Dlouhodobé mechanické srdeční podpory

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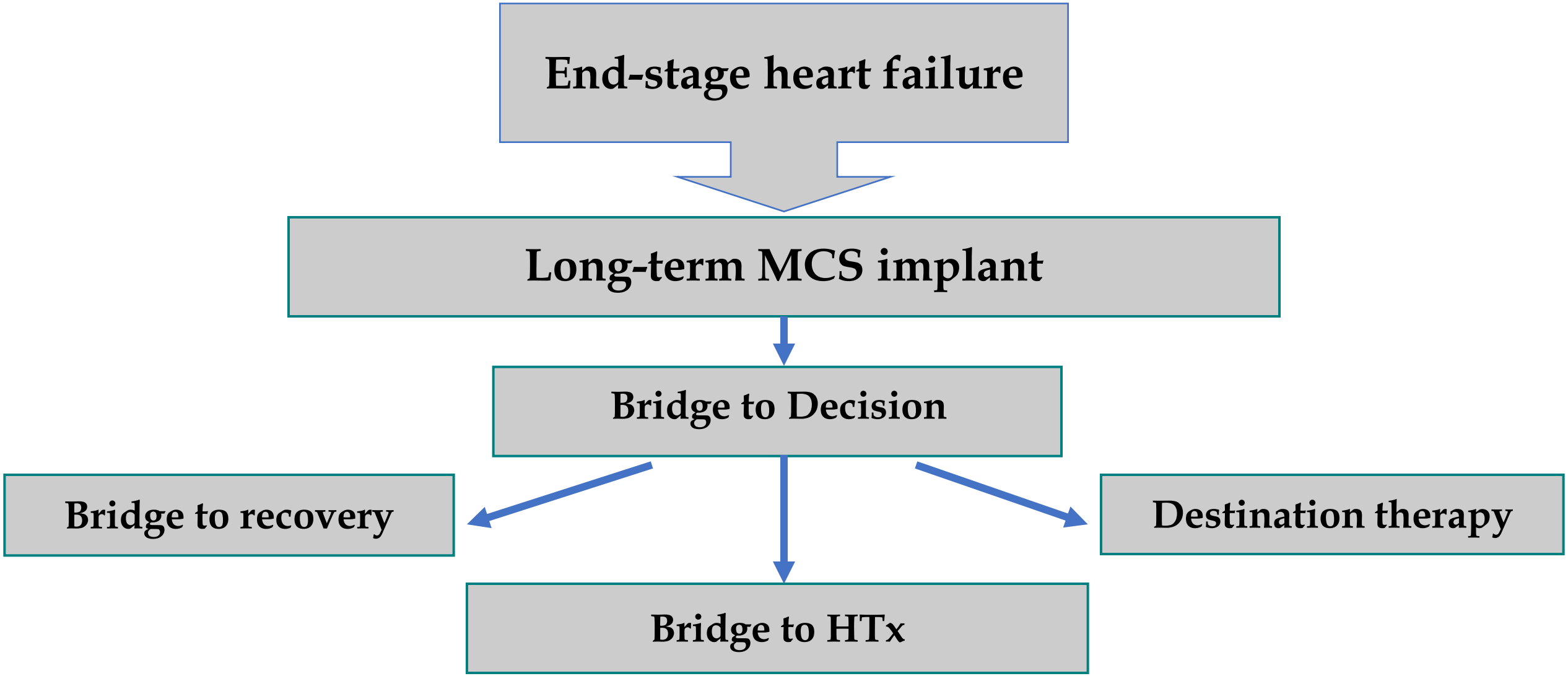
Objectives

- Indications and evolution of the technology
- Advancing surgical strategies
- Contemporary outcomes and survival
- Residual challenges and novel trends in MCS therapy

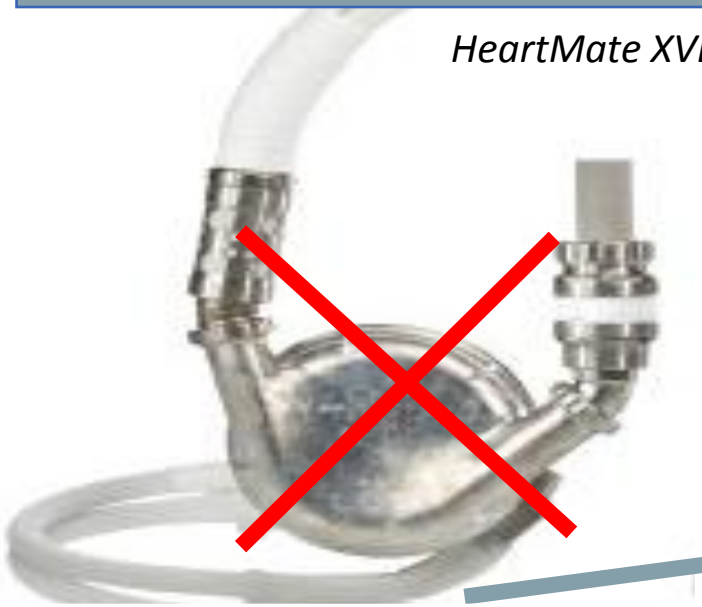
Designation and patients trajectory on durable MCS



Technological evolution of MCS systems

Pulsatile Technology

HeartMate XVE

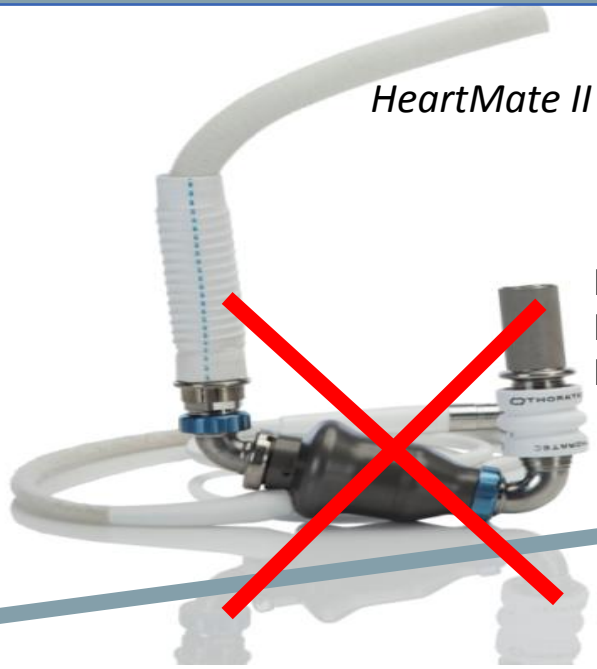


FDA Approved
BTT 1998
DT 2002

Pusher plate &
Inflow and outflow valve

Continuous Flow Technology: Axial Design

HeartMate II

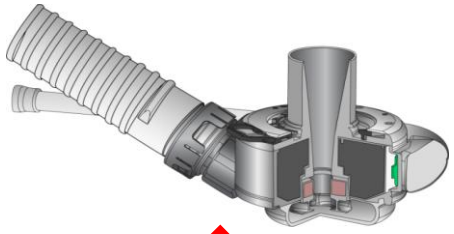


FDA Approved
BTT 2008
DT 2010

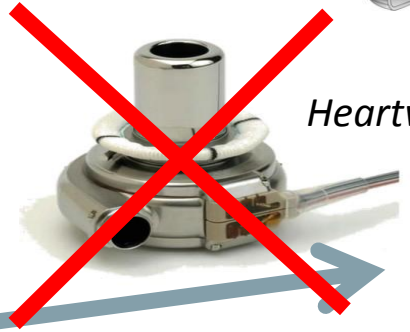
Rotor with bearings

Continuous Flow Technology: Centrifugal Design

HeartMate 3

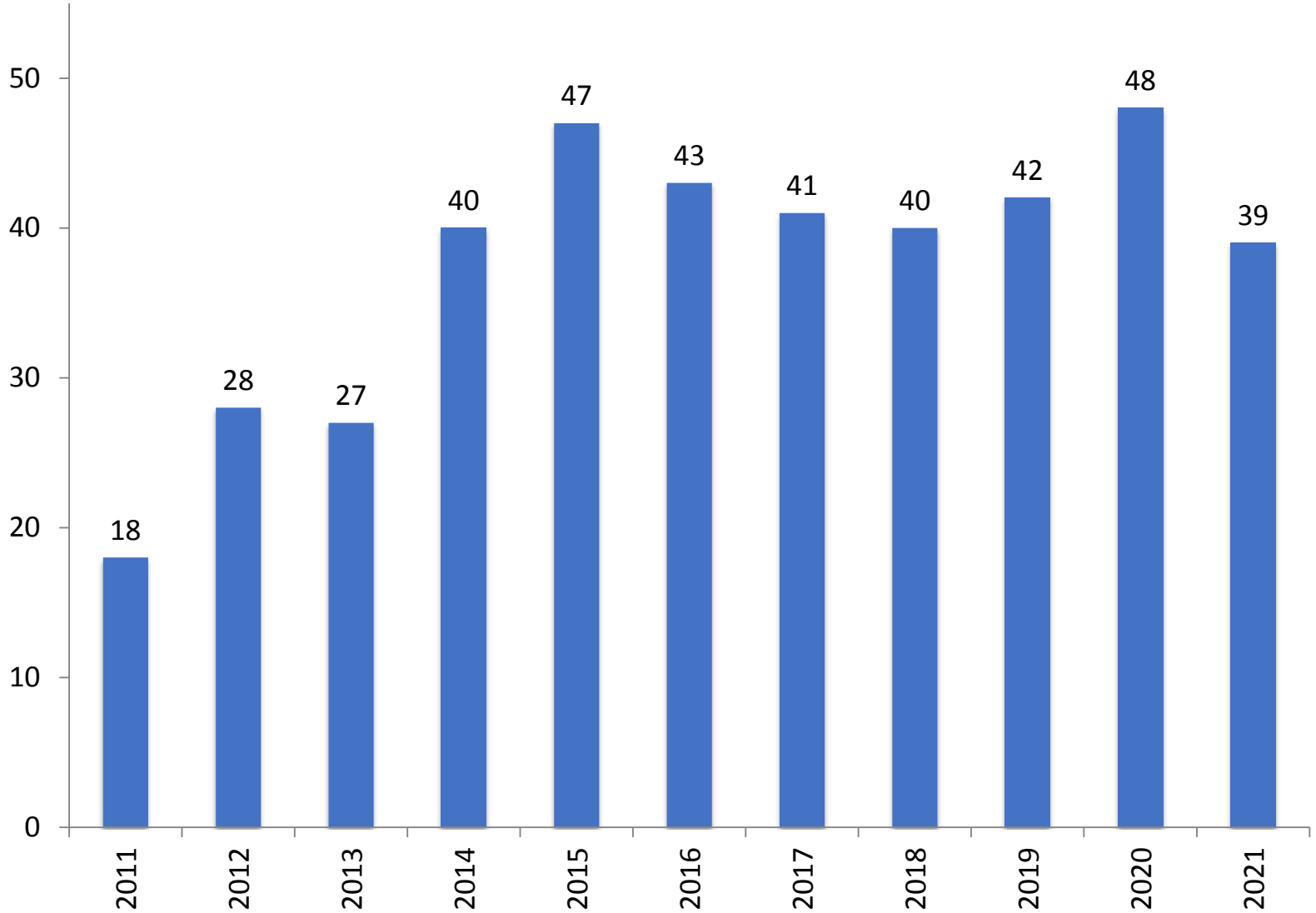


Heartware HVAD

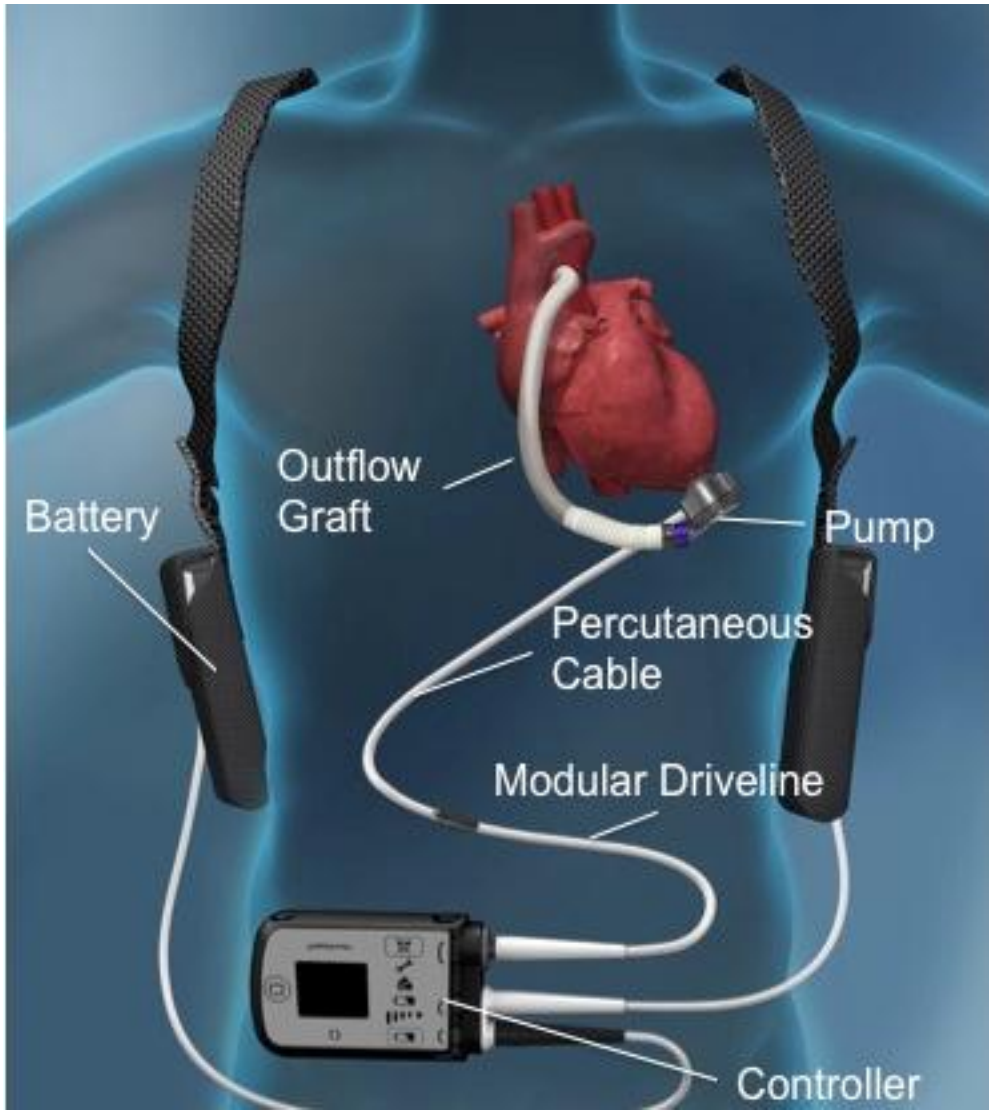


Bearingless rotor with
Magnetic Levitation

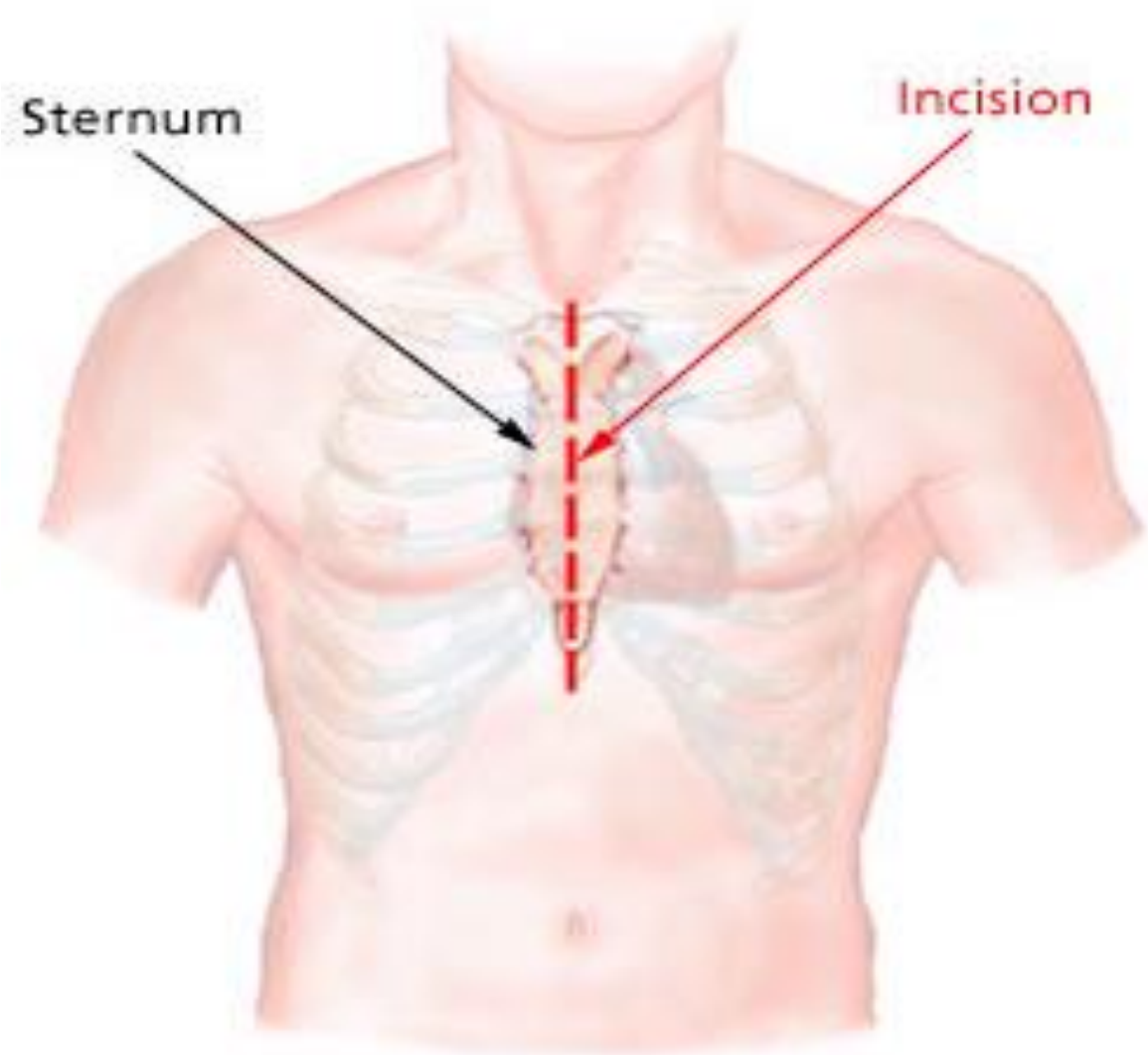
Durable Left Ventricular Assist Devices (LVAD)-IKEM



