the “natural” orientation, and rotated over 90°.

The flow is seeded with light-reflecting particles. Using a pulsed laser sheet for illumination only particles in the sheet will be visible. Two cameras under a different angle see different displacements of particles which can be used to reconstruct the out of plane displacement component (fig 3).

Results
Computational
The computational model shows the development of a jet with a vortex on either side during filling (fig 4).

Experimental
Physiologically relevant pressures and valve flows were realised. Visualisations were performed without the rubber model ventricle. The flow downstream the mitral valve (fig 5) is greatly disturbed by the leaflets when looking in a plane perpendicular to the axes of the leaflets while in the other direction a jet with two vortices on each side develops during filling.

Conclusion and Discussion
The experiments show that mitral valve orientation is important for the flow pattern in the ventricle. Computations with valve geometry and orientation will be done as well as quantitative PIV measurements using a rubber model ventricle.