Clinical Experience with Pressure Sensor Based Autoregulation of Blood Flow in an Artificial Heart

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Disclosures

- Carmat TAH is an investigational device, not available in the USA
- Carmat SA employee

Why Carmat TAH?

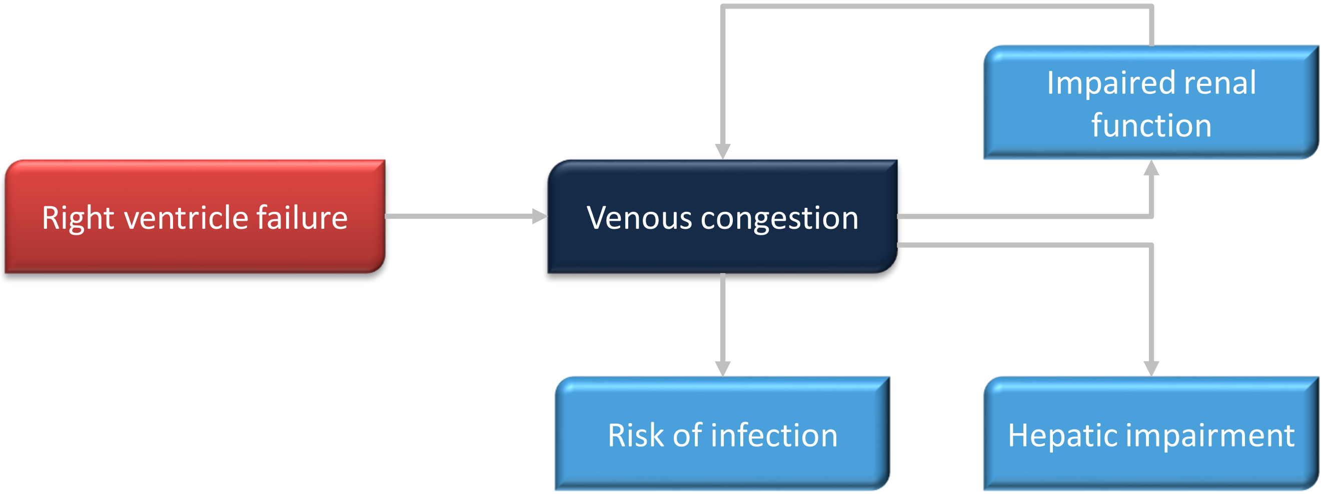
- To provide **Physiological Heart Replacement Therapy** for patients with end stage heart failure*
  - Biventricular failure or risk for RV failure if treated with LVAD
  - Treatment-refractory malignant arrhythmias
  - Restrictive or constrictive etiology (hypertrophic, amyloidosis)

- To address shortcomings of current TAH / bi-ventricular support options
  - Poor hemocompatibility
  - Poor QOL
  - Poor flow regulation
  - Poor pulsatility (BiVAD)
  - Aortic insufficiency (BiVAD)

**The 2013 ISHLT Guidelines for Mechanical Circulatory Support. J Heart Lung Transpl. 2013;32:21*

LVAD: recurring issue of failure of the unassisted right ventricle

- Failure of the right ventricle in patients treated with LVAD:
  - 6-month incidence: 10%*
  - 24-month incidence: 32%**
- Associated with other undesirable events:
  congestion, impaired renal function, hepatic impairment, infection

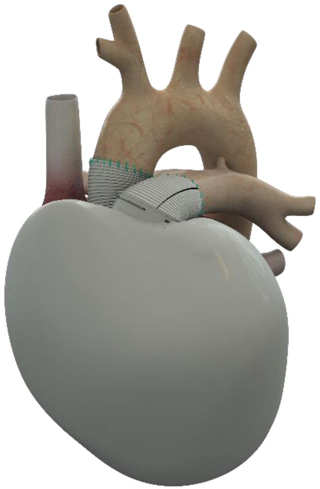


* Netuka I *et al.*, J Am Coll Cardiol 2015;66:2579–89
** Mehra MR *et al.*; N Engl J Med. 2018;378:1386-95.

