



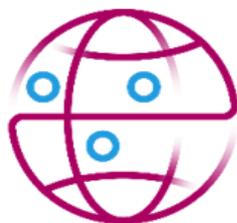
VAD COMORBIDITIES AND EFFECTS ON VAD PARAMETERS

Kimberly Vessels, APRN

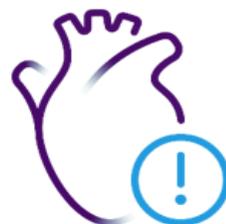
Norton Heart and Vascular Institute

Advanced Heart Failure and Myocardial Recovery

Heart failure is a serious disease with major implications



6.2 MILLION
people have
heart failure¹



APPROXIMATELY
600,000 PATIENTS
have advanced heart
failure (estimated 10%)²



24% INCREASE
in deaths contributed by
heart failure in recent
years (2011-2017)³

1. Virani SS, et al. *Circulation*. 2020.
2. American Heart Association. Accessed March 18, 2022. www.heart.org/en/health-topics/heart-failure/living-with-heart-failure-and-managing-advanced-hf/advanced-heart-failure
3. Sidney S, et al. *JAMA Cardiol*. 2019.

Identify if patient is in the “golden window” to be evaluated by an advanced heart failure center¹

A SCIENTIFIC STATEMENT FROM THE AMERICAN HEART ASSOCIATION

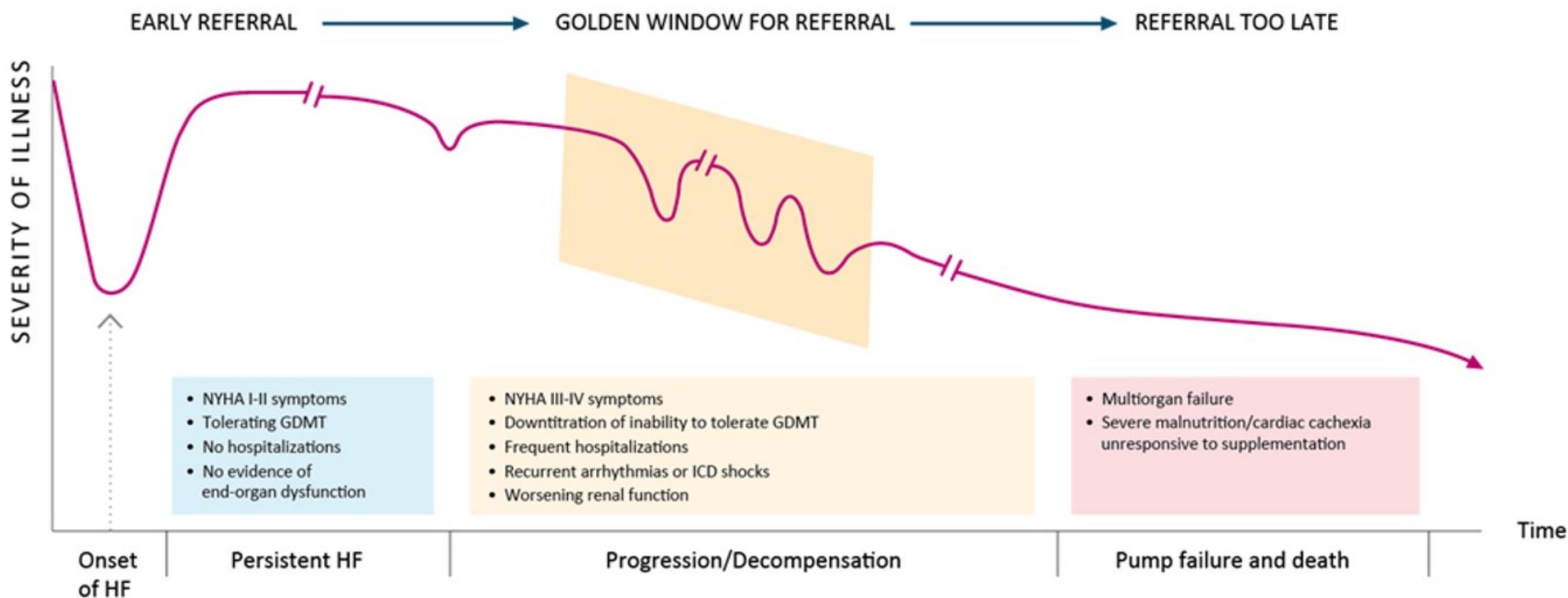


Figure adapted from Morris AA, et al. *Circulation*. 2021.

