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Estimation of left ventricular pressure in patients with a continuous flow LVAD

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Aim

Long-term ventricular support with a Left Ventricular Assist Devices (LVAD) requires intensive and frequent monitoring of the patient.

Left ventricular pressure (plv) is a good measure for LV function. In this study, we aim to assess dynamic left ventricular pressure, using the LVAD as a sensor.

Ex vivo model

The method was validated with a porcine ex-vivo beating heart model (figure 1)[1]. Measurements were done on four hearts supported with a Micromed DeBakey VAD and three hearts supported with a Heartmate II VAD.

Figure 1 Experimental set-up of the ex vivo porcine heart model supported with a Heartmate II VAD. A similar set-up was used for the measurements on the hearts supported with a Micromed DeBakey VAD.

Estimation left ventricular pressure

Pressure head over the LVAD (dp_{lvad}) is estimated from pump flow with a static[2] and dynamic[3] pump model. From pressure head and aortic pressure, left ventricular pressure is estimated:

$$p_{lv,estimated} = p_{ao} + dp_{outflow\ graft} - dp_{lvad,estimated}$$

$Dp_{outflow\ graft}$ is the pressure drop in the outflow graft. Calculated as follows:

$$dp_{outflow\ graft} = R \cdot Q + L \cdot \frac{dQ}{dt}$$

Results

Mean left ventricular pressure was estimated using static pump characterisics (figure 2).
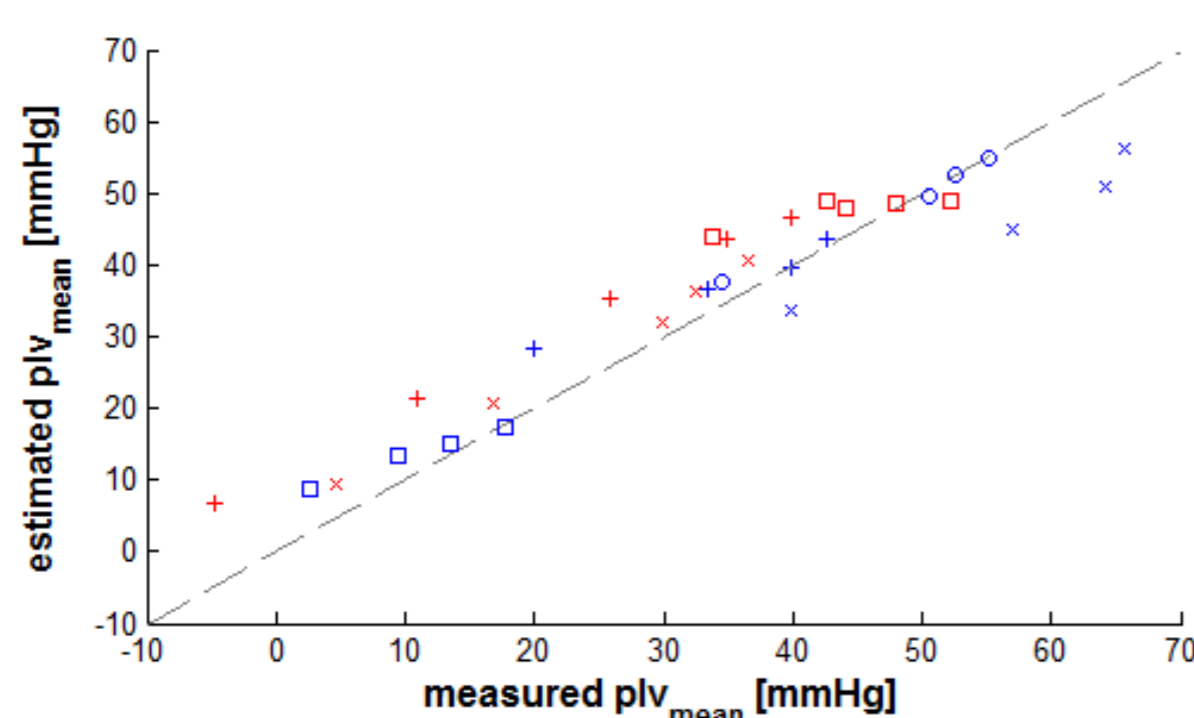

Figure 2 Estimated left ventricular pressure was compared with measured left ventricular pressure for the hearts supported with the Micromed DeBakey (blue) and the Heartmate II (red). Symbols: Heart 1 (+), heart 2 (□), heart 3 (x) and heart 4 (o).

