EVOLVING MCS THAT ARE RESHAPING OUTCOMES IN ADVANCED HEART FAILURE

DR KATHERINE FAN
CONSULTANT CARDIOLOGIST
GRANTHAM HOSPITAL
PreHospital ECMO on the Streets of Paris Service d’aide medical d’urgence (SAMU)
IMPLEMENTING ON-SCENE ECMO

• ECPR is now Recommended by international guidelines in the management of refractory OHCA of suspected reversible cause, such as AMI, pulmonary embolism and intoxication ¹

• ECPR Team was sent out in absence of ROSC after 10 mins of ALS and by 2015, dispatched at the same time of MoICU

• Opposite of “scoop and run” concept, this system can do everything from “stay and treat” such as prehospital ECPR or “run and treat” in case of penetrating trauma for a damage control situation

• Results from implementing on-scene ECMO show an increase in survival rate from 8 to 29% with acceptable neurological status ²

1. LINK ET AL. CIRCULATION 2015;132 (18 SUPPL 2): S444-S464
2. LAMHAUT ET AL. RESUSCITATION 2017;117:109-117
Provide time to heal or heart team to find long term solution.
INITIATING ECPR - IMPORTANCE OF TIMING

Possible outcomes after initiating CPR within 5 min (far left) leading to either favorable or unfavorable outcomes based on timeline decisions to start return of spontaneous circulation (ROSC) or ECLS. Abbreviations as in Figure 5.
CARDIOGENIC SHOCK DIAGNOSIS, **TEAM ACTIVATION** AND TREATMENT ALGORITHM PROTOCOL

Activate multidisciplinary approaches:
1. Interventional cardiologists
2. Cardiac surgical team
3. Advanced Heart failure physicians
4. Critical care team

![Cardiogenic shock algorithm](image)
Before implementation of shock team: baseline 30 days survival for all CS = 47% 

Increased 58% and 77% in 2017 & 2018 respectively

<table>
<thead>
<tr>
<th>Year</th>
<th>2016 (baseline)</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 days survival</td>
<td>47%</td>
<td>57.9%*</td>
<td>76.6%*</td>
</tr>
</tbody>
</table>

P <0.01*

**Central Illustration: Cardiogenic Shock Algorithm**

- **Clinical criteria to rapidly identify shock state:**
  - Systolic blood pressure (SBP) <90 mm Hg for >30 minutes (or use of inotropes/vasopressors to maintain SBP)
  - Evidence of end-organ hypoperfusion
  - Lactate level >2 mmol/L

- **Activate Shock Team through one-call line for multidisciplinary discussion:**
  - Interventional Cardiology; Cardiac Surgery; Advanced Heart Failure; Critical Care

- **Transfer patient to cardiac catheterization lab or cardiac intensive care unit (CICU) for evaluation:**

- **If acute decompensated heart failure cardiogenic shock (ADHF-CS) suspected:**
  - Right heart catheterization
  - Echo

- **If acute myocardial infarction cardiogenic shock (AMI-CS) suspected:**
  - Right heart catheterization
  - Coronary angiography + revascularization
  - Assessment of peripheral vascular anatomy

- **Hemodynamic Criteria for Cardiogenic Shock:**
  - Fick cardiac index <1.8 l/min/m² without inotropes/vasopressors
  - (or <2.2 l/min/m² with inotropes/vasopressors)
  - Pulmonary capillary wedge pressure >15 mm Hg
  - Cardiac power output (CPO) <0.6 W
  - PAP <1.0

- **If Hemodynamic Criteria are met, consider Percutaneous Mechanical Circulatory Support (PMCS)**

- **Admit Patient to CICU**
  - Daily bedside echocardiograms for patients with PMCS
  - Frequent neurovascular assessments for patients with PMCS
  - Serial assessment of end-organ perfusion and hemodynamics: CPO, PAP and lactate
  - Evaluation for weaning vs. escalation of support
Remarks:
• Total no. of ECMO case = 912, Total no. of ECMO patient = 870

Total no. of ECMO Case in Hong Kong (2010 - 2018)
Total no. of ECMO Case (By Type) (2010 - 2018)

Remarks:
• Total no. of ECMO case = 912, Total no. of ECMO patient = 870
SO WHAT’S NEXT?
Survival (%)

1982-1991 (N=21,482)
1992-2001 (N=40,097)
2002-2008 (N=26,046)
2009-6/2016 (N=30,824)

Adult Heart Transplants
Kaplan-Meier Survival by Era
(Transplants: January 1982 – June 2016)

Median survival (years):

All pair-wise comparisons were significant at p < 0.0001.
ADULT AND PEDIATRIC HEART TRANSPLANTS
NUMBER OF TRANSPLANTS BY YEAR AND LOCATION