1. Morris AA, et al. *Circulation*. 2021.

CURRENT VAD PRACTICES

Medtronic HVAD

Ongoing support

FDA removed indication June
3, 2021



Abbott HeartMate II

Heartmate II to HeartMate II
exchanges continue



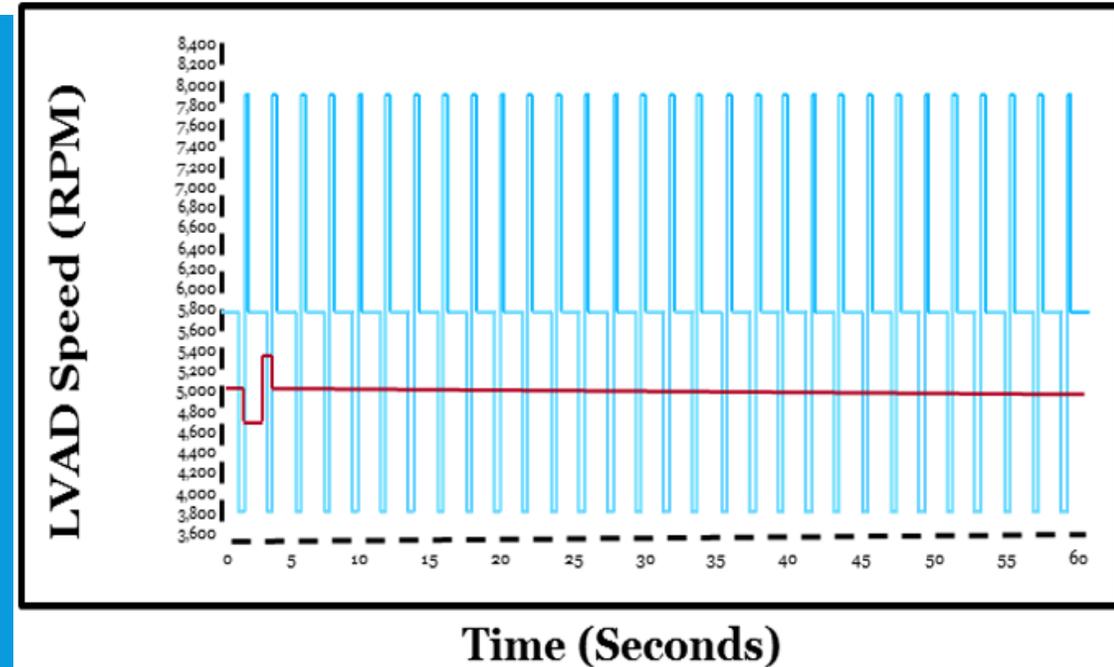
Abbott HeartMate 3

Most centers implanting



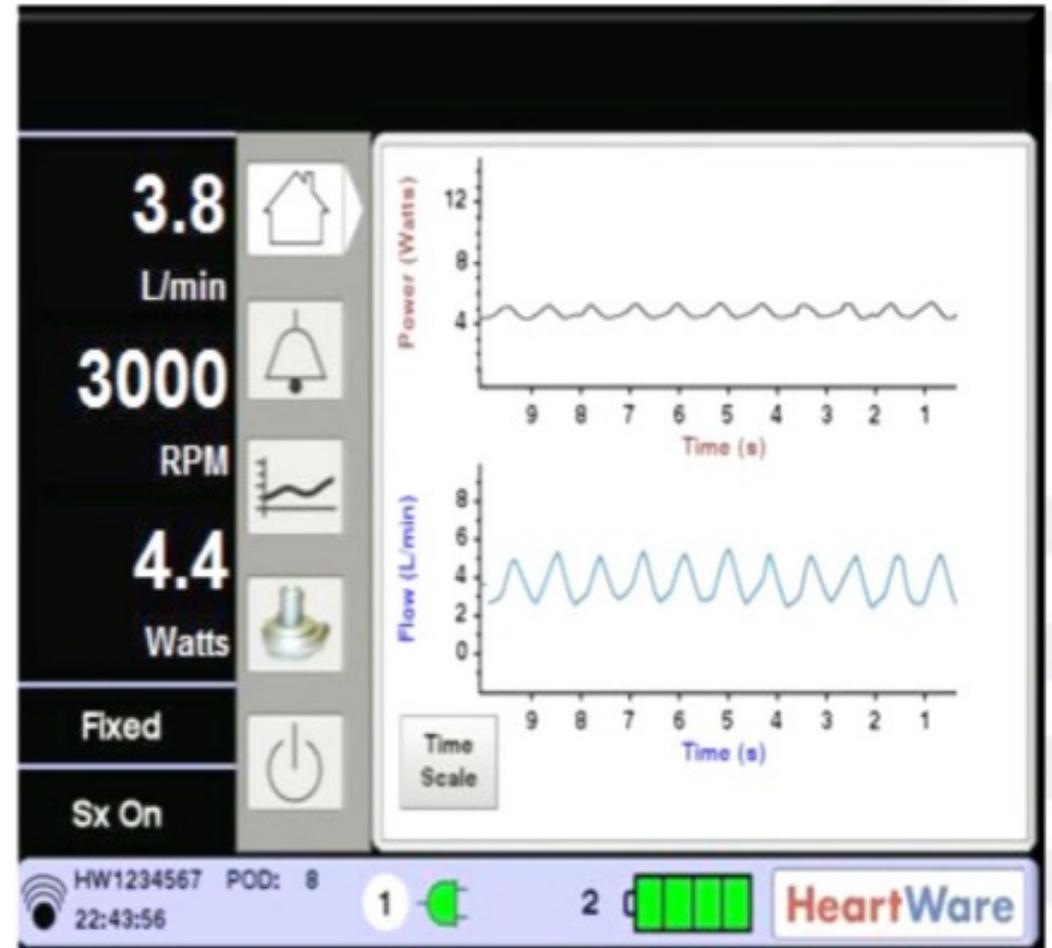
IMPROVEMENTS

- Fully levitated, self-centering rotor
 - No bearings
- Large, consistent blood flow pathways to reduce shear stress
- Intrinsic pulsatility
 - Reduce stasis, minimize thrombus



Pulsatility cycles 30 times per minute without compromising total net outflow.
HVAD Lavare cycle shown in red for comparison³.

