TEL AVIV UNIVERSITY

RABIN MEDICAL CENTER
BEILINSON • HASHARON

Mechanical Assistance for Acute Heart failure

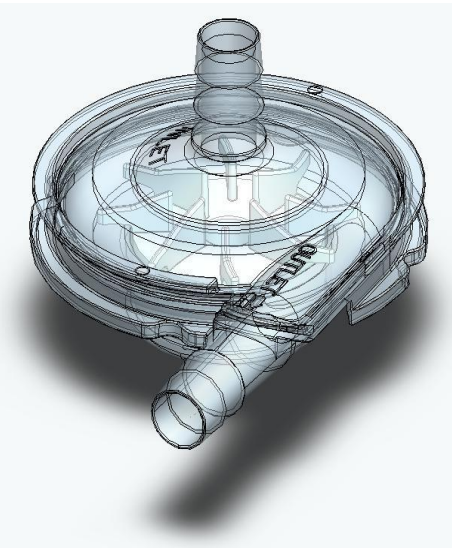
Benjamin Medalion, MD

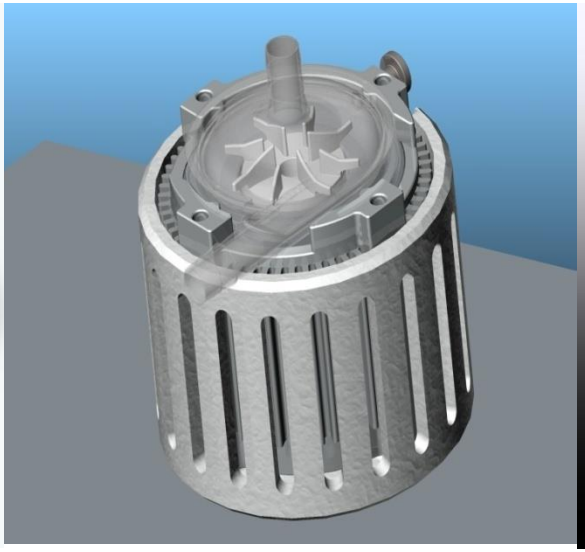
Director Heart and Lung Transplantation
Rabin Medical Center, Petach Tiqva, Israel

Mechanical Assists available

- Short term (Centrifugal pumps)
  - LVAD
  - RVAD
  - BiVAD
  - ECLS (ECMO)
- Long term
  - Pulsatile (Thoratec PVAD, Syncardia TAH)
  - Axial flow (HeartMate II)
  - Centrifugal (HeartWare)

CentriMag

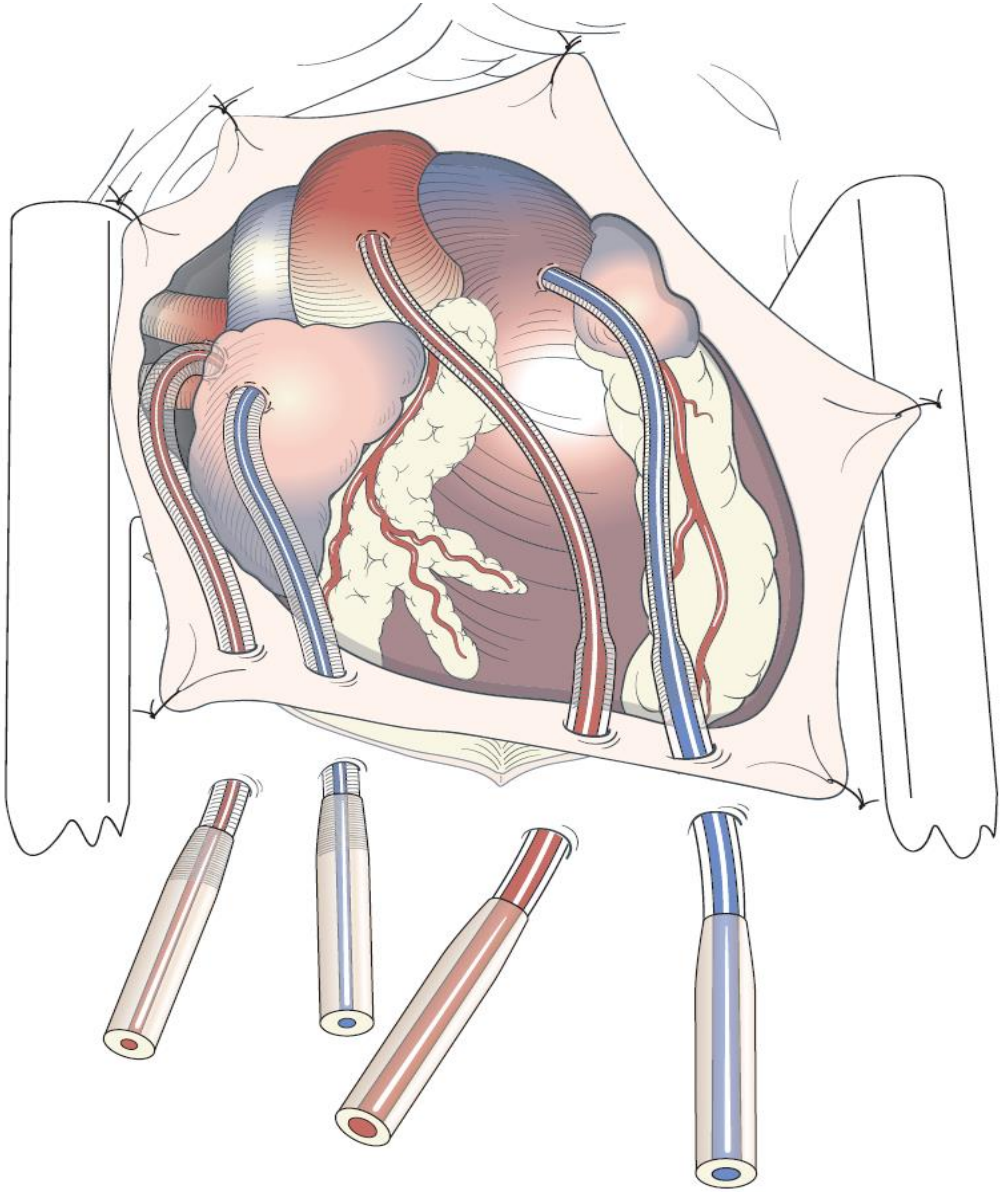




The Levitronix® CentriMag VAS is designed to provide temporary support for patients suffering potentially reversible cardiogenic shock.

FDA approved for up to 30 days of use.

Cannulation



Outcomes of a multicenter trial of the Levitronix CentriMag ventricular assist system for short-term circulatory support

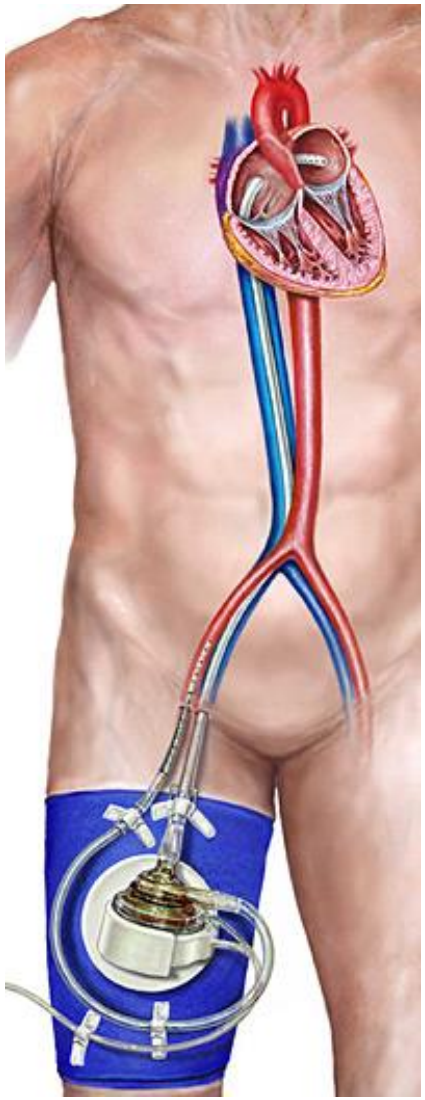
Ranjit John, MD,[a] James W. Long, MD,[b] H. Todd Massey, MD,[c] Bartley P. Griffith, MD,[d] Benjamin C. Sun, MD,[e] Alfred J. Tector, MD,[f] O. Howard Frazier, MD,[g] and Lyle D. Joyce, MD[a]

J Thorac Cardiovasc Surg 141:932-9;2011

TABLE 3. Survival by group

	30 d	Discharge	6 mo
All (n = 38)	18 (47%)	16 (42%)	12 (32%)
RVAD (n = 12)	7 (58%)	5 (42%)	4 (33%)
PMICS (n = 14)	7 (50%)	7 (50%)	6 (43%)
PCCS (n = 12)	4 (33%)	4 (33%)	2 (17%)
LVAD (n = 8)	3 (38%)	2 (25%)	2 (25%)
BVAD (n = 18)	8 (44%)	8 (44%)	6 (33%)

All times are measured from device removal; all data are numbers of patients with percentages. *RVAD*, Right ventricular assist device; *PMICS*, post–acute myocardial infarction cardiogenic shock; *PCCS*, postcardiotomy cardiogenic shock; *LVAD*, left ventricular assist device; *BVAD*, biventricular assist device.



Tandem Heart

The Tandem Heart is inserted percutaneously transeptal.

It provides temporary support for patients suffering potentially reversible cardiogenic shock.

