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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)<sup>[1]</sup>. 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<sup>[2]</sup> and dynamic<sup>[3]</sup> pump model. From pressure head and aortic pressure, left ventricular pressure is estimated:

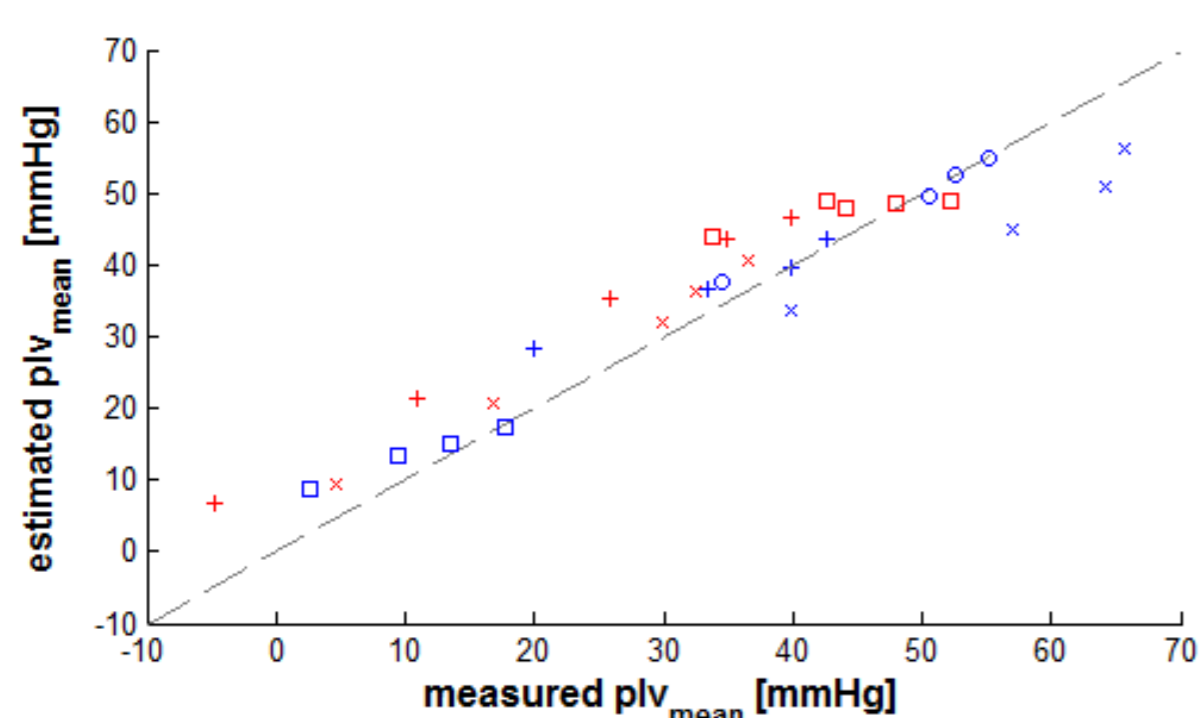
$$p_{lv,estimated} = p_{ao} + dp_{outflow\ graft} - dp_{lvad,estimated}$$

