Temporary Mechanical Circulatory Support Devices: Choosing the Right Tool for the Job

MATTY LORENZ, APRN, CNP
MHI – AT ABBOTT NORTHWESTERN / ALLINA HEALTH
ADVANCED HEART FAILURE CARDIOLOGY SECTION – APRIL 2024

1

Objectives

- Broadly define temporary mechanical circulatory support (tMCS)
- Understand indications for initiation of tMCS
- Become generally familiar with common tMCS devices used in the CVICU and how they work
- Identify relative and absolute contraindications to using various tMCS modalities
- Recognize unique characteristics / properties of the most commonly used tMCS devices
- Apply your knowledge in selecting appropriate tMCS devices for use in different clinical scenarios

2

What is temporary mechanical circulatory support?

1. Temporary: Not permanent or long-term
2. Mechanical: Utilizing a machine with moving parts
3. Circulatory: Move blood throughout the body
3. Support: To off-load or assist struggling ventricle or ventricles

Temporary MCS: Using a machine for a short period of time to assist a struggling heart with circulating blood throughout the body

3

Most common temporary MCS devices

LV
- IABP
- Impella CP or Impella 5.5
- TandemHeart

RV
- Impella RP / Impella RP Flex
- Protek Duo
- TandemHeart RV

Biventricular
- V-A ECMO
- BiVAD (CentriMag pumps in parallel; LVAD + Protek Duo; Impella CP or 5.5 + Impella RP / RP Flex)
- Total Artificial Heart

4

Temporary MCS Utilizes Pumps

Axial Flow
- Continuous flow
- Archimedean screw (like an auger)
- Impella

Centrifugal Flow
- Continuous flow
- Spinning disk with blades that "throw" blood out (like a water wheel)
- ECMO, Protek Duo, TandemHeart, CentriMag

Pneumatic Flow
- Pulsatile flow
- Uses air to move a piston or inflate / deflate balloon → propels blood
- Total artificial heart and IABP

5

When to consider tMCS

1. Cardiogenic shock
   - MI
   - Decompensated systolic heart failure
   - Ruptured papillary muscle or chordae
   - VSD and ventricular free wall aneurysm
   - Severe valvular stenosis / insufficiency
   - Arrhythmias
   - Myocarditis
   - Drug-induced
   - Trauma / contusion

6

When to consider tMCS

2. Periprocedural: High-risk PCI, EP ablations, high-risk percutaneous valve interventions
3. Bridge to durable LVAD or heart transplant
4. Acute rejection of transplanted heart
5. Post-cardiotomy shock
   - Prevent or treat

7

Cardiogenic shock

Hypoperfusion attributable to cardiac dysfunction (pump failure, dysrhythmia, valve disease)
- Not hypovolemia, hemorrhage, sepsis, anaphylaxis, neurogenic, obstructive

High SVR, low cardiac output, elevated wedge pressure

Manifestations:
- Cool, clammy skin
- Decreased urine output
- Lab evidence of end organ dysfunction (elevated creatinine and LFTs commonly)
- Elevated serum lactate
- Elevated BNP
- Low ScVO2
- Pulmonary edema
- CI < 2.2
- PAOP > 15

8

Cardiogenic shock

Patient:

- SOB, orthopneic, elevated JVP, confused, clammy skin, hypotensive, elevated lactate, no urine
- Swan-Ganz placed
- RAP 18, PAOP 26, CI 1.3, SVR 1700

What should we do?

9

Cardiogenic shock

1. Optimize preload → diuresis
2. Reduce afterload → vasodilators (ie SNP)

RAP 8, PAOP 12, CI 1.75, SVR 1100

Now what?