Left ventricular pressure was also estimated as a function of time using dynamic pump characteristics (figure 3).
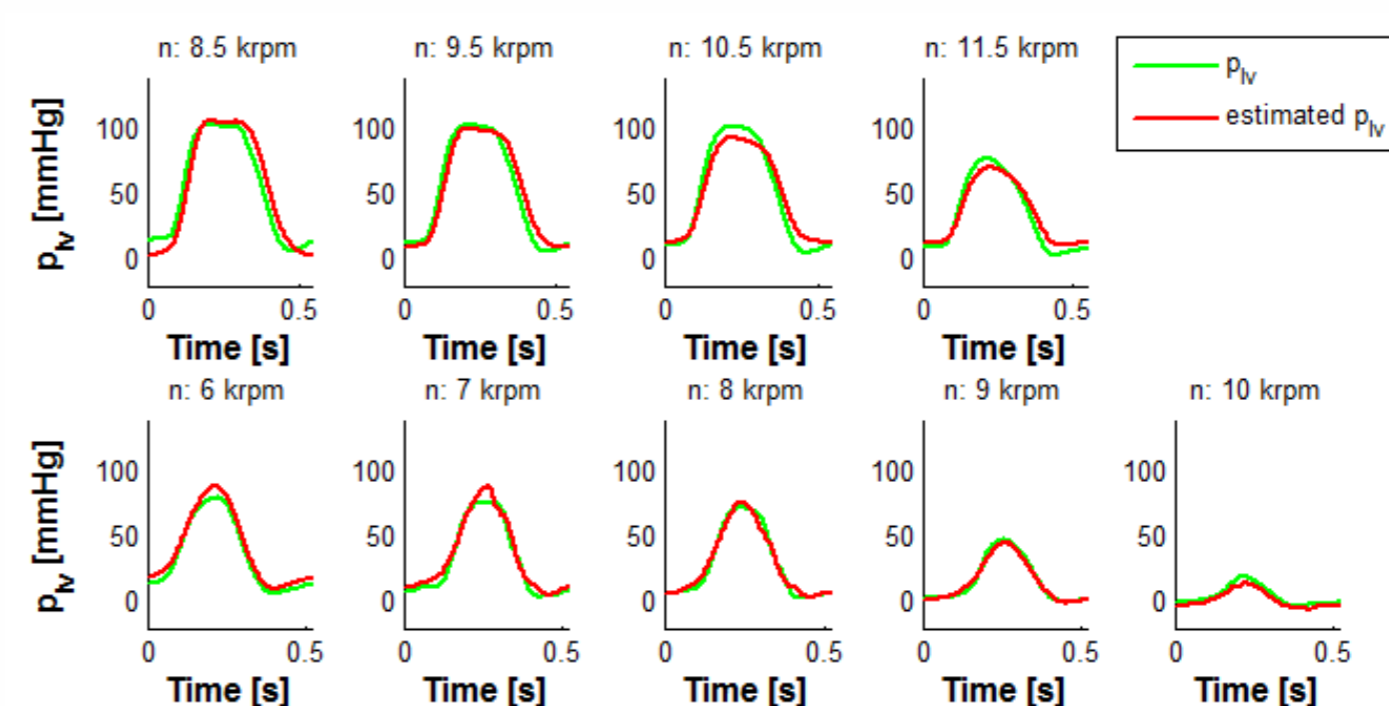

Figure 3 Measured (green) and estimated (red) left ventricular pressure for measurements with heart 1 supported by a Micromed DeBakey (top row) and heart 1 supported by a Heartmate II (bottom row).

