Left Ventricular Assist Device (LVAD)

Daniel Alves Lopes

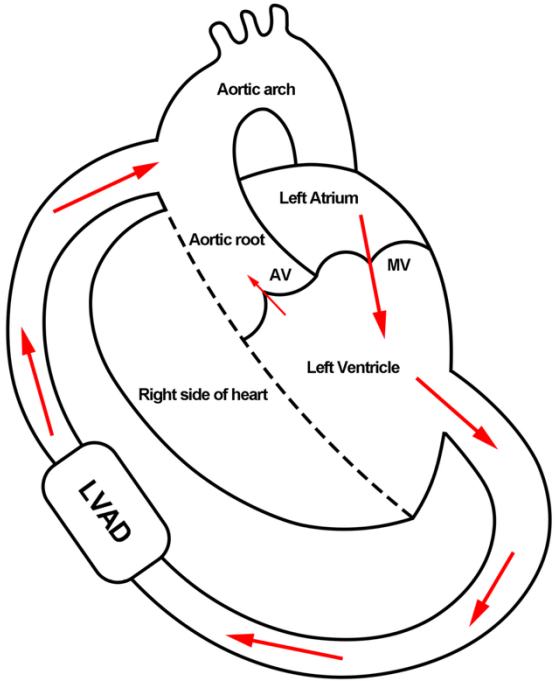
18.12.25

What is a LVAD ?

- Mechanical pump implanted to assist a failing left ventricle (**LV**)
- Parallel circuit, that pumps blood from LV → Normal Cardiac Output (**CO**)

LVAD will :

- Restore Cardiac Output
- Improve organ perfusion
- Reduce left ventricle workload
- Pulsatile Flow → Continuous Flow



Gu et al., 2023, "The Impact of Left Ventricular Assist Device Outflow Graft Positioning on Aortic Hemodynamics"

Heart Failures, what happens?

Systolic Heart Failure (**HFrEF**)

"Pump Too Weak"

- LV loses its "squeezing" power → smaller flow **output**
- Reduced Ejection Fraction (EF < 40%)

Diastolic Heart Failure (**HFpEF**)

"Pump Too Stiff"

- LV loses its relaxation ability → smaller flow **input**
- Preserved Ejection Fraction (EF = 50-70%)