10

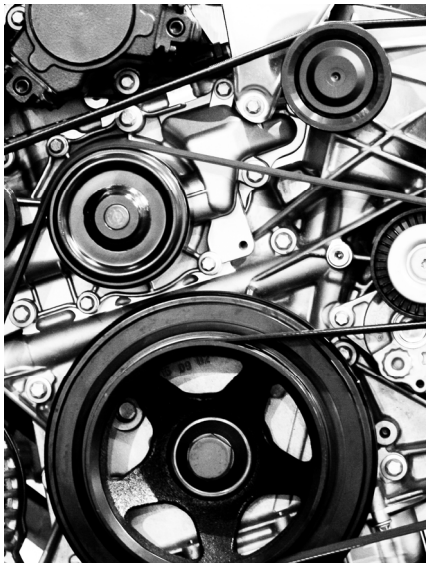
Cardiogenic shock

3. Inotrope (ie dobutamine, dopamine, milrinone)

RAP 7, PAOP 10, CI 1.8, SVR 900

Now what?

11



Cardiogenic shock

4. Declare patient “Titanium Deficient”

Time to start thinking about machines….

12

Goals of tMCS in cardiogenic shock

- Improve hemodynamics: Boost cardiac output to meet body's perfusion needs
- Unload the struggling ventricle(s): Reduce wall stress to reduce oxygen demand and improve ventricular performance

13

How to choose....

1. Univentricular or biventricular?
2. How much support do you need?
3. How long do you think you'll need it?
   - Peri-procedural? Short bridge? Longer recovery?
4. Any contraindications?
   - Severe irreversible neurologic damage
   - Severe PVD
   - Severe infection
   - Widespread malignancy
   - Thrombocytopenia
   - Inability to anticoagulate safely

14

So, time to call the cath lab???

Photo Credit: Education Images / Universal Images Group / Getty Images

Remember: Temporary MCS is a "bridge". Make sure it's not a bridge to nowhere

15

Three possible outcomes of tMCS run

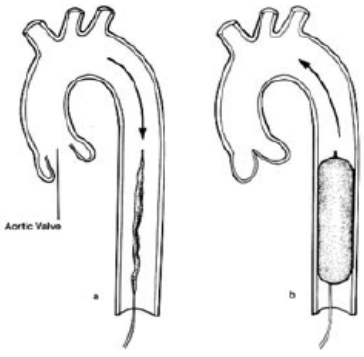
1. Recovery
2. Durable LVAD implant or heart transplantation
3. Death
   - Die on support of complication (0 out of 5 stars – do not recommend)
     - Consider all comorbidities and contraindications
     - Sometimes unanticipated and unavoidable
   - Withdraw support due to lack of options (0 out of 5 stars – do not recommend)
     - This is a risk if unstable or crashing patient is hastily or reflexively put on support
     - Avoidable – consider likelihood of recovery AND candidacy for advanced options (LVAD or transplant)

16

LV Support Devices

17

Intra-aortic balloon pump



18

Intra-aortic balloon pump

Benefits:

- Augments diastolic pressure and coronary perfusion
- Indirectly unloads LV → reduces wall stress and O2 demand

19

Intra-aortic balloon pump

Indications:

- Cardiogenic shock
- Periprocedural (e.g. PCI)
- Helpful in patients with bad MR

Contraindications:

- AI
- Calcified aorta

Potential Pitfalls:

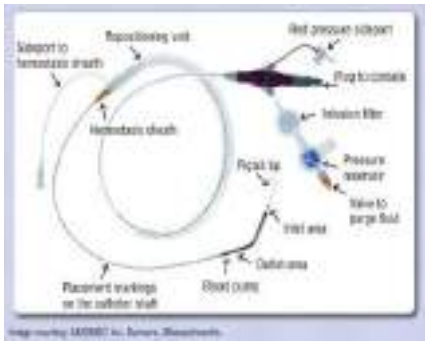
- Hard to time inflation / deflation in atrial fibrillation
- Only modest improvement in CI when compared to other devices

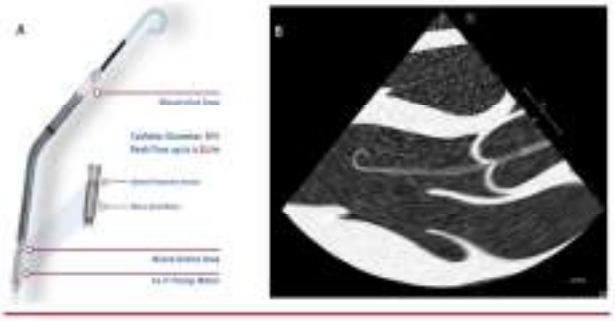
Complications:

- Bleeding
- Limb ischemia
- Stroke
- AKI if balloon is positioned across renal arteries → Follow renal function labs & urine output; check x-ray daily for position

20

Impella CP and Impella 5.5





J INVASIVE CARDIOL 2022;34(10):E709-E719. Epub 2022 August 23

21

Impella CP and Impella 5.5

Benefits:

- Directly unloads the LV
  - Reduces LV end diastolic pressure and volume, PAWP, and RV afterload
  - Reduces LV wall stress → reduces myocardial O2 demand
- Enhances hemodynamics
  - Augments native cardiac output (can flow 2.5-5 liters / minute)
  - Increases DBP → MAP

22

Impella CP and Impella 5.5

Indications:
- Cardiogenic shock (AMI, OHS, progressive cardiomyopathy / LV failure)
- Periprocedural (OHS, PCI, VT ablation)
- Bridge to advanced therapies (waiting for OHT or LVAD)

Contraindications:
- Mechanical AV (absolute)
- LV thrombus (absolute)
- AI and AS (relative)

23

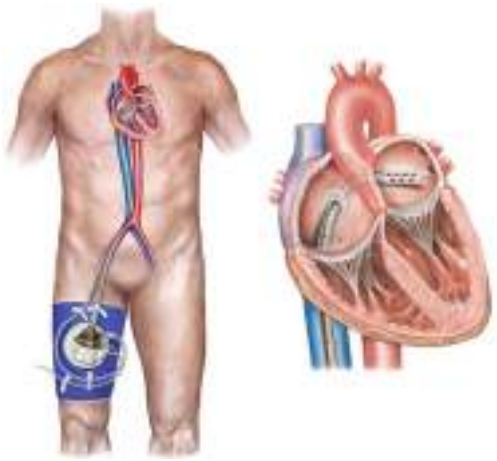
Impella CP and Impella 5.5

Potential Pitfalls:
- Need to be supine with CP in place
- Need surgical cut-down of axillary artery for 5.5 placement
- Pump can move proximally into aorta or distally into LV
- Could interfere with mitral valve apparatus leading to MR

Complications:
- Bleeding
- Limb ischemia
- Stroke
- Device thrombosis
- Hemolysis → follow CBC, LDH, plasma HGB; monitor for pigmenturia and AKI; CXRs and frequent TTEs to confirm position

24

TandemHeart



Mustafa Ahmed and Rene Alvarez. Mechanical Circulatory Support for the Failing Heart: Which Device to Choose. *CVIA*. 2015. Vol. 1(1):119-127. DOI: 10.15212/CVIA.2015.0012

25

TandemHeart

Benefits:

- Directly unloads the LA, which effectively unloads the LV
  - Reduces LV end diastolic pressure and volume, PAWP, and RV afterload
  - Reduces LV wall stress → reduces myocardial O2 demand
- Enhances hemodynamics
  - Augments native cardiac output (can provide up to 5 liters / minute of flow)
- Because it *indirectly* unloads LV, can be used in presence of LV thrombus

26

TandemHeart

Indications:
- Cardiogenic shock
- Periprocedural (e.g. PCI)
- Acute mechanical complications of MI (acute MR, VSD)

Contraindications:
- IVC filter
- PVD
- Severe AI

27

TandemHeart

Potential Pitfalls:
- Requires trans-septal puncture

Complications:
- Bleeding
- Limb ischemia
- Stroke
- Sepsis
- LA perforation

28

RV Support Devices

29

Protek Duo

30

Protek Duo

Benefits:

- Unloads RV (via RA)
  - Lowers CVP / RAP / RVEDP → reduces systemic congestion → beneficial for congestive hepatopathy and cardiorenal syndrome
  - Decrease RV wall stress → decrease myocardial oxygen demand
- Enhances hemodynamics → forward flow fills the LV → increases CO
- Mobility / early ambulation
- Can place an oxygenator in-line in the case of respiratory failure