It is intended to be used up to 7 days

Randomized comparison of intra-aortic balloon support with a percutaneous left ventricular assist device in patients with revascularized acute myocardial infarction complicated by cardiogenic shock

Holger Thiele*, Peter Sick, Enno Boudriot, Klaus-Werner Diederich, Rainer Hambrecht, Josef Niebauer, and Gerhard Schuler

European Heart Journal (2005) 26, 1276–1283

- IABP = 20
- Tandem Heart = 21

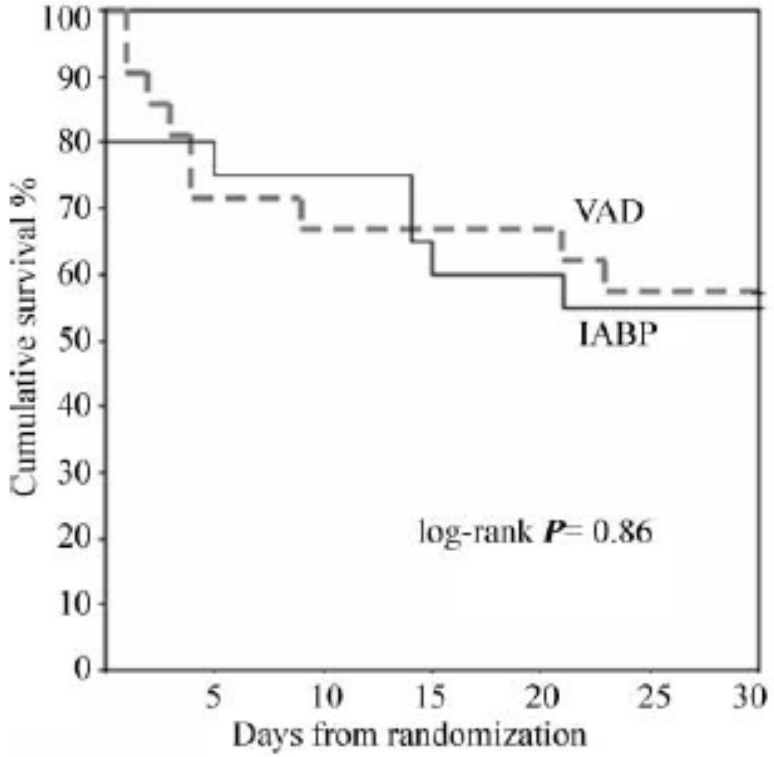
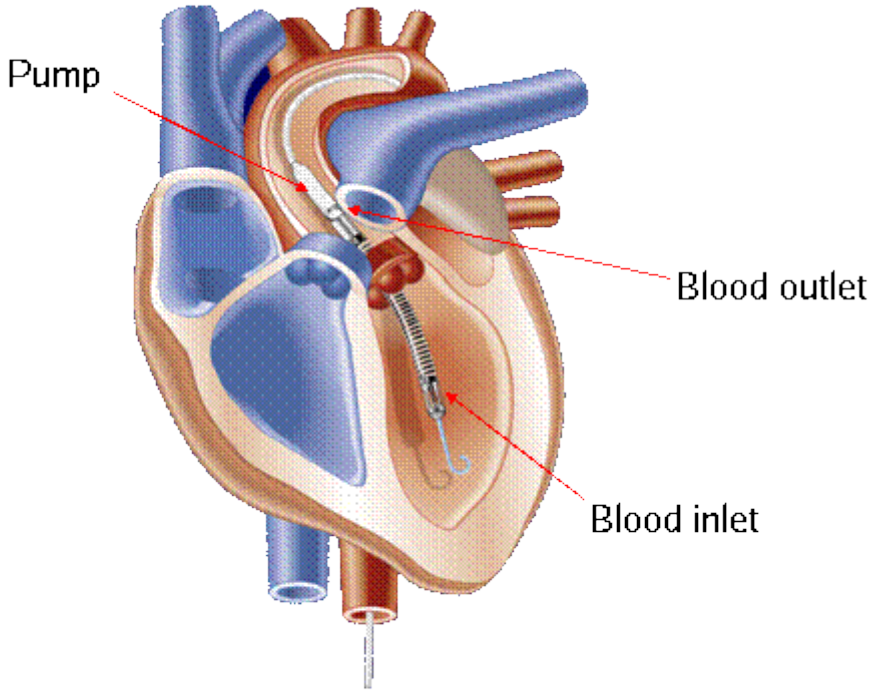


Figure 4 Kaplan–Meier survival estimates for 30 day survival for IABP and VAD.

Impella



The Impella 2.5 is inserted percutaneously The Impella 5 is inserted surgically

Both provide temporary support for patients suffering potentially reversible cardiogenic shock.

It is intended to be used up to 7 days

The Impella 2.5 and 5.0 devices for ST-elevation myocardial infarction patients presenting with severe and profound cardiogenic shock: The Academic Medical Center intensive care unit experience*

Annemarie E. Engström, MD; Ricardo Cocchieri, MD; Antoine H. Driessen, MD; Krischan D. Sjauw, MD; Marije M. Vis, MD; Jan Baan, MD, PhD; Mark de Jong, RN; Wim K. Lagrand, MD, PhD; Jos A. P. van der Sloot; Jan G. Tijssen; Robbert J. de Winter; Bas A. S. de Mol; Jan J. Piek; José P. J. M. Henriques, MD, PhD

Crit Care Med 2011 Vol. 39, No. 9

- At 30 days - alive
  - 6/23 (26%) Impella 2.5
  - 6/12 (50%) Impella 5

Comparative outcomes in cardiogenic shock patients managed with Impella microaxial pump or extracorporeal life support

Yoan Lamarche, MD,[a] Anson Cheung, MD,[a] Andrew Ignaszewski, MD,[a] Jennifer Higgins, MD,[a] Annemarie Kaan, MCN RN,[a] Donald E. G. Griesdale, MD, MPH,[b] and Robert Moss, MD[a]

(J Thorac Cardiovasc Surg 2011;142:60-5)

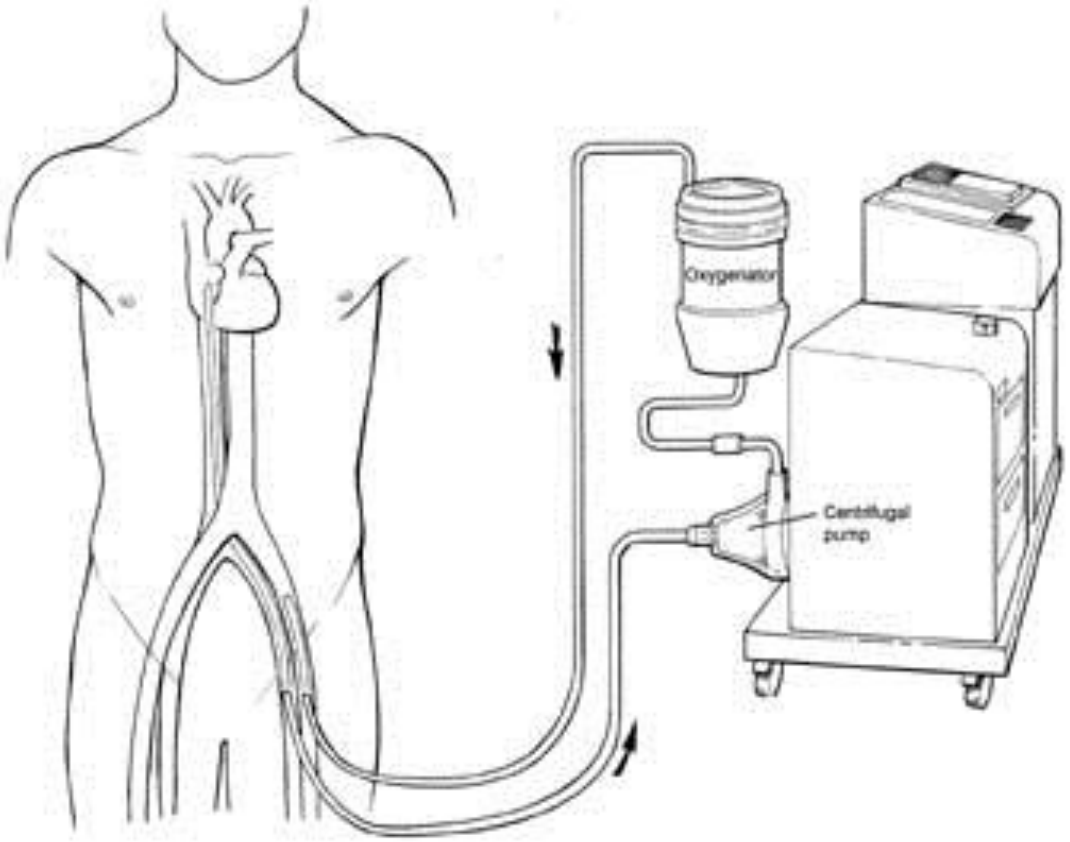
- At 30 days - alive
  - 11/29 (38%) Impella 5
  - 13/32 (41%) ECLS

ECLS (ECMO)

- Modified mobile cardiopulmonary bypass
  - Easy to insert
  - Fast
  - Bed side
  - Both circulatory and respiratory support

  However
  - Does not unload LV (afterload increased)
  - Patient is relatively immobilized

VA ECMO



ECMO and CPR

ECMO No CPR ~ 40%-60%

ECPR survival to discharge ~ 20%

Lazzeri C et al. European Heart Journal: Acute Cardiovascular Care 2013;2048872613484687

European Heart Journal Acute Cardiovascular Care

TABLE 1.