PUMP PARAMETERS



PARAMETERS



Speed

Flow

Power

Pulsatility

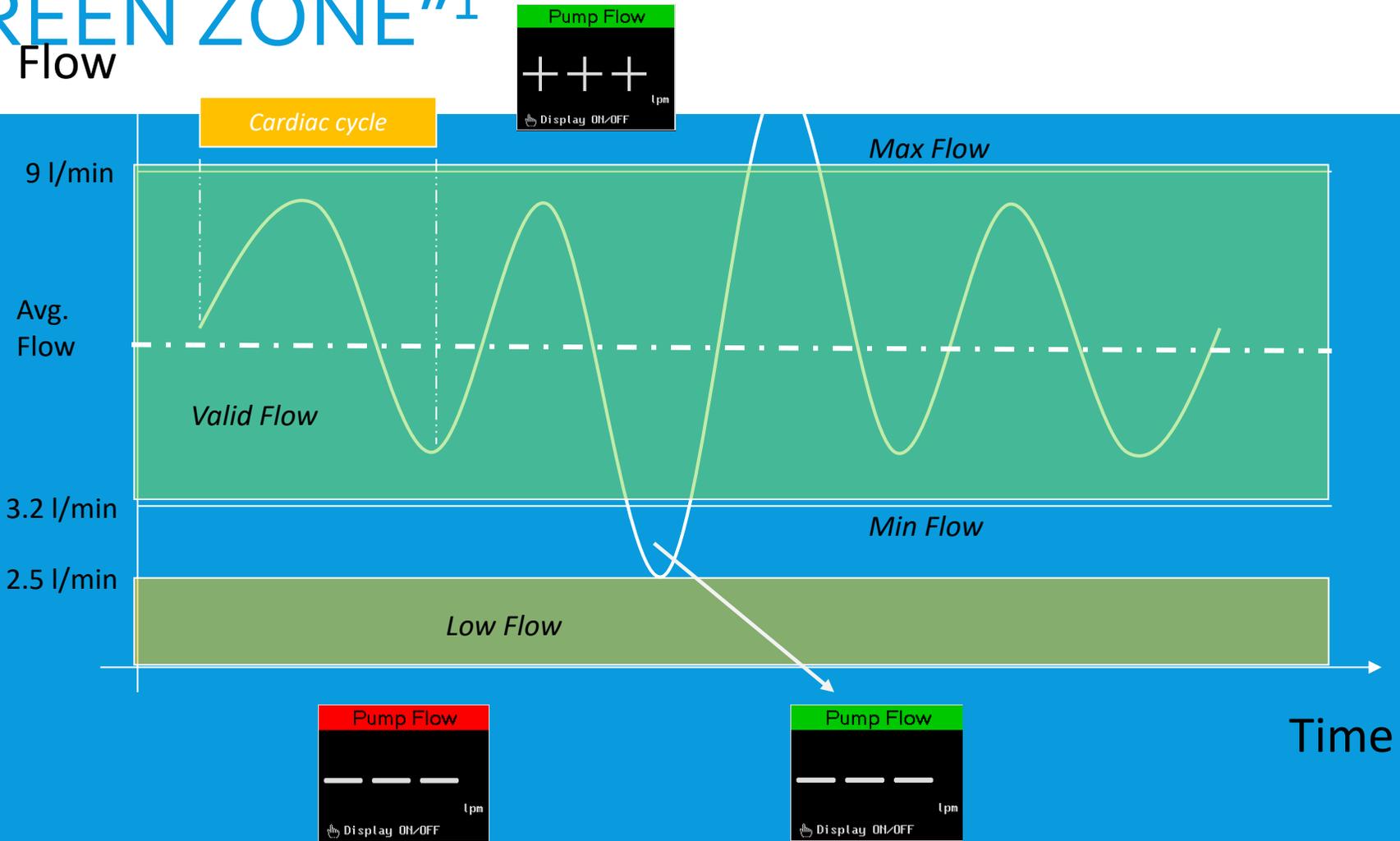
SPEED

- Only parameter to adjust
-  speed -> impeller spins more rapidly -> greater volume of blood displaced
- HVAD-~2400-3200 rpm
- HeartMate 2 ~ 8000-10,000 rpm
- HeartMate 3 ~ 5000-6000 rpm

FLOW

- VAD can provide up to 10L per minute of VAD flow
- The flow is an estimate. More accurate in HeartWare and HeartMate 3. Uses viscosity to determine flow
- Estimate based on power
- Normal value 3-7lpm

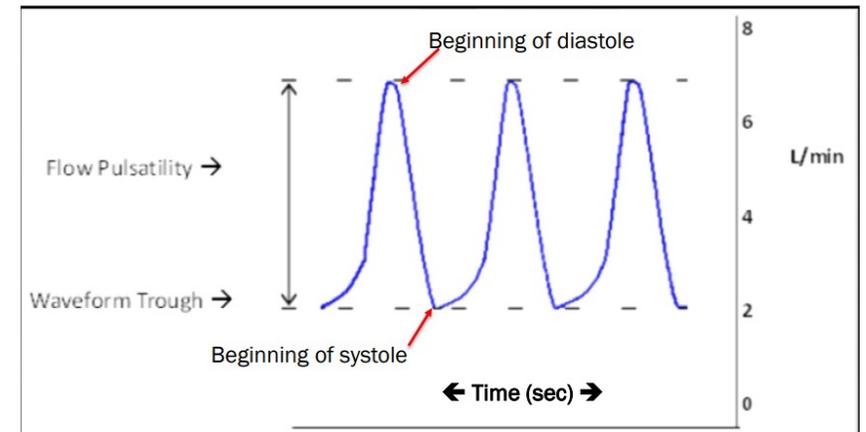
HEARTMATE II™ LVAD FLOW ESTIMATOR – “GREEN ZONE”¹



1. HeartMate 3 LVAS IFU 10006135.B: Introduction: Explanation of Parameters

PULSATILITY

- HeartMate 2/3-pulsatility index
 - The magnitude of flow pulses through the pump are measured and averaged over 15-second intervals to produce a “Pulsatility Index.”
- The PI attempts to convey the degree of pump power variability, representing pump flow variability and ultimately native heart contractility.
 - Normal value 3-7
- HeartWare-waveforms

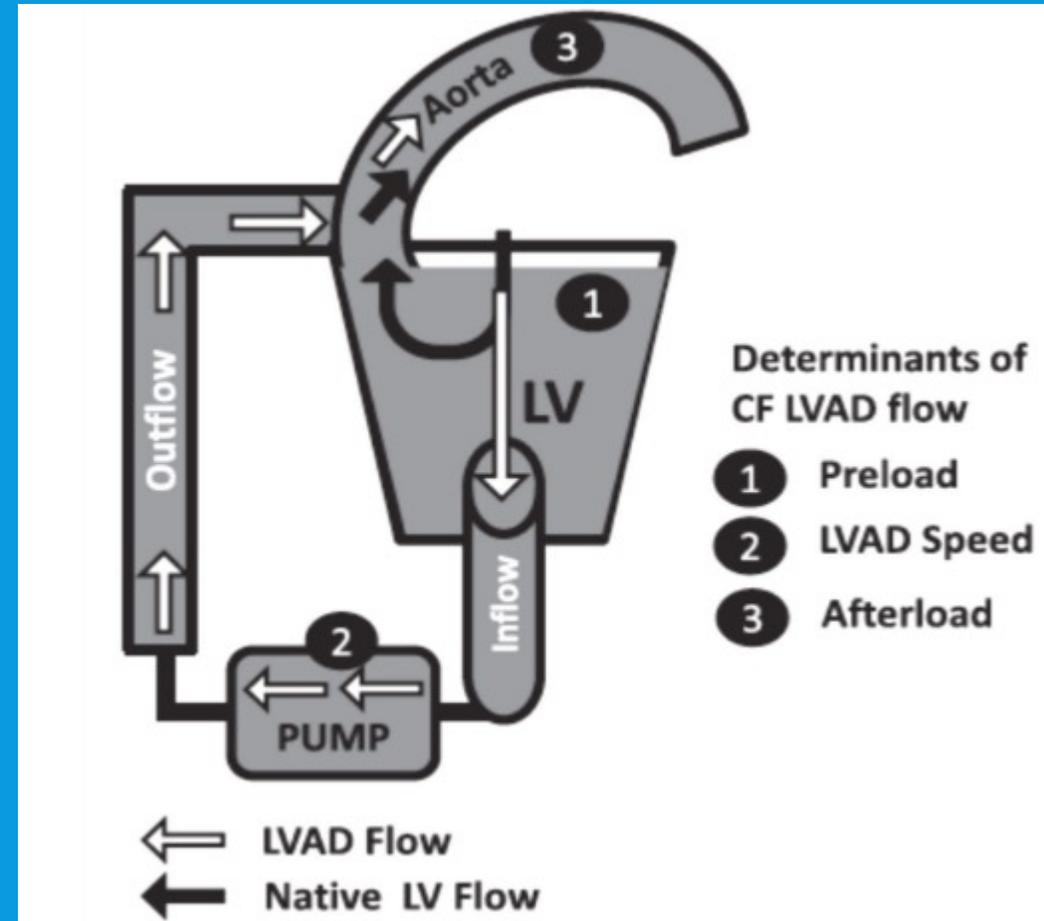


POWER

- Measured in watts
- Amount of power to run the rotor, not battery power

Basic VAD Management

- ALL VADs are:
 - Preload-dependent
 - EKG-independent
 - Afterload-sensitive
 - Anticoagulated
 - Susceptible to:
 - infection
 - bleeding
 - thrombosis/stroke
 - Right heart failure
 - mechanical malfunction