Carmat: *Physiological Heart Replacement Therapy*

Pulsatile

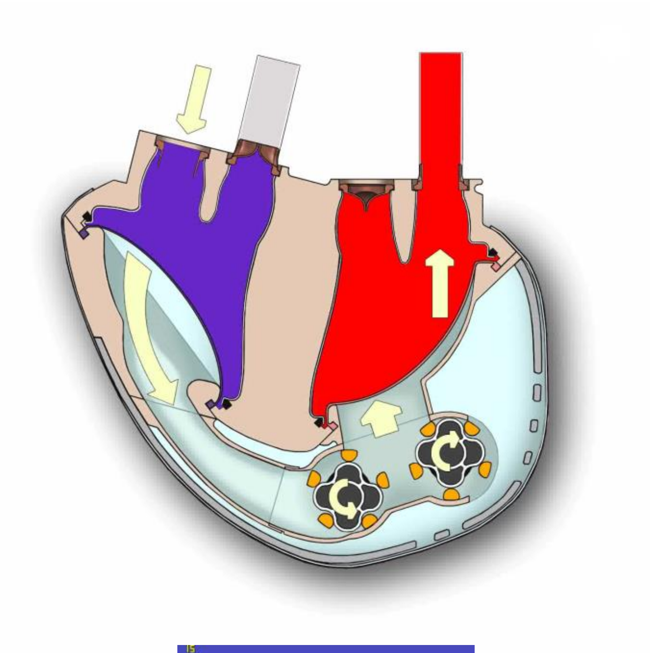
Biventricular

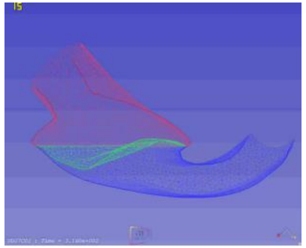


Hemocompatible

Auto-regulated

How does the device work?





Principle:

Volumetric pumps move the silicone oil within the bag to activate the hybrid membranes allowing the blood to enter and leave the chambers

Mode of operation:

1 – Blood flow assessment:

Preload measured by pressure sensors every millisecond to calculate flow required

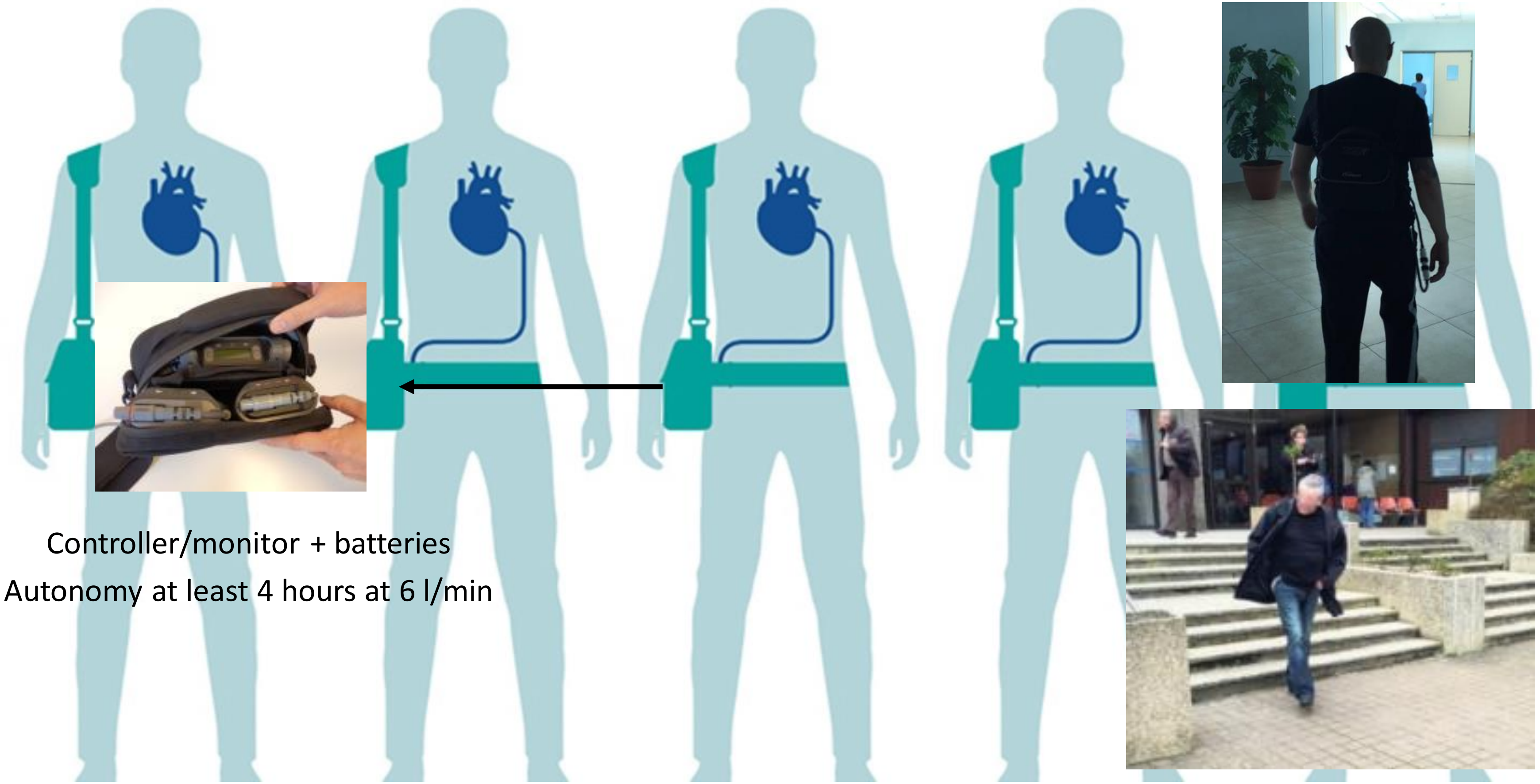
2 – Flow auto-regulation:

Speed and direction of rotation of volumetric pumps adapted every 2 milliseconds to deliver the necessary pulsatile flow

3 – Flow Control:

Position of the membranes checked by 2 ultrasound sensors every 2 milliseconds to ensure full ejection at every beat, to avoid stasis in blood compartment

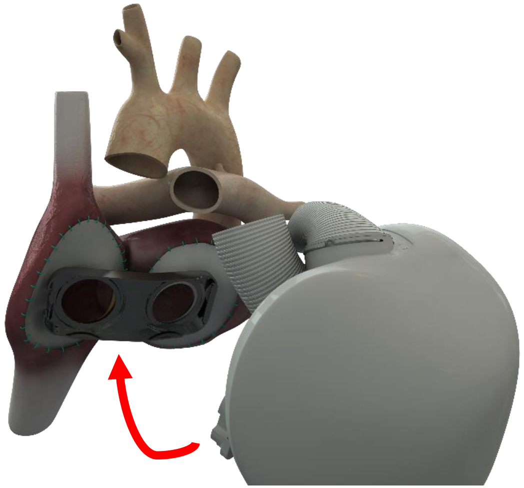
System Configuration

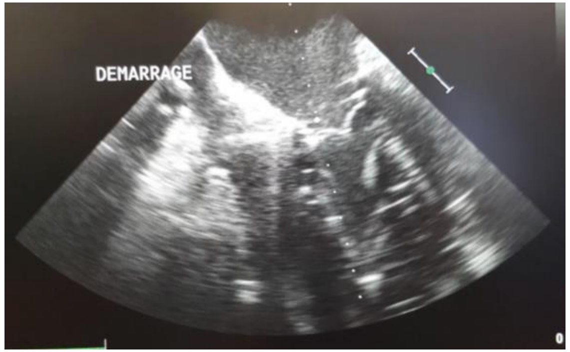


Controller/monitor + batteries

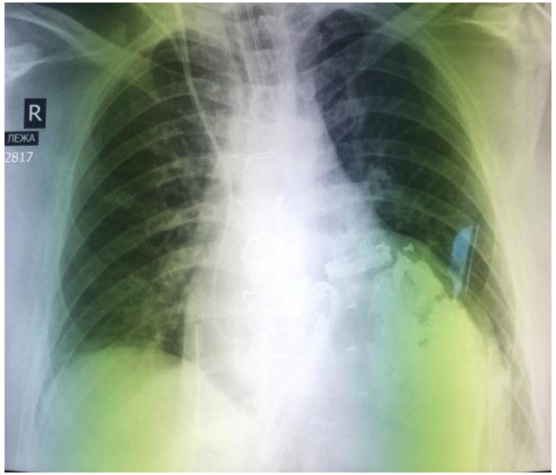
Autonomy at least 4 hours at 6 l/min

Implantation Technique



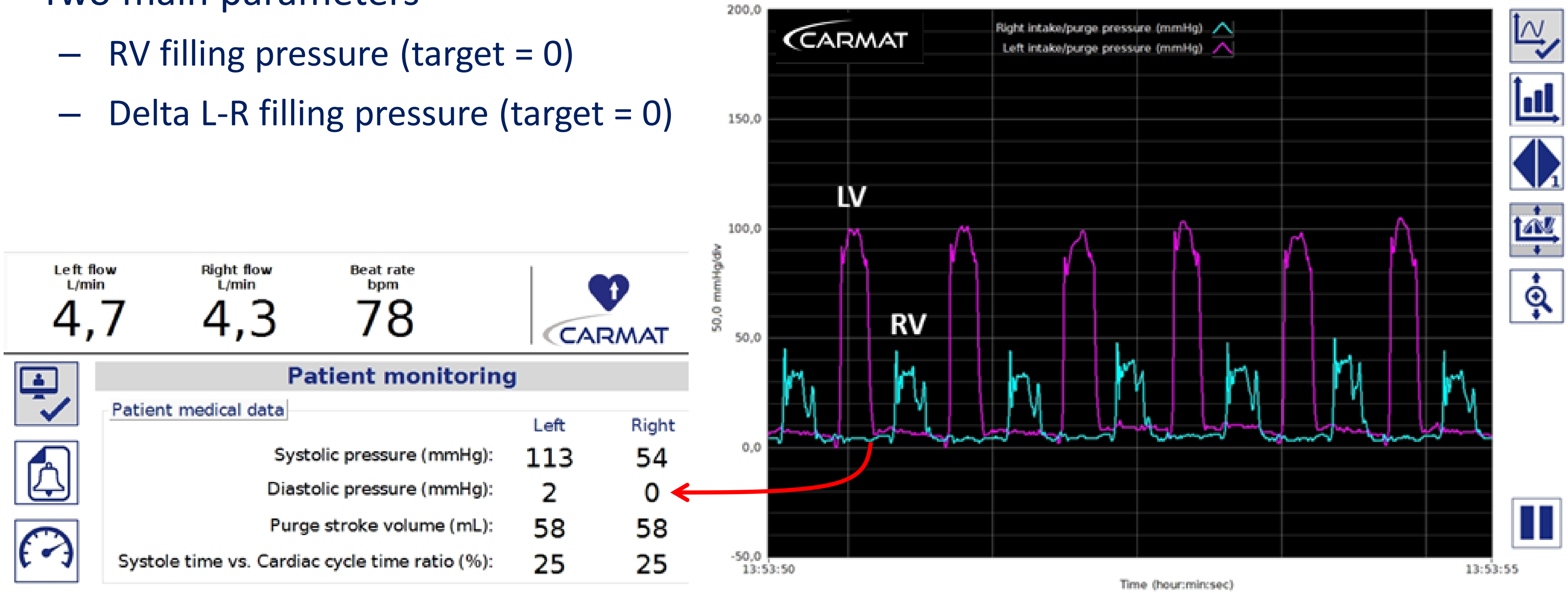