(Section I)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Raithel et al[15] (1989)		29 patients	CA during catheterization (10 pts), shock secondary to AMI (10 pts), high risk PTCA (4 pts), postcardiotomy failure (4 pts), hypothermia (1 pt).	6 /29 (20.6%)	6 /29 (20.6%)		
Reedy et al[16] (1990)	prospective	38 pts; 35 pts successfully implanted	AMI (12 pts), ischemic disease (15 pts), end-stage cardiomyopathy (7 pts), congenital heart disease (3 pts), or postoperative cardiac transplant graft rejection (1 pt)	24 pts (24/38, 63.1%)	9 pts (24%)		
Younger et al[17] (1994)		25 patients (2 children) in 4 pts failure to cannulate	drowing (3 pts), AMI (9 pts), viral cardiomyopathy (2 pts) procedure complications (1 pt), pulmonary embolism (9), aortic endocarditis (1 pt)	9/25 (36%)			
Chen et al[28] (2003)	retrospective	57 pts	post cardiotomy (14 pts), pumonary embolism (2 pt), AMI (3 pts), cardiomyopathy (14) CS (25 pts)) CA (21 pts)	38/57 (66.7%)	18/57 (31.6%)	16/57 (28%)	15/57 (26%)
Schwarz et al[29] (2003)		46 pts 4 cannulation failure 1 ECMO failure		28/46 (61%)	13/46 (28.2%)	01/12/46	

(Section II)

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Massetti et al[31] (2005)		40 pts	AMI (16 pts), pulmonary embolism (3 pts) postcardiotomy (4 pts), cardiomypathy (4 pts), myocardial intoxication (4 pts) myocarditis (2 pts) arrhythmias (4 pts)	6 pts (15%) 9 bridge to VAD 2 bridge to transplantation	8 (8/40, 20%)	8 (8/40, 20%)	8 (8/40, 20%)
Chen et al[25] (2006)	retrospective	36 patients	AMI	Weaned 25 pts Withdrawn 6 wean-but-die 13 pts	12 pts (33 %)		
Megarbane et al[3] (2007)	prospective cohort study	17 patients 3 ECMO failure	toxic cardiac arrest (12 pts) non toxic cardiac arrest (5 pts)	4 (4/17, 25%)	4 (4/17, 25%)	3 (3/17, 18%)	3 (3/17, 18%)
Chen et al[18] (2008)	observational cohort study	135 IHCA	ACS (66 pts), post cardiotomy (23 pts) cardiomyopathy (22 pts) myocarditis (12 pts) pulmonary embolism (5 pts), others (7 pts)	79 (79/132) 58.5%	46 (46/135, 34.1%)		
Chen et al[19] (2008)	3-year prospective study	59 IHCA	ACS (37 pts), congestive heart failure (6 pts), myocarditis (5 pts) post-cardiotomy (7 pts), pulmonary embolism (1 pt), unspecified causes (3 pts)	29 (29/59, 49%)	17 (17/9, 28%)		9 (15.3%)

(Section III)

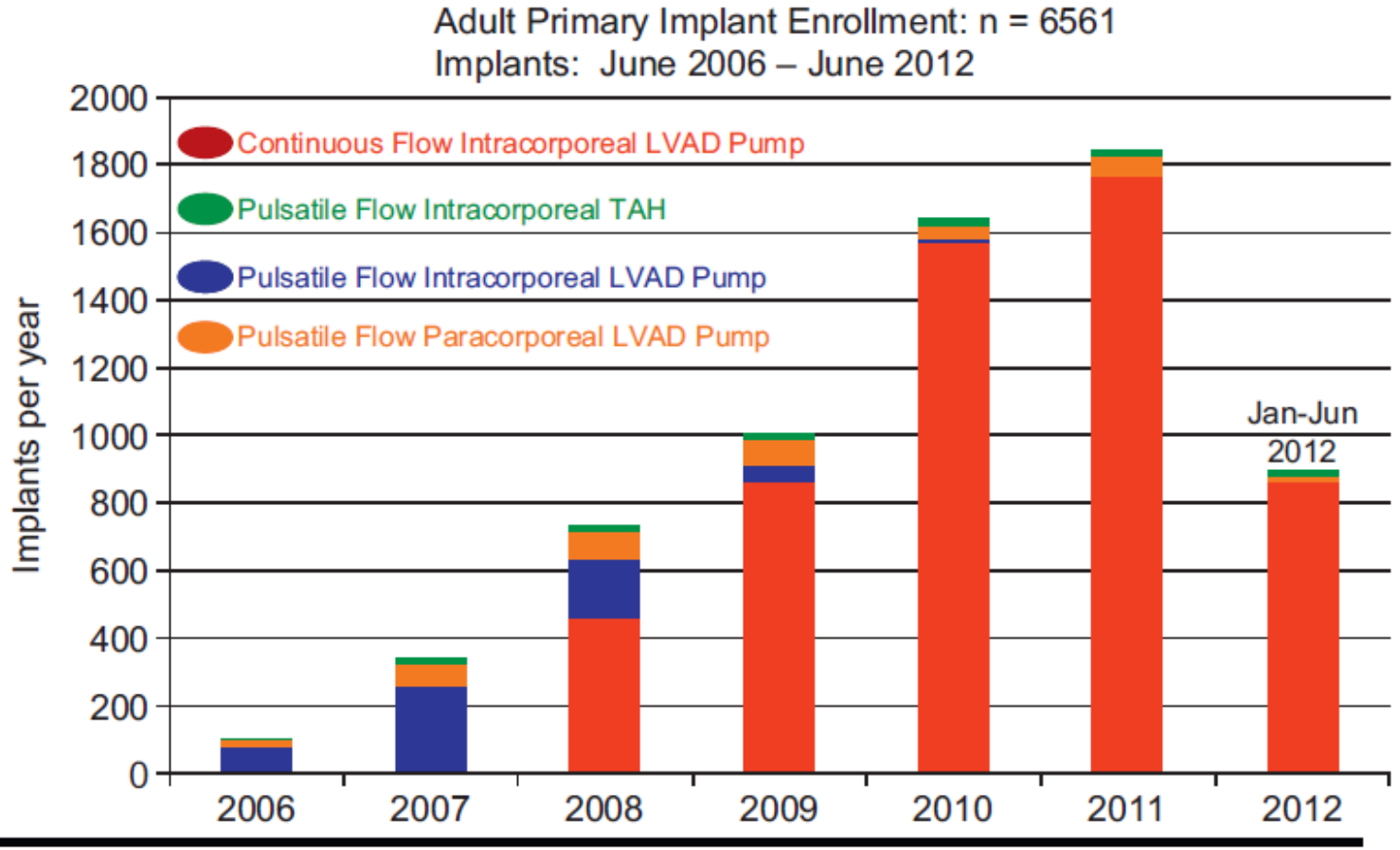
	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Thiagarajan et al[30] (2009)	prospective (ELSO registry)	297 pts	cardiac origin (221 pts), non cardiac origin (76 pts)		81 (81/297, 27%)		
Nagao et al (2010)[11]	prospective	171	ACS (131 pts), cardiomypathy (8 pts), others (32 pts)		33 (33/171, 19%)		1-year 20 (11.7%)
Kagawa et al[9] (2010)	retrospective	77 patients	38 IHCA 39 OHCA	IHCA:23 pts OHCA: 14 pts	NA	IHCA: 13 (34%) OHCA: 5 (13%)	IHCA: 10/38 (26%) OHCA:4/39 (10%)
Jaski et al[32] (2010)	prospective registry	150 patients (127 for cardiac arrest, 23 refractory shock)	CA (127 pts) cardiogenic shock (23 pts)	61 patients		39 (26%)	
Liu et al[20] (2011)	retrospective chart-review	11 patients	AMI	7 pts (63.6%)	4 pts (36.4%)	NA	NA
Megarbane et al (2011)[33]	prospective cohort study	66 pts 1 cannulation failure	IHCA: 47 pts (71%) OHCA:19 pts (29%)		4 (4/66, 6%)	NA	NA
Le guen et al[12] (2011)		51 OHCA patients *8 ECMO failure* *1 cannulation failure* 42 ECMO pts	cardiac origin (44 pts), trauma (3 pts), drug overdose (2 pts), respiratory (1 pt), eletrocaution (1%),		5 (5/42, 12%)	2 pts (4%)	2 pts (4%)
Morimura et al[34] (2011)	meta-analysis -indepth review	139 OHCA		59 pts (58.4%)			
Shin et al[24] (2011)	retrospective	85 IHCA 3 cannulation failure 2 ECMO failure	cardiac origin (79 pts), non cardiac origin (6 pts)		29 pts (34%)	24 (28%)	24 (28%)

Section IV

	Study design	Number of patients	Etiologies	Weaned from ECMO	in-Hospital survival	30-day survival	CPC 1-2
Avalli et al[17] (2012)	retrospective	42 patients (24 pts IHCA; 18 pts OHCA)		IHCA: 14 (14/42, 33%) OHCA: 3 (7%)	NA	IHCA: 10 OHCA: 1	IHCA:9 (37.5%) OHCA: 1 (5.5%)
Kim et al[33] (2012)	retrospective	27 pts	cardiogenic shock (27 pts): CA in 21 pts (77.8%)	22 (81.5%)	16 (59.3%)	13 (48%)	13 (48%)
Sakamoto et al[22] (2012)	single-center, retrospective study cohort	98 patients	ACS: cardiogenic shock (28 pts, 28.6%), cardiac arrest (36, 36.7%)	54 pts (55.1%)	32 (32.7%)	NA	NA
Kagawa et al[34] (2012)	multicenter cohort study	86 pts	ACS IHCA: 44 (51.1%) OHCA: 42 (48.9%)	53 pt (50%)		25 (25/88, 29%)	21 (21/88, 24%)

ECMO: extracorporeal mebrane oxygenation; ACS: acute coronary syndrome; AMI: acute myocardial infarction; CA: cardiac arrest; IHCA: in-hospital cardiac arrest; OHCA: out-of-hospital cardiac arrest; CPC: cerebral performance categories.