31

Protek Duo

Indication: RV failure

- MI
- Acute MR
- PH crisis (PE, etc.)
- Post-LVAD implant

Contraindications:

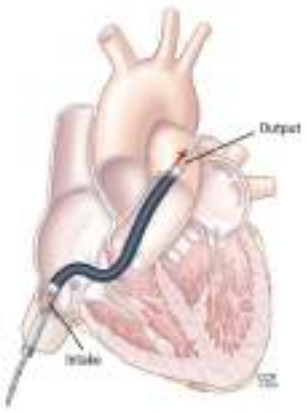
- Mechanical TV or PV
- Severe TR/TS; severe PI/PS
- RV thrombus

Complications:

- SVC syndrome
- Myocardial perforation
- Bleeding
- Pump or cannula thrombosis
- PE
- Vascular injury

32

Impella RP and RP-Flex



Cleveland Clinic Journal of Medicine April 2017, 84 (4) 287-295; DOI: https://doi.org/10.3949/ccjm.84gr.17002

Graphic from Abiomed.com

33

Impella RP and RP-Flex

Benefits:

- Unloads the failing RV (via IVC with RP and ~ SVC-RA junction with RP-Flex)
  - Lowers CVP / RAP / RVEDP → reduces systemic congestion
  - Decrease RV wall stress → decrease myocardial oxygen demand
- Enhances hemodynamics → flow fills the LV → increases CI
- Mobility / early ambulation with RP-Flex (inserted via RIJ)
- Smaller catheter than other RVADs

34

Impella RP and RP-Flex

Indications:
- CS from acute RV MI
- PH crisis (PE, etc.)
- Post-OHS and post-transplant RV failure
- Acute severe MR
- Support in setting of malignant arrhythmias
- Post-LVAD implant

Contraindications:
- Mechanical TV or PV
- Severe TR/TS; severe PI/PS
- RV thrombus; mural thrombus of RA or vena cava
- IVC filter (with RP)

35

Impella RP and RP-Flex

Pitfalls:
- Supine positioning for Impella-RP (placed in femoral vein)
- Can't add oxygenator

Complications:
- Bleeding
- Hemolysis
- Vascular injury
- PE
- Pump migration
- Arrhythmia

36

TandemHeart RV

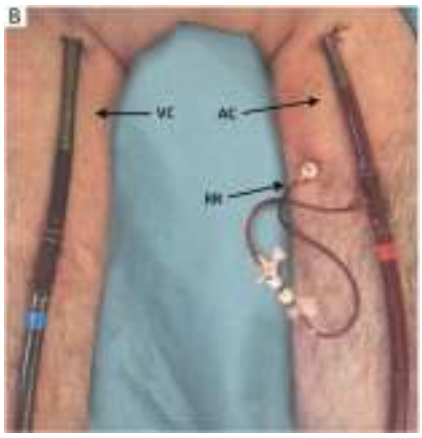
Draws from RA and returns to PA
- Inflow cannula via left femoral vein into RA
- Return cannula either right femoral vein into PA or right IJ into PA
- OR can use Protek Duo cannula with TandemHeart pump
- Used in RV failure associated with:
  - Post-MI
  - Severe PH (massive PE, acute severe MR)
  - Post-LVAD implant
- Can't use with:
  - IVC filter
  - Mechanical TV or PV
  - Severely stenotic or regurgitant TV or PV

37

Biventricular Support Devices

38

Venoarterial (V-A) ECMO



Banfi, Carlo et al. "Veno-arterial extracorporeal membrane oxygenation: an techniques." *Journal of thoracic disease* 8 9 (2016): E875-E885 .