NUMBER OF TRANSPLANTS

Europe
North America
Other

2018

JHLT. 2018 Oct; 37(10): 1155-1206
ADULT HEART TRANSPLANTS
% OF PATIENTS BRIDGED WITH MECHANICAL CIRCULATORY SUPPORT* BY YEAR AND DEVICE TYPE

* LVAD, RVAD, TAH, ECMO

JHLT. 2018 Oct; 37(10): 1155-1206
INCREASING ROLE OF TEMPORARY MCS MODALITIES
STABILIZE PATIENT IN HEMODYNAMIC EXTREMIS
IMPELLA – A LONGER-TERM TEMPORARY SUPPORT

• Miniature rotary pump
• Inserted retrograde across AV to provide short term ventricular support
• Very hemocompatible- minimal hemolysis
• Impella RP- tests RV tolerance
  • If RV doing well- predictive of tolerance of durable LVAD
CONSIDERATIONS BEFORE FINALIZED MCS STRATEGY

• Guidelines strongly recommend consideration of use of temporary MCS in patients with multi-organ failure, sepsis or on mechanical ventilation to allow successful optimization of clinical status and neurologic assessment prior to placement of a long term MCS device.

• Considerations prior to finalizing an individualized MCS strategy
  • Underlying cause of cardiac dysfunction and projected time course of recovery
  • Severity of pulmonary dysfunction and projected course of recovery
  • Functional reserve of each ventricle
  • Presence and severity of valvular pathology
  • Risk of arterial access and size of vessels
  • Severity of coagulopathy
  • Risk of sternotomy
  • Planned future surgery such as long-term VAD or transplant
For the larger group of individuals who face a high risk of short-term mortality and little chance of receiving a transplant, that the emergence of continuous flow LVAD holds the greatest promise.

Durable VADs devices are capable of augmenting the circulation to meet the body’s physiological needs, both at rest and with exercise, extending survival and improving QoL.

Centrifugal flow with levitating magnetic discs

Axial flow pump
SURVIVAL IMPROVEMENT OVER TIME

- Optimized medical therapy
- HM II
- XVE

Graph showing survival improvement over time with different therapies.
CURRENT CONSIDERATIONS IN LVADS: WHERE ARE WE NOW?

• New pump design changes
• Outcome benefits
OVERCOMING THE CHALLENGE OF ADVERSE EVENTS

- Conceptually 3 categories AEs
  - **Intrinsic to the pump and its constituents**
    - Pump malfunction
    - Controller faults
    - Driveline faults
    - Short-to-shield malfunctions
  - **Patient-related liability of native heart**
    - Arrhythmias
    - Valvular insufficiency
    - RV failure
  - **Pump-patient interface**
    - Acquired von Willebrand disease
    - Infection
    - Stroke
    - Pump thrombosis

<table>
<thead>
<tr>
<th>Table 2 Most frequent adverse events during HeartMate II support as BTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author (Ref.), study period</td>
</tr>
<tr>
<td>Adverse events</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Miller (8), 03/2005-05/2006</td>
</tr>
<tr>
<td>Pagani (9), 03/2005-04/2008</td>
</tr>
<tr>
<td>Starling (10), 04/2008-08/2008</td>
</tr>
<tr>
<td>John (11), 06/2005-06/2010</td>
</tr>
<tr>
<td>Lok (12), 03/2006-12/2011</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Bleeding</td>
</tr>
<tr>
<td>Re-exploration</td>
</tr>
<tr>
<td>31%</td>
</tr>
<tr>
<td>26%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>16%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>Gastrointestinal</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>17%</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>CVA</td>
</tr>
<tr>
<td>Stroke</td>
</tr>
<tr>
<td>8%</td>
</tr>
<tr>
<td>8%</td>
</tr>
<tr>
<td>6%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>TIA</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>2%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>RV failure</td>
</tr>
<tr>
<td>Inotropic</td>
</tr>
<tr>
<td>13%</td>
</tr>
<tr>
<td>13%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>27%</td>
</tr>
<tr>
<td>MCS</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>6%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>Driveline infection</td>
</tr>
<tr>
<td>14%</td>
</tr>
<tr>
<td>14%</td>
</tr>
<tr>
<td>17%</td>
</tr>
<tr>
<td>21%</td>
</tr>
<tr>
<td>14%</td>
</tr>
<tr>
<td>Pump thrombosis (replacement)</td>
</tr>
<tr>
<td>2%</td>
</tr>
<tr>
<td>1%</td>
</tr>
<tr>
<td>NR</td>
</tr>
<tr>
<td>0.98%</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>BTT, bridge-to-transplantation; NR, not reported; CVA, cerebrovascular accidents; TIA, transient ischemic attack; RV, right ventricle; MCS, mechanical circulatory support.</td>
</tr>
</tbody>
</table>
Biocompatibility refers to the ability of an implantable device to function without perturbing the body’s homeostatic systems.