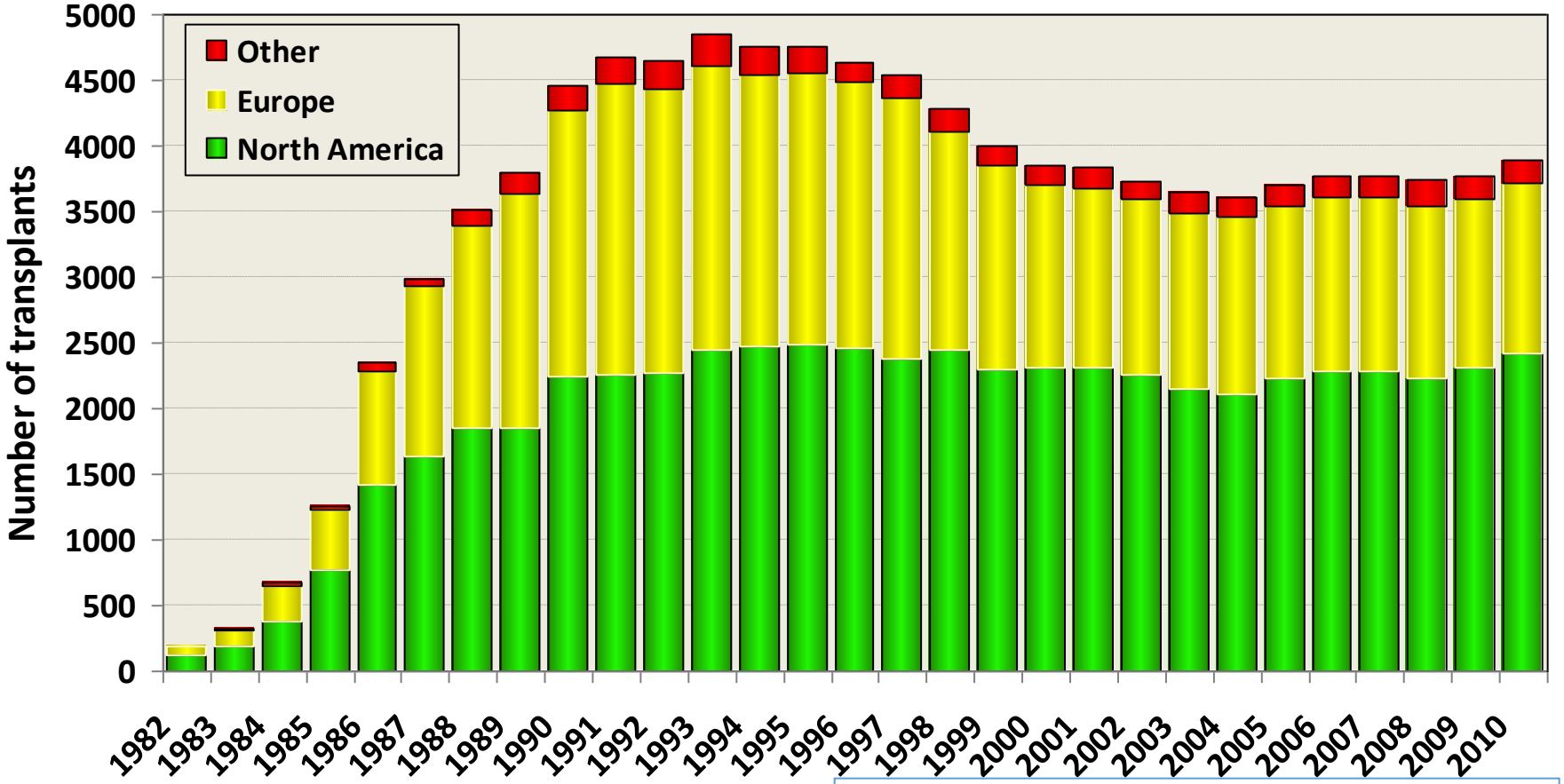
Patients Need to be referred **Early**, before irreversible End Organ Failure Exist



	2006	2007	2008	2009	2010	2011	2012
Cont Intra Pump	0	0	458	860	1570	1765	862
Puls Intra TAH	1	22	23	24	29	21	16
Puls Intra Pump	78	260	181	53	14	3	1
Puls Para Pump	18	60	73	69	31	55	14

J Heart Lung Transplant 2013;32:141–156

NUMBER OF HEART TRANSPLANTS BY YEAR AND LOCATION



NOTE: This figure includes only the heart transplants that are reported to the ISHLT Transplant Registry. As such, the presented data may not mirror the changes in the number of heart transplants performed worldwide .

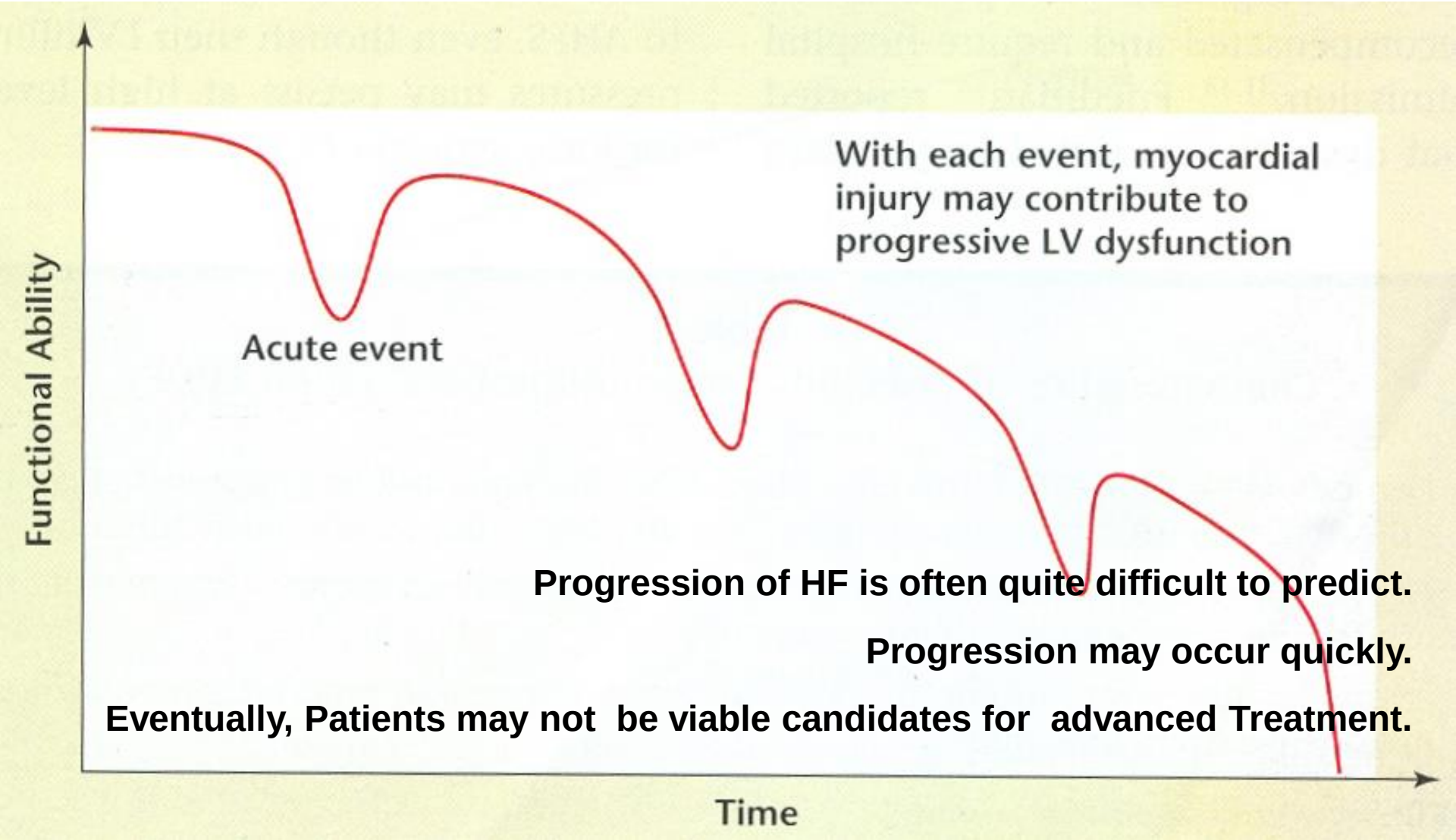
ISHLT

2012

J Heart Lung Transplant. 2012 Oct; 31(10): 1045-1095

When is medical therapy not enough?

Episodes of Acute Exacerbation of Heart Failure



Progression of HF is often quite difficult to predict.

Progression may occur quickly.

Eventually, Patients may not be viable candidates for advanced Treatment.

Timing of VAD

Medical therapy of heart failure

Slow disease progression

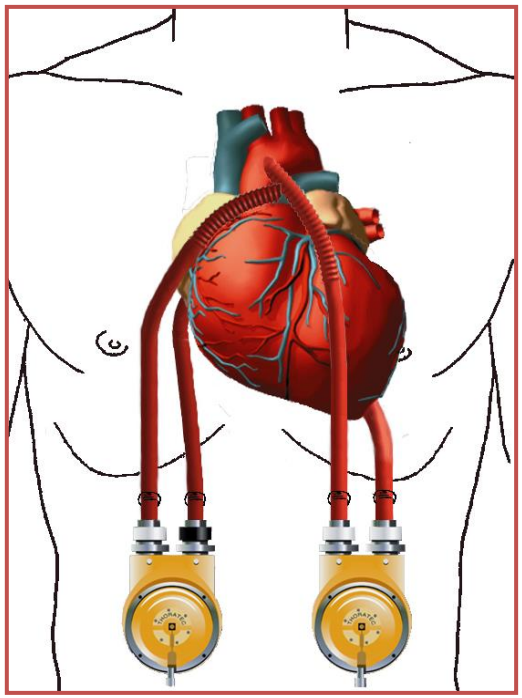
Pacemakers in HF

Delay disease progression

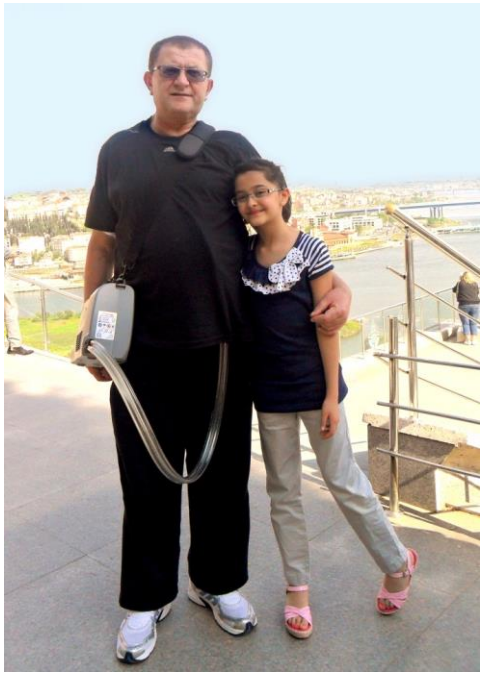
But: NEVER CURE!!!

