

# Strain echocardiography in cardiac surgery

## Studies on the effects of loading conditions and inotropic agents on myocardial contraction and relaxation

Akademisk avhandling

Som för avläggande av medicine doktorsexamen vid  
Sahlgrenska akademien, Göteborgs universitet kommer att offentligen försvaras i  
Hjärtats aula, Sahlgrenska universitetssjukhuset, den 24 januari 2020, klockan 09.00

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### Avhandlingen baseras på följande delarbeten

- I. Fredholm M, Jörgensen K, Houltz E, Ricksten SE. *Load-dependence of myocardial deformation variables —A clinical strain-echocardiographic study.*  
Acta Anaesthesiol Scand. 2017;61(9):1155-1165.
- II. Fredholm M, Jörgensen K, Houltz E, Ricksten SE. *Inotropic and lusitropic effects of levosimendan and milrinone assessed by strain echocardiography —A randomised trial.*  
Acta Anaesthesiol Scand. 2018;62(9):1246-1254.
- III. Fredholm M, Jörgensen K, Houltz E, Ricksten SE. *Levosimendan or milrinone for right ventricular inotropic treatment? —A secondary analysis of a randomized trial.*  
Acta Anaesthesiol Scand. 2019;00:1-9. In press.
- IV. Fredholm M, Ricksten SE, Bartfay SE, Karason K, Dellgren G, Bech-Hanssen O. *A multi-parameter echocardiographic approach offers better assessment of right ventricular function in patients with chronic left heart disease —A proposal for a new right ventricular failure score.*  
Manuscript.

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## Studies on the effects of loading conditions and inotropic agents on myocardial contraction and relaxation

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### Abstract

**Background:** Although reductions in myocardial contractility and relaxation are key components in heart failure (HF), assessment of them is difficult, as clinical measurements deal with a net effect of myocardial contractility, heart filling (preload), outflow impedance (afterload) and heart rate (HR). Echocardiographic (echo) deformation parameters, like strain (myocardial shortening) and strain rate (the speed of deformation, SR), have been proposed to more accurately measure myocardial function, but incongruent previous studies have raised concerns that they may be load-dependent. This load-dependency of echo measurements in general also explains the difficulties assessing right ventricular (RV) function whenever left ventricular (LV) failure is present. Lastly, the inodilators milrinone (MIL) and levosimendan (LEV), often used in treating severe HF, have never been compared head-to-head taking this load-dependency into account.

**Aims and methods:** We wanted to evaluate whether strain and SR were dependent on preload, afterload and HR (paper I). While keeping cardiac loading and HR constant, we compared the myocardial effects of MIL vs. LEV in a randomized trial, combining echo (for strain and systolic (SR-S) and diastolic (SR-E) SR) with hemodynamic measurements from a pulmonary artery catheter (papers II–III). We included post-cardiac surgery aortic stenosis patients with normal LV function for papers I–III. In paper IV, we retrospectively compared echo indices of RV function with right heart catheterization data in patients with severe HF, creating three groups: A) right atrial pressure (RAP) <10 mmHg and stroke volume index (SVI)  $\geq 35$  ml/m<sup>2</sup>, B) RAP <10 mmHg and SVI <35 ml/m<sup>2</sup>, and C) RAP  $\geq 10$  mmHg. The RV echo indices were assessed for their ability to identify group B from C.

**Results:** With increased preload by passive leg elevation, cardiac output (CO), strain, SR-S, and SR-E increased significantly, while increased HR by atrial pacing increased only CO, SR-S, and SR-E. Under constant loading and HR, MIL and LEV increased CO by 20%, RV and LV strain by almost 20%, and SR-S and SR-E by almost 30% in both ventricles, with no differences between groups. In paper IV, echo indices of RV longitudinal function (such as TAPSE, S', FAC and strain) failed to distinguish group B from C, while all RV dimensional measurements could. By combining six RV echo indices into a novel score, the RV failure (RVF) score, significant discrimination between group B and C was found.

**Conclusions:** 1) Strain is preload- and HR-dependent while SR depends on HR. 2) MIL and LEVO have comparable effects on LV and RV systolic and diastolic function. 3) To assess RVF in LV disease, a single-parameter approach is inadequate and we propose a combination of six parameters into a novel RVF score.

**Keywords:** strain echocardiography, right heart catheterization, cardiac surgery, heart failure, levosimendan, milrinone, left ventricular function, right ventricular function, systole, diastole, preload, afterload, pacing, longitudinal function, ventricular dimensions, ventricular interdependence