In theory, a fully compatible device would neither activate nor suppress the immune system and would not have any disruptive effect on blood elements, the coagulation system or thrombus formation.

Thrombus formation = “Hemocompatibility” – a complex interaction between pump-patient interface and is influenced at micro level by the blood-contacting surfaces and at a macro level by pump design and flow dynamics.

Inadequate hemocompatibility- Gastrointestinal bleeding, stroke (both hemorrhagic and ischemic), hemolysis and pump thrombosis.
HEMOCOMPATIBILITY
DESIGNED FOR BETTER BLOOD HANDLING

Better blood handling

- wide blood flow pathways
- artificial pulsatility
- minimal pump thrombosis
- reduced blood shearing and stasis
- low hemolysis
- frictionless design
A FULLY MAGNETICALLY LEVITATED CIRCULATORY PUMP FOR ADVANCED HEART FAILURE

MOMENTUM 3
Mehra et al. NEJM 2017;376:440-450

- Primary end-point= composite of survival free of disabling stroke (modified Rankin score >3 or
  Survival free of reoperation to replace or remove the device at 6 mths after implant
• Pts with advanced HF to receive either centrifugal flow pump or axial flow pump irrespective of intended goal of use
• Composite primary end point:
  • Survival at 2 years free of disabling stroke or reoperation to replace or remove malfunctioning device
• Secondary end point:
  • Pump replacement at 2 years
METHODS & DEMOGRAPHICS

• From Sept 2014 to Aug 2016
• Total 1028 pts underwent randomization: CF pump 516 pts vs axial flow pump 512 pts (8 pts did not have LVADs implantation)
• A total of 126 surgeons performed 1020 implantations at 69 sites
• Discharge from hospitals:
  • CF flow VADS- 94.2% (mean LOS 19 days)
  • Axial flow VADs- 93.3% (mean LOS 17 days)
## PRINCIPAL SAFETY OUTCOMES IN PER-PROTOCOL POPULATION

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Centrifugal-Flow Pump</th>
<th>Axial-Flow Pump</th>
<th>Relative Risk (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspected or confirmed pump thrombosis</td>
<td>7 (1.4)</td>
<td>70 (13.9)</td>
<td>0.01</td>
<td>0.08 (0.04–0.16)</td>
</tr>
<tr>
<td>Any stroke</td>
<td>51 (9.9)</td>
<td>98 (19.4)</td>
<td>0.08</td>
<td>0.42 (0.30–0.57)</td>
</tr>
<tr>
<td>Disabling stroke</td>
<td>26 (5.0)</td>
<td>38 (7.5)</td>
<td>0.04</td>
<td>0.54 (0.34–0.85)</td>
</tr>
<tr>
<td>Any bleeding</td>
<td>225 (43.7)</td>
<td>278 (55.0)</td>
<td>0.61</td>
<td>0.64 (0.57–0.72)</td>
</tr>
<tr>
<td>Gastrointestinal bleeding</td>
<td>126 (24.5)</td>
<td>156 (30.9)</td>
<td>0.31</td>
<td>0.64 (0.54–0.75)</td>
</tr>
<tr>
<td>Other neurologic event</td>
<td>59 (11.5)</td>
<td>47 (9.3)</td>
<td>0.09</td>
<td>1.25 (0.88–1.79)</td>
</tr>
<tr>
<td>Any major infection</td>
<td>300 (58.3)</td>
<td>285 (56.4)</td>
<td>0.82</td>
<td>1.00 (0.89–1.12)</td>
</tr>
<tr>
<td>Right heart failure</td>
<td>176 (34.2)</td>
<td>143 (28.3)</td>
<td>0.27</td>
<td>1.15 (0.94–1.42)</td>
</tr>
<tr>
<td>Cardiac arrhythmia</td>
<td>185 (35.9)</td>
<td>207 (41.0)</td>
<td>0.37</td>
<td>0.82 (0.70–0.97)</td>
</tr>
<tr>
<td>Respiratory arrhythmia</td>
<td>111 (21.6)</td>
<td>98 (19.4)</td>
<td>0.19</td>
<td>1.10 (0.86–1.40)</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>73 (14.2)</td>
<td>56 (11.1)</td>
<td>0.11</td>
<td>1.36 (0.98–1.89)</td>
</tr>
<tr>
<td>Hepatic dysfunction</td>
<td>25 (4.9)</td>
<td>27 (5.3)</td>
<td>0.03</td>
<td>0.78 (0.46–1.34)</td>
</tr>
</tbody>
</table>
IMPROVED EVENT-FREE SURVIVAL OF STROKE OR RE-OPERATION