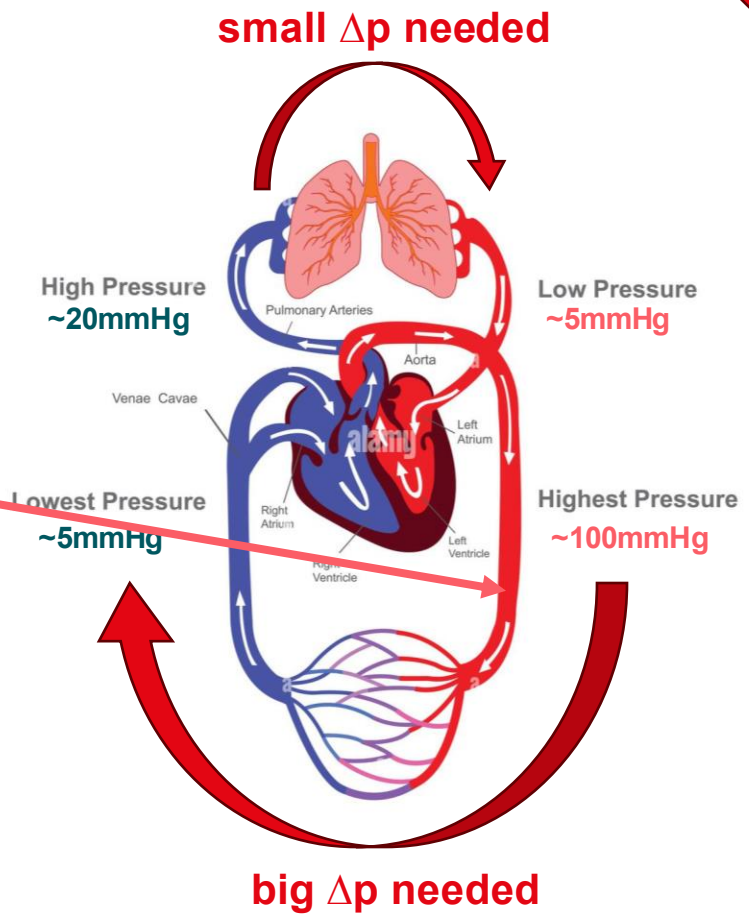
~95% of LVAD implants

Ejection Fraction : % of blood that is pumped out
HFrEF = Heart Failure with **R**educed Ejection Fraction (Systolic)
HFpEF = Heart Failure with **P**reserved Ejection Fraction (Diastolic

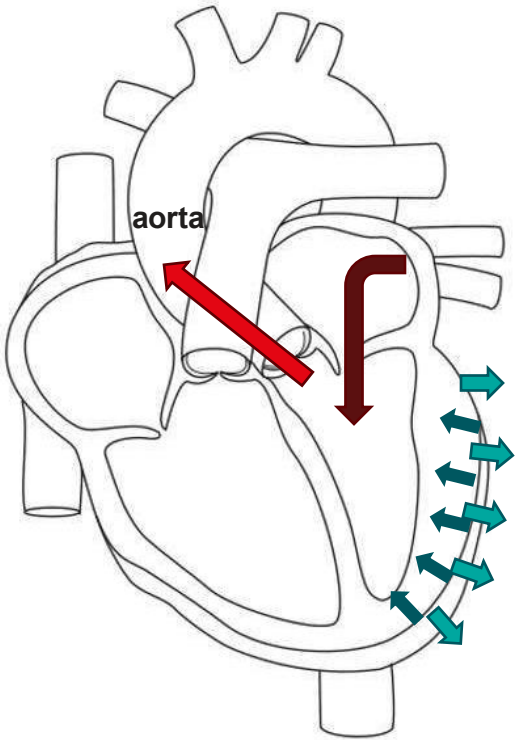
How does the blood circulate ?

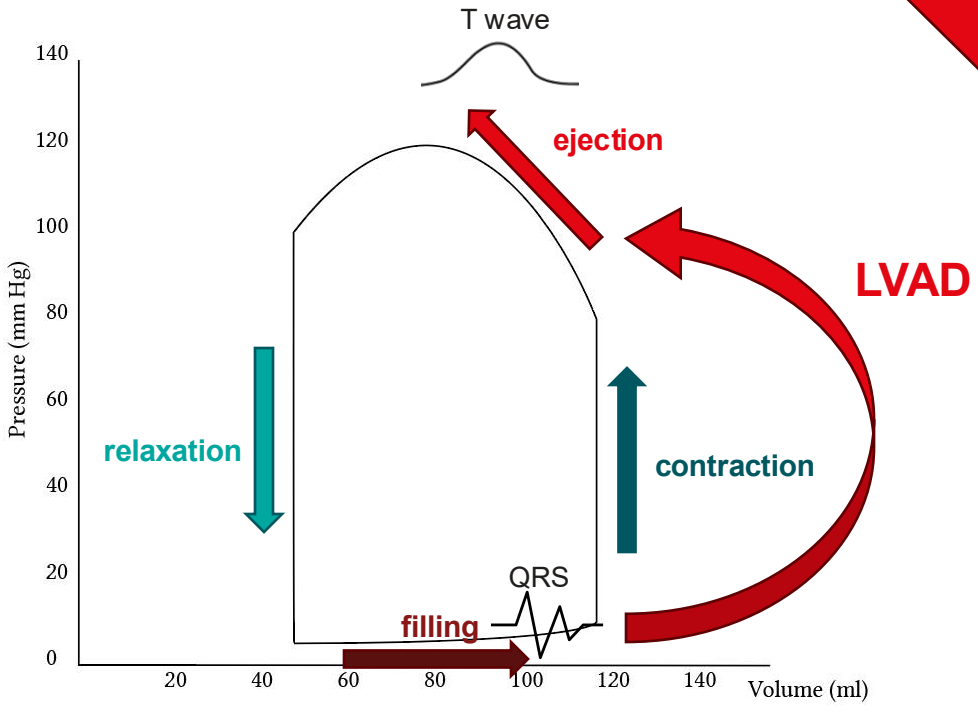
- Systemic Circulation vs Pulmonary Circulation
- Systemic = High Resistance