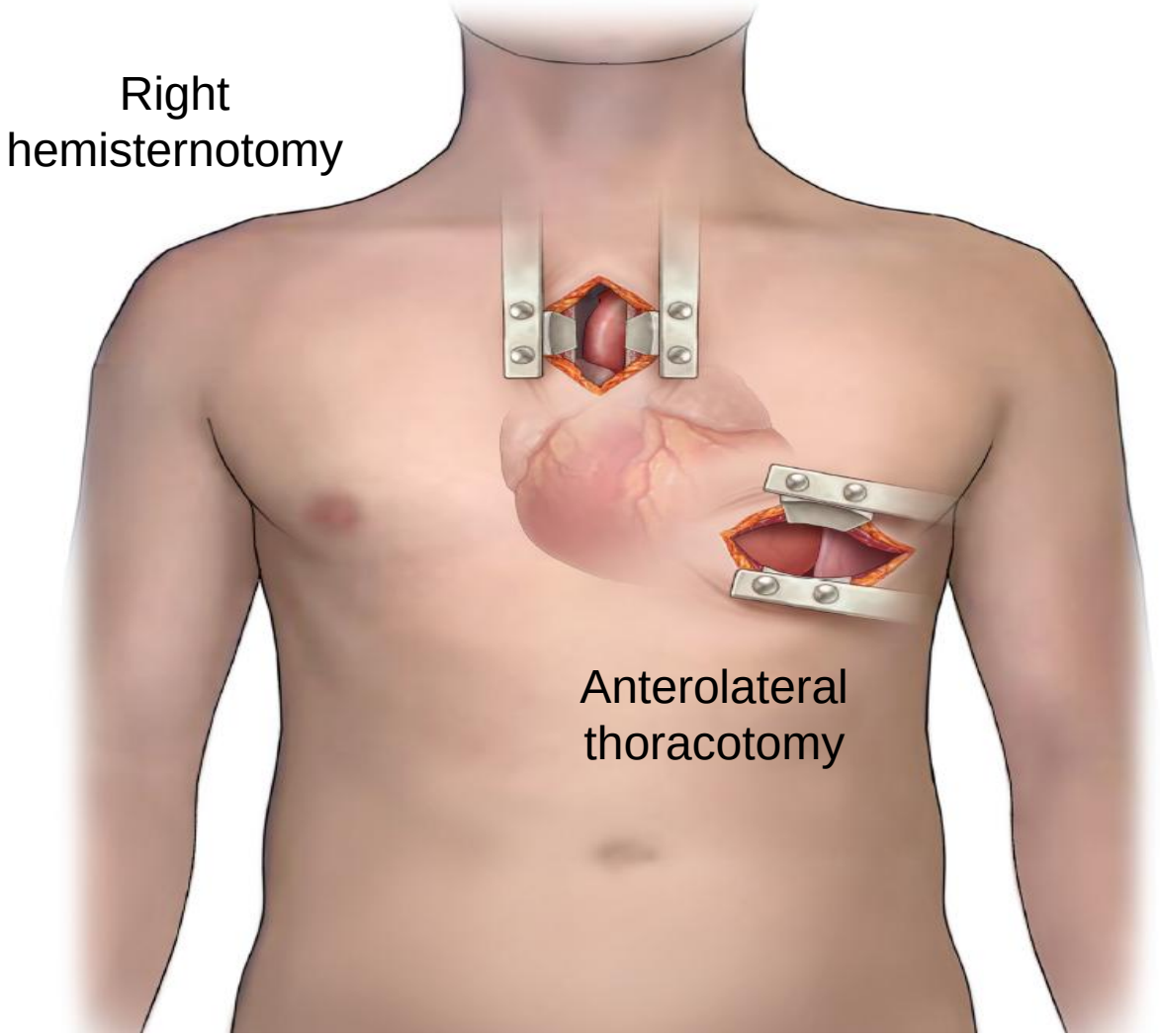
HeartMate 3 LVAS



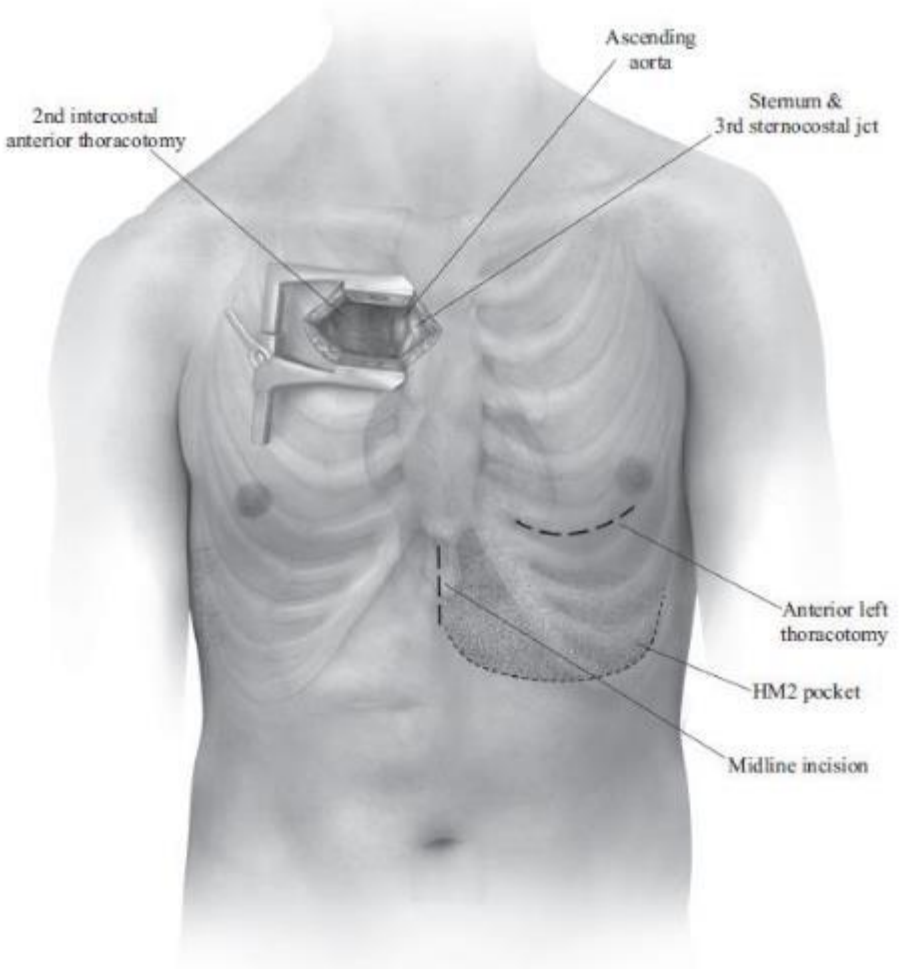
Conventional implant strategy – full sternotomy



Less invasive implant strategy

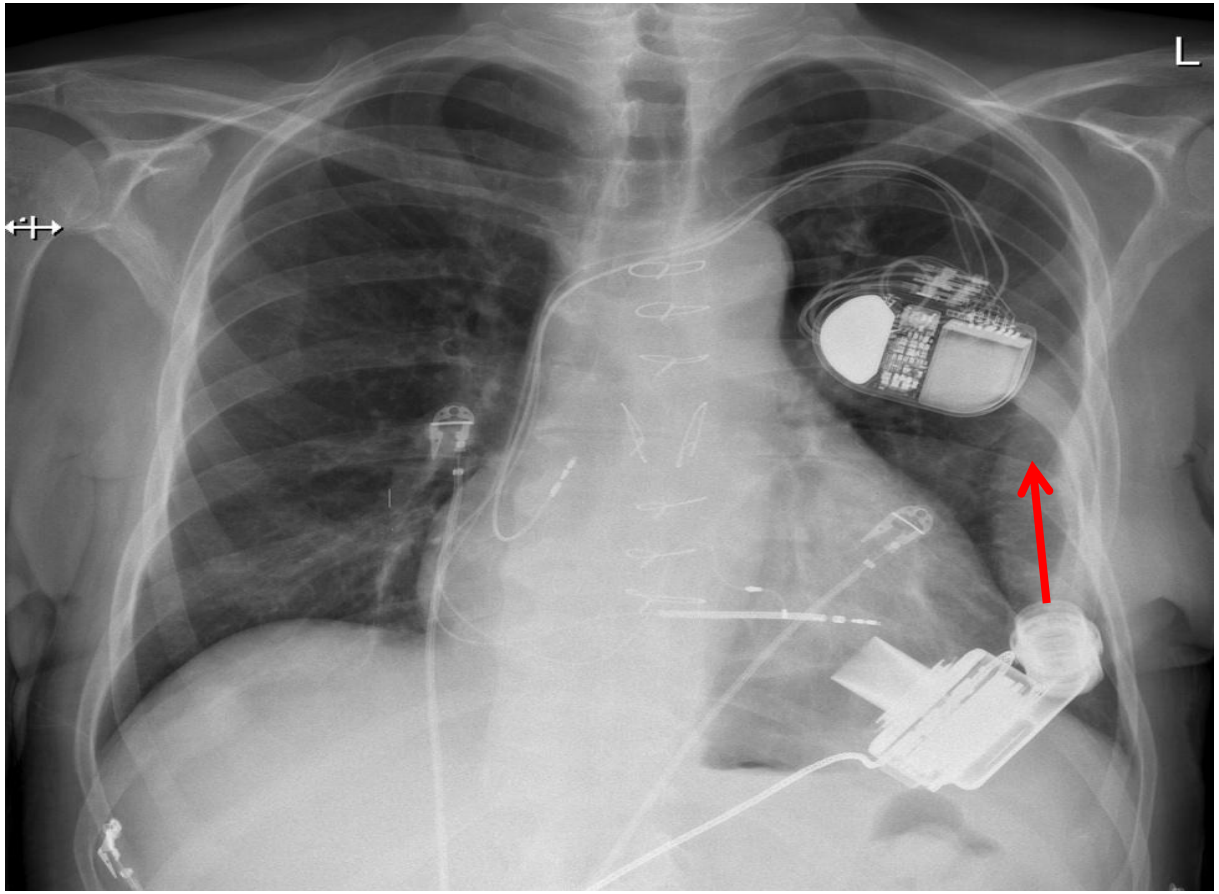


Less invasive implant strategy



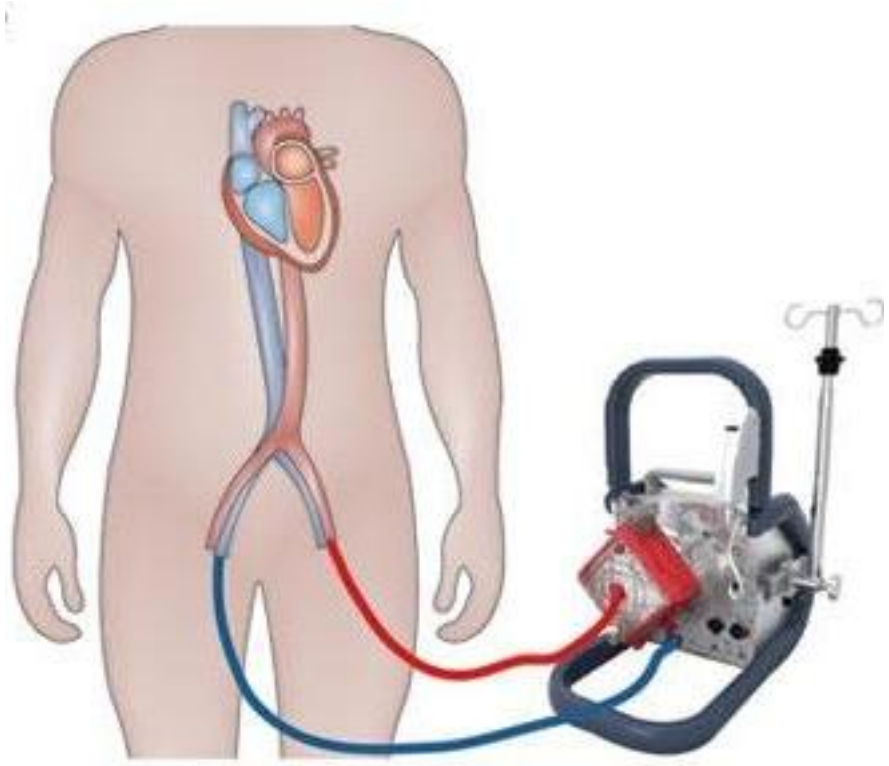
Maltais et al, OTTCVS 19:276-291.2018

Alternative implant strategy – via left hemithorax



Cardiopulmonary bypass avoidance strategies

on ECMO

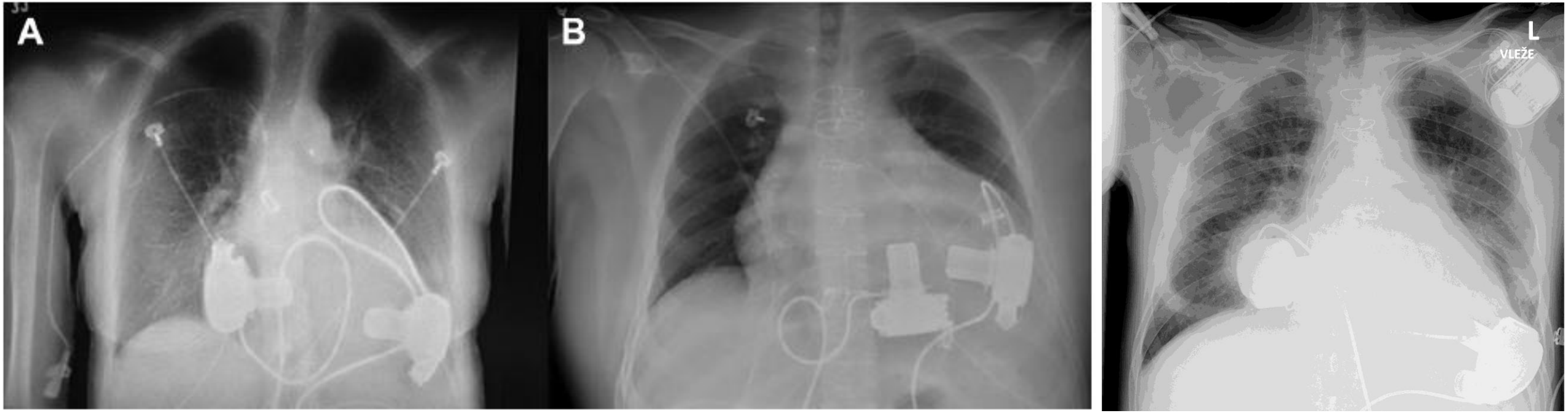


on Impella 5.0

<u>Full OFF-CPB</u>

- Semi-infectious status
- HIT

Biventricular LVAD implant (BIVAD)