TEE: de-airing/weaning

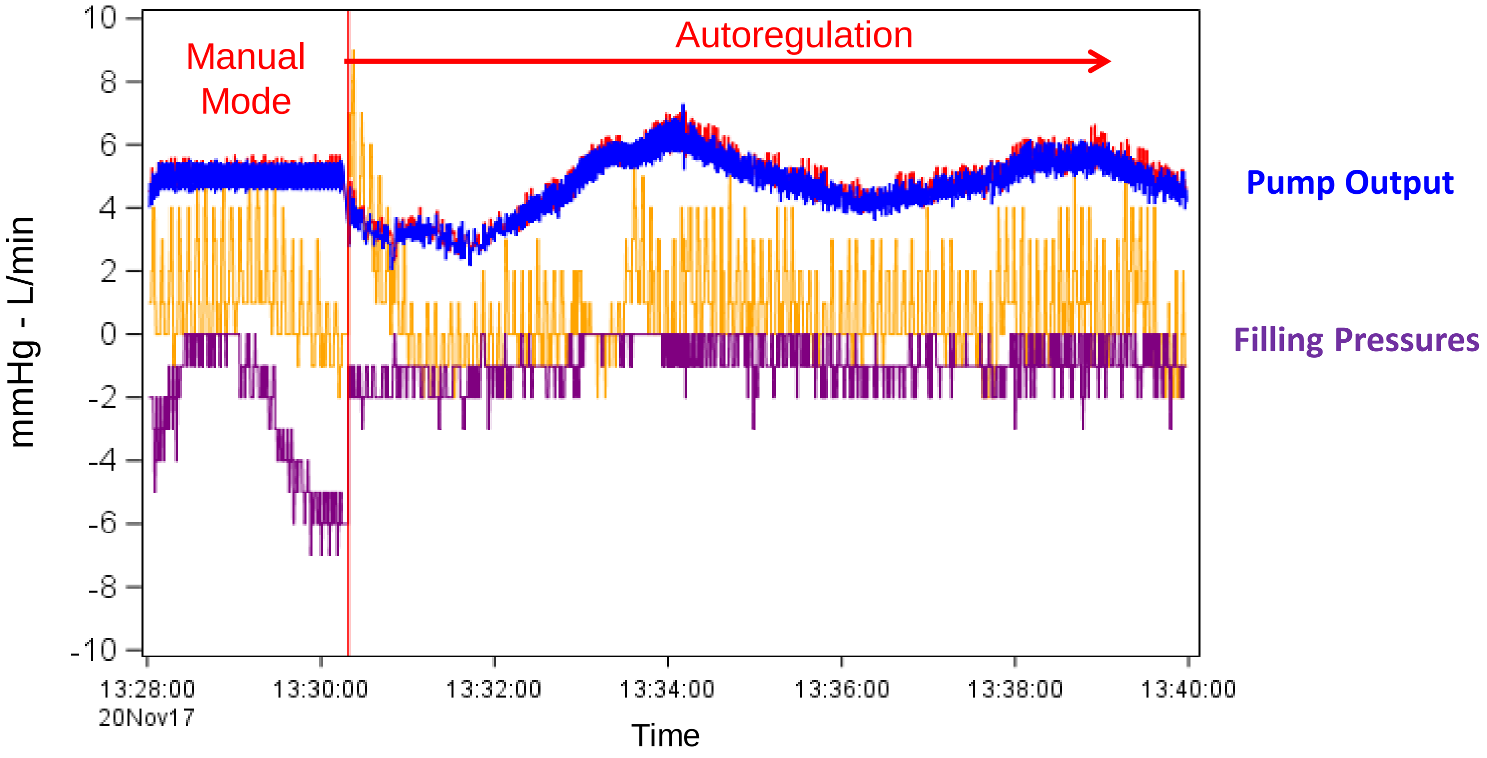


Autoregulation

- Objective
  - Automatically adapt flow to patient needs
- Two main parameters
  - RV filling pressure (target = 0)
  - Delta L-R filling pressure (target = 0)



Autoregulation initiated after CPB weaning



First Clinical Experience with Autoregulation

The Journal of
Heart and Lung
Transplantation

RESEARCH CORRESPONDENCE

Effects of pre-load variations on hemodynamic parameters with a pulsatile autoregulated artificial heart during the early post-operative period