  → bigger Δp needed



The Heart Cycle





→ Aorta deformation creates a wave pressure and a pulsatile flow

In the case of LVAD

- Restore Cardiac Output (4–6 L/min).

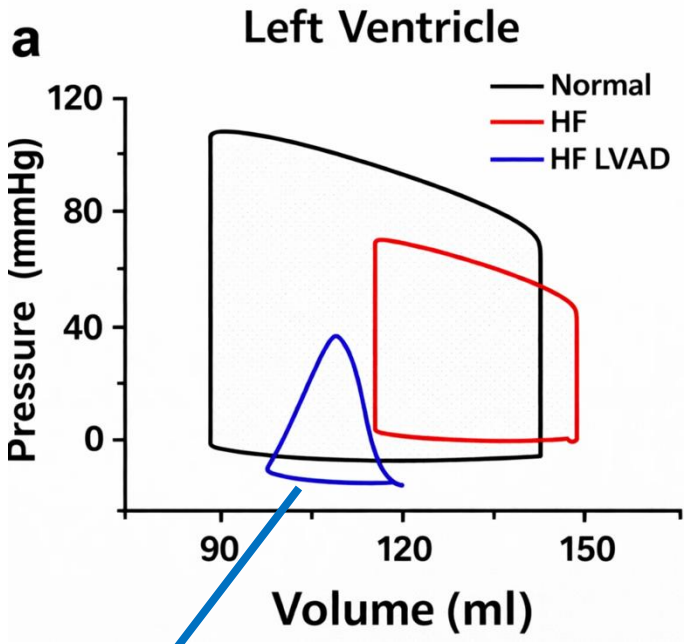
→ Unloads the LV → Reduces wall stress & oxygen demand

Measured Parameters:

- RPM (Speed)
- Power Consumption (Watts)

Calculated Parameters :

- Pulsatility Index (**PI**): How much native heart is contributing
- Flow (L/min)



Park et al., 2018, The effect of heart failure and left ventricular assist device treatment on right ventricular mechanics