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

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

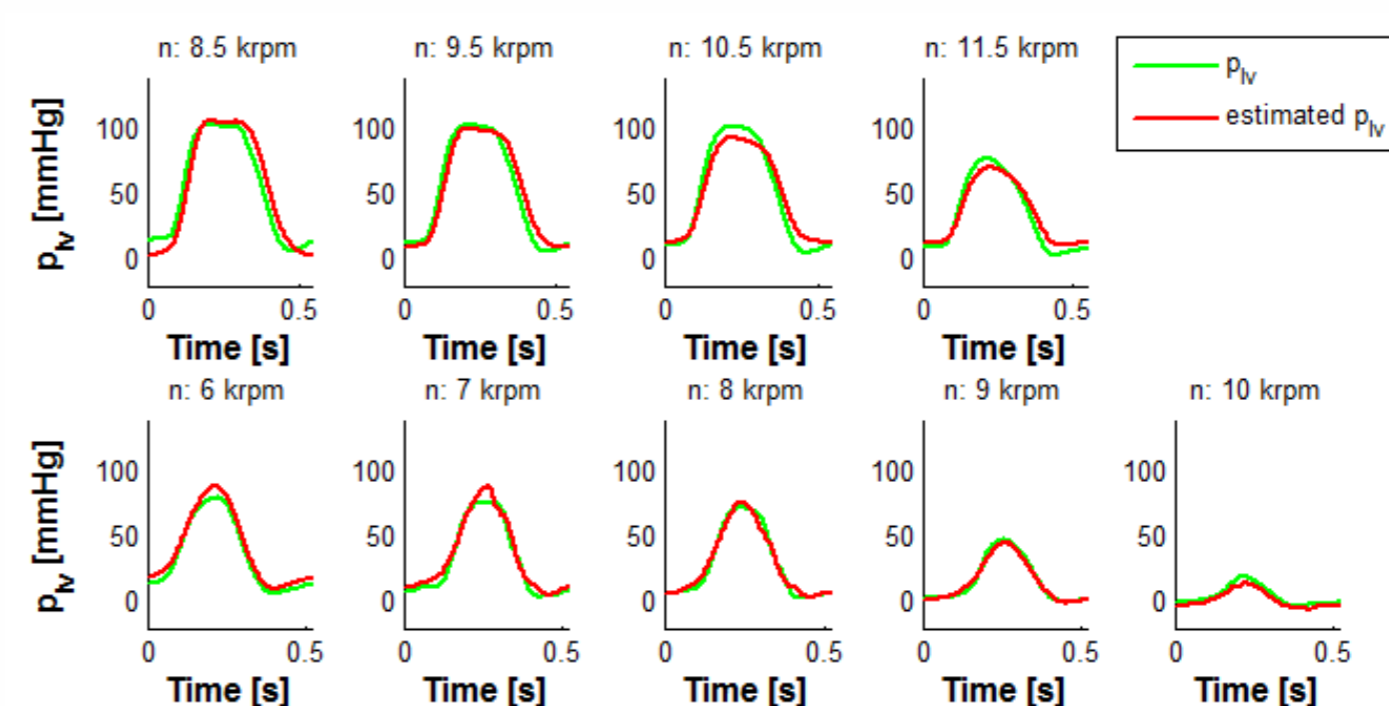
## Results

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



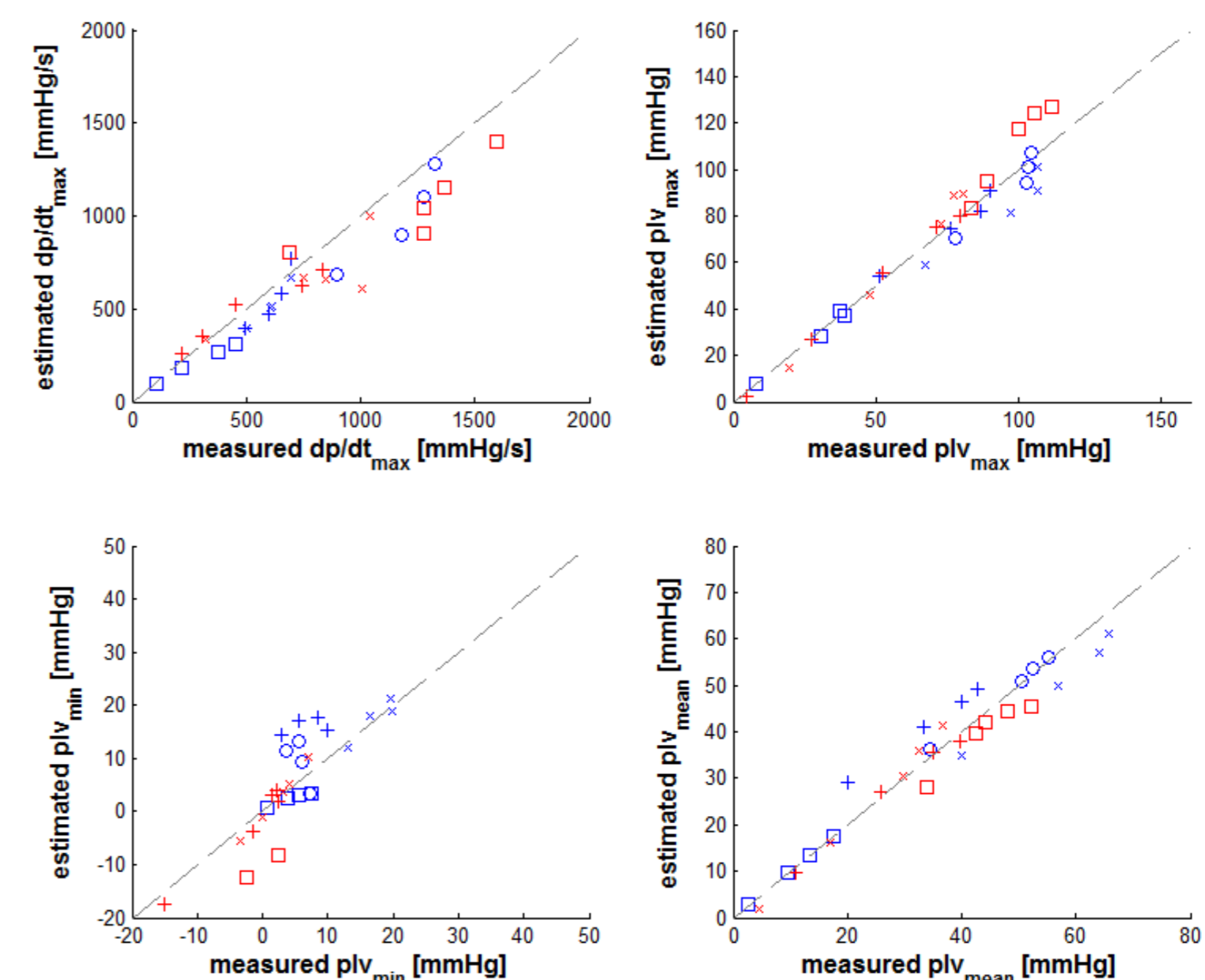
**Figure 2** Estimated left ventricular pressure was compared with measured left ventricular pressure for the hearts supported with the Micromed DeBakey (blue) and the Heartmate II (red). Symbols: Heart 1 (+), heart 2 (□), heart 3 (x) and heart 4 (o).

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.