Initial bridge to transplant experience with a bioprosthetic autoregulated artificial heart

Ivan Netuka, MD, PhD,[a] Yuriy Pya, MD,[b] Makhabbat Bekbossynova, MD,[b] Peter Ivak, MD, PhD,[a] Miroslav Konarik, MD,[a] Finn Gustafsson, MD, PhD,[c] David M. Smadja, PharmD, PhD,[d] Piet Jansen, MD, PhD,[e] and Christian Latrémouille, MD, PhD[d]

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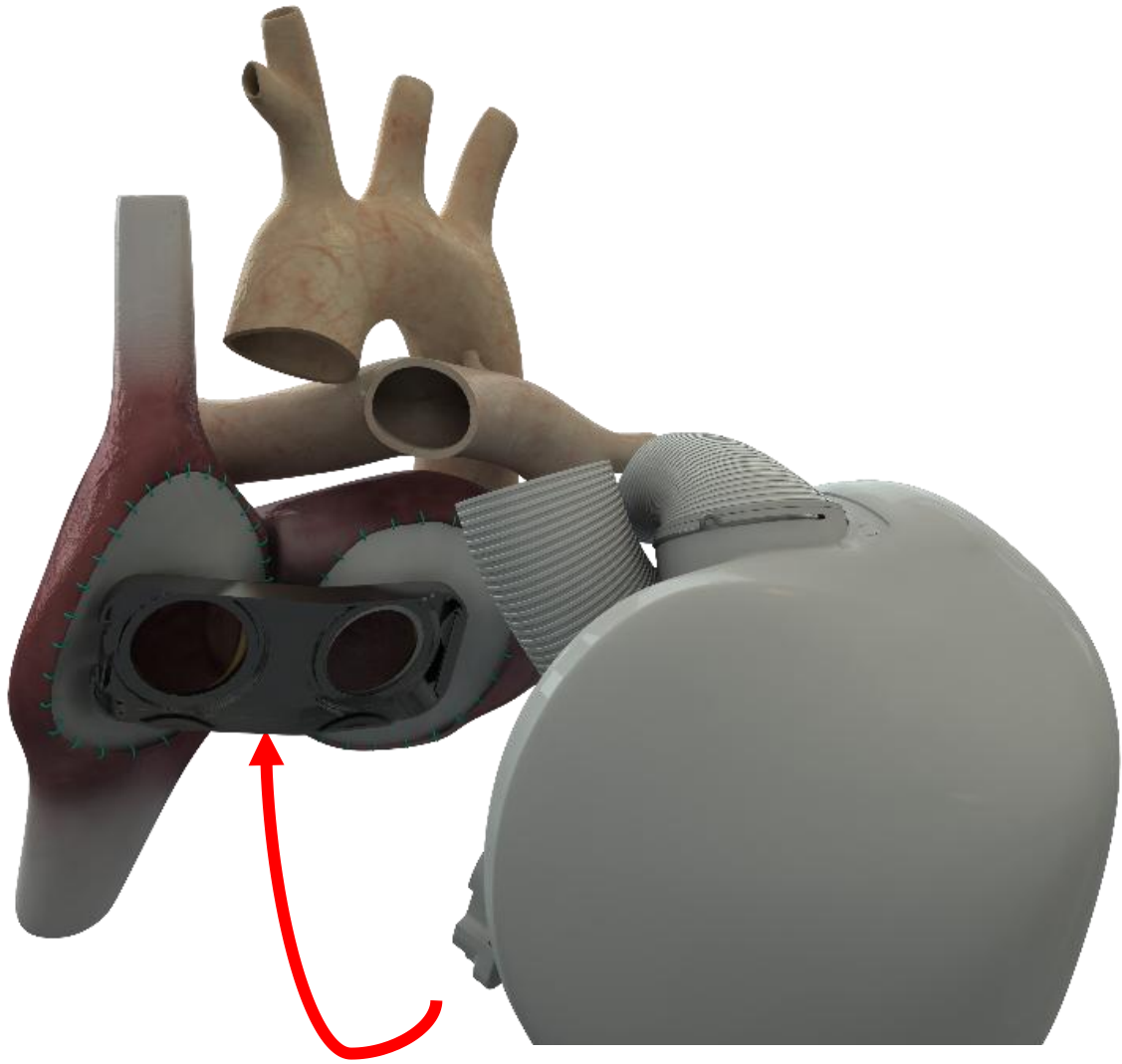
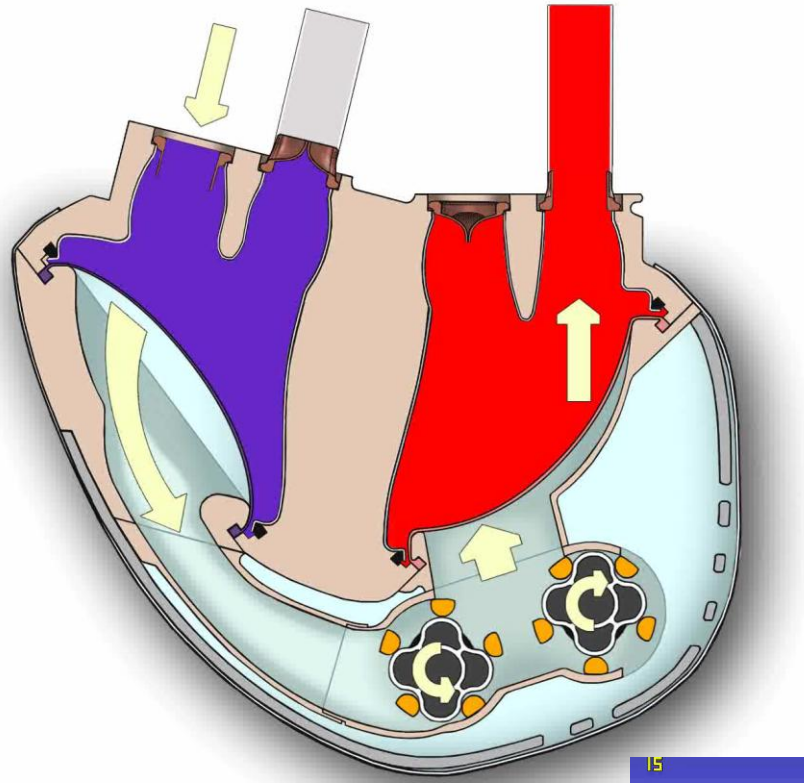
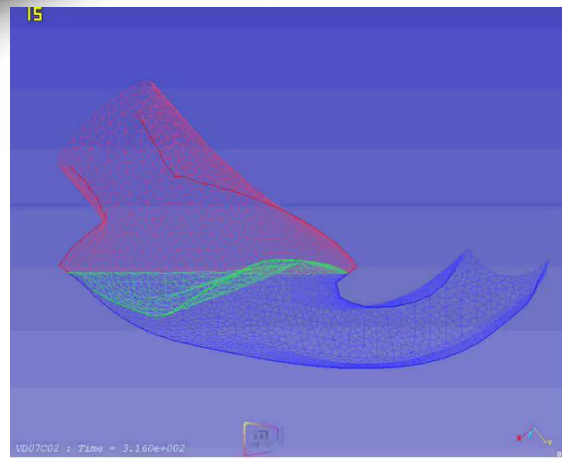
Carmat Total Artificial Heart



Principle of Carmat TAH operation – Sensors autoregulation





1 – Blood flow assessment

Inflow pressure measured by sensors every millisecond to calculate flow required

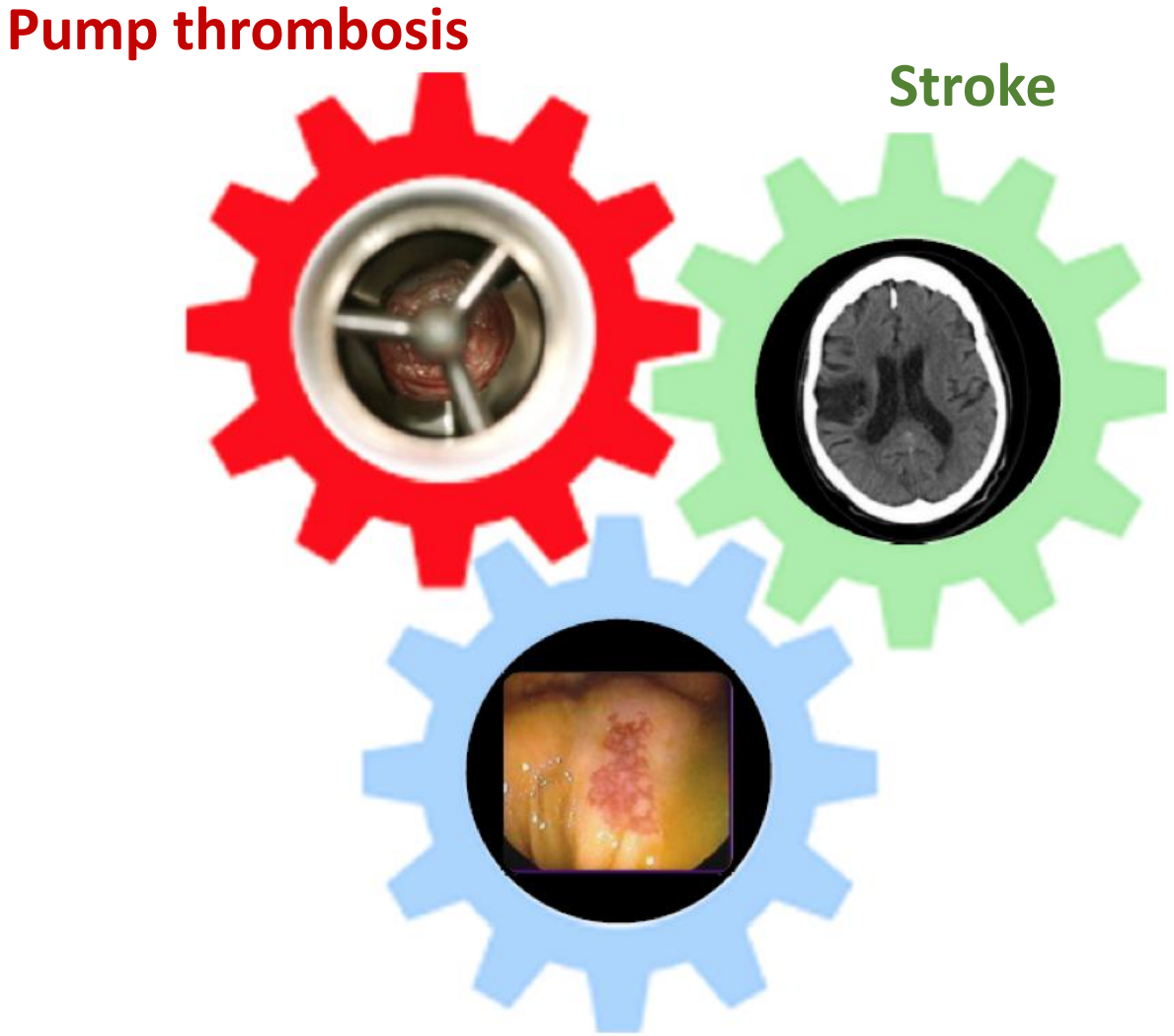
2 – Flow auto-regulation

Speed and direction of rotation of volumetric pumps adapted every 2 milliseconds to deliver the necessary pulsatile flow

3 – Flow Control

Position of the membranes checked by 2 ultrasound sensors every 2 milliseconds to ensure full ejection at every beat, to avoid stasis in blood compartment

Limited hemocompatibility of LVADs



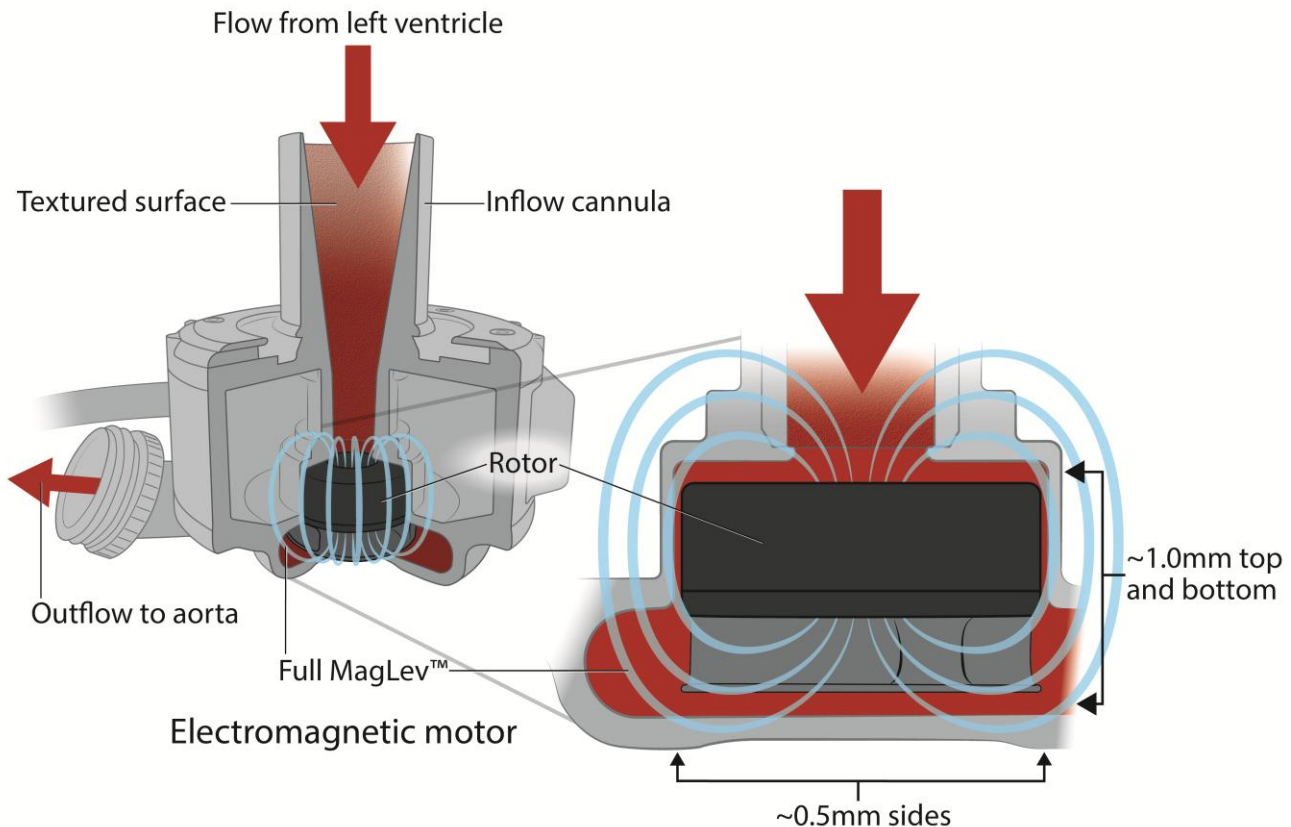
ORIGINAL INVESTIGATIONS

Fully Magnetically Levitated Left Ventricular Assist System for Treating Advanced HF

A Multicenter Study

Ivan Netuka, MD, PhD,*† Poornima Sood, MD, MBA,‡ Yuriy Pya, MD,§ Daniel Zimpfer, MD,‖
Thomas Krabatsch, MD, PhD,¶ Jens Garbade, MD, PhD,# Vivek Rao, MD, PhD,** Michiel Morshuis, MD,††
Silvana Marasco, MBBS,‡‡ Friedhelm Beyersdorf, MD,§§ Laura Damme, RN, MPH,‡ Jan D. Schmitto, MD, PhD‖‖

JACC 2015



A Fully Magnetically Levitated Left Ventricular Assist Device

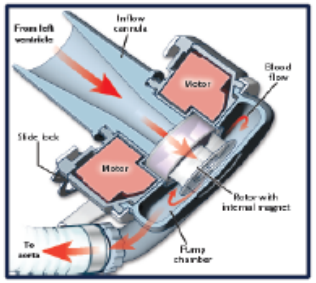
Final Report of the MOMENTUM 3 Trial

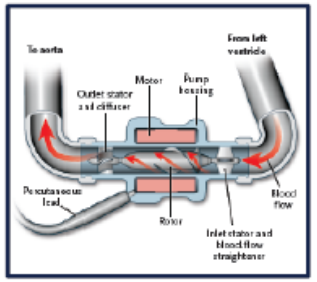
Mandeep R. Mehra, MD, Nir Uriel, MD, Joseph C. Cleveland, Jr., MD, Daniel J. Goldstein, MD,