MOST COMMON COMPLICATIONS

- GI bleed
- Stroke
- Driveline infection
- Thrombosis
- Arrhythmias
- Right Heart Failure
- HTN
- Aortic insufficiency

PRE LOAD COMORDITIES

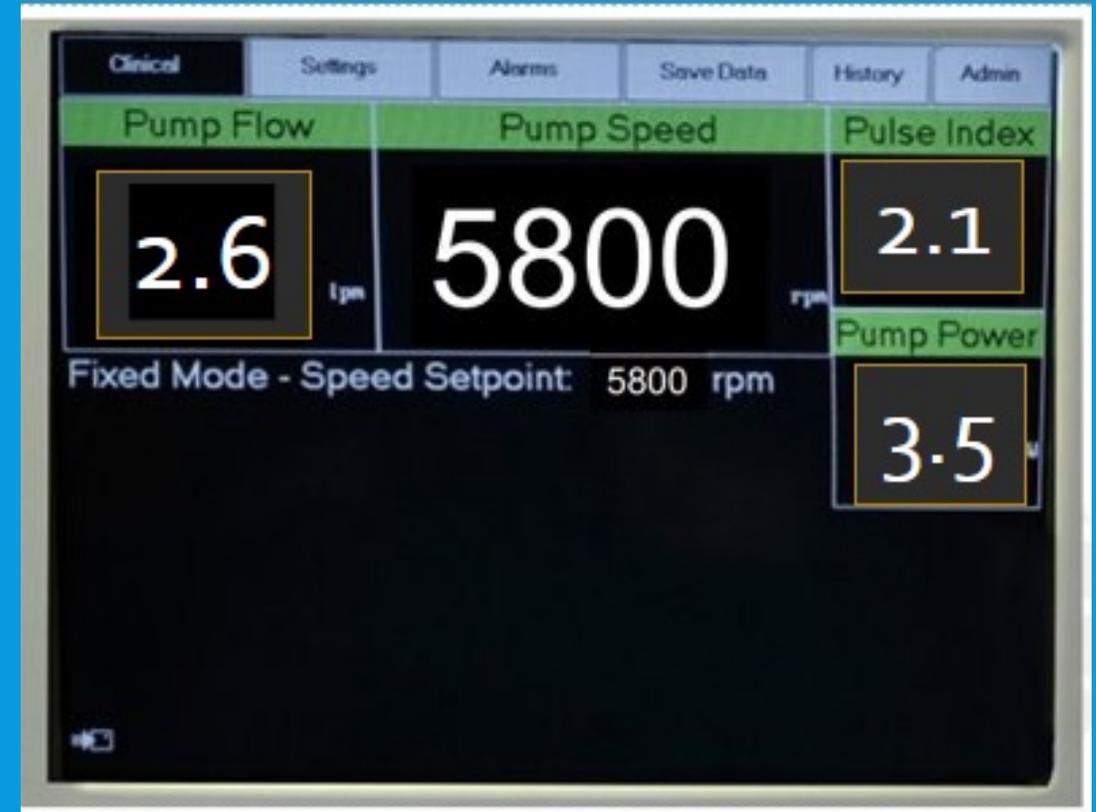
- Hypovolemia
 - Bleeding
 - Infection
- RV failure
- Ventricular arrhythmias
- Too high of pump speed
 - Ventricular collapse

- Decrease in Flow
- Decrease in pulsatility



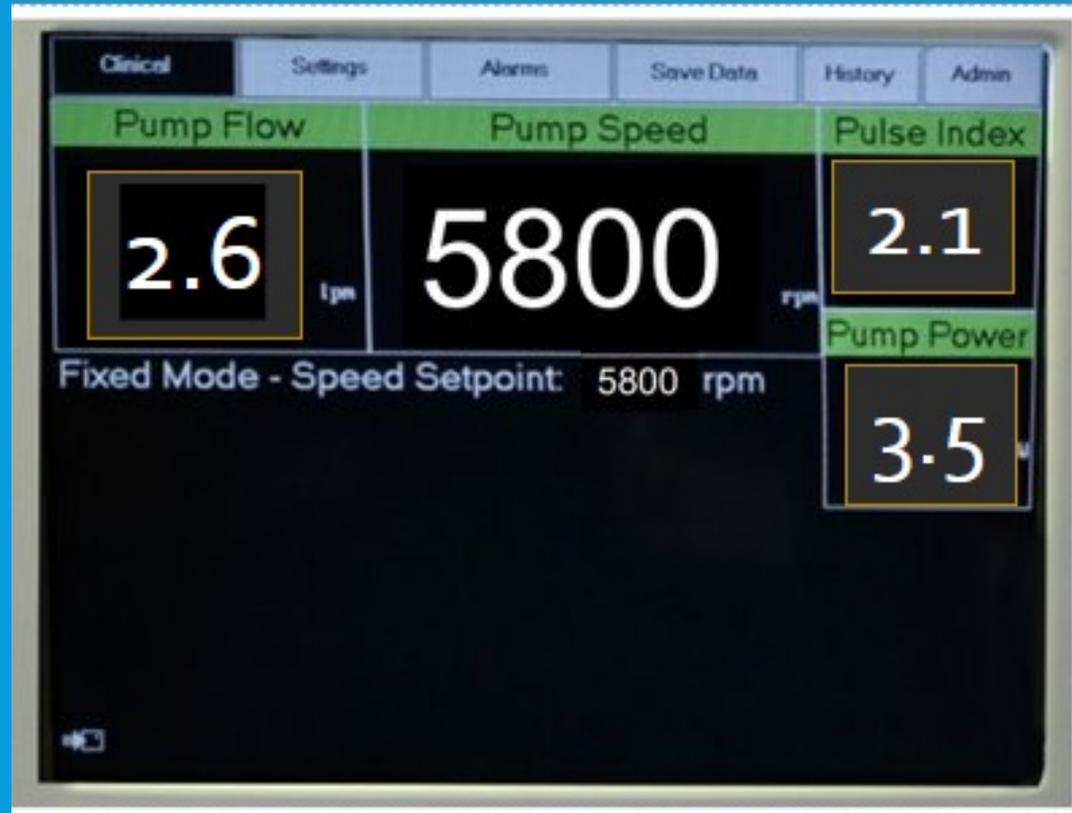
HYPOVOLEMIA VS RIGHT HEART FAILURE

- Labs
- CVP
- Echo
- Add inotropes
- Decrease speed—allow the ventricle to fill
- Mechanical RV support-add IABP