dp/dt_{max}, maximum, minimum and mean left ventricular pressure were derived from the estimated p_{lv} (figure 4).
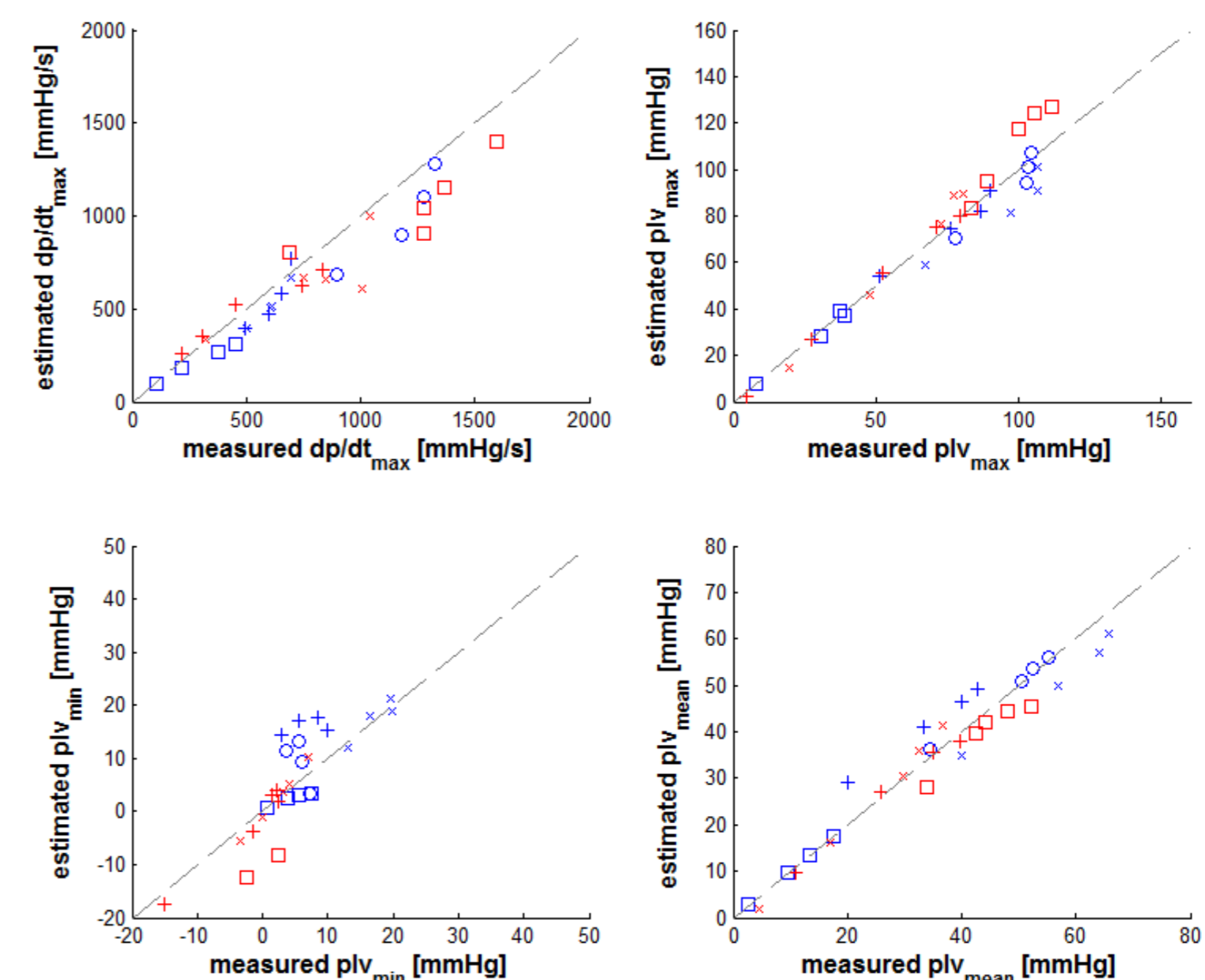

Figure 4 Estimated compared to measured dp/dt_{max} (top left), maximum p_{lv} (top right), minimum p_{lv} (bottom left) and mean p_{lv} (bottom right) for measurements on the Micromed DeBakey (blue) and the Heartmate II LVAD (red). Symbols: Heart 1 (+), heart 2 (□), heart 3 (x) and heart 4 (o).

Conclusions

In our beating heart experiments, a reliable estimation of left ventricular pressure was possible using static or dynamic pump characteristics.

Once combined with a focused clinical study we infer that left ventricular pressure in LVAD supported patients can be monitored sufficiently reliably in case pump flow and aortic pressure are measured. This will give a good indication for unloading of the ventricle and native heart function, in case of recovery of the heart or destination therapy during long-term support.

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