National Principal Investigators, on behalf of the MOMENTUM 3 Investigators

MOMENTUM 3

Full Cohort





Full Cohort
N=1028
24-month follow-up

HeartMate 3
N=516

HeartMate II
N=512

Intent-to-Treat (ITT) Population
N=1028

Withdrawn before implant
N = 1
Death: 1

Withdrawn before implant
N = 7
Death: 2
No LVAD implant: 2
Withdrawal of consent: 1
Transplant: 1
Implanted with non-study LVAD: 1

As-Treated Population
N=1020

Implanted with HeartMate 3
N=515

Implanted with HeartMate II
N=505

Withdrawn after implant
N = 6
Implanted with non-study device: 2
Withdrawal of consent: 1
Non-compliance: 1
Other reason: 2

Withdrawn after implant
N = 15
Implanted with non-study device: 5
Withdrawal of consent: 1
Implanted with HM3: 6
Other reason: 3

Completed study follow-up
N=509

Completed study follow-up
N=490

MOMENTUM 3

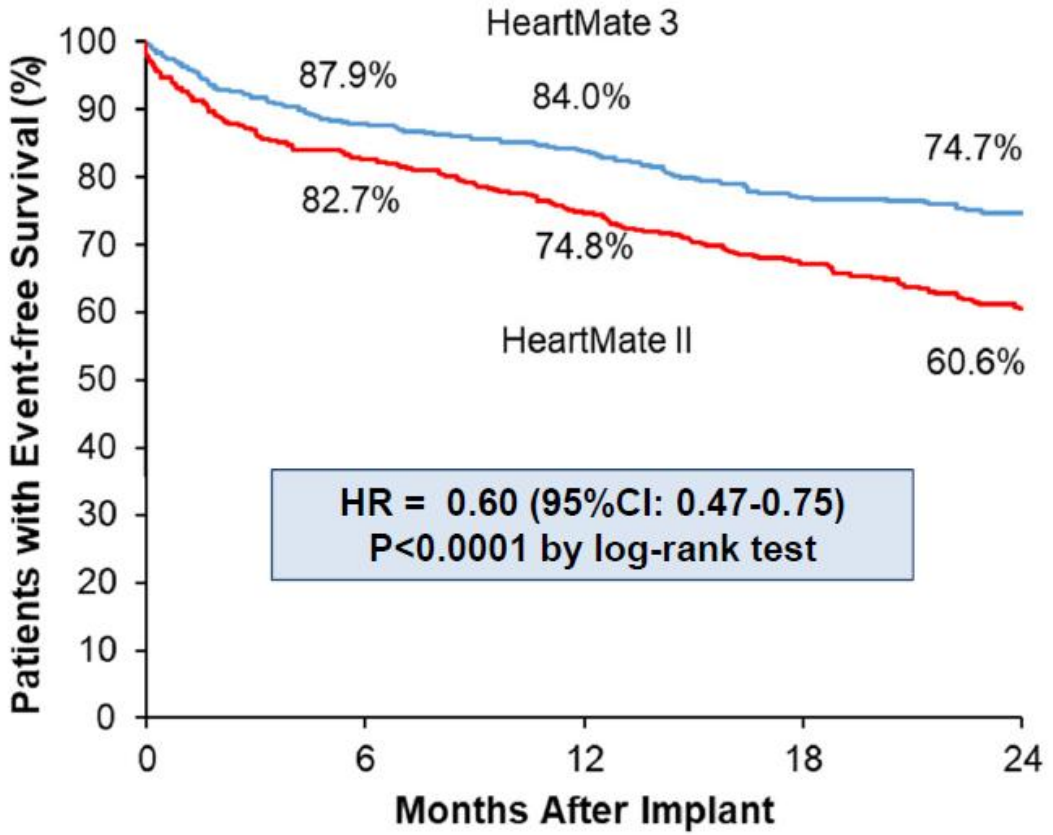
Baseline Characteristics

Characteristic	HeartMate 3 (n=516)	HeartMate II (n=512)
Mean age - years	59 ± 12	60 ± 12
Male - no. (%)	411 (79.7)	419 (81.8)
Race - no. (%)		
White	342 (66.3)	367 (71.7)
Black or African American	145 (28.1)	120 (23.4)
Asian	8 (1.6)	3 (0.6)
Native Hawaiian or Pacific islander	0 (0)	4 (0.8)
Other	21 (4.1)	18 (3.5)
Ischemic cause of heart failure - no. (%)	216 (41.9)	240 (46.9)
Intravenous inotropic agents - no. (%)	445 (86.2)	423 (82.6)
Intra aortic balloon pump - no. (%)	64 (12.4)	79 (15.4)
Serum creatinine - mg/dl	1.4 ± 0.4	1.4 ± 0.4
Serum sodium – mmol/liter	135.4 ± 4.1	135.5 ± 4.2
Mean arterial pressure - mmHg	79.2 ± 10.4	79.2 ± 10.1
INTERMACS profile - no. (%)		
1	11 (2.1)	18 (3.5)
2	156 (30.2)	146 (28.5)
3	272 (52.7)	251 (49.0)
4	67 (13.0)	82 (16.0)
5-7 or not provided*	10 (1.9)	15 (2.9)
Intended goal of pump support - no. (%)		
Bridge to transplantation (BTT)	113 (21.9)	121 (23.6)
Bridge to candidacy for transplantation	86 (16.7)	81 (15.8)
Destination therapy (DT)	317 (61.4)	310 (60.5)

There were significant differences between groups for race (P=0.04). *Assessments were not performed in 2 HeartMate 3 patients and 5 HeartMate II patients.

Primary End Point (ITT)

Survival at 2 years free of disabling stroke (>3 mRS) or reoperation to replace or remove a malfunctioning device



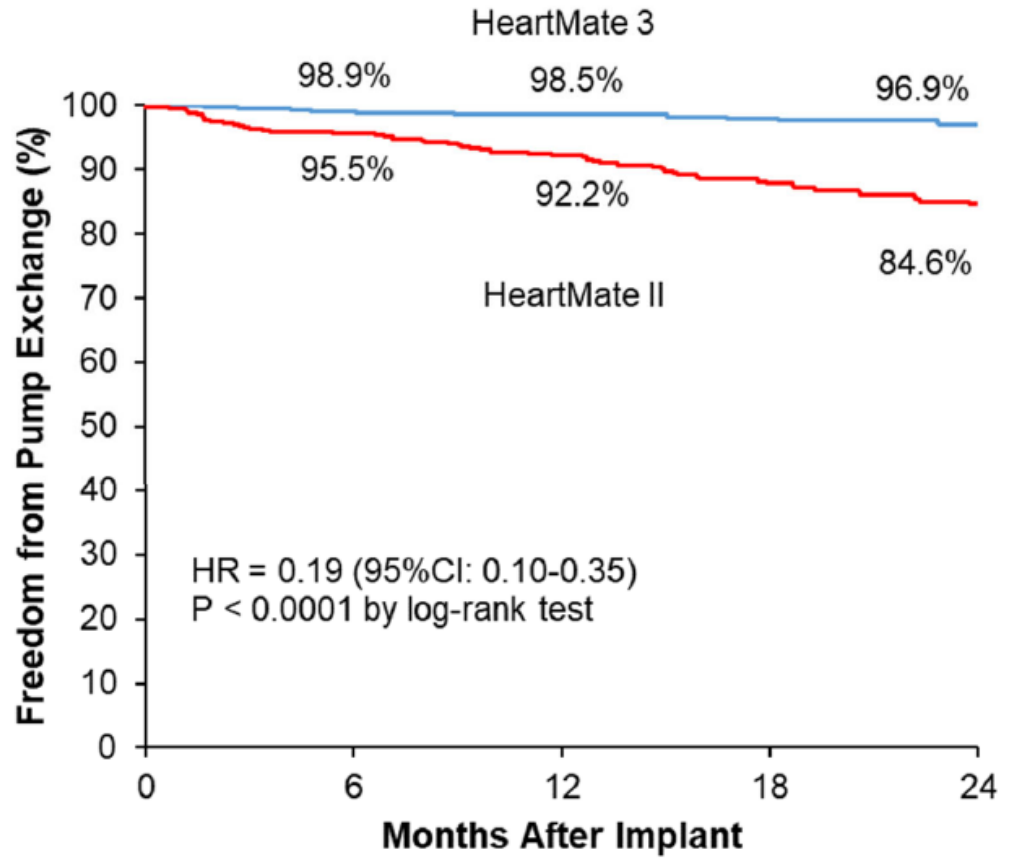
No. at Risk:					
HeartMate 3	516	438	373	313	280
HeartMate II	512	401	321	264	223

MOMENTUM 3

mRS denotes modified Rankin Score; HR, hazard ratio; CI, confidence interval

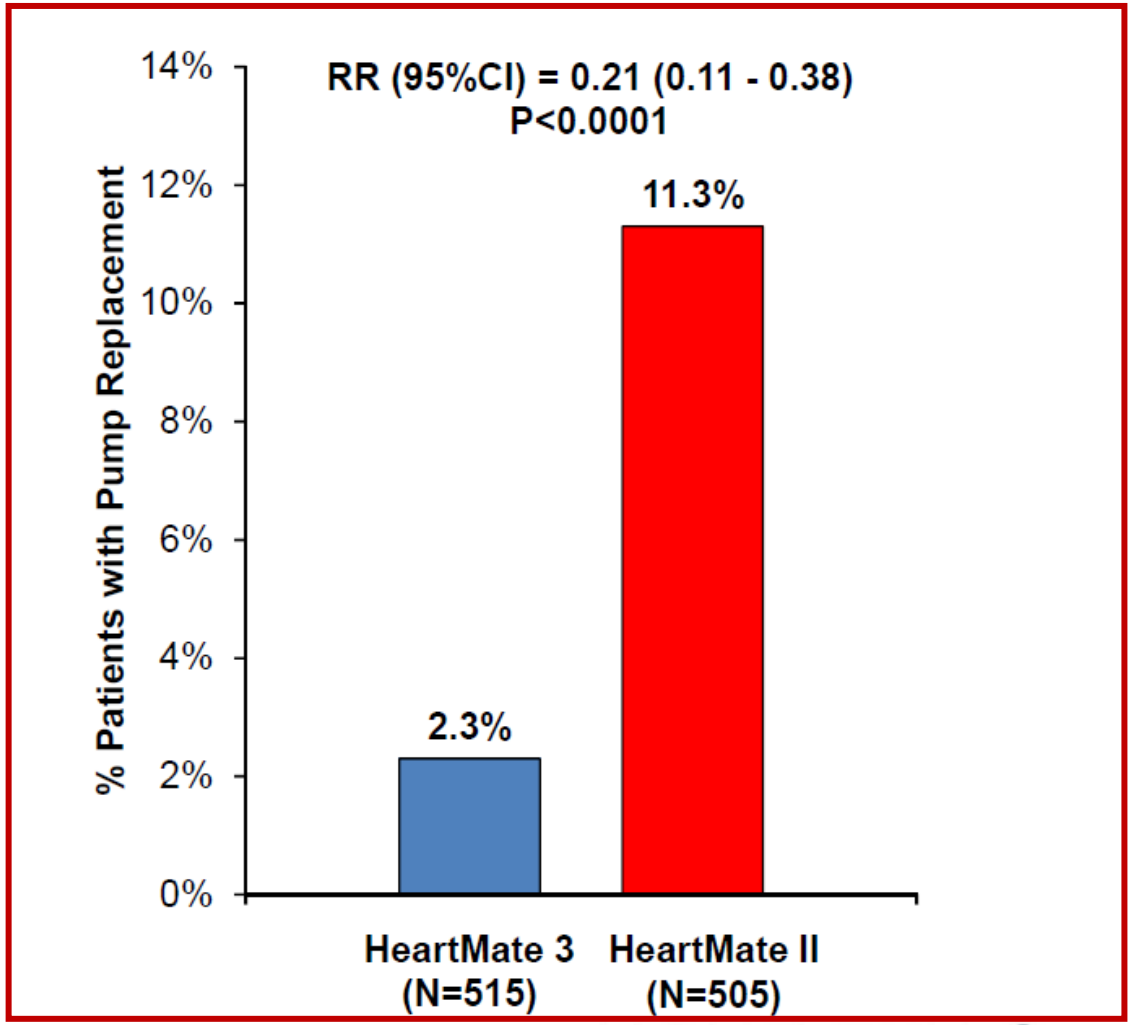
Principal Secondary End Point

Pump replacement at 2 years



No. at Risk:

HeartMate 3	515	444	379	317	283
HeartMate II	505	403	322	264	226

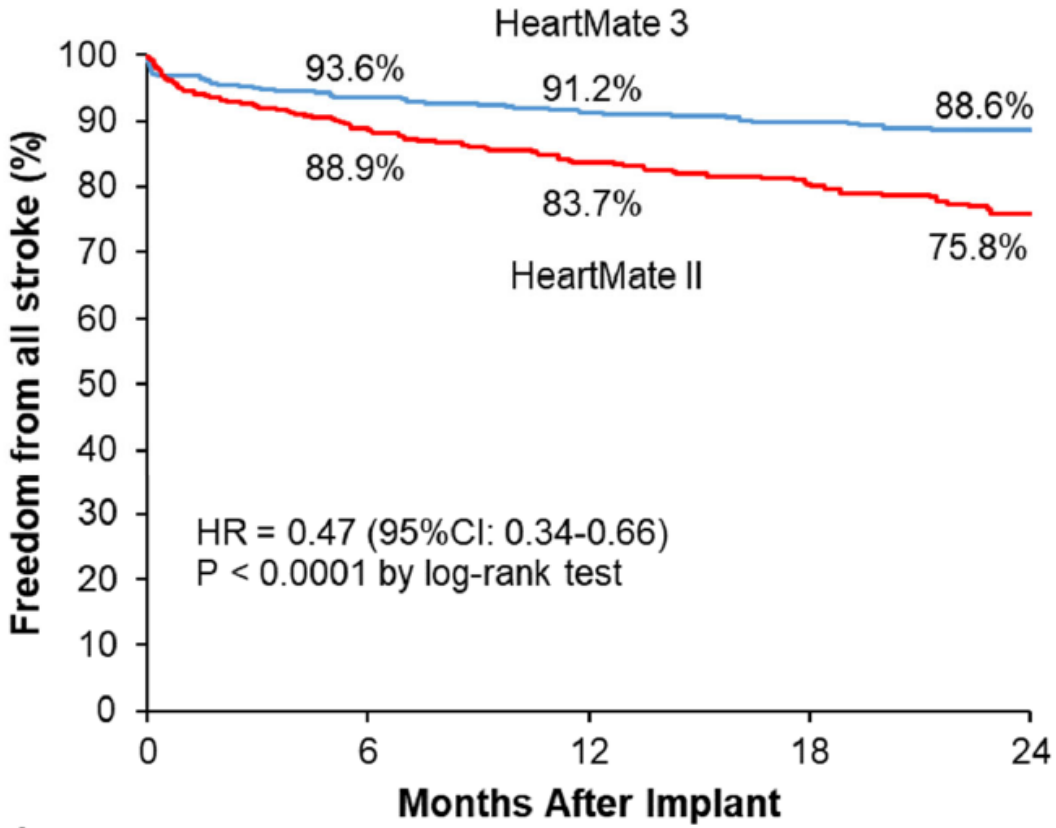


MOMENTUM 3

RR denotes relative risk; CI, confidence interval; HR, hazard ratio

Stroke

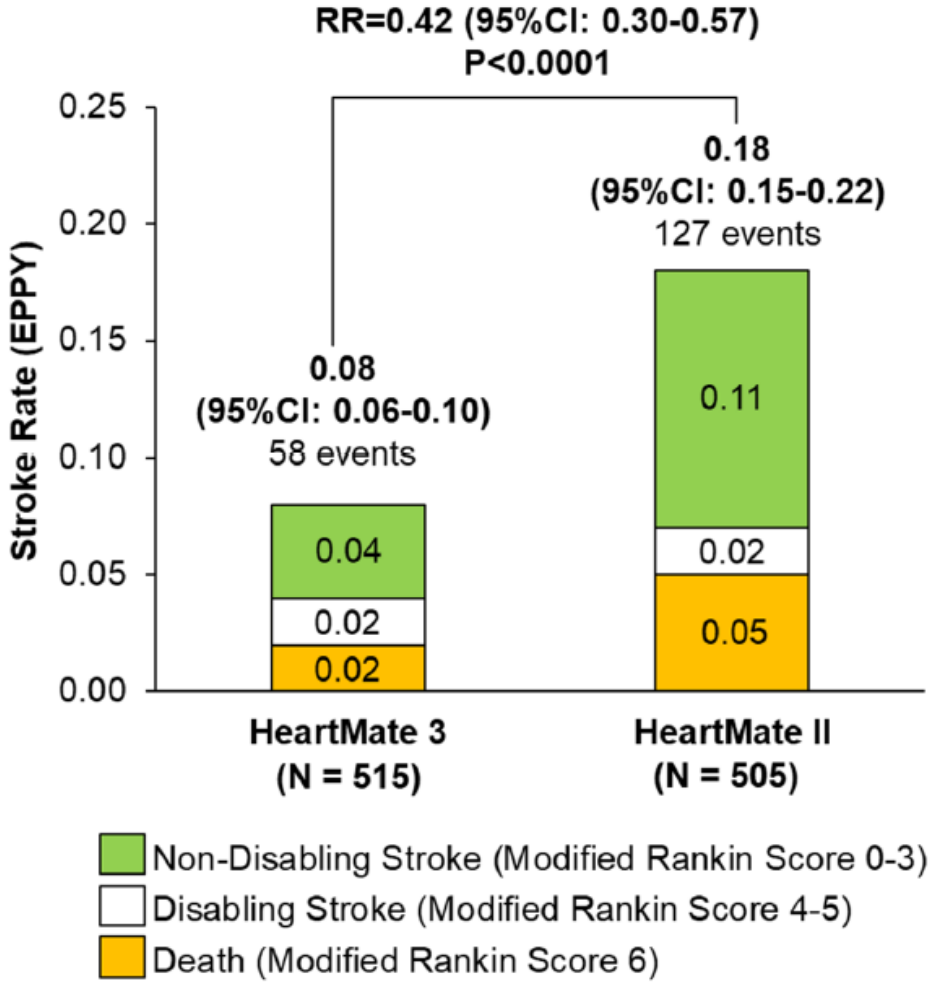
Freedom from All Stroke



No. at Risk:

HeartMate 3	515	429	361	304	270
HeartMate II	505	384	299	252	210

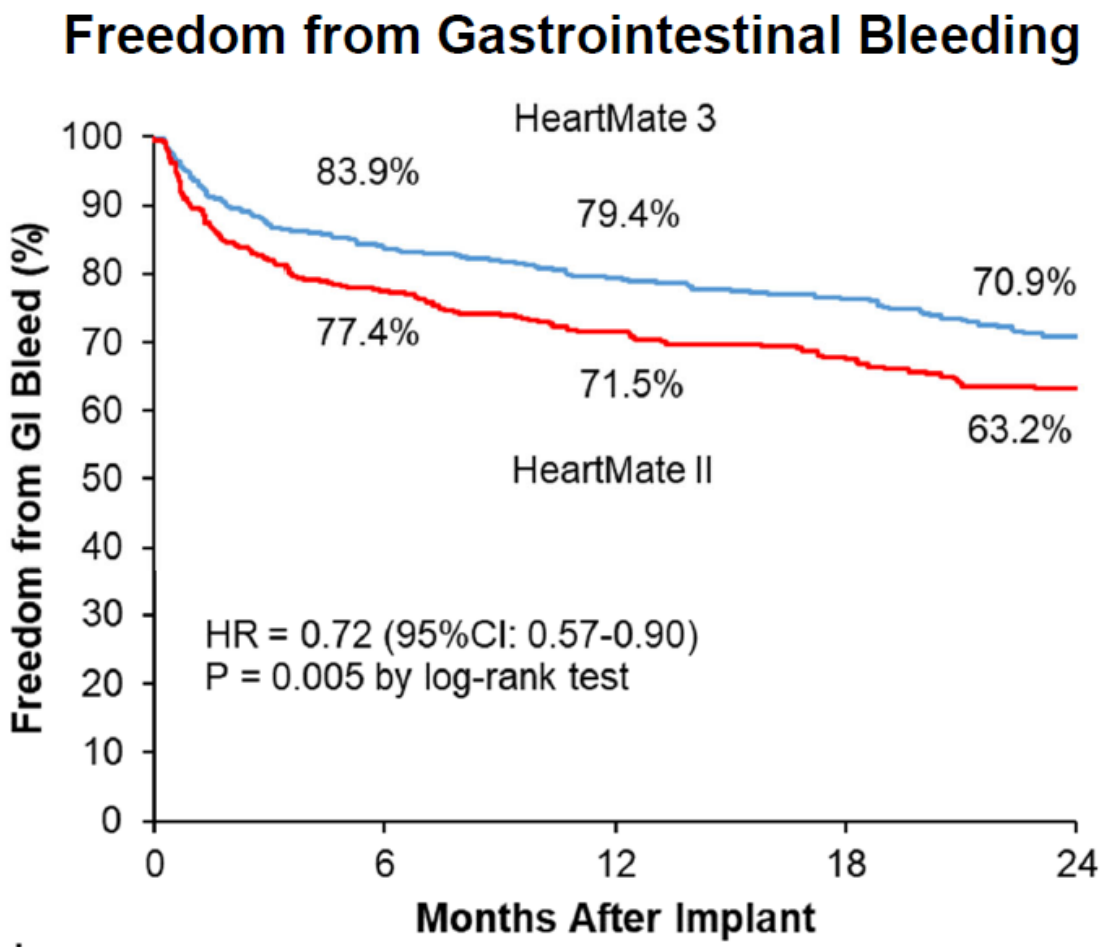
Stroke Severity



MOMENTUM 3

HR denotes hazard ratio; CI, confidence interval; RR, relative risk; EPPY, events per patient year

Gastrointestinal Bleeding

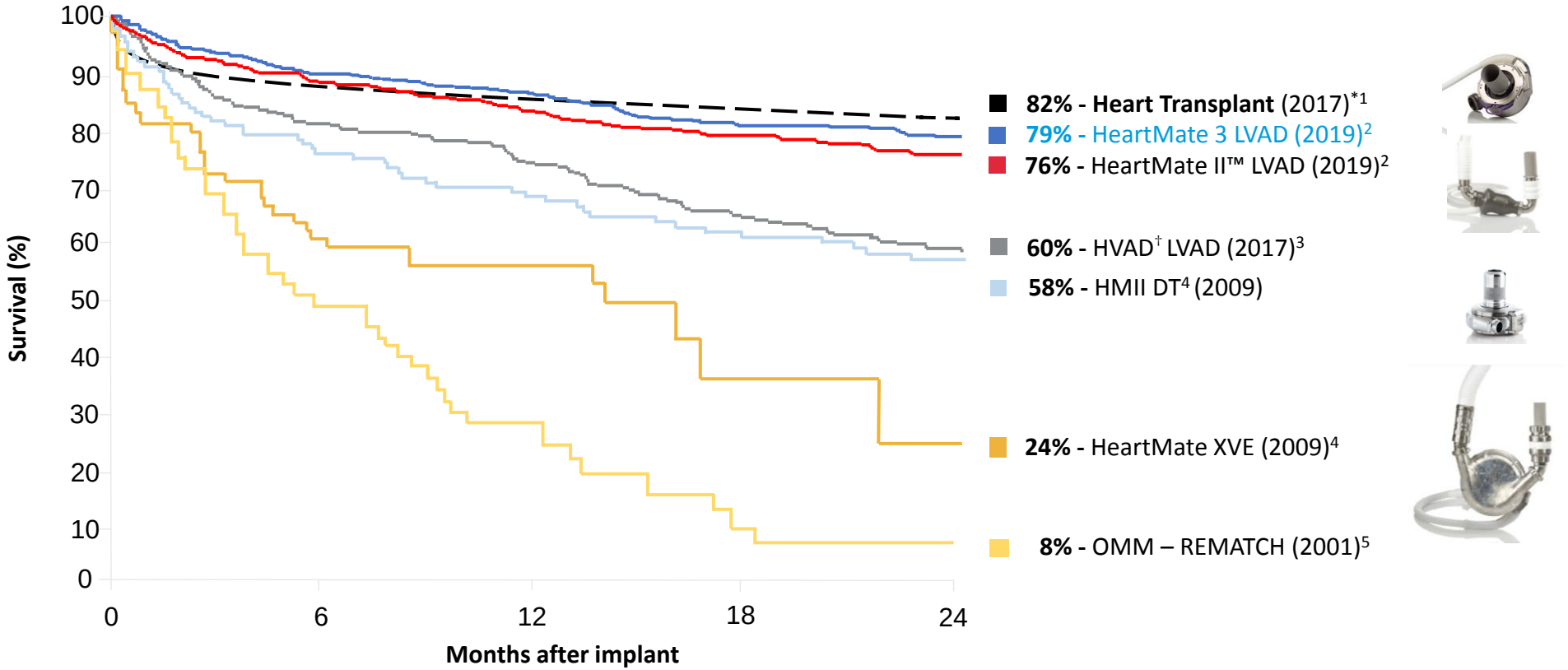


No. at Risk:					
HeartMate 3	515	381	308	251	204
HeartMate II	505	325	248	202	167

MOMENTUM 3

GI denotes gastrointestinal; HR hazard ratio; CI, confidence interval

Impact of advancing technology and the best practice



Based on published data from multicenter experience and separate studies, which may involve different patient populations and other variables. Not a head to head comparison. Data presented for informational purposes only.

*82% 2-year survival for adult heart transplants patients between 2009 and 2015[1]

References: 1. Lund LF, Khush KK, Cherikh WS, et al. The Registry of the International Society for Heart and Lung Transplantation: Thirty-fourth Adult Heart Transplantation Report—2017; Focus theme: allograft ischemic time. *J Heart Lung Transplant*. 2017;36:1037-1046**. 2.** Mehra MR, Uriel N, Naka Y, et al. A Fully Magnetically Levitated Ventricular Assist Device-Final Report. N Engl J Med. 2019. **3.** Rogers JG, Pagani FD, Tatooles AJ, et al. Intrapericardial Left Ventricular Assist Device for Advanced Heart Failure. *N Engl J Med*. 2017;376:451-60**. 4.** Slaughter MS, Rogers JG, Milano CA, et al. Advanced heart failure treated with continuous-flow left ventricular assist device. *N Engl J Med*. 2009;361:2241-2251. **5.** Rose EA, Gelijns AC, Moskowitz AJ, et al. Long-term use of a left ventricular assist device for end-stage heart failure. *N Engl J Med.* 2001 Nov 15;345(20):1435-43.

First 5-year multicentric clinical trial experience with the HeartMate 3 left ventricular assist system

Ivan Netuka, MD, PhD,[a,1] Yuriy Pya, MD,[b] Daniel Zimpfer, MD,[c]
Evgenij Potapov, MD,[d] Jens Garbade, MD, PhD,[e] Vivek Rao, MD, PhD,[f]
Michiel Morshuis, MD,[g] Friedhelm Beyersdorf, MD,[h]
Silvana Marasco, PhD, FRACS,[i] Poornima Sood, MD, MBA,[j]
Carlo Gazzola, BSc,[j] and Jan D. Schmitto, MD, PhD[k,1]

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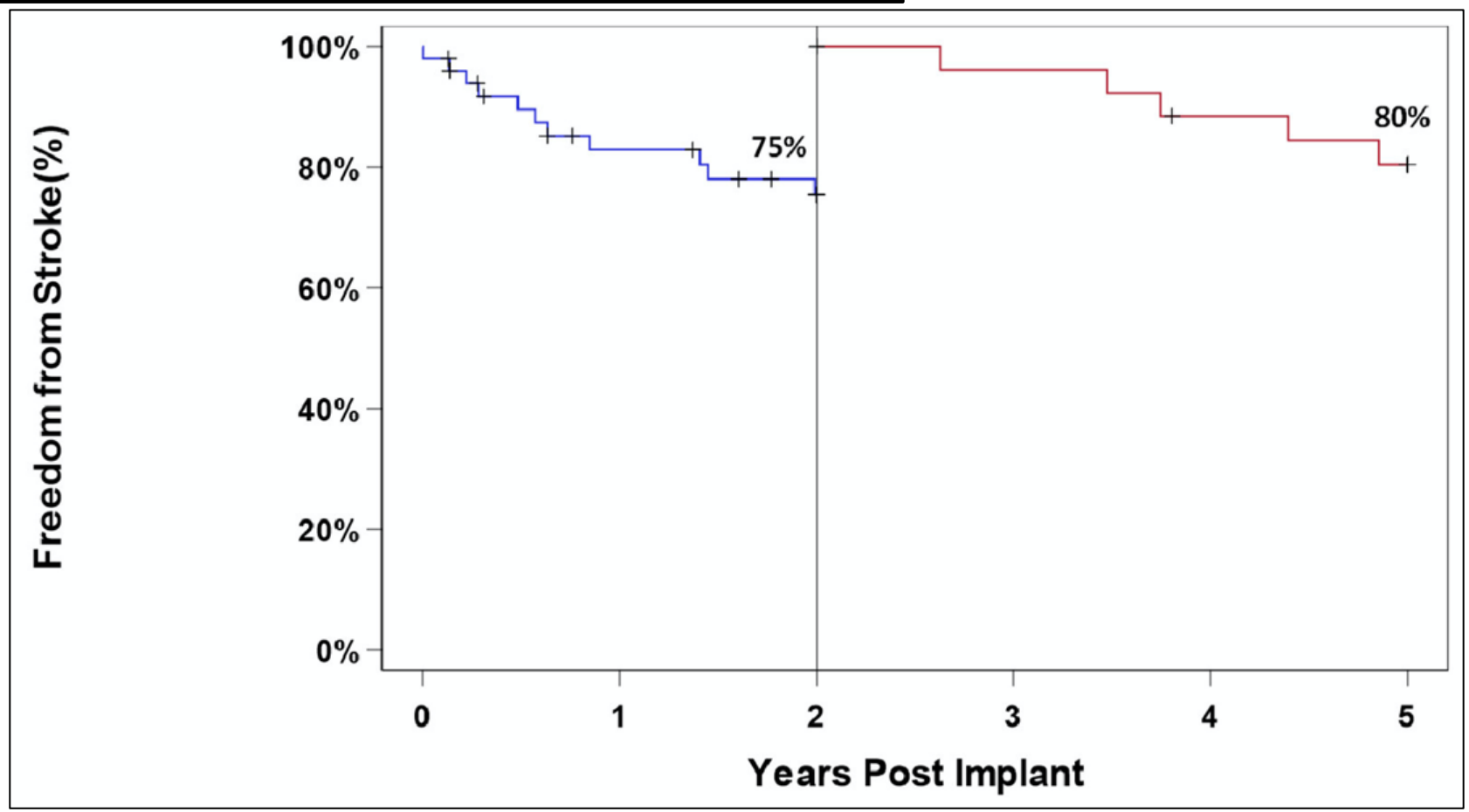
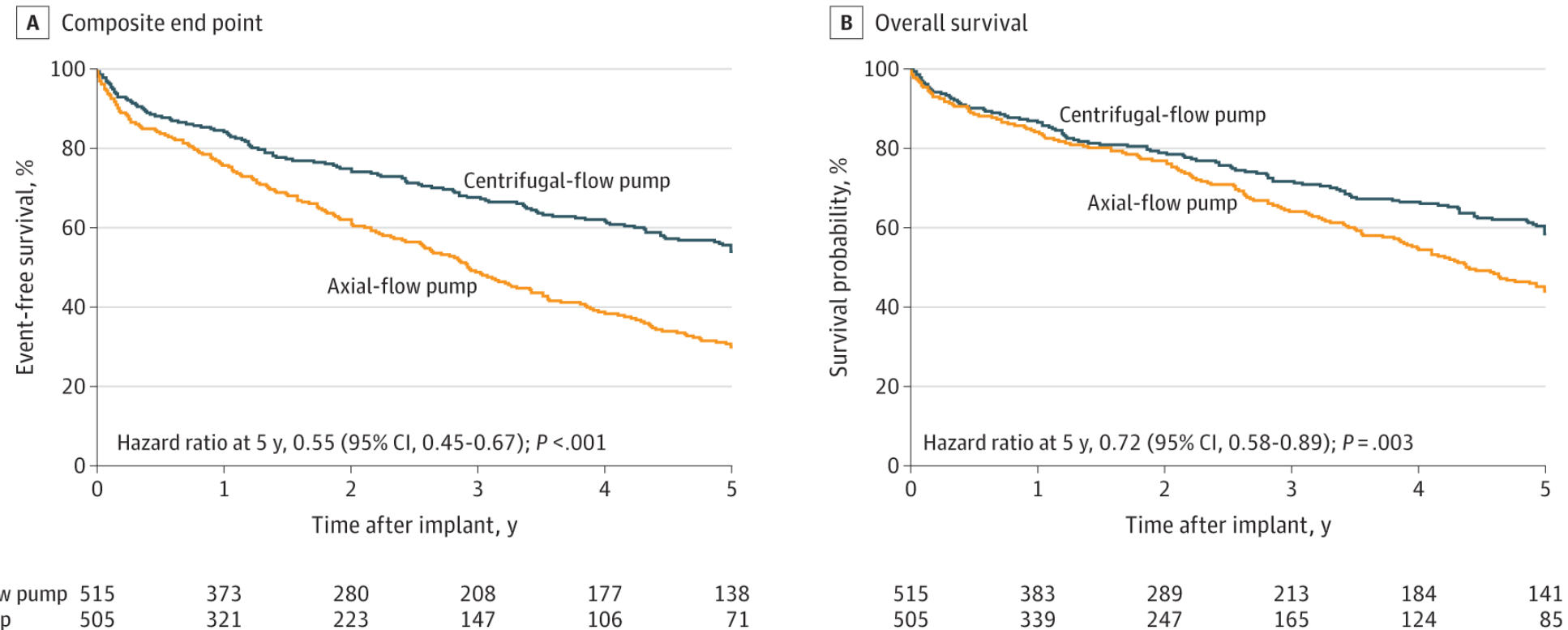