Pulsatile Devices

Thoratec®:
Paracorporeal VAD



Syncardia
Total Artificial Heart



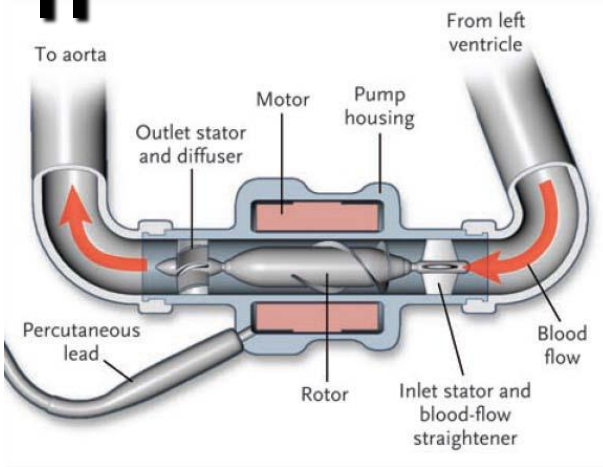
Continuous Flow Devices

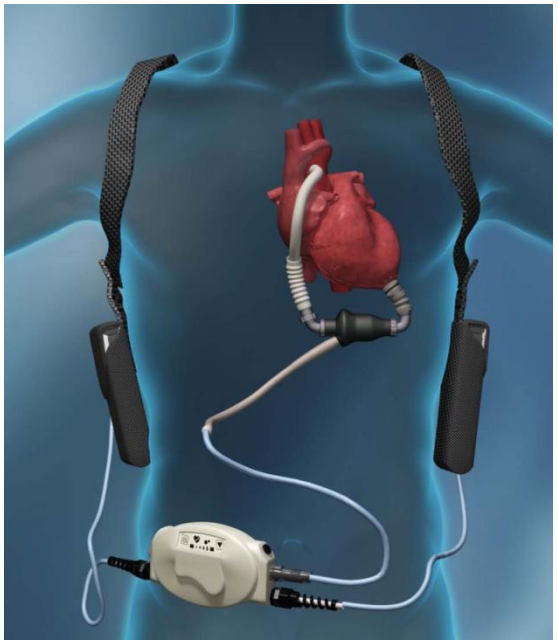
- Adequate end organ perfusion in normal blood flow

Axial Flow Pumps

HeartMate II

- magnetically suspended
- Small
- Silent
- Valveless
- 7,000-12,000 RPM
- Afterload dependent
- Can deliver up to 10 lit/min

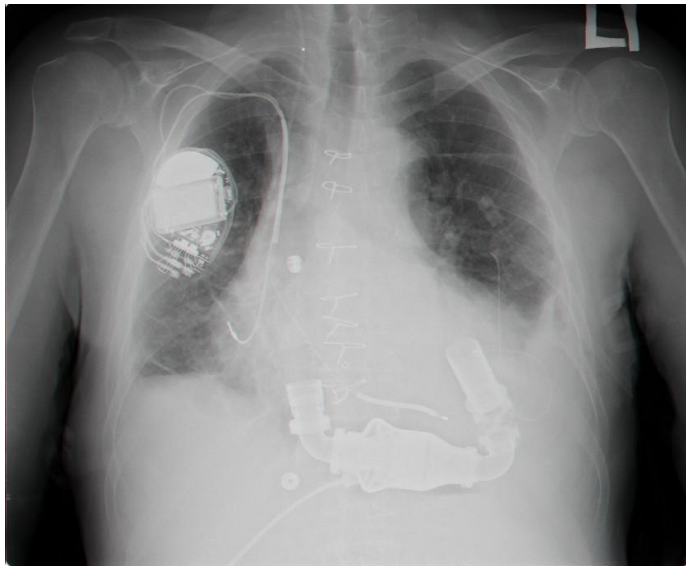


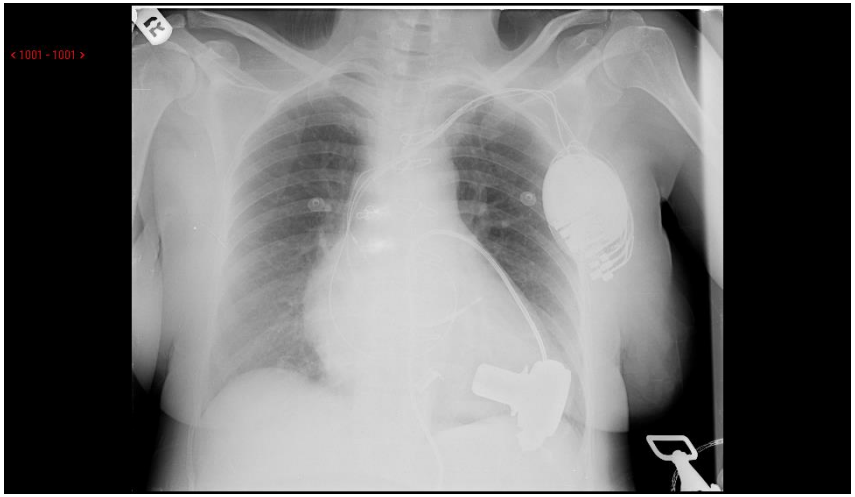


Centrifugal Pumps

HeartWare

- magnetically levitated
- Small
- Silent
- Valveless
- 2,000-3,000 RPM
- Afterload dependent
- Can deliver up to 10 lit/min

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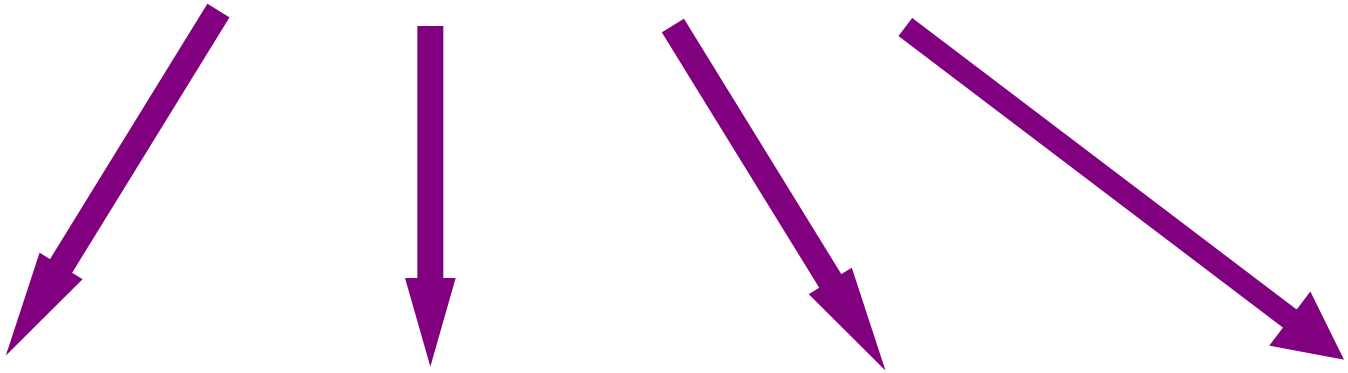
Intended Use



Bridge to transplant

Bridge to recovery

Long term therapy

Bridge to decision

Bridge to Transplantation

- Was the initiative to those devices
- Most require LVAD only
- About 10% will require additional RVAD

Bridge to Recovery

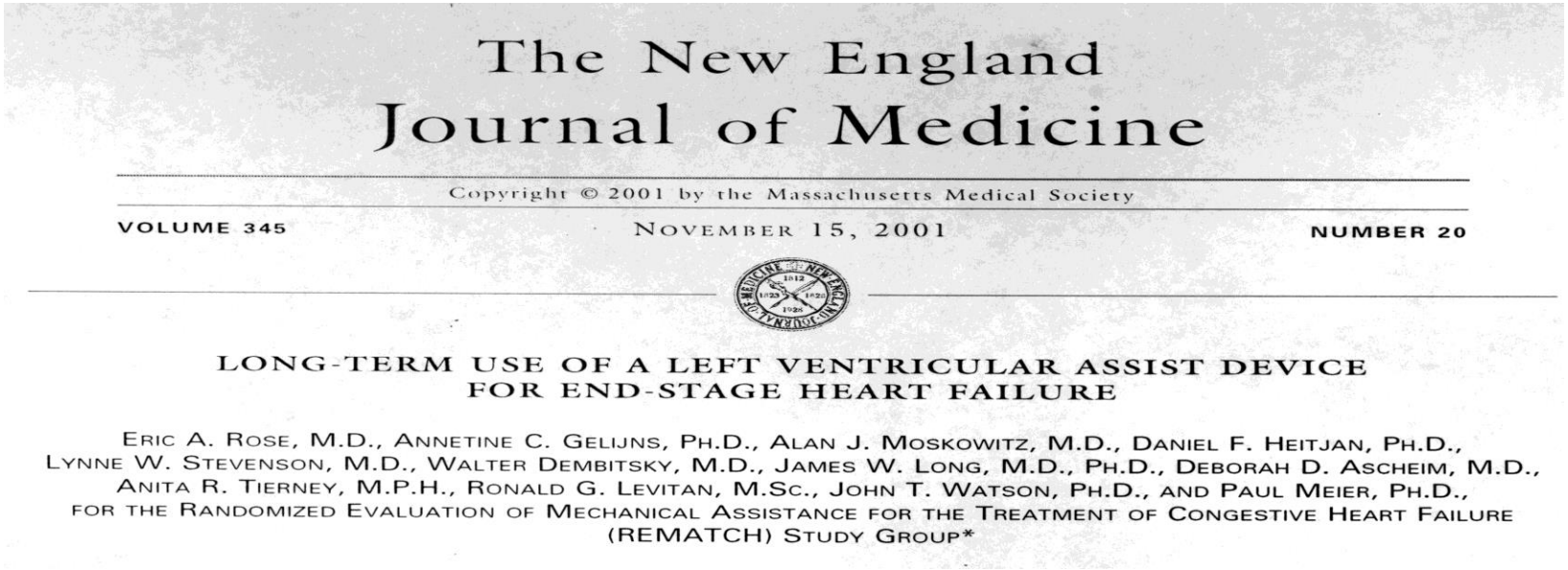
- Currently unpredictable results
- It is yet to be discovered who are the patients that will recover and will not fail shortly after removal of device