ARRHYTHMIAS

- If awake
 - Treat rhythm
- Unstable
 - DCCV



AFTERLOAD COMORBIDITIES

- Hypertension
- Aortic insufficiency

- Both resulting in different parameters

AFTERLOAD COMORBIDITIES

HYPERTENSION

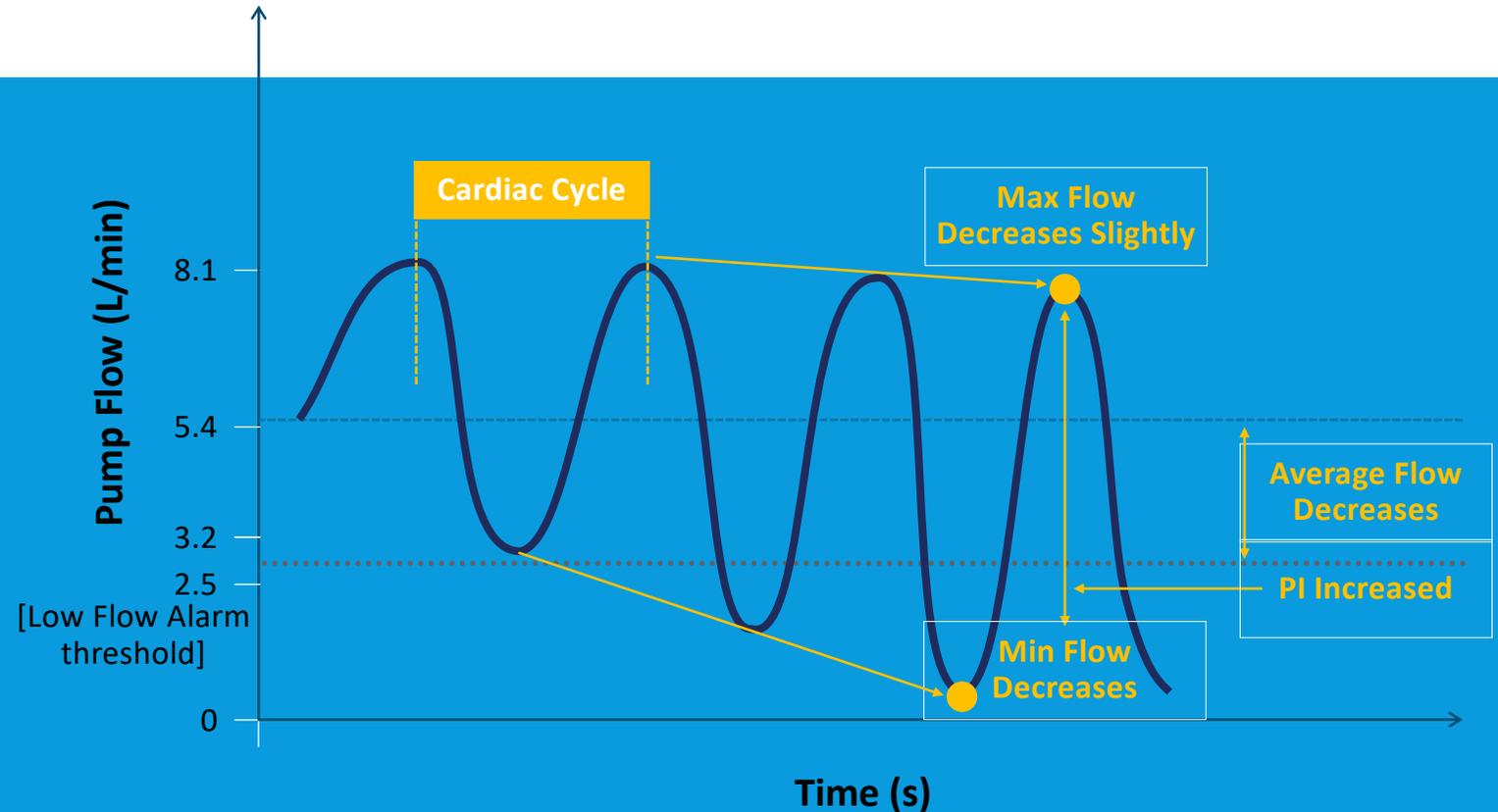
- Hypertension

Hypertension **increases afterload**, reducing pump flow during diastole

- Pump cannot push against high pressure
- Similar result of newly diagnosed patients with low EF
- Decreased flow
- Increased pulsatility

HEARTMATE 3™ LVAD PI RESPONSE — HYPERTENSION¹

In hypertension, **min and AVG flow decrease** resulting in low flow and high PI (>10)
Similar to Hypovolemia (decreased LVP)