JAMA | Original Investigation

Five-Year Outcomes in Patients With Fully Magnetically Levitated vs Axial-Flow Left Ventricular Assist Devices in the MOMENTUM 3 Randomized Trial

Mandeep R. Mehra, MD, MSc; Daniel J. Goldstein, MD; Joseph C. Cleveland, MD; Jennifer A. Cowger, MD, MS; Shelley Hall, MD; Christopher T. Salerno, MD; Yoshifumi Naka, MD, PhD; Douglas Horstmanshof, MD; Joyce Chuang, PhD; AiJia Wang, MPH; Nir Uriel, MD, MSc

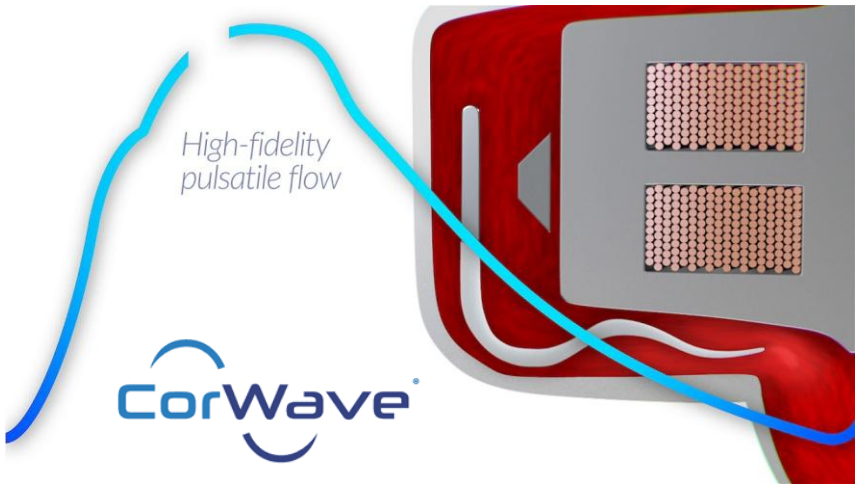


No. of patients						
Centrifugal-flow pump	515	373	280	208	177	138
Axial-flow pump	505	321	223	147	106	71

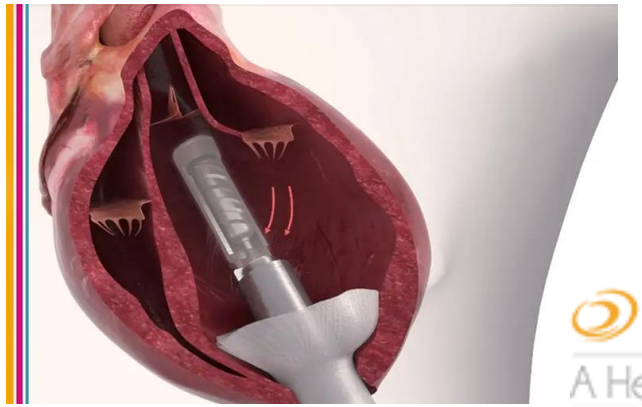
515	383	289	213	184	141
505	339	247	165	124	85

Novel Technological MCS Platforms

CARMAT TAH

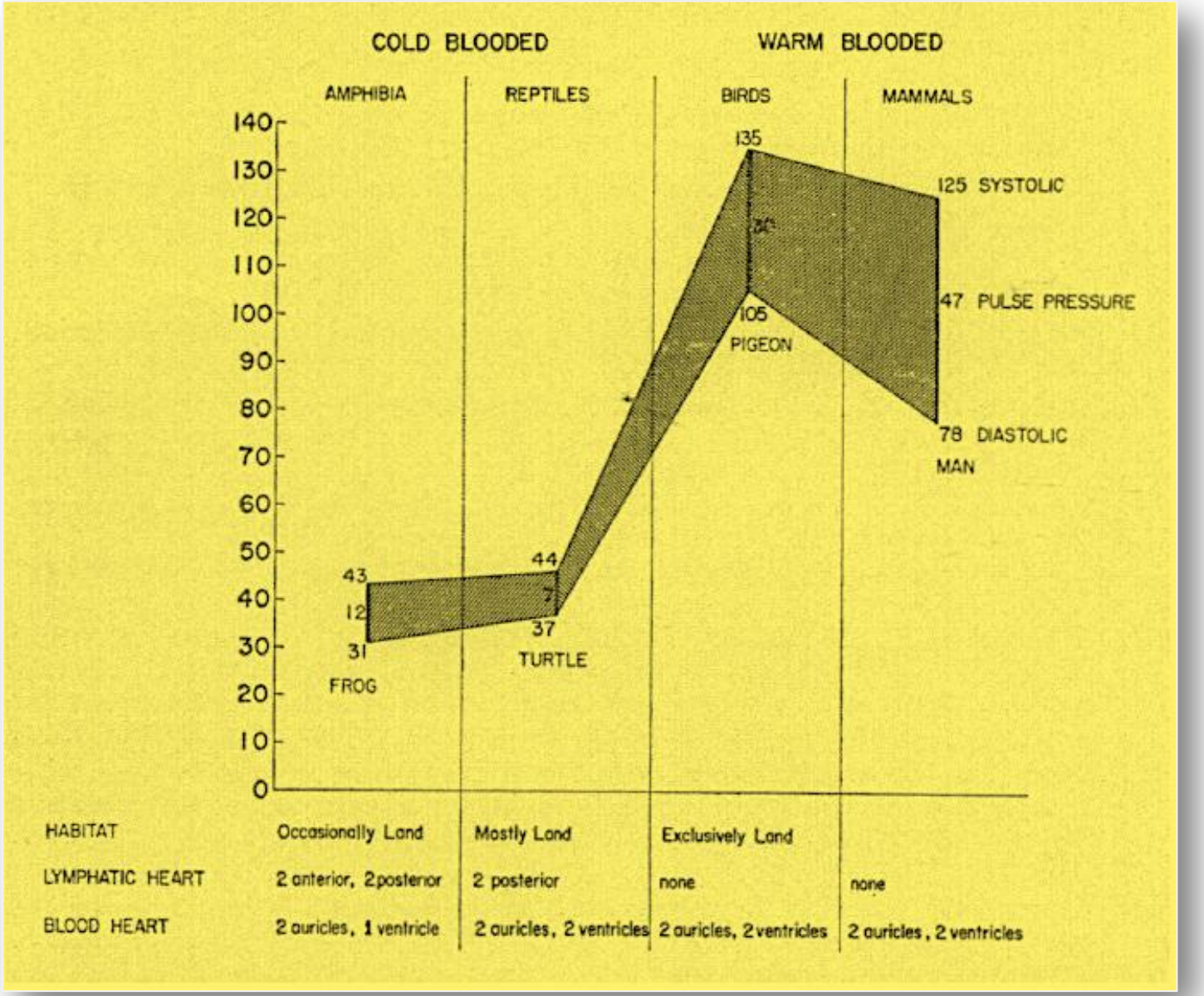


CALON CARDIO



FineHeart
A Healthier Life With Every Beat

Evolution and pulse pressure…



Pulsatility deficit and adverse events

Circulation: Heart Failure

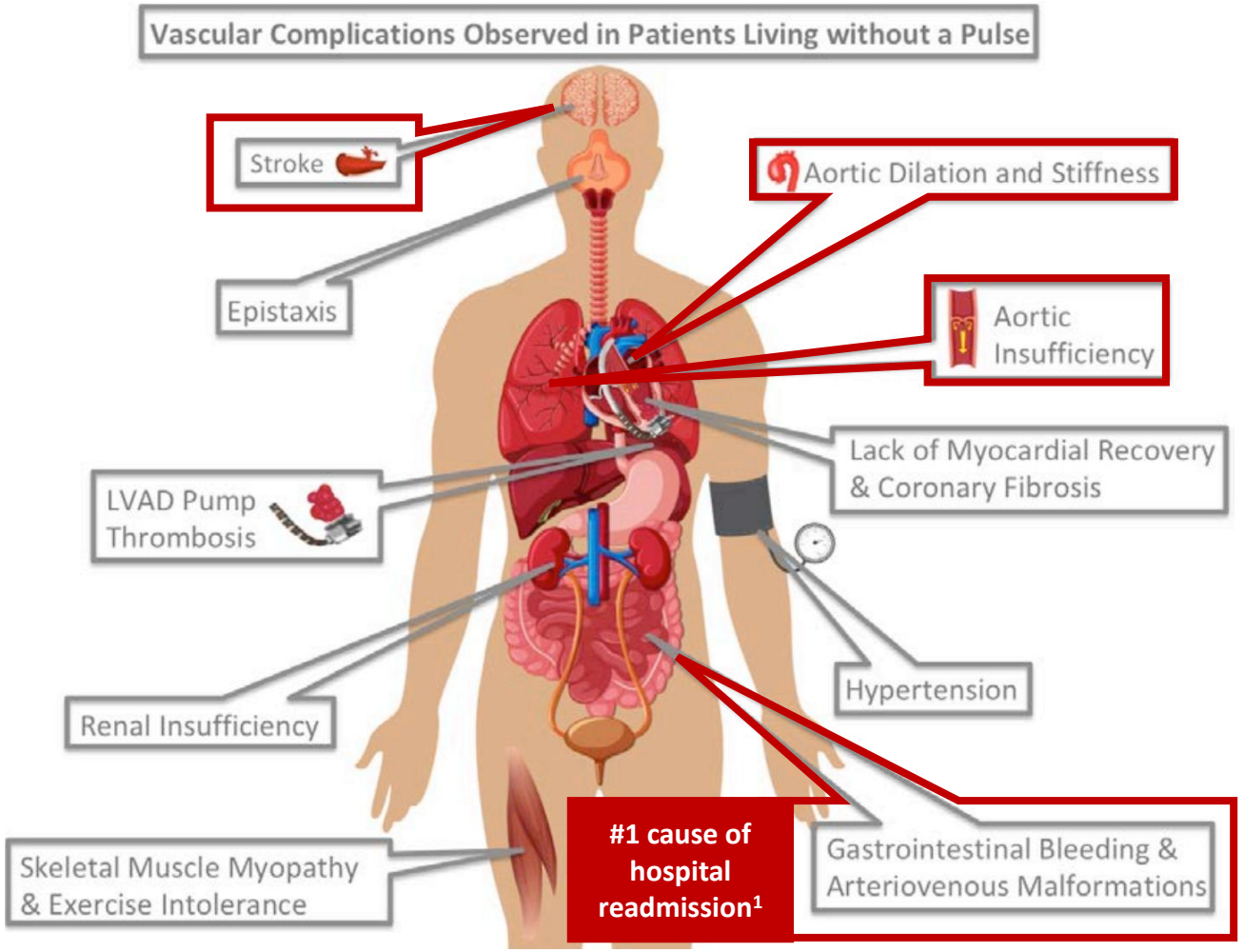
ADVANCES IN MECHANICAL CIRCULATORY SUPPORT

Living Without a Pulse

The Vascular Implications of Continuous-Flow Left Ventricular Assist Devices

ABSTRACT: Pulsatility seems to have a teleological role because evolutionary hierarchy favors higher ordered animals with more complex, multichamber circulatory systems that generate higher pulse pressure compared with lower ordered animals. Yet despite years of such natural selection, the modern generation of continuous-flow left ventricular assist devices (CF-LVADs) that have been increasingly used for the last decade have created a unique physiology characterized by a nonpulsatile, nonlaminar blood flow profile with the absence of the usual large elastic artery Windkessel effect during diastole. Although outcomes and durability have improved with CF-LVADs, patients supported with CF-LVADs have a high rate of complications that were not as frequently observed with older pulsatile devices, including gastrointestinal bleeding from arteriovenous malformations, pump thrombosis, and stroke. Given the apparent fundamental biological role of the pulse, the purpose of this review is to describe the normal physiology of ventricular-arterial coupling from pulsatile flow, the effects of heart failure on this physiology and the vasculature, and to examine the effects of nonpulsatile blood flow on the vascular system and potential role in complications seen with CF-LVAD therapy. Understanding these concomitant vascular changes with CF-LVADs may be a key step in improving patient outcomes as modulation of pulsatility and flow characteristics may serve as a novel, yet simple, therapy for reducing complications.

Suneet N. Purohit, MD
William K. Cornwell III, MD
Jay D. Pal, MD, PhD
JoAnn Lindenfeld, MD
Amrut V. Ambardekar, MD

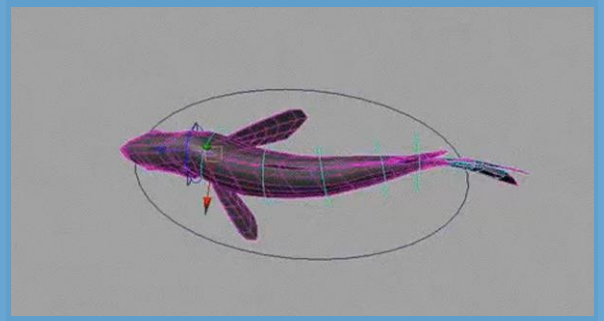


Purohit et al. Circ Heart Fail. 2018;11:e004670.

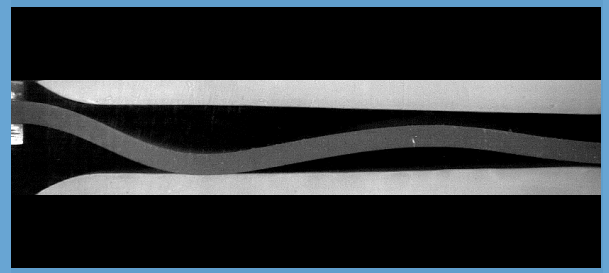
1) Mehra MR et al. Circulation. 2018,30;138(18):1923–34.