Long Term Therapy

- Lack of donors and successful long term support as bridge, opened a new era

REMATCH study

***R**andomized **E**valuation of **M**echanical **A**ssistance for the **T**reatment of **CH**F*



The New England Journal of Medicine

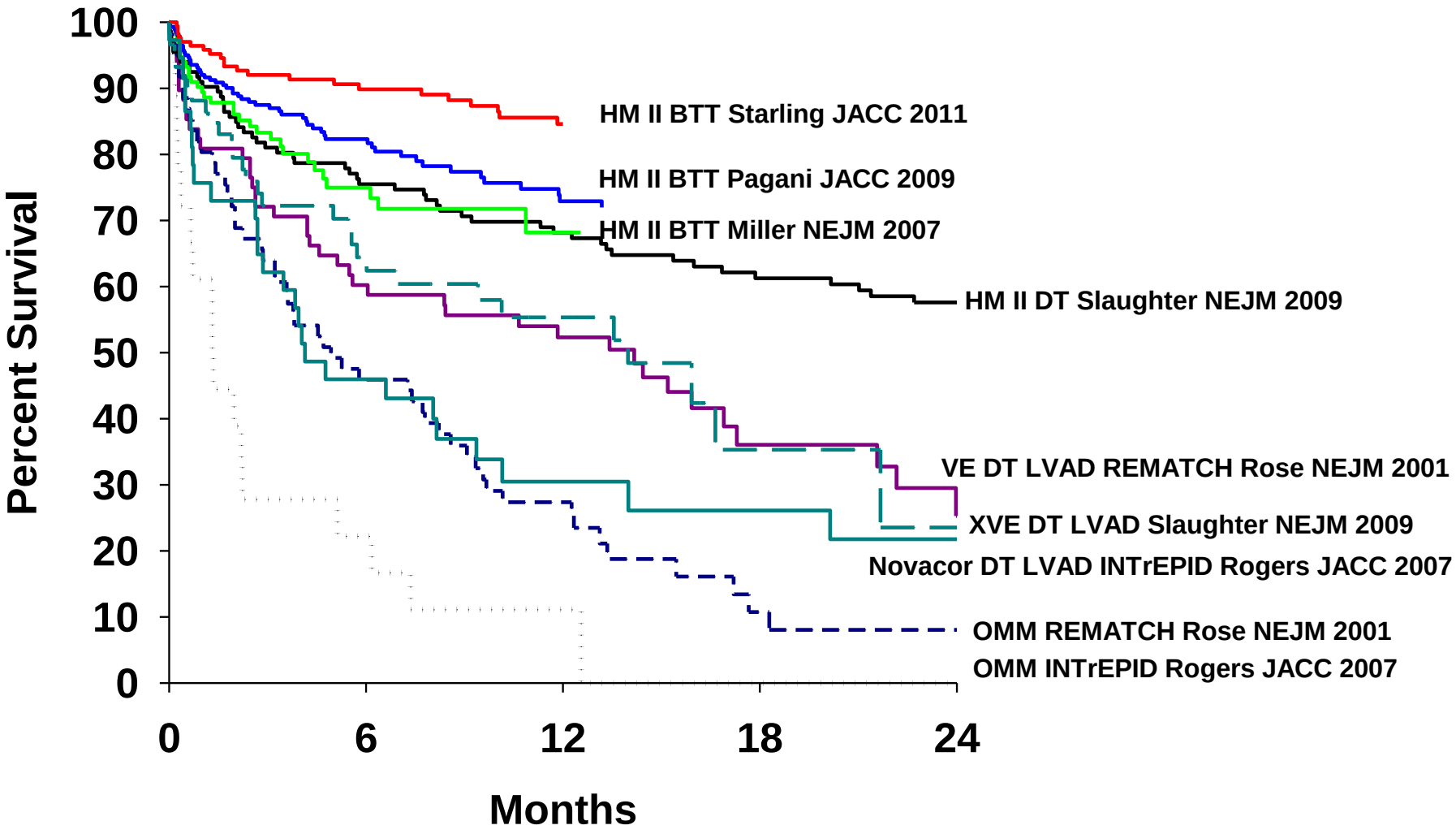
VOLUME 345 NOVEMBER 15, 2001 NUMBER 20

LONG-TERM USE OF A LEFT VENTRICULAR ASSIST DEVICE FOR END-STAGE HEART FAILURE

ERIC A. ROSE, M.D., ANNETINE C. GELIJNS, PH.D., ALAN J. MOSKOWITZ, M.D., DANIEL F. HEITJAN, PH.D., LYNNE W. STEVENSON, M.D., WALTER DEMBITSKY, M.D., JAMES W. LONG, M.D., PH.D., DEBORAH D. ASCHEIM, M.D., ANITA R. TIERNEY, M.P.H., RONALD G. LEVITAN, M.SC., JOHN T. WATSON, PH.D., AND PAUL MEIER, PH.D., FOR THE RANDOMIZED EVALUATION OF MECHANICAL ASSISTANCE FOR THE TREATMENT OF CONGESTIVE HEART FAILURE (REMATCH) STUDY GROUP*

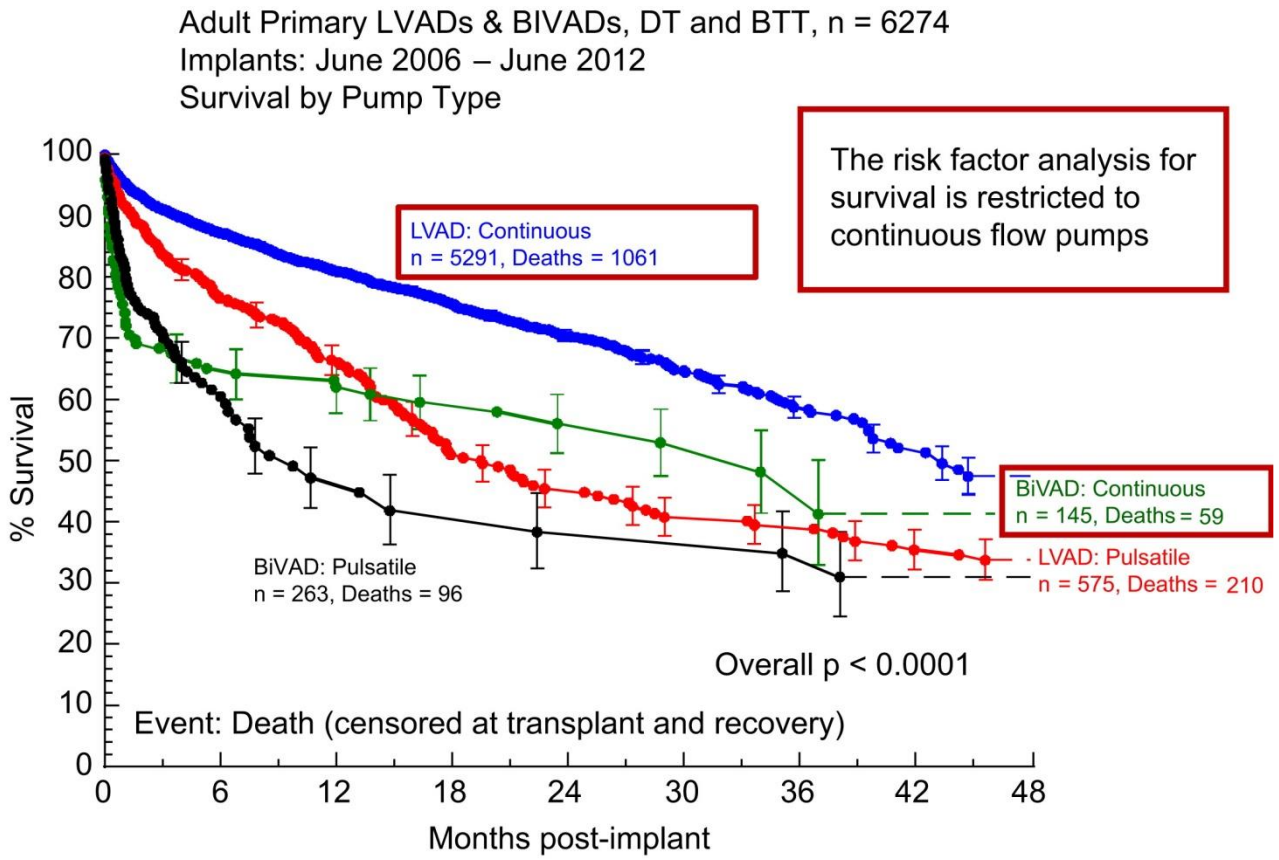
- 129 patients (68 – LVAS, 61 – optimal medical)
- Mean age: 66 ± 9 years
- 48% reduction in risk of death
- 1 year survival: 52% vs. 25%
- 2 year survival: 23% vs. 8%
- Improved quality of life at 1 year