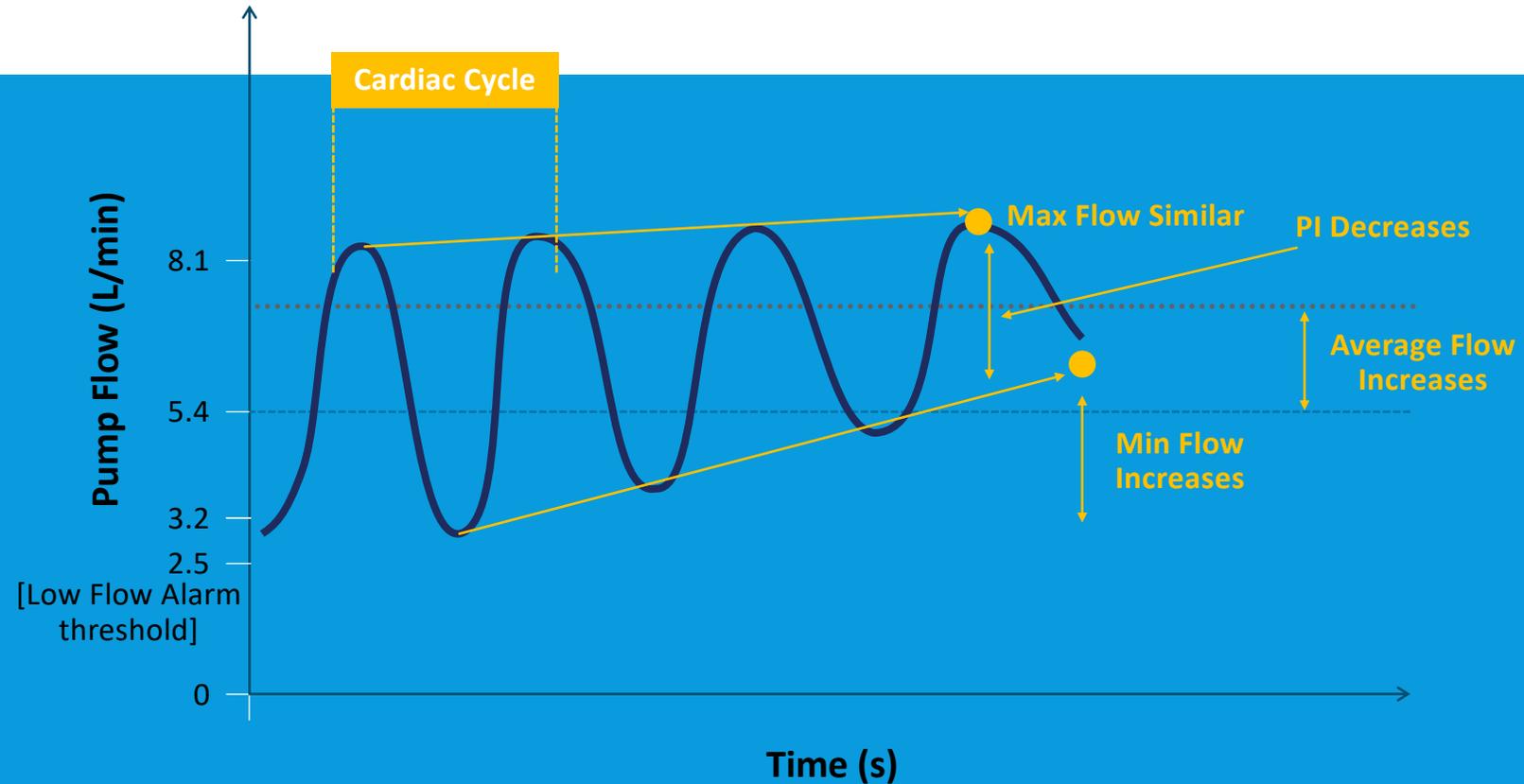


1. HeartMate 3 LVAS IFU 10006135.B Introduction Principles of Operation

AORTIC INSUFFICIENCY

Estimated Flows appear generally higher for a given speed **LVP** increased, Afterload decreased = increased flows

Generally low PIs (1.5-2.5)



HEARTMATE 3™ LVAD CLINICAL SCENARIOS — TAMPONADE¹

In tamponade, ventricular filling is restricted, reducing LV volume

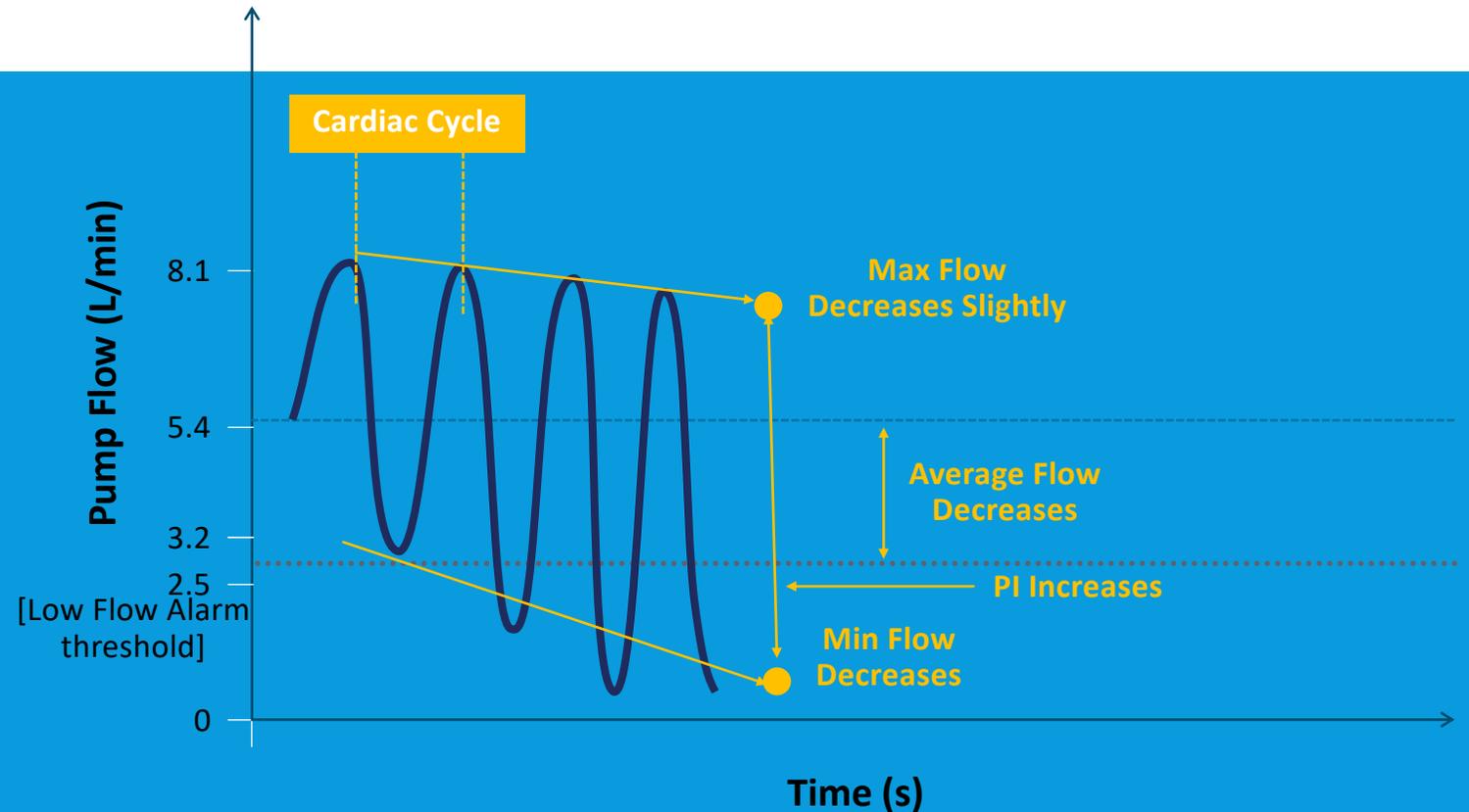
Late tamponade could result in reduced PI if the LV remains patent but non-contractile

Parameter		HM3 Behavior
Estimated Flow		Reduced
PI		Increased

1. HeartMate 3 LVAS IFU 10006135.B Introduction Principles of Operation

HEARTMATE 3™ LVAD CLINICAL SCENARIOS — TAMPONADE¹

In tamponade, both average and minimum flow decrease, initially PI increases



1. HeartMate 3 LVAS IFU 10006135.B Introduction Principles of Operation

PI EVENT-HEARTMATE 2/3

- If Per-Second PI and Average PI differ by >45%, a PI event is triggered.
 - PI events can be driven by changes in both $Power_{max}$ or $Power_{min}$.
- When a PI event is triggered:
 - Pump speed drops to the “low speed limit”.
 - Pump speed ramps back up to set speed in 50 rpm increments unless another PI event is detected.
 - Cycle repeats as long as PI events are detected.
 - Large changes in speed may indicate an abnormal condition that should be evaluated for cause.