A Novel Heart Pump Inspired by Nature

Inspired by fish tail motion



CorWave membrane is a unique technology



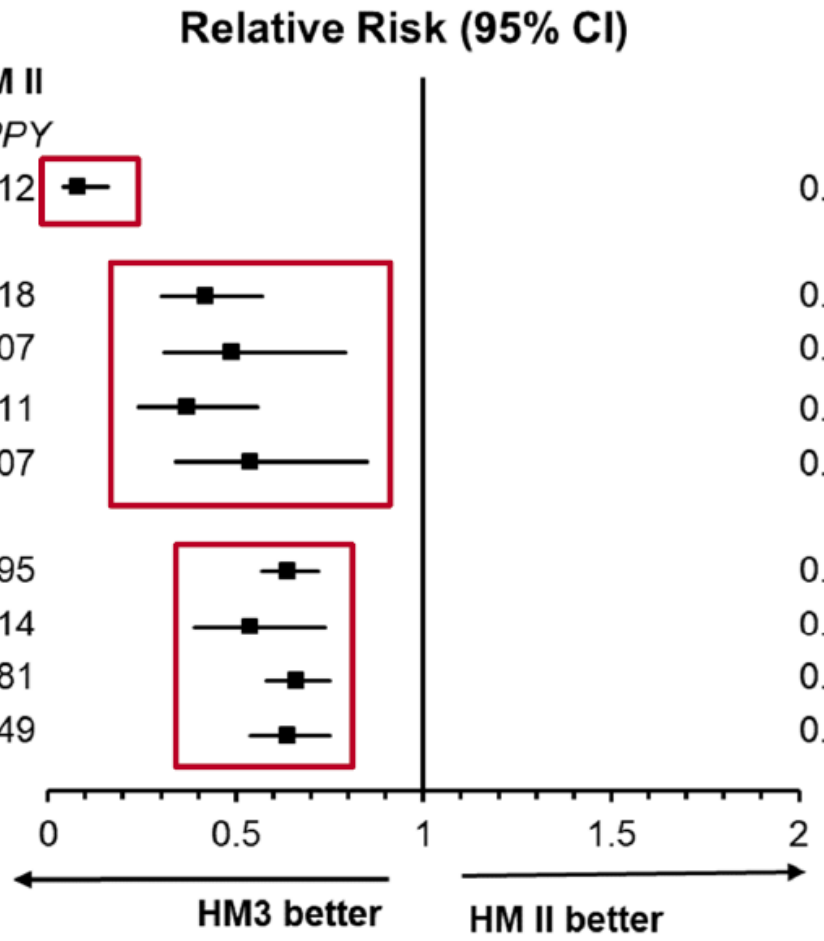
Advantages for Pump Design

- High-Fidelity Pulsatility
- Lower Shear Pumping
- Adaptive Pumping

CorWave Neptune Video

Principal Hemocompatibility-Related Adverse Events

Adverse Event	HM3 n (%)	HM II n (%)	HM3 EPPY	HM II EPPY	Relative Risk (95% CI)	P-Value*
Suspected pump thrombosis	7 (1.4)	70 (13.9)	0.01	0.12	0.08 (0.04 - 0.16)	<0.0001
Any stroke	51 (9.9)	98 (19.4)	0.08	0.18	0.42 (0.30 - 0.57)	<0.0001
Hemorrhagic stroke	25 (4.9)	43 (8.5)	0.03	0.07	0.49 (0.31 - 0.79)	0.004
Ischemic stroke	29 (5.6)	65 (12.9)	0.04	0.11	0.37 (0.24 - 0.56)	<0.0001
Disabling stroke	26 (5.0)	38 (7.5)	0.04	0.07	0.54 (0.34 - 0.85)	0.008
Any bleeding	225 (43.7)	278 (55.0)	0.61	0.95	0.64 (0.57 - 0.72)	<0.0001
Requiring surgery	50 (9.7)	89 (17.6)	0.08	0.14	0.54 (0.39 - 0.74)	<0.001
Not requiring surgery	197 (38.3)	251 (49.7)	0.53	0.81	0.66 (0.58 - 0.75)	<0.0001
Gastrointestinal bleeding	126 (24.5)	156 (30.9)	0.31	0.49	0.64 (0.54 - 0.75)	<0.0001



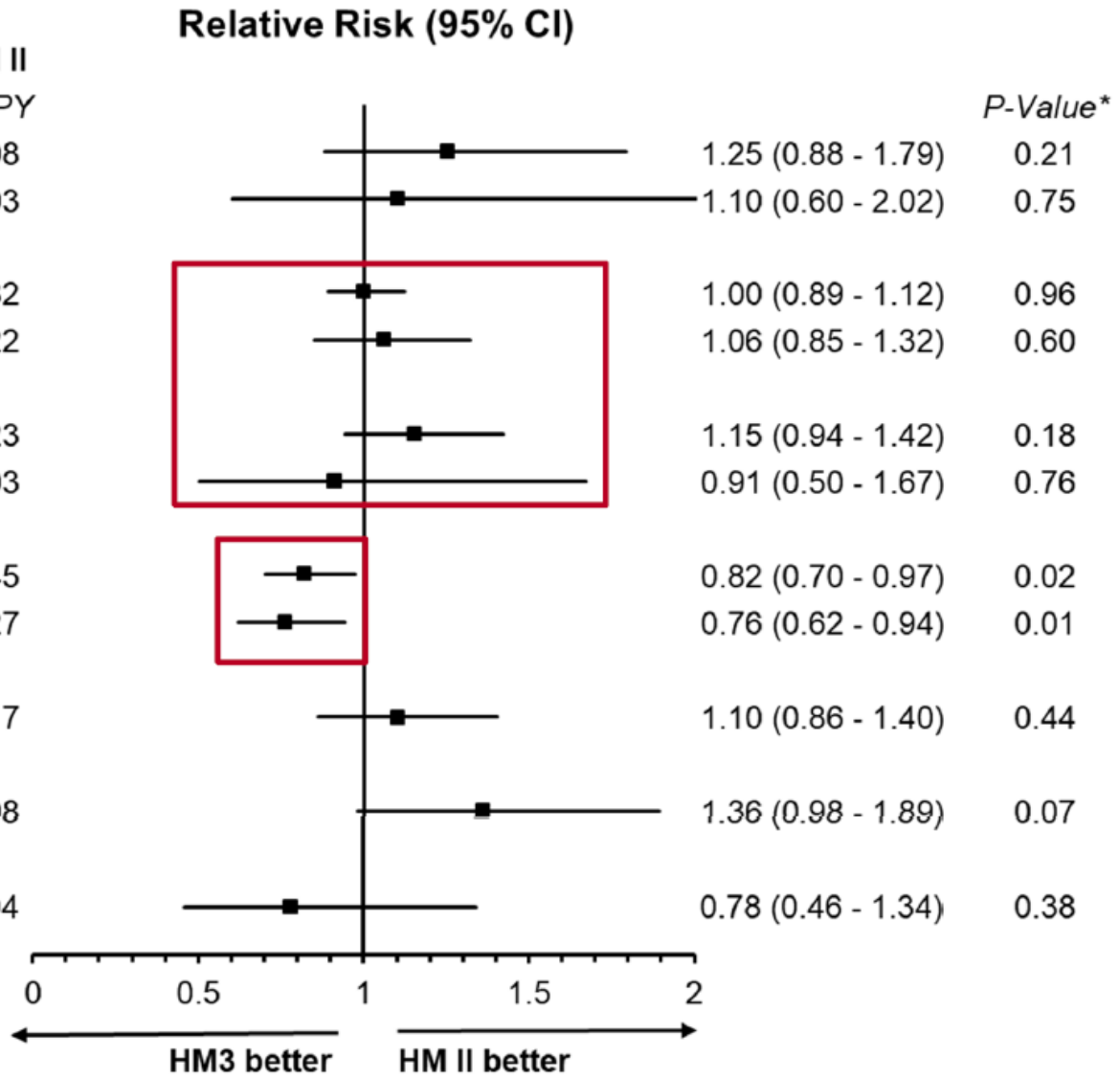
54%

MOMENTUM 3

HM3 denotes HeartMate 3; HMII HeartMate II; EPPY events per patient year; CI, confidence interval. *P values were calculated with Poisson regression.

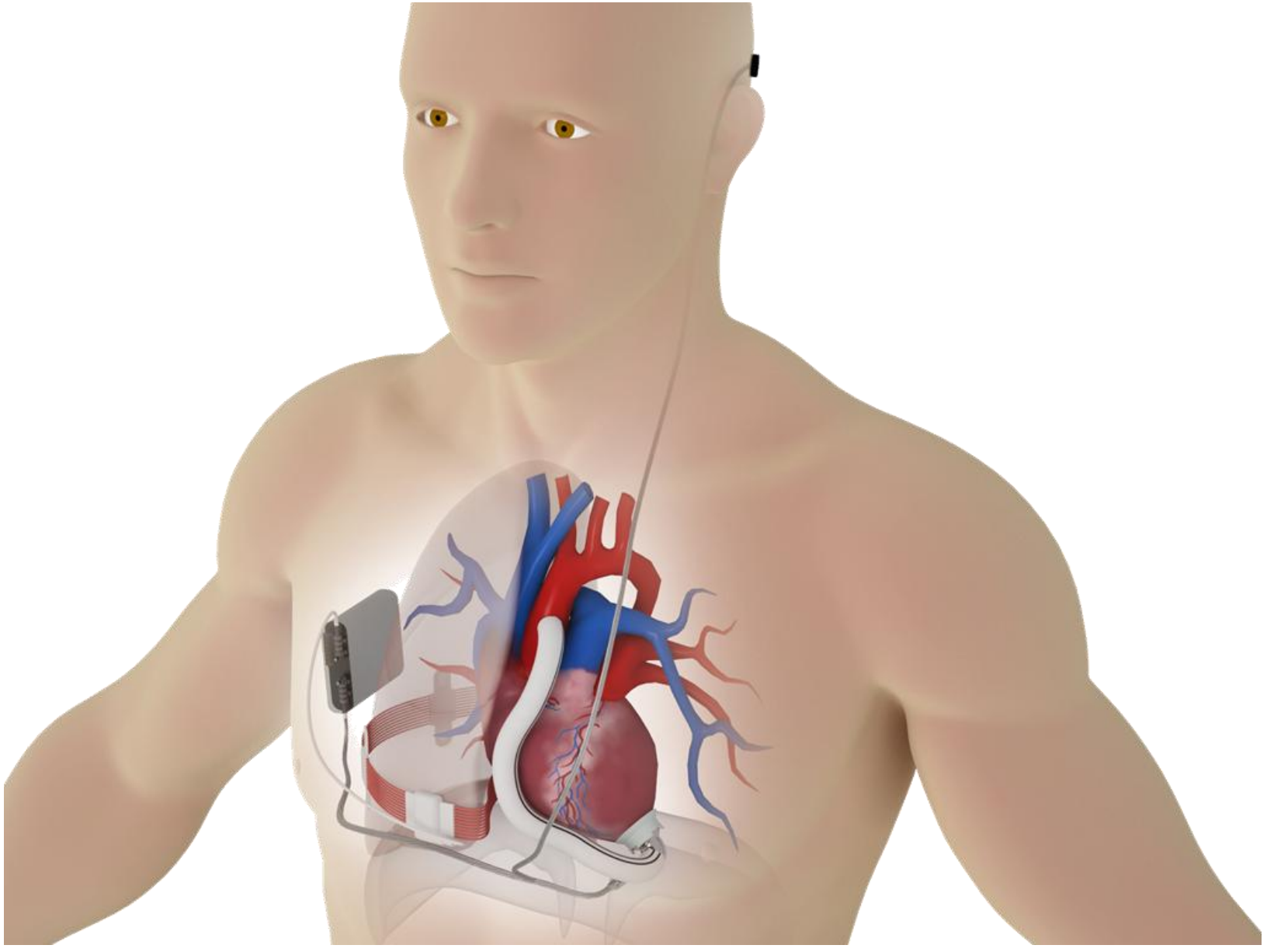
Other Adverse Events

Adverse Event	HM3 *n (%)*	HM II *n (%)*	HM3 *EPPY*	HM II *EPPY*	*P-Value**
Other neurologic event+	59 (11.5)	47 (9.3)	0.09	0.08	0.21
TIA	16 (3.1)	19 (3.8)	0.03	0.03	0.75
Any major infection	300 (58.3)	285 (56.4)	0.82	0.82	0.96
40% LVAS driveline infection	120 (23.3)	98 (19.4)	0.23	0.22	0.60
Any right heart failure	176 (34.2)	143 (28.3)	0.27	0.23	0.18
Managed with RVAS	21 (4.1)	21 (4.2)	0.03	0.03	0.76
Cardiac arrhythmia	185 (35.9)	207 (41.0)	0.37	0.45	0.02
Ventricular arrhythmia	107 (20.8)	128 (25.3)	0.20	0.27	0.01
Respiratory failure	111 (21.6)	98 (19.4)	0.19	0.17	0.44
Renal dysfunction	73 (14.2)	56 (11.1)	0.11	0.08	0.07
Hepatic dysfunction	25 (4.9)	27 (5.3)	0.03	0.04	0.38



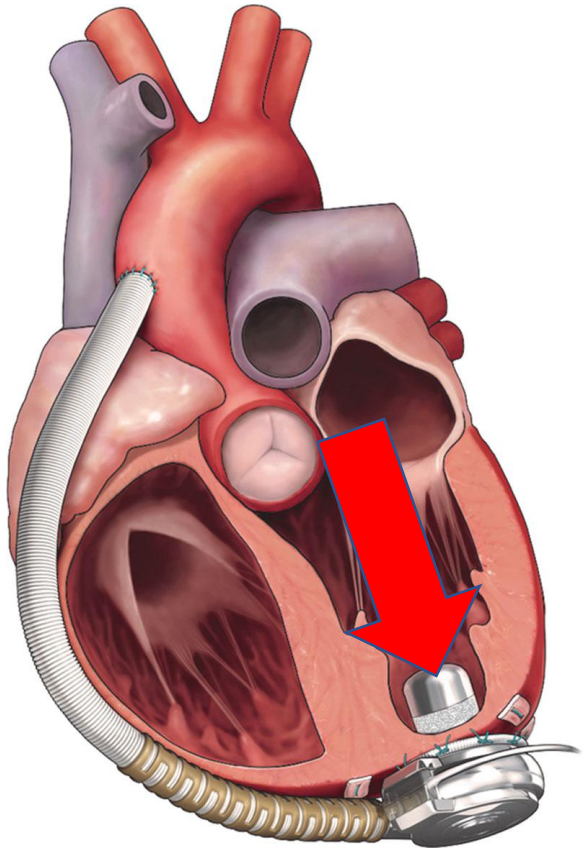
HM3 denotes HeartMate 3; HMII HeartMate II; EPPY events per patient year; CI, confidence interval; TIA transient ischemic attack; RVAS right ventricular assist system.
*P values were calculated with Poisson regression. +Includes TIA, encephalopathy, seizure and neurologic events other than stroke