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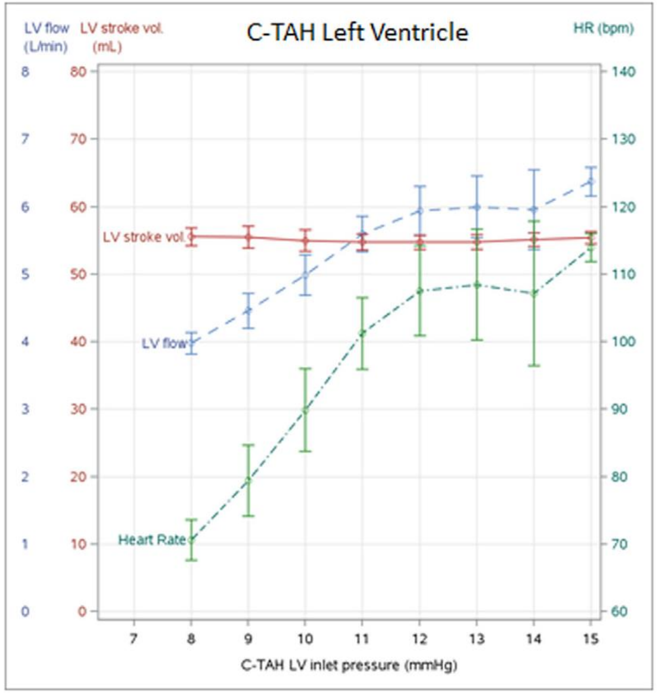
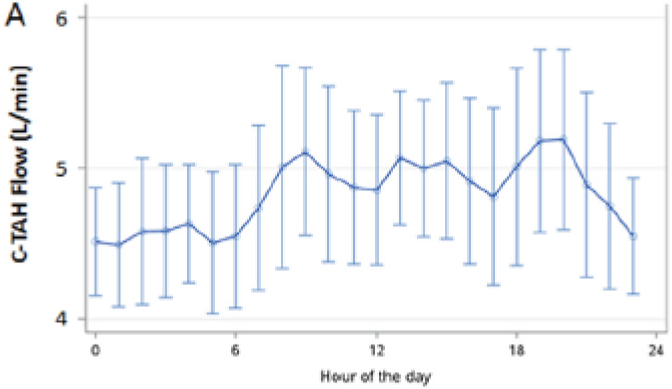
JHLT 2018 Jan;37(1):161-163





Study Design

- Objectives
  - Evaluate variation in cardiac output in response to preload changes
  - Evaluate the need for device settings change
- Methods
  - First 10 patients cohort of the CE Mark study, representing a cumulative support duration of 1,947 days (5.3 years).
  - Device data log analysis
- Endpoint
  - Number of device setting changes during clinical course