EXAMPLES OF TRIGGERS OF PI EVENTS:

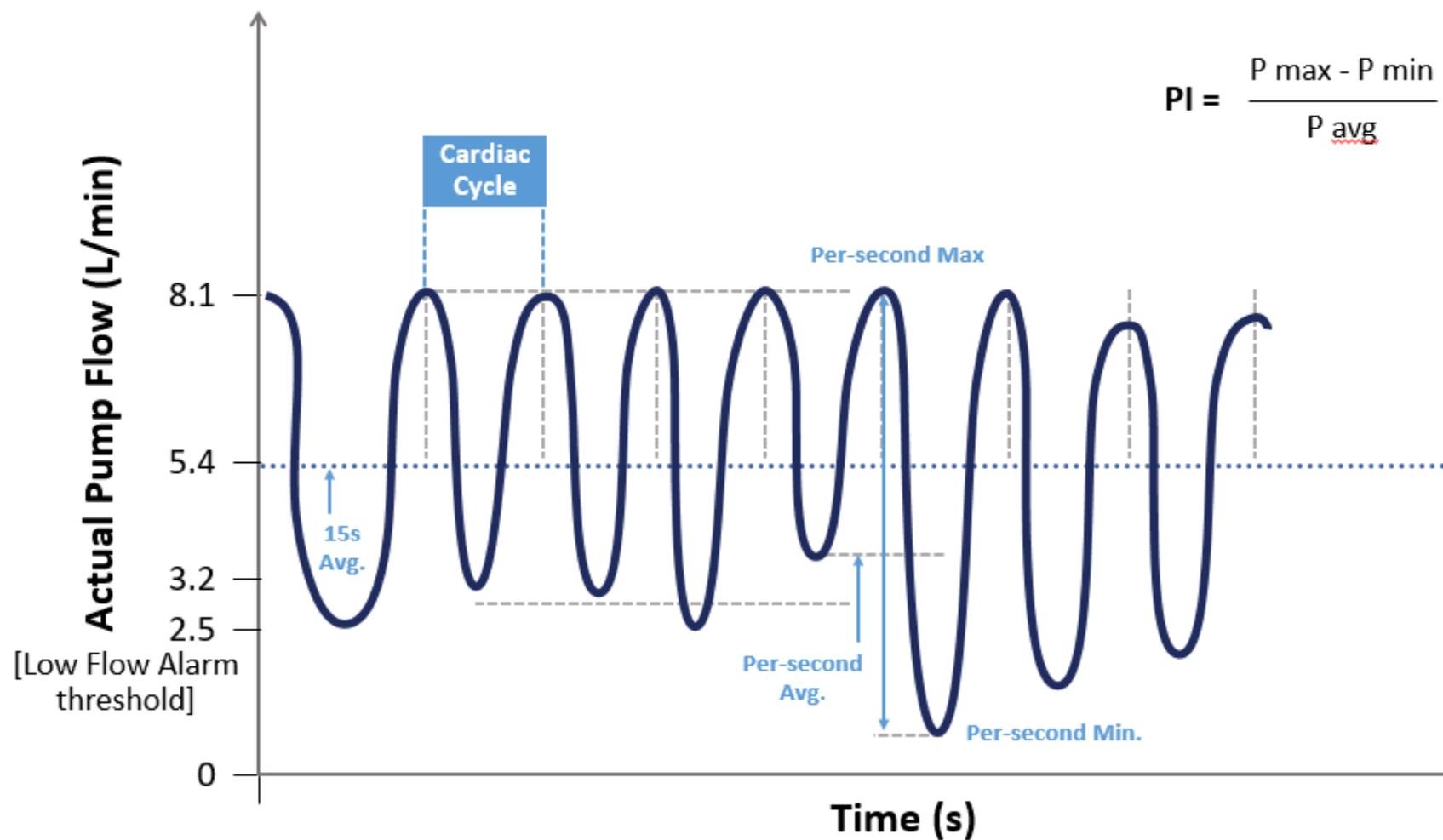
- Sudden changes in a patient’s volume status
- Arrhythmias, Atrial Fibrillation
- Sudden changes in power or pump speed
- Ventricular suction
- Coughing/sneezing
- Beat-to-beat variations in left ventricular volume
- IABPs

Remember, most PI events are not suction events.

HEARTMATE 3™ LVAD PI EVENTS¹

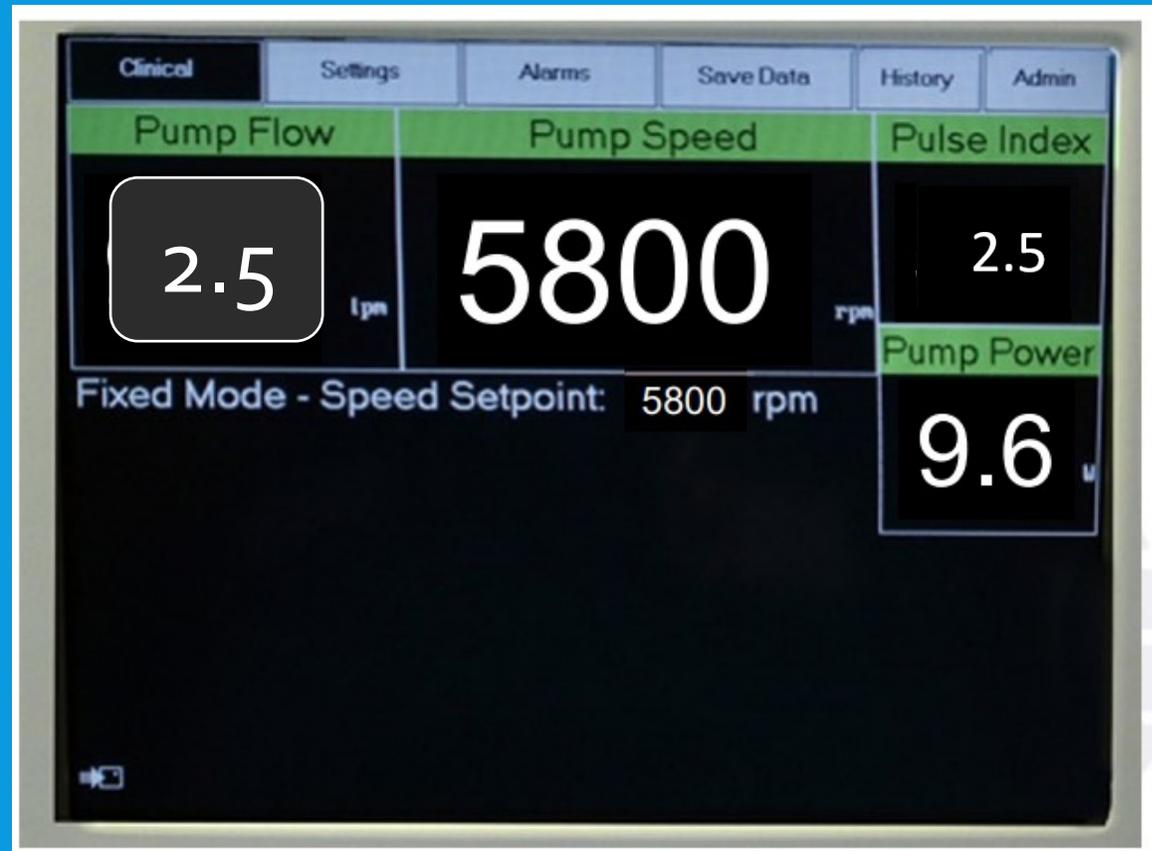
PI event triggers when per-second PI differs from 15-s average by 45%

