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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.

Estimation left ventricular pressure
Pressure head over the LVAD (dpLVAD) 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:

\[ dp_{outflow\; graft} = R \cdot Q + L \frac{dQ}{dt} \]

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

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

\[ \frac{dp}{dt}_{max}, \text{maximum, minimum and mean left ventricular pressure were derived from the estimated } p_{LV} \text{ (figure 4).} \]

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.

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.

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 (○).

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).

Figure 4 Estimated compared to measured \( \frac{dp}{dt}_{max} \) (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 (○).

References