39

Venoarterial (V-A) ECMO

Benefits:

- Provides most robust biventricular support of all MCS options→ can meet perfusion demands without any native cardiac contribution
- Unloads RV
  - Reduces systemic congestion
  - Decreases flow through lungs
- Oxygenator in-line: Provides respiratory support in cardiopulmonary failure

40

Venoarterial (V-A) ECMO

Indications:

Cardiogenic shock / cardiorespiratory failure
- Primary graft dysfunction after heart transplant
- Post-MI
- Myocarditis
- PE
- Decompensated heart failure
- Post-cardiotomy shock
- Cardiac arrest resuscitation (ECPR)
- Post-cardiac arrest

Bridge to transplant or LVAD

Periprocedural: High-risk PCI, EP ablations, high-risk valve interventions

41

Venoarterial (V-A) ECMO

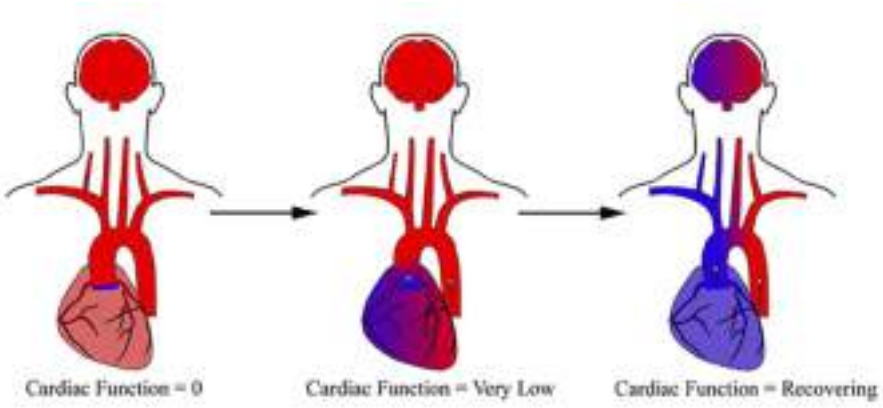
Contraindications:
- Aortic dissection
- Severe AI
- No options forward

Pitfalls:
- North-South / Harlequin Syndrome
- "Loads" the LV → LV distension

Complications:
- Bleeding → ECMO requires a lot of anticoagulation
- Limb ischemia → use distal perfusion catheter and follow LE regional sats
- Stroke → early neuro assessments and brain imaging
- Infection
- Arrhythmia (LV distension)
- Coronary and cerebral hypoxia (North-South Syndrome)
- Cardiac thrombosis (LV distension)
- Pump thrombosis / oxygenator clotting / pump malfunction / displaced cannula

42

North-South Syndrome / Harlequin Syndrome



Prisco, A.R., Aguado-Sierra, J., Butakoff, C. *et al.* Concomitant Respiratory Failure Can Impair Myocardial Oxygenation in Patients with Acute Cardiogenic Shock Supported by VA-ECMO. *J. of Cardiovasc. Trans. Res.* **15**, 217–226 (2022). https://doi.org/10.1007/s12265-021-10110-2

43

North-South Syndrome / Harlequin Syndrome

Can lead to cerebral anoxia / anoxic brain injury

Important:
- Follow right radial ABGs
- SpO2 probe on right hand
- Follow regional sats (placed on head and lower extremities)

Options:
- Convert to central cannulation → return cannula placed in ascending aorta proximal to brachiocephalic take-off → anterograde flow through arteries serving head and upper extremities
- Add third limb to circuit
  - VVA – additional drainage cannula→ reduces RV and LV preload → reduces volume of deoxygenated blood from LV
  - VAV – additional return cannula (usually via RIJ vein) → oxygenated blood goes through lungs and back to LV
- Convert to VV ECMO if cardiac function is recovered to satisfactory extent but pulmonary support is still required (e.g. ARDS)

44

LV Distension

Key Point: Peripheral ECMO fixes cardiac output / perfusion issues but "loads" the LV
- Increases afterload of LV → increases LV myocardial workload → sick ventricle can't "rest"
- Increases PCWP → pulmonary edema / worsening respiratory status
- Changes dimension of LV → arrhythmias
- Stagnation of blood → cardiac thrombosis → bad deal