Improved Survival in LVAD Trials



INTERMACS Report 2013

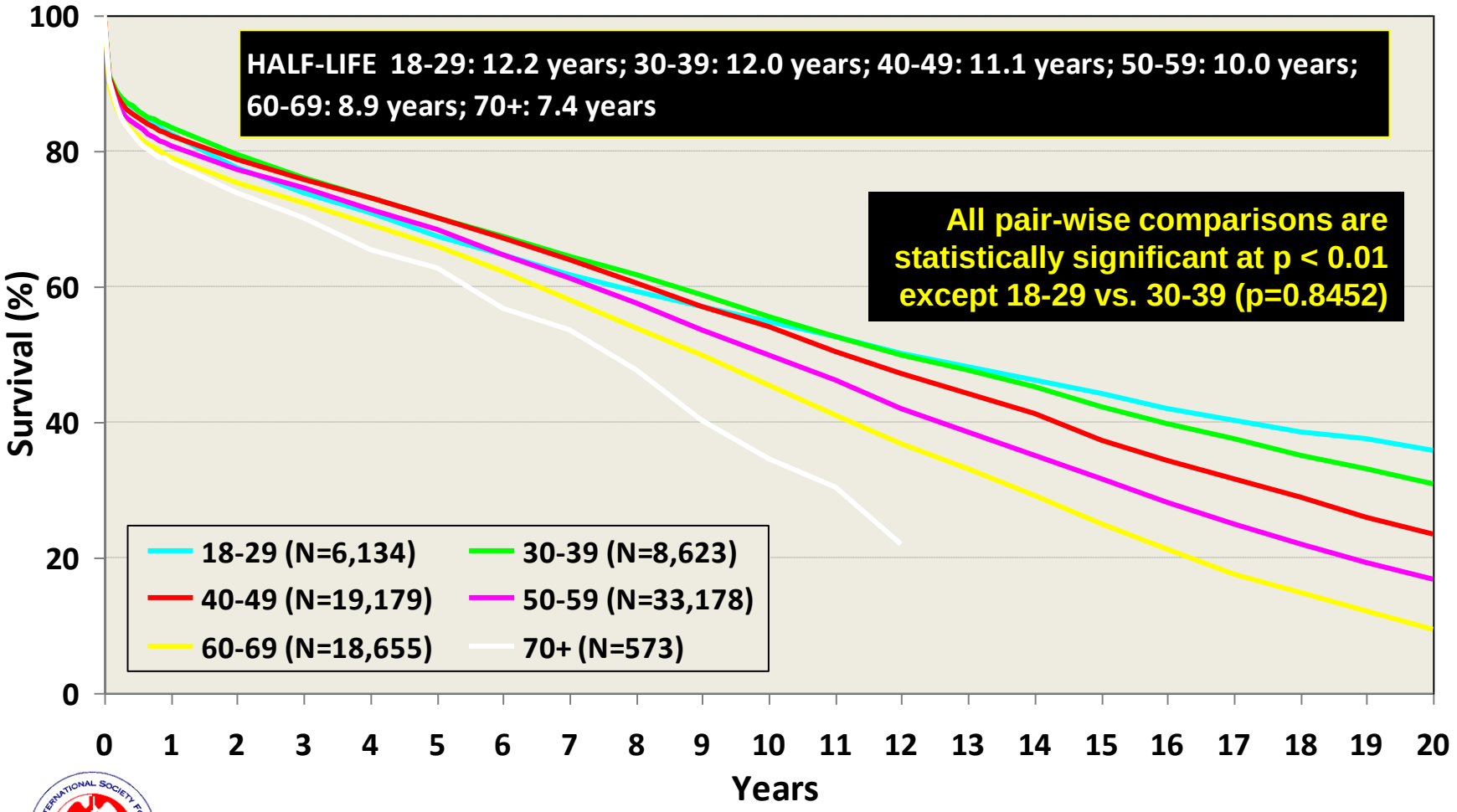
HeartMate II Continuous Flow LVAD



Kirklin, Naftel, Kormos et al JHLT 2013;2:141-56

ADULT HEART TRANSPLANTS

Kaplan-Meier Survival by Age Group
(Transplants: January 1982 - June 2010)



ISHLT

2012

J Heart Lung Transplant. 2012 Oct; 31(10): 1045-1095

INTERMACS Profiles
HMII BTT Post-Approval Study

Baseline INTERMACS Profiles

INTERMACS Profile	HeartMate II (n=169)
1	41 (24%)
2	63 (37%)
3	33 (20%)
4	21 (12%)
5-7	11 (7%)

61% of patients in the study were in profile 1 or 2.

Profile	Description
1	Critical cardiogenic shock
2	Progressive decline
3	Stable, but inotrope dependant
4	Recurrent advanced heart failure
5	Exertion tolerant
6	Exertion limited
7	Advanced NYHA III

INTERMACS Profiles

Table 8. INTERMACS Clinical Profiles

Level	Description	Hemodynamic Status	Time Frame for Intervention
1	Critical cardiogenic shock, "crash and burn"	Persistent hypotension despite rapidly escalating inotropic support and eventually IABP, and critical organ hypoperfusion	Within hours
2	Progressive decline on inotropic support, "sliding on inotropes"	Intravenous inotropic support with acceptable values of blood pressure and continuing deterioration in nutrition, renal function, or fluid retention	Within days
3	Stable but inotrope dependent, "dependent stability"	Stability reached with mild to moderate doses of inotropes but demonstrating failure to wean from them because of hypotension, worsening symptoms, or progressive renal dysfunction	Elective over weeks to months
4	Resting symptoms, "frequent flyer"	Possible weaning of inotropes but experiencing recurrent relapses, usually fluid retention	Elective over weeks to months
5	Exertion intolerant, housebound	Severe limited tolerance for activity, comfortable at rest with some volume overload and often with some renal dysfunction	Variable urgency, dependent on nutrition and organ function
6	Exertion limited, "walking wounded"	Less severe limited tolerance for activity and lack of volume overload, fatigue easily	Variable urgency, dependent on nutrition and organ function
7	Advanced NYHA III "symptoms, placeholder"	Patient without current or recent unstable fluid balance, NYHA class II or III	Not currently indicated

INTERMACS indicates Interagency Registry for Mechanically Assisted Circulatory Support; IABP, intra-aortic balloon pump; and NYHA, New York Heart Association.
Adapted from Alba et al.[76]

Fifth INTERMACS annual report: Risk factor analysis from more than 6,000 mechanical circulatory support patients

James K. Kirklin, MD,[a] David C. Naftel, PhD,[a] Robert L. Kormos, MD,[b] Lynne W. Stevenson, MD,[c] Francis D. Pagani, MD, PhD,[d] Marissa A. Miller, DVM, MPH,[e] J. Timothy Baldwin, PhD,[e] and James B. Young, MD[f]

JHLT 2013;2:141-56

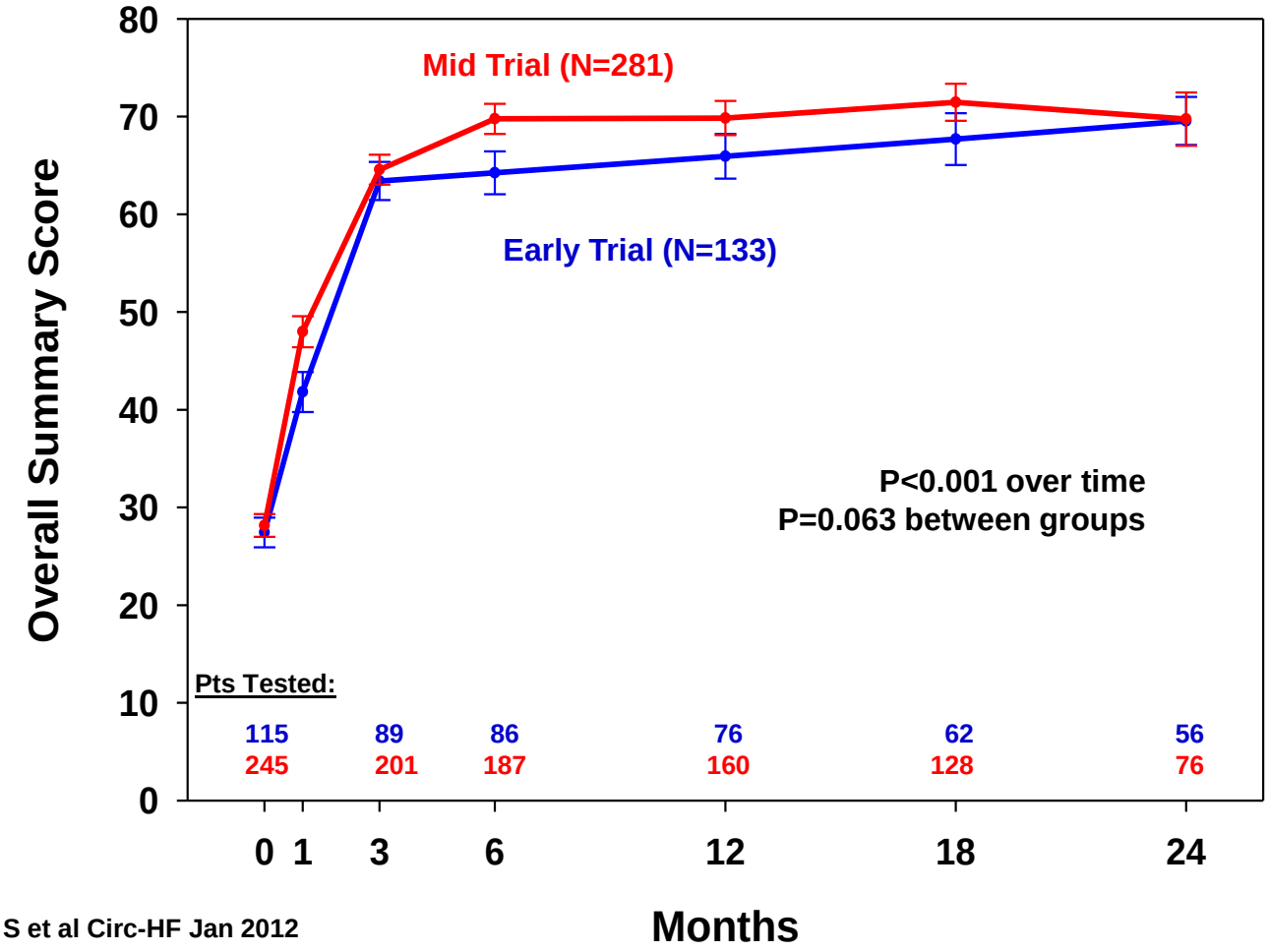
Table 3 Implants: June 2006–June 2012, Adult Primary Continuous-Flow LVADs and BiVADS, DT and BTT (n = 5,436)

