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

Published: 01/01/2014

Document Version
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:
• A submitted manuscript is the author's version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):
Estimation of left ventricular pressure in patients with a continuous flow LVAD

Kim Pennings¹,², Niels Petterson², Stephanie Schampaert², Sjoerd van Tuijl², Frans van de Vosse², Marcel Rutten²
¹ Academic Medical Centre, Amsterdam; ² Eindhoven University of Technology;

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:

$$p_{LV,\text{estimated}} = p_{ao} + dp_{\text{outflow graft}} - dp_{\text{LVAD,estimated}}$$

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

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

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

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 (o), heart 3 (x) and heart 4 (a).

Estimation 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).

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

Figure 4 Estimated compared to measured $\frac{dp}{dt}_{\text{max}}$ (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 (o), heart 3 (x) and heart 4 (a).

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.

References