- HM III fully magnetically centrifugal flow pump was superior to HM II axial-flow pump with respect to survival free of disabling stroke or reoperation to replace or remove malfunctioning device.
- CF pump associated with lower incidence of either ischemic or hemorrhagic strokes.
PUTTING INTO PERSPECTIVES...
VAD QUALITY OF LIFE

Mean Visual Analog Scale (VAS) across time for patients who completed the EuroQol Instrument

Mean Kansas City Cardiomyopathy Questionnaire (KCCQ) Summary Score* across time for patients who completed the KCCQ Instrument

Best health

Worst health

N* denotes patients who completed the EuroQol questionnaire and the VAS question.

N* denotes patients who completed the KCCQ instrument. The KCCQ was implemented in Intermacs as of May 2012

INTERMACS report ISHLT 2019
NUMBERS OF HEART TRANSPLANTS, HEART-LIVER & HEART-LUNG TRANSPLANTS IN HK

* Total numbers of Heart Transplants: 212 (include, 2 Heart-Liver), and 4 Heart-Lung as at 31 May 2019
NUMBERS OF HEART TRANSPLANT & LVAD IN HK

*Total numbers of LVAD: 82 as at 31 May 2019
# ECMO AS BRIDGE IN ADVANCED HEART FAILURE
## PRELIMINARY HK DATA

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Bridge from VA-ECMO</th>
<th>1 year/ current Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durable LVAD</td>
<td>82</td>
<td>12 (14%)</td>
<td>9 (82.5%)</td>
</tr>
<tr>
<td>CentriMag L/RVAD</td>
<td>52</td>
<td>32 (61.5%)</td>
<td>16 (50%)</td>
</tr>
</tbody>
</table>

Only 1 pt directly bridge from VA-ECMO to Heart Transplantation

5 patients severe PAH received VA-ECMO
1 bridge to Lung Transplant
1 bridge to salvage triple PAH therapy
3 died on VA-ECMO support
CASE – MR L

- M/59
- History of R MCA infarct due to thromboembolism
- AF on NOAC
- Presented with extensive anterolateral STEMI on 25th March 2019
- Primary PCI to Left main and LAD - TIMI III
- Post procedure: Cardiogenic shock/ APO/ VT
- IABP 26th March - removed soon due to lower limb ischemia
- ECMO 26th March
VENTRICULAR ARRHYTHMIAS BEFORE AND POST-LVAD PERIOD

- Recurrent VTs requiring repeated DC shocks
- Amiodarone/ mexiletine/ metoprolol
- ECHO: EF 19% apical/ anteroseptal hypokinesia
- **LVAD 18/4/2019**
- Post op incessant VT- failed to be controlled despite iv amiodarone/ lignocaine/ mexiletine/ overdrive pacing
- RV failure- RVAD inserted
VT ABLATION
FUTURE OF THE FIELD

• Promise offered by LVADs = a viable alternative to heart transplantation
• Newer generation of LVAD capable of providing long-term support free of major disabling AEs
• Patient not in cardiogenic shock at time of LVAD implant can enjoy survival that is compatible with heart transplantation to approx 2 years
• More biocompatible device- meaningful clinical benefit with improved durability and fewer AEs.
• Future advances in QoL will come with a fully implantable device without need for an external driveline which will reduce infection risks and allow patients to swim and bathe.
Fully-Implantable LVAS (FILVAS)

Project Objectives

- Develop a left ventricular assist system incorporating an implantable battery and control system enabling patients to have some duration of "un-tethered time" without external components.
- Mitigate the need for a standard percutaneous lead, reducing the incidence of infection.
- Minimize the need for external components, reducing the burden for patients and enhancing quality of life.

Conventional FILVAS

Alternative FILVAS

With permission of Thoratec
SUMMARY

- Technology advances in MCS have improved survival and clinical outcome
- Team based approach important for rapid response as well as long term strategy planning
- Clinical outcome of newer generation of LVAD is equal to and even better than heart transplant
BENEFITS OF HEART TEAM APPROACH

- Utilizing a multidisciplinary Heart Team for complex patients with severe advanced heart failure leads to improved outcomes for patients, clinicians and health systems

**Patients:**
- Improved patient knowledge and satisfaction
- Incorporation of patient preferences through shared decision making
- Increased QoL and improved survival

**Improved clinician outcomes**
- Improved skill sets
- Increased job satisfaction

**Improved health system outcomes**
- More effective utilization of health care resources, leading to increased value
Thank You!