Coplanar Energy System - LeviticusCardio



Coplanar Energy System - LeviticusCardio

New concepts in a long-term LVAD support



Power consumption: 4-5 W

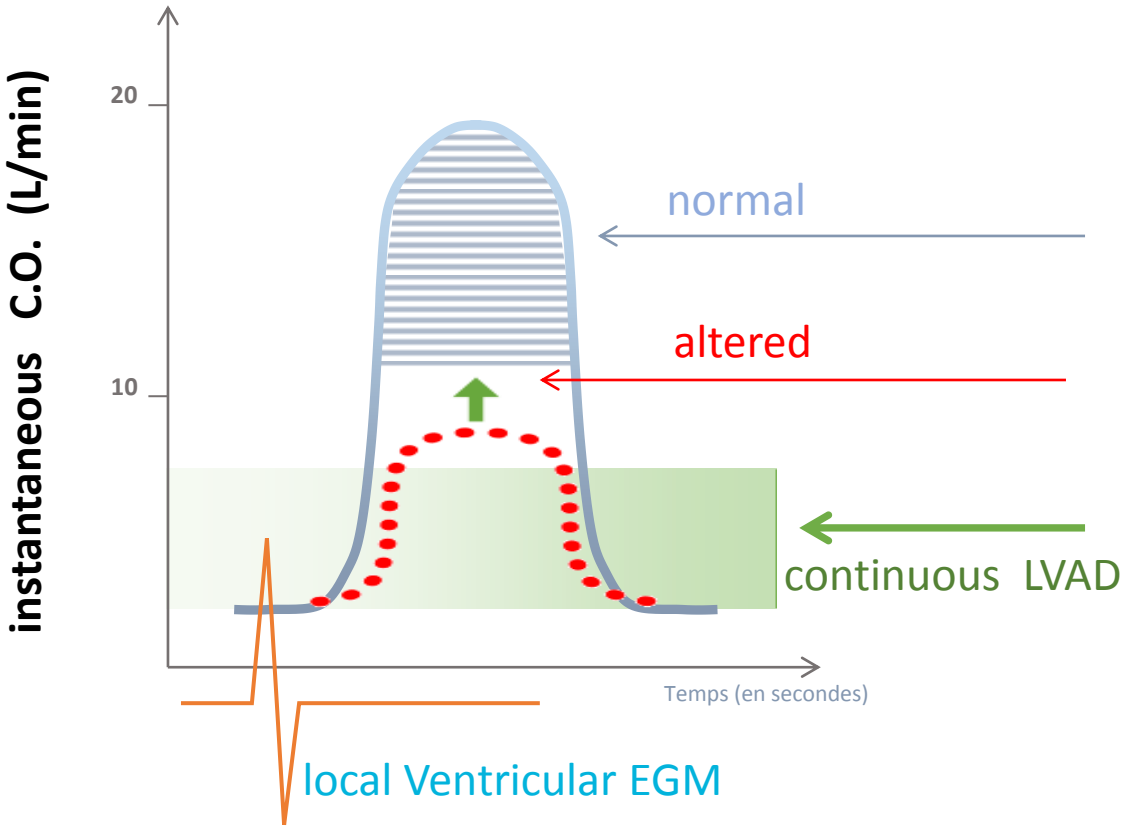
Karate

Aikido

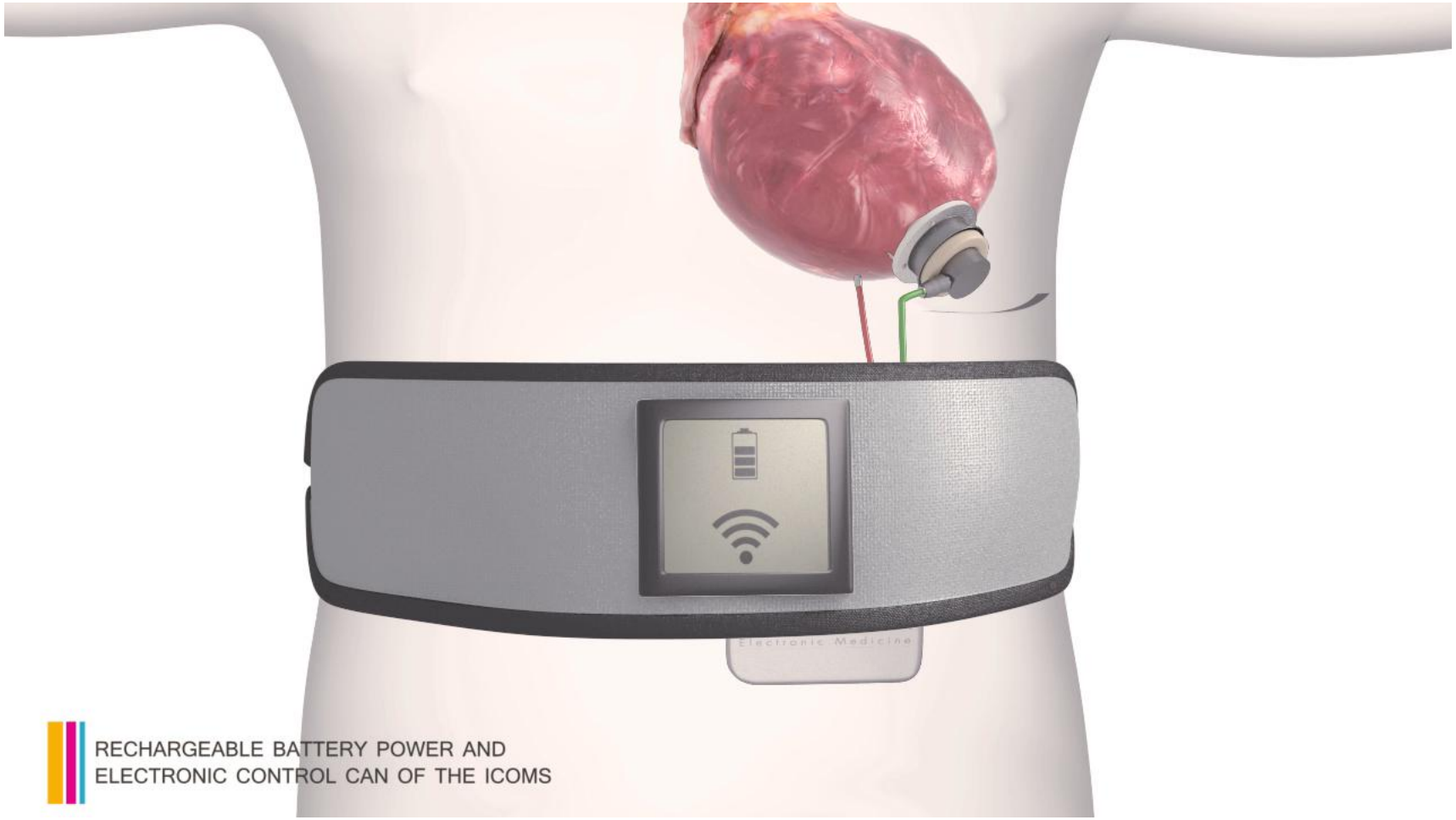
Power consumption: approx. 1.2 W

ICOMS Fineheart

restored C.O. = spontaneous C.O. + ICOMS C.O.



Transcutaneous Energy System - ICOMS Fineheart

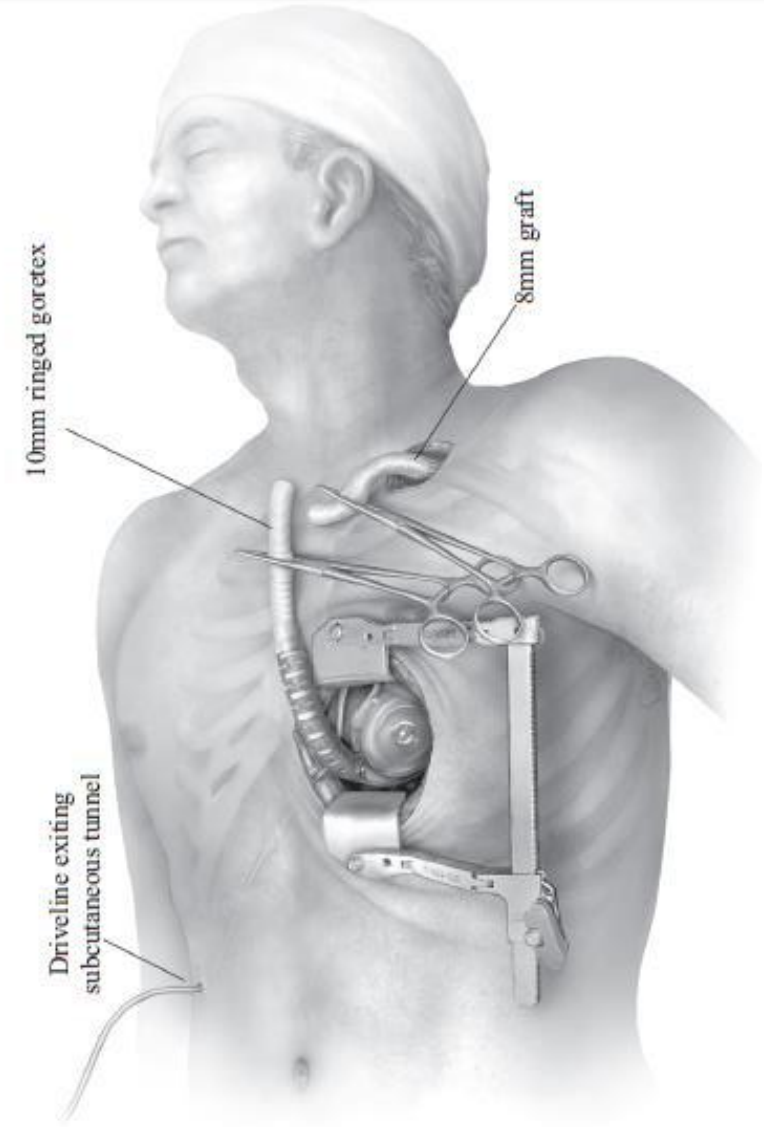


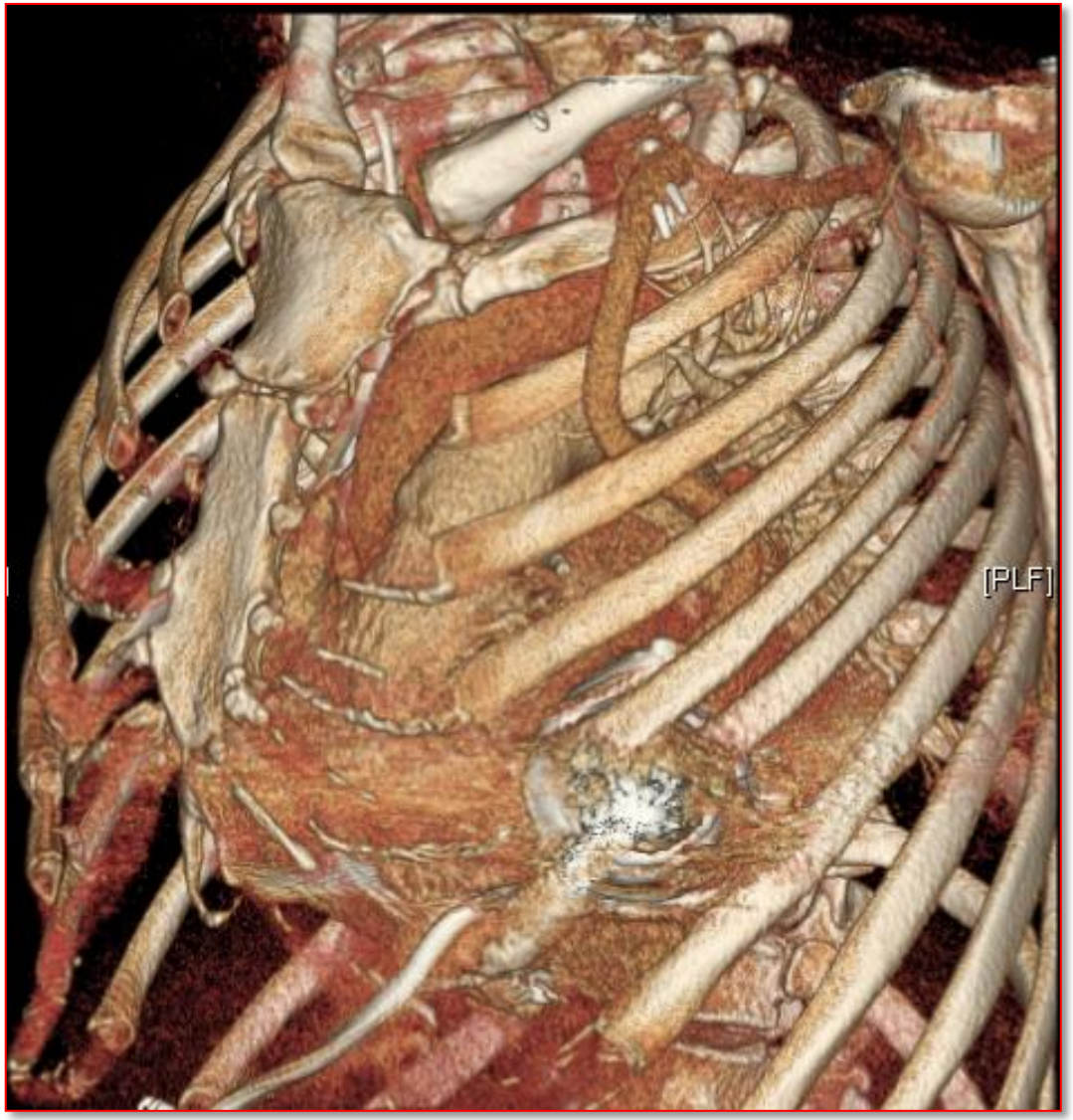
Conclusions

- LVADs - established end-stage heart failure therapy
- Minimally invasive and off-CPB implant amenable
- Survival outcomes equivalent to HTx at 2 years
- Strong signal of enhanced hemocompatibility
- ”Fully internalized, ECG synchronized & pulsatile systems”

  to address residual risks are warranted

Alternative implant strategy – subclavian artery





Maltais S. et al, OTTCVS 19:276-291.

Shrnutí

- Zásadní zlepšení dlouhodobého přežívání
- Výsledky ekvivalentní s TxS ve 2 letech
- Zvýšená tromborezistence – modifikovaná anti-trombotická Rx
- Implantabilní pulsatilní systémy již klinickou realitou
- Další snižování komplikací a zvýšení funkční kapacity 

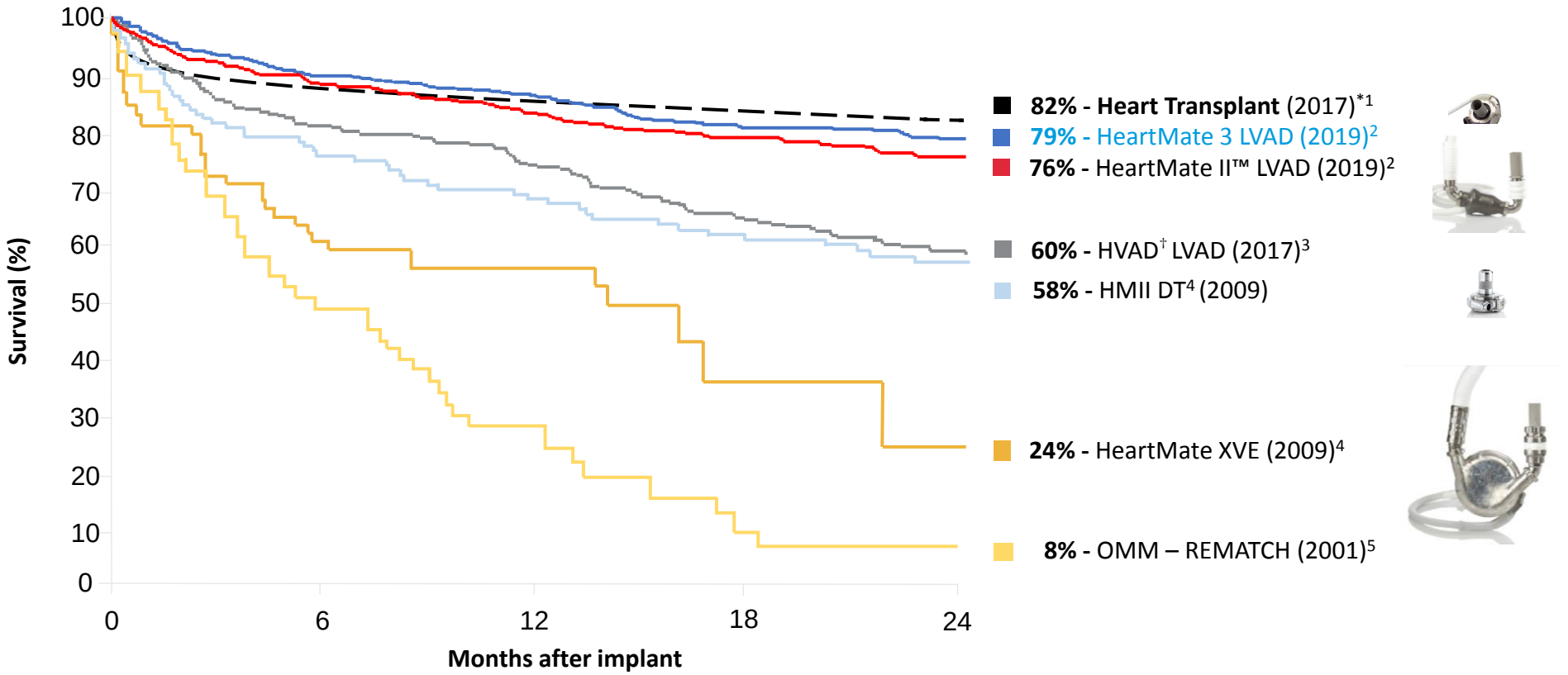
“Smart pumps” + ”Fully internalized systems”

Inferences

- LVADs - established end-stage heart failure therapy
- Minimally invasive and off-CPB implant amenable
- Survival outcomes equivalent to HTx at 2 years
- Strong signal of enhanced hemocompatibility
- ”Fully implantable systems & smart pumping features”

  to address residual risks are warranted

Impact of advancing technology and best practices



Based on published data from multicenter experience and separate studies, which may involve different patient populations and other variables. Not a head to head comparison. Data presented for informational purposes only.

*82% 2-year survival for adult heart transplants patients between 2009 and 2015[1]

References: 1. Lund LF, Khush KK, Cherikh WS, et al. The Registry of the International Society for Heart and Lung Transplantation: Thirty-fourth Adult Heart Transplantation Report—2017; Focus theme: allograft ischemic time. *J Heart Lung Transplant*. 2017;36:1037-1046**. 2.** Mehra MR, Uriel N, Naka Y, et al. A Fully Magnetically Levitated Ventricular Assist Device-Final Report. N Engl J Med. 2019. **3.** Rogers JG, Pagani FD, Tatooles AJ, et al. Intrapericardial Left Ventricular Assist Device for Advanced Heart Failure. *N Engl J Med*. 2017;376:451-60**. 4.** Slaughter MS, Rogers JG, Milano CA, et al. Advanced heart failure treated with continuous-flow left ventricular assist device. *N Engl J Med*. 2009;361:2241-2251. **5.** Rose EA, Gelijns AC, Moskowitz AJ, et al. Long-term use of a left ventricular assist device for end-stage heart failure. *N Engl J Med.* 2001 Nov 15;345(20):1435-43.