This is inside the heart! Not inside the pump

History of the Different Types of Devices

- **Pulsatile Pumps (1st Gen):**

Tried to mimick nature, large, noisy and wore out quickly

- **Axial Flow Pumps (2nd Gen → HeartMate II):**

Propeller in a pipe. Smaller, but used mechanical bearings = friction

- **Centrifugal Flow (3rd Gen → HeartMate 3)**

Road map of LVADs

HeartMate IP (BTT)
1st Gen

Heartmate II
2nd Gen
1-year 72% survival rate

HeartMate 3 (DT)
FDA Approved

1994 — 2001 — 2009 — 2017 — 2019 — 2022

HeartMate VE (DT)
1st Gen
1-year 61% survival rate

HeartMate 3 (BTT)
3rd Gen
1-year 86% survival rate

99.8% Monopoly of HeartMate 3

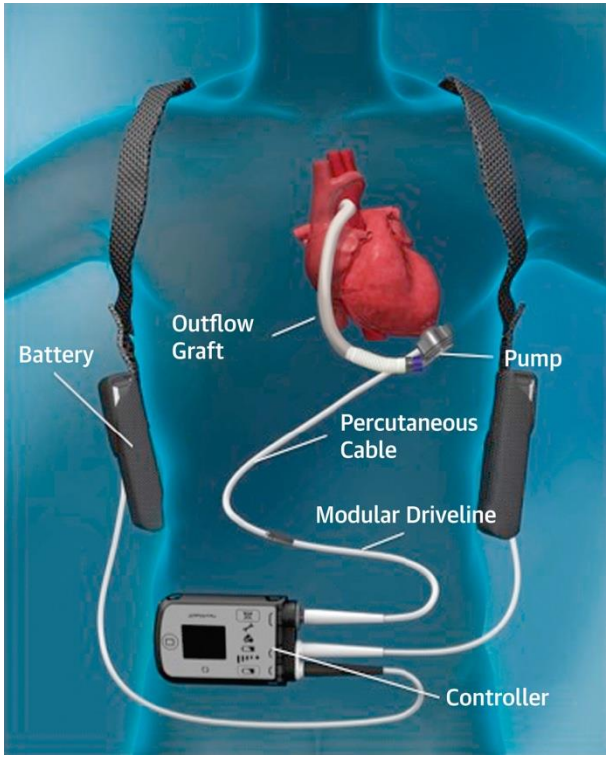
Modern LVAD

Flow Components

- Inflow Canula → inserted into LV apex
- Pump → creates Δp
- Outflow Graft → inserted into aorta

Other Components

- Driveline → delivers power, adjust pump speed, brings feedback data
- Controller → allows monitoring and adjusting
- Battery → Power Supply



Netuka et al., 2015, Fully Magnetically Levitated Left Ventricular Assist System for Treating Advanced

HeartMate 3

- **99.8%** of LVAD implanted in 2022
- Only one who uses MagLev™ Technology

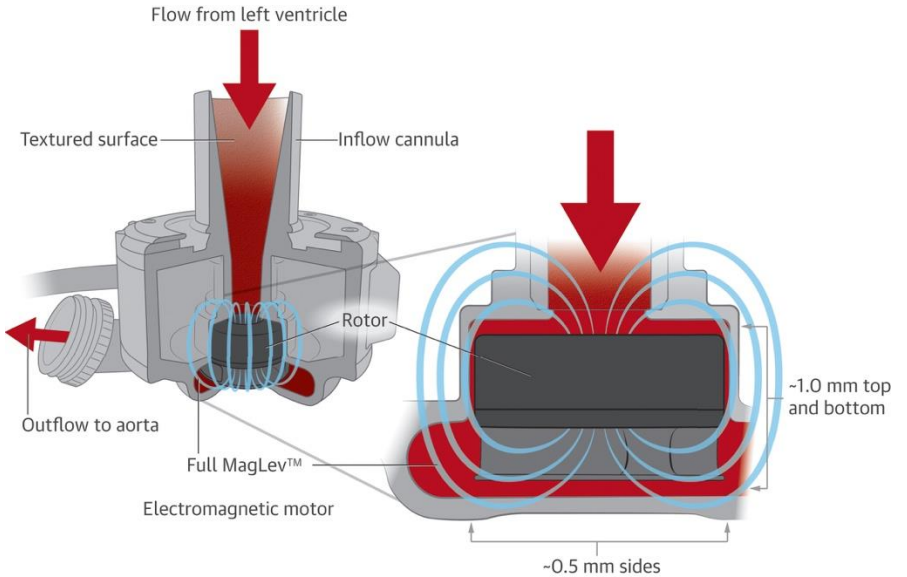
Specifications

- Weight: ~200g (implantable)
- Pump dimensions: ~50mm height x ~34mm thick
- Speed: 3’000 to 9’000 RPM
- Flow capacity: up to 10 L/min.
- Power: 5 Watts typically (low consumption)
- Mobility: 10 to 17 hours on battery power

How does the pump work

- MagLev™ Flow Technology
- **Rotor thar hovers in place** using magnets → no friction
- Centrifugal Force → Generates Δp
- Every 2 seconds, **the rotor slows**, then speeds back up.

  → anti-clotting feature



Why this design wins?