Patient Characteristics and Clinical Course

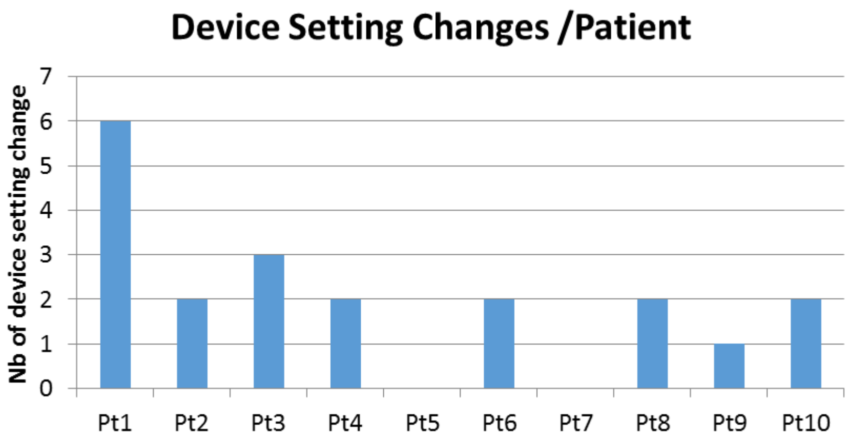
Age	60 (35-70)
Diagnosis	4 IHD, 6 DCM
Indication	6 BTT/BTC, 4 DT
INTERMACS	All 2 or 3

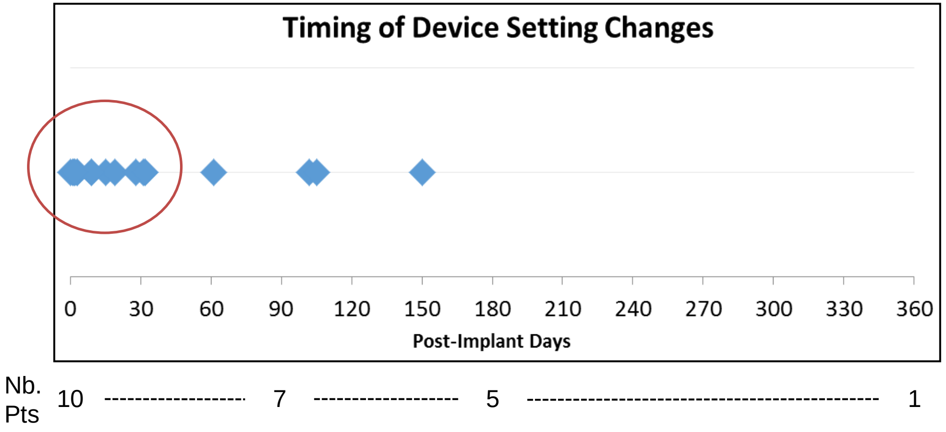
- 8/10 patients were discharged from ICU; median time to discharge 8 days
- 7/10 patients were discharged from hospital; median time to discharge 53 days
- Longest duration (ongoing) 16 months

	Baseline	Day 1	Day 7	M1	M3	M6
LAP (mmHg)	28±5	10±3	11±6	Catheter not in place		
CVP (mmHg)	15±5	10±3	12±6	Catheter not in place		
SBP (mmHg)	99±10	105±16	110±12	117±13	114±7	125±23
DBP (mmHg)	66±5	57±7	60±11	68±12	75±8	79±6
CO (L/min)	2.9±0.7	5.7±0.6	5.9±0.8	6.1±0.7	5.9±0.6	6.1±0.6

