Further devices to treat heart failure

Pr. Matthias Kirsch
Department of Cardiac Surgery
Centre Hospitalo-Universitaire Vaudois
Université de Lausanne
e-mail: matthias.kirsch@chuv.ch
Strategies for Mechanical Circulatory Support

1. Systolic augmentation
2. Diastolic augmentation
3. Blood pumps
Systolic Augmentation
Direct Cardiac Compression Devices

*Dynamic Cardiomyoplasty*

![Latissimus dorsi muscle wrapped around the heart](image)

*Anstadt cup*

![Diagram of cardiac compression device](image)

Fig 3: The latissimus dorsi muscle is wrapped around the heart in cardiomyoplasty. Muscle stimulation during systole was designed to augment the cardiac contraction.
Systolic Augmentation
Direct Compression Devices for Long-term Support

Heart Booster

Apical Torsion Device

Trumble DR et al. J Biomed Eng 2011
Diastolic Augmentation
Arterial Counter-Pulsation

1. Systole (withdrawal)
   ↓ LV afterload
   ↑ LV ejection

2. Diastole (reinjection)
   ↑ diastolic pressure
   ↑ systemic perfusion
   ↑ coronary perfusion
Diastolic Augmentation
Para-Aortic Counterpulsation

Kantrowitz CardioVAD  
C-Pulse System

Abraham WT et al. JACC Heart Failure 2014;2:526-33
Diastolic Augmentation Counter-Pulsation Pumps

**Symphony device (Abiomed)**

**PulVAD**


Blood Pumping Systems

Volume-displacement

Pulsatile perfusion

Rotary pumps

Reduced pulsatility
Rotary Pump Hydrodynamics

Rotary pump flow varies:

- Increases directly with pump rotor speed
- Inversely with the pressure difference between inlet and outlet orifices
Rotary Pumps Hydrodynamics

Axial versus centrifugal
Rotary Blood Pumps
Outcomes in Clinical Trials

HeartMate II

HeartWare
Rotary Blood Pumps
INTERMACS Registry

Intermacs - Implants per Year by Device Type
Primary Prospective Implants: June 23, 2006 to December 31, 2015

Number of Implants per Year

- LVAD
- RVAD
- BiVAD
- TAH

$81\%$, $70\%$, $60\%$

Intermacs - Kaplan-Meier Survival by Flow Type and Device
Primary Prospective Implants: June 23, 2006 to December 31, 2015

- Continuous - LVAD (n = 14373, Deaths = 3982)
- Continuous - BiVAD (n = 484, Deaths = 221)
- Pulsatile - LVAD (n = 611, Deaths = 239)
- Pulsatile - BiVAD (n = 348, Deaths = 136)
- Pulsatile - TAH (n = 344, Deaths = 111)

Survival Rates:
- At Risk:
  - 344
  - 348
  - 611
  - 484
  - 14373

Survival Analysis:
- Shaded areas indicate 70% confidence limits
- p (log-rank) = .0001
- Event: Death (censored at transplant or recovery)

https://www.uab.edu/medicine/intermacs/  12th June 2016
Rotary Blood Pumps
Functional Improvement (HMII)

~ 80% of patients
In NYHA class I ou II

Mean increase 150 meters

Rogers, J Am Coll Cardiol 2010;55:1826-34
Adverse Events Burden

First infection, bleeding, device malfunction, stroke, death

Readmission

Kirklin JK, J Heart Lung Transpl 2015;34:1495-1504
Future Developments

1. Smaller, more biocompatible devices
2. Less invasive implantation
3. Tackling the right ventricle
4. Getting rid of the driveline
HeartMate III (Thoratec)

- **Full MagLev Technology**
  - Large, consistent pump gaps designed to reduce blood trauma
  - Artificial pulse
  - Wide range of operation
    - Full support (2 – 10 L/min)
- **Textured blood contacting surfaces**
- **Advanced Design for Surgical Ease**
  - Engineered apical attachment
  - Modular Driveline

---

[Image of HeartMate III diagram]
HeartMate III (Thoratec)

CE Mark Trial, 50 patients, 10 centers
6-month survival, 92%
No hemolysis, no pump thrombosis or failure

⇒ MOMENTUM 3
Prospective Multicenter RCT HM III vs HM II

Devices Under Development
Further Miniaturization, Intra-ventricular Pumps

- Thoratec HeartMate X
- HeartWare MVAD
- ReliantHeart aVAD
Towards Less Invasive Implantation

- **Sternotomy**
- **Reduced incisions**
- **Off pump implantation**
  - Automated LV apical anastomotic device
- **CPB**
Alternative Routes

Trans-mitral approach

Circulite Synergy

Outflow Graft
Inflow Cannula
Micro-pump
Percutaneous Lead

Trans-apical approach

Standpipe
Outflow Cannula

MVAD Core Assembly
Anchor
RV Failure after LVAD Implantation
Temporary RV support

2012-16, 4 centers
35 LVAD pts
28 (80%) weaned
7.9 ± 4 days

Towards Implantable Biventricular Support

HeartWare

- **System peripherals** (i.e. controllers and batteries)
  - Single BiVAD Controller
  - Powered by a single battery set
  - BiVAD compatible peripherals (monitors, power modules)

- **Driveline configuration**
  - Single percutaneous exit site with implanted “Y” lead or “Y” connector

- **Cross platform compatibility**
  - (e.g. HM II, HM-X)

Krabatsch et al. Circulation 2011;124:S179-86; n =17 pts
Total Artificial Heart

Syncardia TAH
Former Cardiowest

Getting rid of the Driveline
Transcutaneous Energy Transfer (TET)

Abiocor TAH
LionHeart LVAD

Position Tolerant
Advanced Energy Transmission (TETS)

Integrated Controller / Battery / Coil Module

High Capacity, Long Life Battery
Conclusions

- LVADs already play a pivotal role in the management of end-stage heart failure
- LVADs implantation will be one of the most commonly performed procedures in cardiovascular medicine
- Future progress:
  - Minimally invasive implantation
  - Implantable bi-ventricular support
  - Transcutaneous energy transmission