- Strong : can generate full CO (5-6 L/min)
- Gentle : Wide design minimises blood trauma
- Reliable : No parts rub together → built to last

Control, Repair and Measurements

Control

- Fixed Speed (RPM) with patient specific adjustements
- Artificial pulsatility algorithms to prevent clots (Slows & Restart)

Repair

- Pump non-repairable (only 2.3%)
- Driveline Infections (29.3%)

Measurements

- Speed, Power, Pulsatility Index (**PI**) and Flow

$$PI = \frac{Max(Power) - Min(Power)}{Mean(Power)}$$

or

$$PI = \frac{Max(Flow) - Min(Flow)}{Mean(Flow)}$$

Medical Significance Of Measurements

Safety Features

Low PI: Suction Alarms → Inlet sucking on the wall of LV → Slows rotor to let heart recover

High Power: Clot inside the pump causing friction

Low Flow:

- Obstructed inflow/outflow graft
- Hypovolemia (Dehydration / Blood loss)
- HF worsening

Clinical Application

Works for:

- Bridge to Transplant (BTT)

→ wait for a donor heart

- Destination Therapy (DT)

→ permanent transplant uneligible patients

- Rare case

→ the heart recovers and device is removed

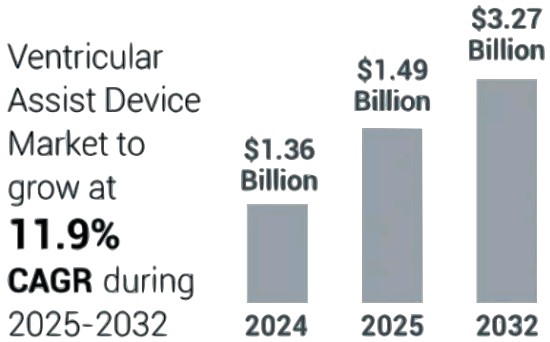
FDA: Class III Medical Device (Premarket approval needed)

Key Trial: MOMENTUM 3 which established MagLev superiority

The Product

Main Company : Abbott

Growing Market :



Average Revenue per Patient for implant stay

~$193k ± $111k

Average Revenue for inpatient readmissions

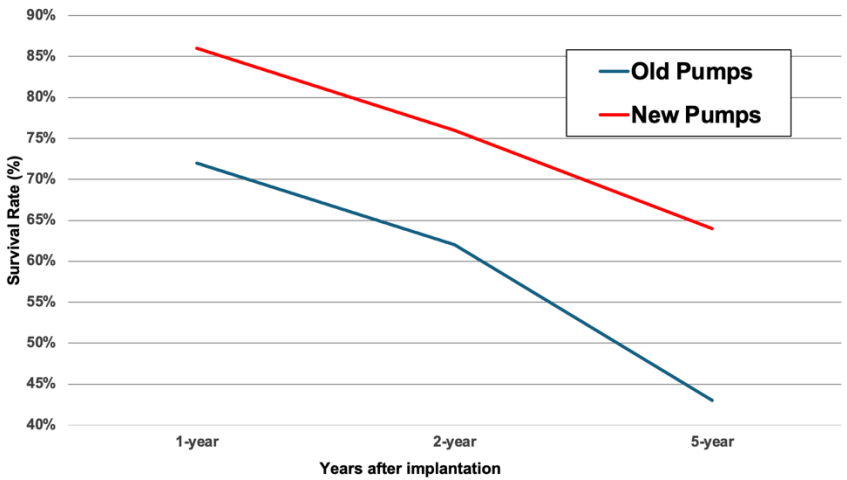
~$52k ± $116k

Average Revenue for outpatient care

~$53k ± $62k

Future Perspectives

Survival Rates :
→ Improved significantly with new technology



Improvements to be made :