Highly variable diastolic flow can trigger PI events



PUMP THROMBOSIS

- Increased Power-always great to review trends
- Decrease flow and PI
- Hemolysis
- LDH

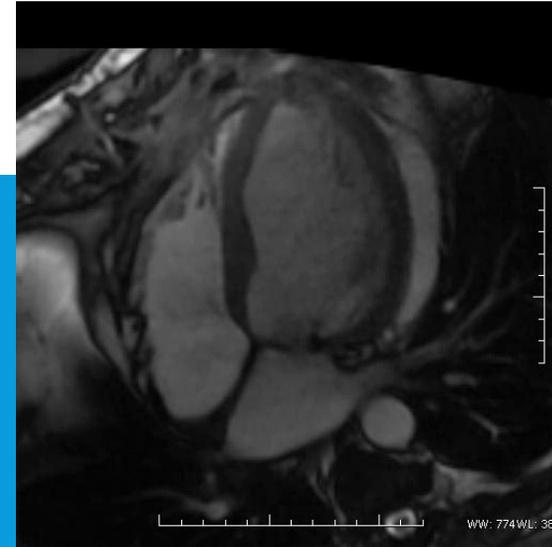
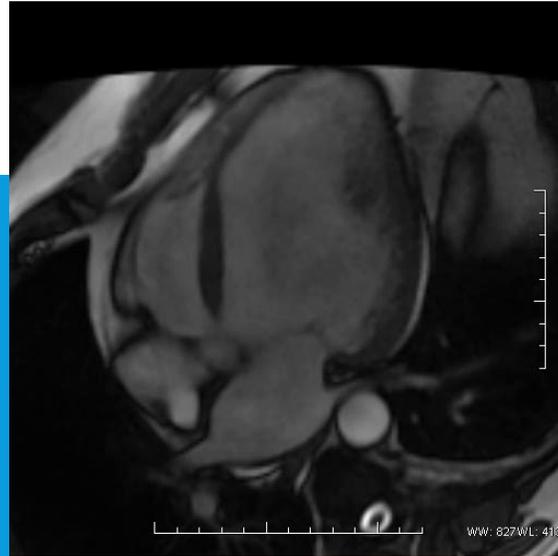


RECOVERY

LVEDD
8.0

EDV 505

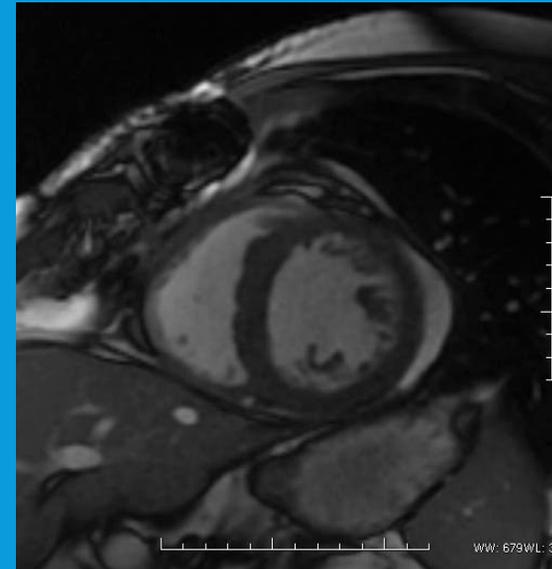
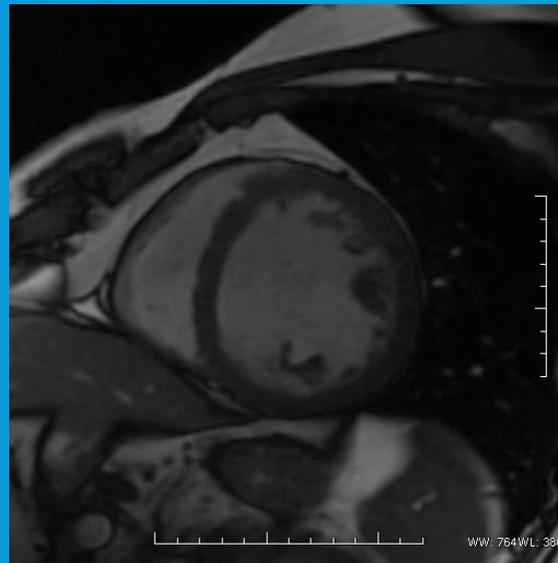
EF 15%



LVEDD
6.2

EDV 268

EF 35%



Despite looking at VAD
parameters, always treat the
patient and not the pump

CASE STUDY

- 60 year old male – 3 months post operative HM3
 - Presents to clinic with complaints of dizziness
 - VAD speed 5600
 - Flow 2.6 (normal 3.5-7)
 - PI 1.7
 - Power 3.4
 - Concerns?
- Same patient presents 2 months later to clinic with low flow alarms
 - VAD speed 5600
 - Flow 2.5
 - PI 9.5 (normal 3-7)
 - Power 3.6
 - MAP 120
 - Concerns?

HEARTMATE 3™ LVAD TROUBLESHOOTING¹

HeartMate 3™ LEFT VENTRICULAR ASSIST SYSTEM

PARAMETER	SIGNIFICANCE OF CHANGES
Pump Rotor Speed	<ul style="list-style-type: none"> • Pump operates at speed setpoint with a periodic artificial pulse (every 2 seconds). • Large speed changes could mean: <ul style="list-style-type: none"> –PI event recently occurred. –Abnormal condition: failure of the system.
Power	<ul style="list-style-type: none"> • Varies directly with pump speed and flow. • Slight increase over postoperative period may indicate cardiac recovery. • Abrupt changes may indicate thrombus issues or flow obstruction or VT event.
Flow	<ul style="list-style-type: none"> • Estimated flow through the pump may change due to patient conditions or device operation. • Abnormal rotor drive power elevation may result in overestimation of flow.
Pulsatility Index (PI)	<ul style="list-style-type: none"> • Corresponds to the magnitude of the native pulse wave through the pump (does not include contribution from artificial pulse). • Varies with the volume status of the left ventricle. • Increase in PI and decrease in flow may indicate transiently evacuated LV (i.e., at the end of systole). • Slight increase in PI and flow over postoperative period may indicate cardiac recovery. • PI decreases in case of inflow/outflow obstruction.

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