Options: Need to unload and "vent" the LV
- Inotropes → least invasive → if pulse pressure is reasonable
- IABP
- Impella
- Surgical LV vent
- Atrial septostomy
- Daily weaning attempts, frequent echocardiograms → remove ECMO as soon as possible

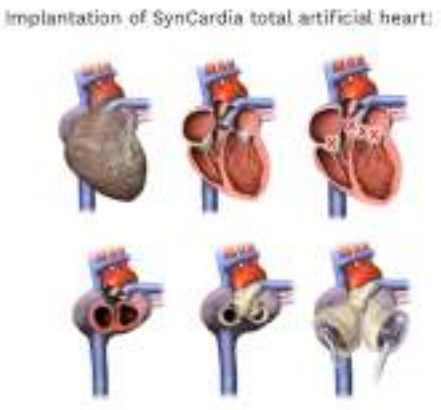
45

BiVAD

Iterations:
- Bi-Pella (Impella CP or 5.5 PLUS Impella RP / RP-Flex)
  - Only two access sites needed
  - Anticoagulation less critical than ECMO, Protek Duo, CentriMag pumps
- ProtekDuo plus Impella CP or 5.5
  - Early mobilization with Impella 5.5 plus Protek Duo
  - Can add oxygenator if needed
- Surgically-placed CentriMag pumps in parallel (RA to PA and LA or LV to Aorta)
  - Anterograde flow is a bonus (versus peripherally-placed circuit)
  - Can add oxygenator if needed
  - Mobility?

46

Total Artificial Heart



Syncardia Total Artificial Heart - Mercé V. Electromedicina (mercev.com)

47

Total Artificial Heart

Indications → bridge to transplant
- End-stage biventricular failure
- Persistent malignant arrhythmias
- Congenital heart disease
- Graft dysfunction or rejection after transplant

Longest run: Almost 4 years

Can produce 9.5 liters / minute of CO → correct hemodynamics and reverse end-organ dysfunction

Pneumatic driver pushes and pulls a set volume of air into chamber at a set rate → moves diaphragm in and out like a pisoton to fill and expel blood

Run at faster heart rates to achieve CO → Sizes available: 50 or 70 cc stroke volume

Remember: No ECG tracing!!!

48

Total Artificial Heart

Complications:
- Bleeding
- Clotting
- Stroke
- Infection
- Device malfunction

Future: Being looked at as possible destination therapy for those ineligible for heart transplantation

49

Key Points

1. Don't wait –> Think ahead
2. It takes a big team to make tMCS runs successful
   - HF cardiologists
   - Intensivists
   - Interventionalists and/or surgeons
   - RNs (YAY!)
   - Social work, palliative care, dietitians, PT / OT
3. Consider weaning every day – Can mitigate risk of complications
4. Knowledge and skill are important….but wisdom and experience are just as important
   - Which device is best option
   - When to use and when NOT to use
     - Avoid potentially-avoidable disasters / complications, and avoid having to withdraw support due to lack of paths forward

50

Questions?

51

References

Atti, V., Narayanan, M., Patel, B., et al. A Comprehensive Review of Mechanical Circulatory Support Devices. *Heart International.* 2022, 16(1): 37-48

Dangl, M., Albosta, M., Butros, H., Loebe, M. Temporary Mechanical Circulatory Support: Left, Right, and Biventricular Devices. *Current Cardiology Reviews.* 2023, 19(5). doi: 10.2174/1573403X19666230314115853

DeFilippis, E., Topkara, V., Kirtane, A., Takeda, K., Naka, Y., Garan, A. Mechanical Circulatory Support for the Right Ventricle. *Cardiac Failure Review.* 2022(8):e14. https://doi.org/10.15420/cfr.20211

52

Thank You!!!

To Contact Me:

Matthew Lorenz, APRN, CNP

Minneapolis Heart Institute at Abbott Northwestern Hospital

800 East 28th St – MR 33300

Minneapolis, MN 55407

Cell: 612-799-0166

Email: matthew.lorenz@allina.com

53