- Reduce Driveline Infections

→ wireless charging through skin

- Miniaturize pumps

→ easier surgery procedure

Ultimate goal

→ invisible pump with no apparent cables

Thank you for listening
Q&A

References

- Jorde, U.P.; Saeed, O.; Koehl, D.; et al. The Society of Thoracic Surgeons Intermacs 2023 Annual Report: Focus on Magnetically Levitated Devices. *Ann. Thorac. Surg.* 2024, 117, 33-44
- Netuka I, Sood P, Pya Y, et al. Fully Magnetically Levitated Left Ventricular Assist System for Treating Advanced HF: A Multicenter Study. 2579–2589.
- Mehra, M. R., et al. A fully magnetically levitated left ventricular assist device — Final report. *New England Journal of Medicine* ***380**, 1618–1627 (2019).
- Koken ZO, Yalcin YC, van Netten D, de Bakker CC, van der Graaf M, Kervan U, Verkaik NJ, Caliskan K. Driveline exit-site care protocols in patients with left ventricular assist devices: a systematic review. Eur J Cardiothorac Surg. 2021 Sep 11;60(3):506-515. doi: 10.1093/ejcts/ezab195. PMID: 33963835; PMCID: PMC8434872.
- Welp H, Sindermann J, Dell'Aquila AM, Deschka H, Hoffmeier A, Scherer M. Economic aspects of long-term left ventricular assist device treatment for chronic heart failure. ESC Heart Fail. 2024 Oct;11(5):2849-2856. doi: 10.1002/ehf2.14774. Epub 2024 May 20. PMID: 38769653; PMCID: PMC11424323.
- Berardi C, Bravo CA, Li S, Khorsandi M, Keenan JE, Auld J, Rockom S, Beckman JA, Mahr C. The History of Durable Left Ventricular Assist Devices and Comparison of Outcomes: HeartWare, HeartMate II, HeartMate 3, and the Future of Mechanical Circulatory Support. J Clin Med. 2022 Apr 5;11(7):2022. doi: 10.3390/jcm11072022. PMID: 35407630; PMCID: PMC9000165.
- McNamara N, Narroway H, Williams M, Brookes J, Farag J, Cistulli D, Bannon P, Marasco S, Potapov E, Loforte A. Contemporary outcomes of continuous-flow left ventricular assist devices-a systematic review. Ann Cardiothorac Surg. 2021 Mar;10(2):186-208. doi: 10.21037/acs-2021-cfmcs-35. PMID: 33842214; PMCID: PMC8033255.

Websites Sources

- https://www.cardiovascular.abbott
- https://www.kansashealthsystem.com/care/treatments/ventricular-assist-device
- https://www.mayoclinic.org/tests-procedures/ventricular-assist-device/about/pac-20384529#:~:text=A%20left%20ventricular%20assist%20device,small%20opening%20in%20the%20skin.
- https://www.medicaldevice-network.com/projects/heartmate-iii-heart-pump/#:~:text=The%20HeartMate%203%20LVAD%20is,batteries%20to%20the%20system%20controller.
- https://myactioneducation.org/topic/heartmate-3/#:~:text=You%20must%20avoid%20being%20away,heart%20is%20available%20for%20transplant.
- FDA.gov
- https://healthcare.utah.edu/transplant/lvad-mcs/ventricular-assist-device-types
- https://www.fortunebusinessinsights.com/ventricular-assist-device-market-106377

Images Sources

- https://www.kansashealthsystem.com/care/treatments/ventricular-assist-device
- https://www.pinterest.com/pin/google-image-result-for-httpsimagestemplatenetwpcontentuploads201503freeblankhumanheartdia-in-2025--581246514366825552/
- https://derangedphysiology.com/main/cicm-primary-exam/cardiovascular-system/Chapter-029/ventricular-pressure-volume-loops
- https://www.mdpi.com/2313-7673/8/6/465
- https://www.cardiovascular.abbott

Supplementary Slides

Other treatments for Heart Failure

Compared Technique	LVAD Advantages	LVAD Disadvantages
Heart Transplant	Immediate Availability No need for anti-rejection drugs	External Equipment (cables…) Durability
Drugs/Pills	Better survival rates Better Quality of Life (exercise…) Organ Recovery (not only Heart)	Invasive Mobility (Batteries…)
Total Artificial Heart	Less Invasive Better Mobility (Smaller) Heart can recover (rare)	Can only support one ventricle
Palliative Care	Life extension You can live a normal life	End of life quality

