# Patient-specific modeling of hemodynamics and cardiac mechanics using rules for adaptation to mechanical load

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In modeling the dynamics of heart and circulation patient-specifically, information about geometry, myofiber structure, tissue properties and hemodynamics is lacking. Measurement of these parameters is often cumbersome, and not realistic in clinical practice.

In heart and blood vessels, geometry and structure is known to adapt to mechanical load. In stead of performing detailed geometric measurements, we estimate geometry and structural parameters by using adaptation rules. Stresses and strains determine tissue orientation and geometry. Myocytes (heart) and smooth muscle cells (blood vessels) are ‘glued’ at the optimal working range within the passive matrix. Thus, adaptation rules for ventricles, atria and blood vessels appear quite similar, albeit parameters values are different for the different types of tissues.

In a trial, patient-specific modeling has been focused on non-invasive quantification of the complete pressure-volume loop of the left ventricle. For that purpose the CircAdapt model (Am J Physiol, 2005) has been developed, simulating whole heart and circulation dynamics.

In 11 patients with and without cardiac overload (4 hypertension, 3 mitral regurgitation, 4 control), we made patient-specific fits of whole circulation hemodynamics using CircAdapt modeling. To this aim, we identified a novel smart combination of measured 2-dimensional- (2DE) and Doppler echocardiographic parameters, and armcuff-measured blood pressure. Peak systolic (range 115-161 mmHg) and end-diastolic LV pressures (range 4-18 mmHg) agreed within ±8% and ±15% (sd) with the invasively measured pressures during cardiac catheterization in the same patients, respectively, showing the reliability of CircAdapt. With CircAdapt, systolic and diastolic myofiber stress could also be obtained (55±14 kPa and 2.7±1.2 kPa, respectively).

In conclusion, measuring global hemodynamics, adaptation rules were used to determine the most likely cardiovascular geometry and hemodynamic status. Using non-invasive techniques only, dynamic pressures and flows and wall stresses and strains can be simulated realistically. Bringing measured information together in a comprehensive model renders more accurate assessment than the separate measurements would do.