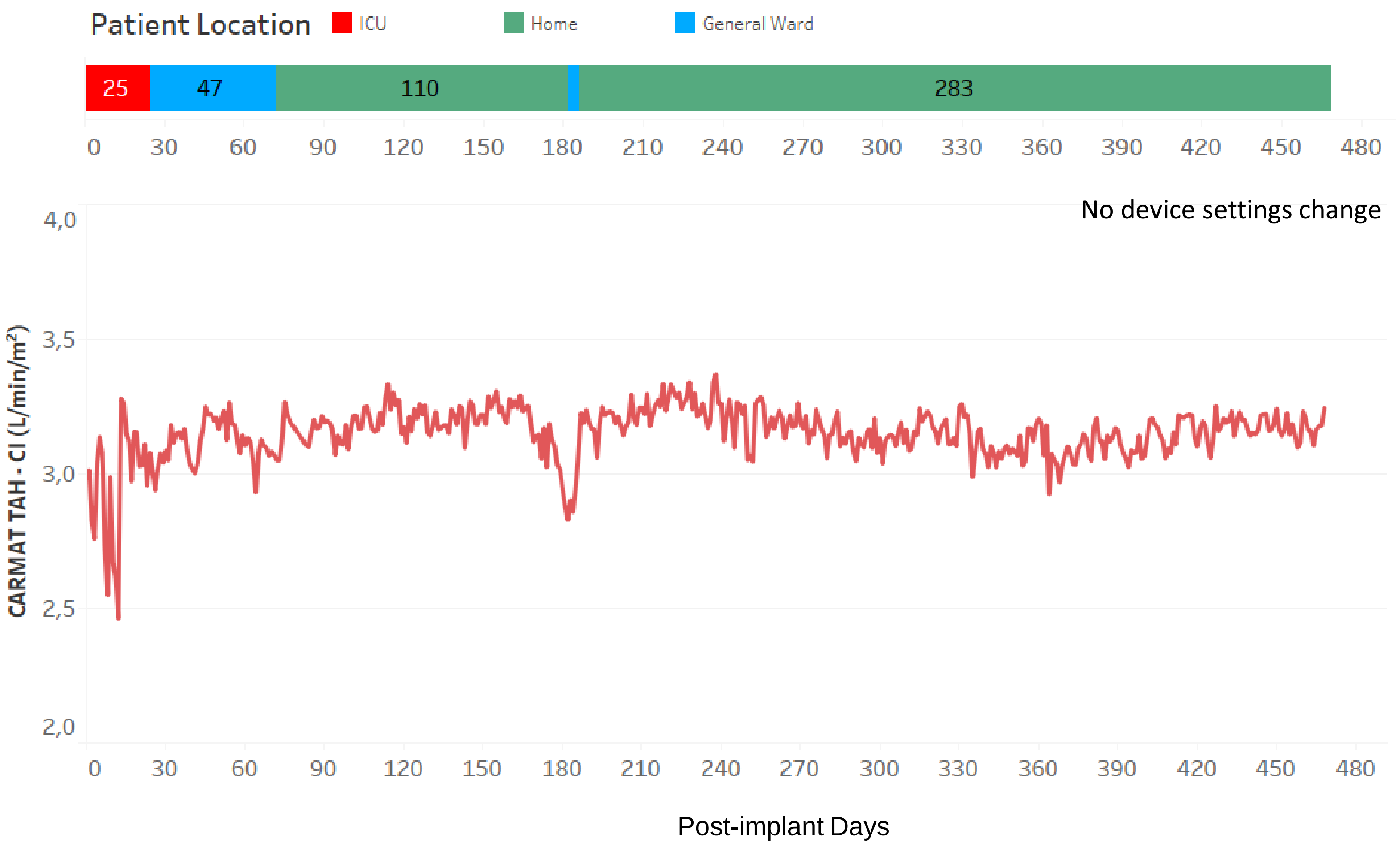
Device settings change

- Device settings were changed 20 times in 10 patients, during 5.3 pt.yrs observation
  - 65% occurred in the first month (ICU),
  - 90% of the changes were done on 1 setting (RV admission pressure)
  - Only 1 change was needed after hospital discharge
- With experience, less changes were performed