Pulsatile Flow vs Continuous Flow

- Increased risk of **Gastro Intestinal Bleeding** (GI Bleeding)

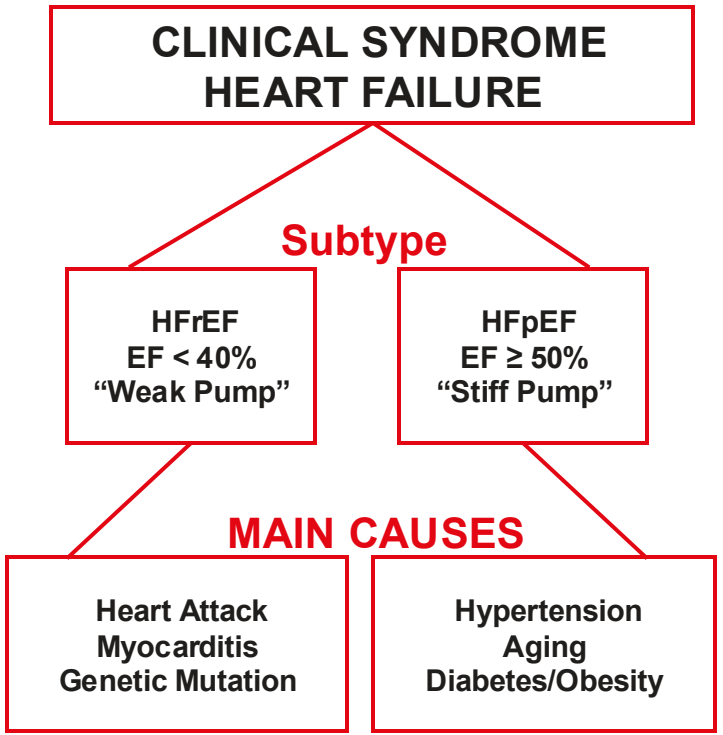
→ 35%

- Increased **Right Heart Failures** (RHF)

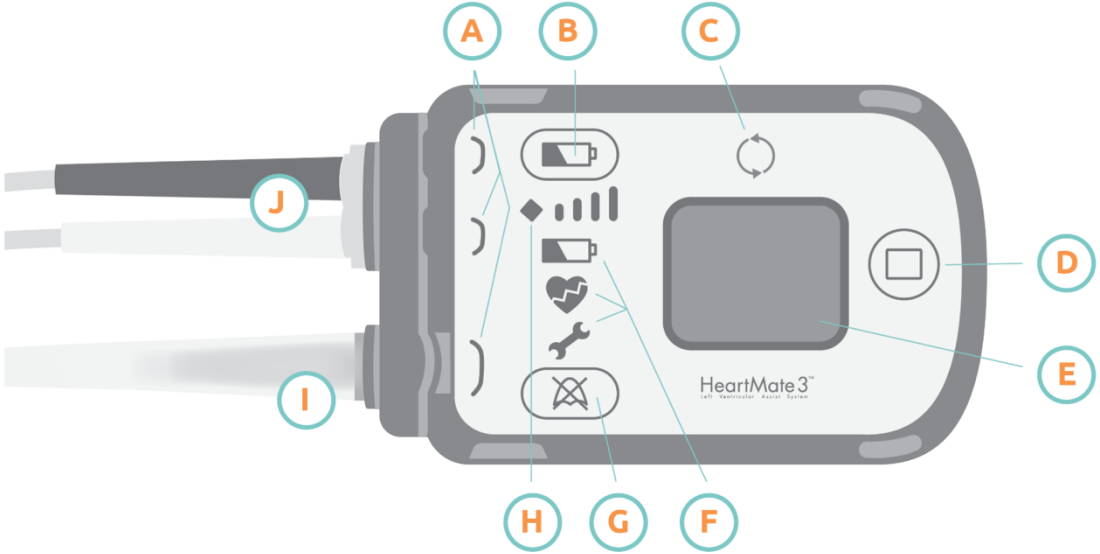
→ 40%

- Increased Neurological Events

Causes of HRr/pEF

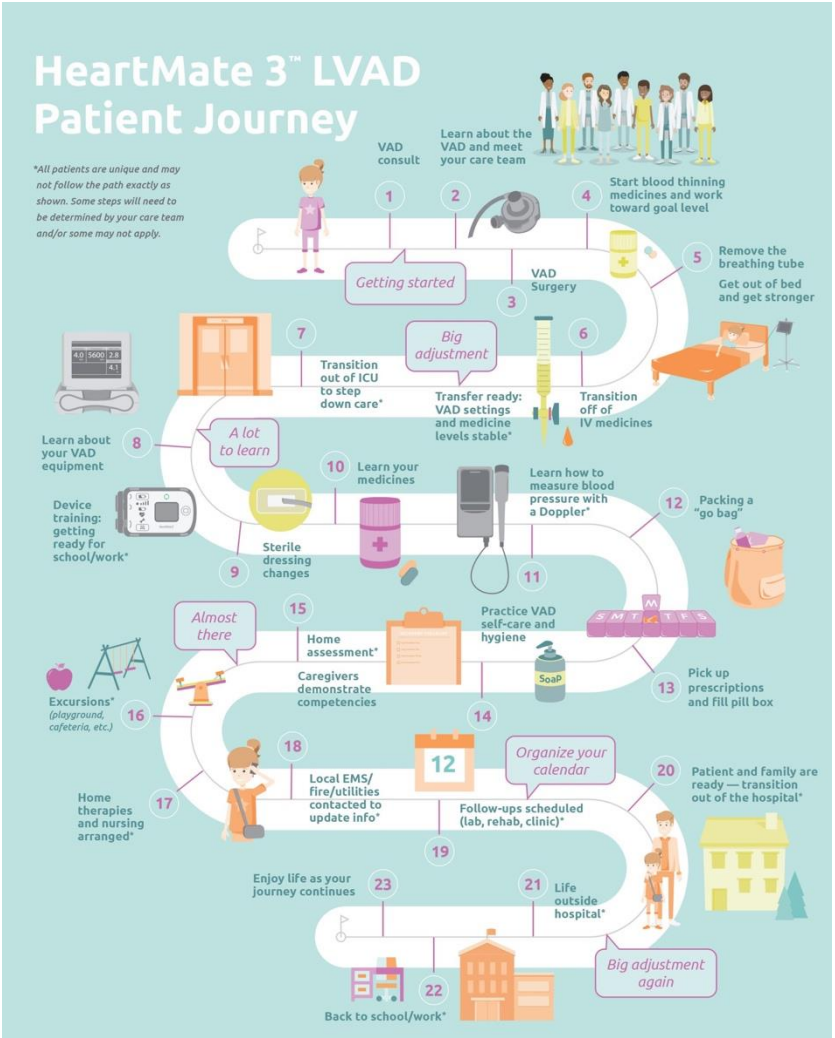


Control Unit



(A) Cable Disconnect Symbols
(B) Battery Button
(C) Pump Running Symbol
(D) Display Button
(E) User Interface Screen
(F) Alarm Symbols
(G) Silence Alarm Button
(H) Battery Status Symbol
(I) Driveline Connector
(J) Power Cable Connectors

LVAD Patient Journey



New Pump vs Old pump

ORIGINAL ARTICLE

A Fully Magnetically Levitated Left Ventricular Assist Device — Final Report

Authors: Mandeep R. Mehra, M.D., Nir Uriel, M.D., Yoshifumi Naka, M.D., Joseph C. Cleveland, Jr., M.D., Melana Yuzefpolskaya, M.D., Christopher T. Salerno, M.D., Mary N. Walsh, M.D., +33, for the MOMENTUM 3 Investigators* Author Info & Affiliations

Published March 17, 2019 | N Engl J Med 2019;380:1618-1627 | DOI: 10.1056/NEJMoa1900486 | VOL. 380 NO. 17

- HeartMate 3 (New) : 2.3% needed pump replacement
- HeartMate II (Old) : 11.3%