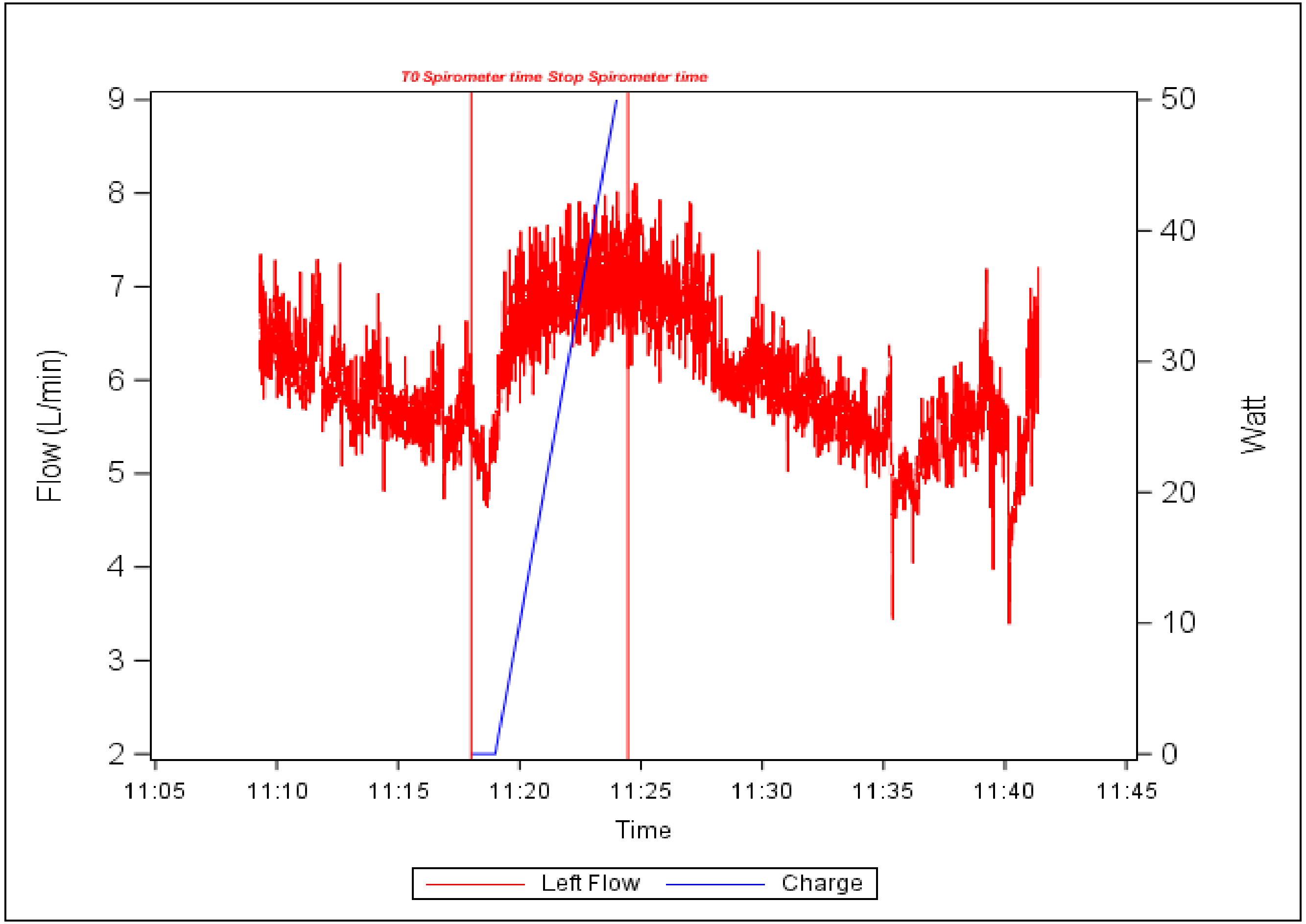




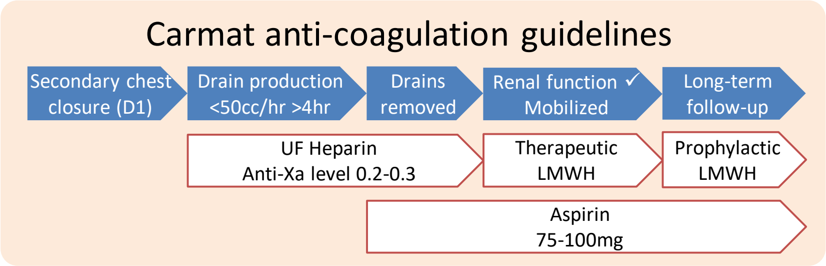
Hemodynamic Performance



Exercise-induced flow changes



Clinical Outcome and Safety Profile



Comparative outcomes 10 cases - 6 months follow up

	Survival rate	Bleeding – surgical repair	Stroke	Gastrointestinal bleeding	Driveline infection
CARMAT	**70%**	**40%**	**0%**	**0%**	**0%**
SynCardia*	54% - 62%	41%	23%	20%	22%
BIVAD**	46% - 68%	n/a	7%	7%	7%
LVAD***	90% - 92%	14%	8%	8%	10%

* Kirklin JK *et al.*, JHLT 2018;37:685-691. Arabia F *et al.*, JHLT, 2018;37:1304–1312. Demondion P *et al.*, EJCS. 2013 Nov;44(5):843-8
** Lavee J *et al.*, JHLT 2018;37:1399−1402. Arabia F *et al.*, ATS 2018;105:548–56
*** Strueber M *et al.* JACC 2011;57:1375–82. Netuka I *et al.*, JACC 2015;66:2579–89

Conclusions

- Carmat automatic flow regulation is controlled effectively by preload-sensitive algorithm
- Autoregulated flow results in immediate and durable hemodynamic recovery
- Autoregulation: « **Start and Forget** »
- Autoregulation provides the hemodynamic condition for positive safety profile and improved quality of life

Merci Beaucoup!

67 y/o man, DT indication, 16 months on Carmat