	Early hazard		Constant hazard	
Risk factors for death	Hazard ratio	p-value	Hazard ratio	p-value
Demographics				
Age (older)	1.69	<0.0001		
Body mass index (higher)	1.47			
Clinical status				
Ventilator	1.65	0.009		
History of stroke	1.69	0.009		
INTERMACS Level 1	2.45	<0.0001		
INTERMACS Level 2	1.89	0.0004	1.30	0.003
Destination therapy			1.25	0.01
Non-cardiac systems				
Diabetes			1.22	0.02
Creatinine (higher)			1.10	0.008
Dialysis	2.22	0.002		
Blood urea nitrogen (higher)	1.10	<0.0001		
Right heart dysfunction				
RVAD in same operation	3.73	<0.0001		
Right atrial pressure (higher)	1.36	0.002		
Bilirubin (higher)	1.08	<0.0001		
Ascites			1.32	0.05
Surgical complexities				
History of cardiac surgery			1.50	<0.0001
Concomitant cardiac surgery	1.34	0.02		

Independent risk factors for failure

BiVAD, biventricular assist device; BTT, bridge to transplant; DT, destination therapy; INTERMACS, Interagency Registry for Mechanically Assisted Circulatory Support LVAD, left ventricular assist device; RVAD, right ventricular assist device.

Heart Failure Related Quality of Life Kansas City Cardiomyopathy Questionnaire



Park S et al Circ-HF Jan 2012

Adverse Events – INTERMACS

Table 5 Implants: June 2006–June 2012[a]

	Pulsatile ($n = 594$)		Continuous ($n = 5,358$)		Pulsatile/Continuous	
Adverse event	Events	Rate	Events	Rate	Ratio	p-value
Device malfunction	119	3.26	660	1.60	2.04	<0.0001
Bleeding	630	17.28	3895	9.45	1.83	<0.0001
Cardiac/vascular						
Right heart failure	90	2.47	737	1.79	1.38	0.001
Myocardial infarction	2	0.05	30	0.07	0.75	0.47
Cardiac arrhythmia	254	6.96	1919	4.66	1.50	<0.0001
Pericardial drainage	64	1.75	251	0.61	2.88	<0.0001
Hypertension[b]	118	3.24	351	0.85	3.80	<0.0001
Arterial non-CNS thrombosis	14	0.38	74	0.18	2.14	0.001
Venous thrombotic event	59	1.62	289	0.70	2.31	<0.0001
Hemolysis	23	0.63	299	0.73	0.87	0.69
Infection	832	22.81	3302	8.01	2.85	<0.0001
Neurological dysfunction	139	3.81	754	1.83	2.08	<0.0001
Renal dysfunction	108	2.96	582	1.41	2.10	<0.0001
Hepatic dysfunction	48	1.32	247	0.60	2.20	<0.0001
Respiratory failure	206	5.65	1038	2.52	2.24	<0.0001
Wound dehiscence	18	0.49	74	0.18	2.75	<0.0001
Psychiatric episode	87	2.39	425	1.03	2.31	<0.0001
Total burden	2811	77.07	14927	36.22	2.13	<0.0001

CNS, central nervous system.

[a]Adverse event rates (events/100 patient months) in the first 12 months after implant for primary left ventricular assist device with implant device strategy bridge to transplant, bridge to candidacy, and destination therapy.

[b]With current reporting, identification of hypertension with continuous-flow pumps is unreliable.

J Heart Lung Transplant 2013;32:141–156

The Most Difficult Group

- Ambulatory patients with advanced heart failure (INTERMACS profile 4-7)
- Factors known to be associated with worsening prognosis should be taken into account.
- Risk models need to be developed

Advanced Heart Failure:
Prognostic markers

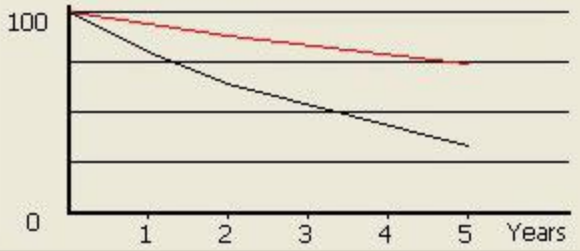
Clinical markers predicting poor outcome:

- **Inability to walk one block without shortness of breath.**
- **HF related hospitalizations in past 6 months.**
- **Diuretic dose > 1.5 mg/kg/d.**
- **Serum sodium < 136 mmol/L.**
- **BUN>40 mg/dL or creatinine >1.8mg/DL.**

Seattle Heart Failure Model Calculator

File Info

	Baseline 1 Year	Baseline 2 Year	Baseline 5 Year	Intervention 1 Year	Intervention 2 Year	Intervention 5 Year
Survival	80%	64%	33%	94%	88%	74%
Mortality	20%	36%	67%	6%	12%	26%
Mean life expectancy	4.1	years		9.4	years	



Clinical

Age: 65

Gender: Male

NYHA Class: 3A

Weight (kg): 80

EF: 30

Syst BP: 120

☑ Ischemic

Medications

☐ ACE-I

☐ Beta-blocker

☐ ARB

☐ Statin

☐ Allopurinol

☐ Aldosterone blocker

Diuretics

Furosemide: 80

Bumetanide: 0

Torsemide: 0

Metolazone: 0

HCTZ: 0

Lab Data

Hgb (g/dL): 14

Lymphocyte %: 25

Uric Acid (mg/dL): 8

Total Chol (mg/dL): 190

Sodium: 137

☐ QRS > 120 msec

Devices

◉ None

○ BiV Pacer

○ ICD

○ BiV ICD

Default Values

Interventions

☑ ACE-I ☐ ARB ☑ Beta-blocker

☑ Statin ☑ Aldosterone blocker

Devices

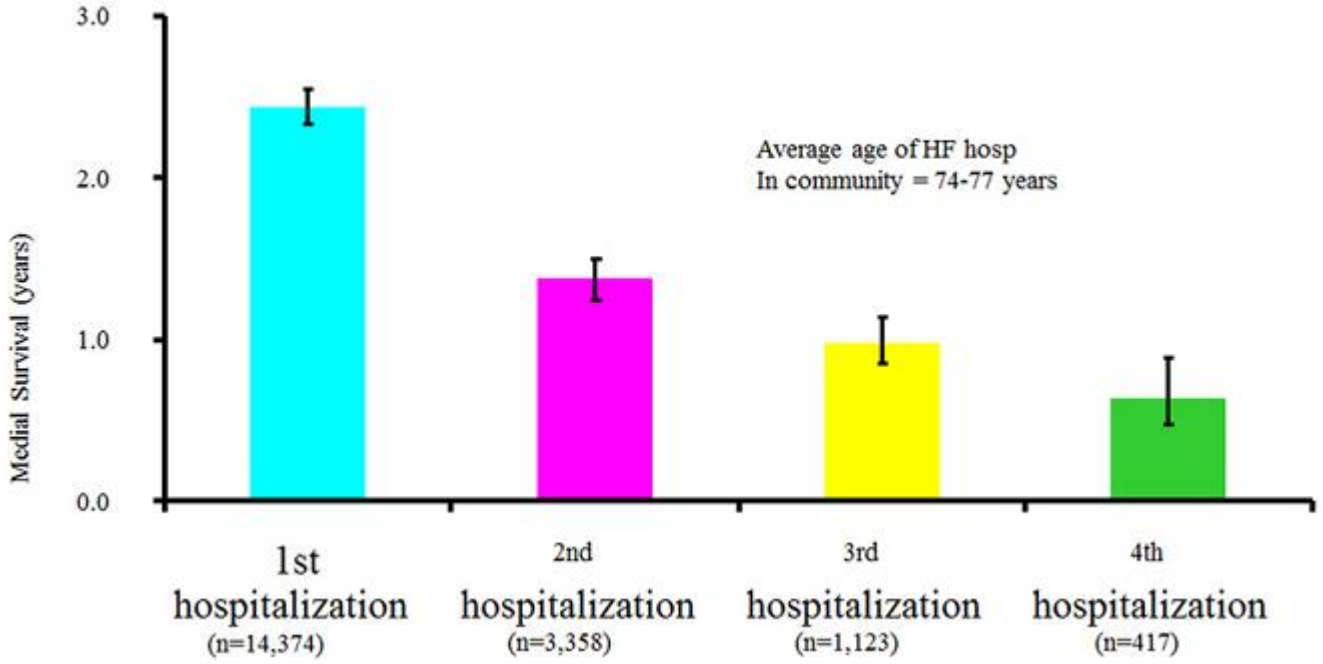
◉ None

○ BiV Pacer ○ BiV ICD

○ ICD ○ LVAD

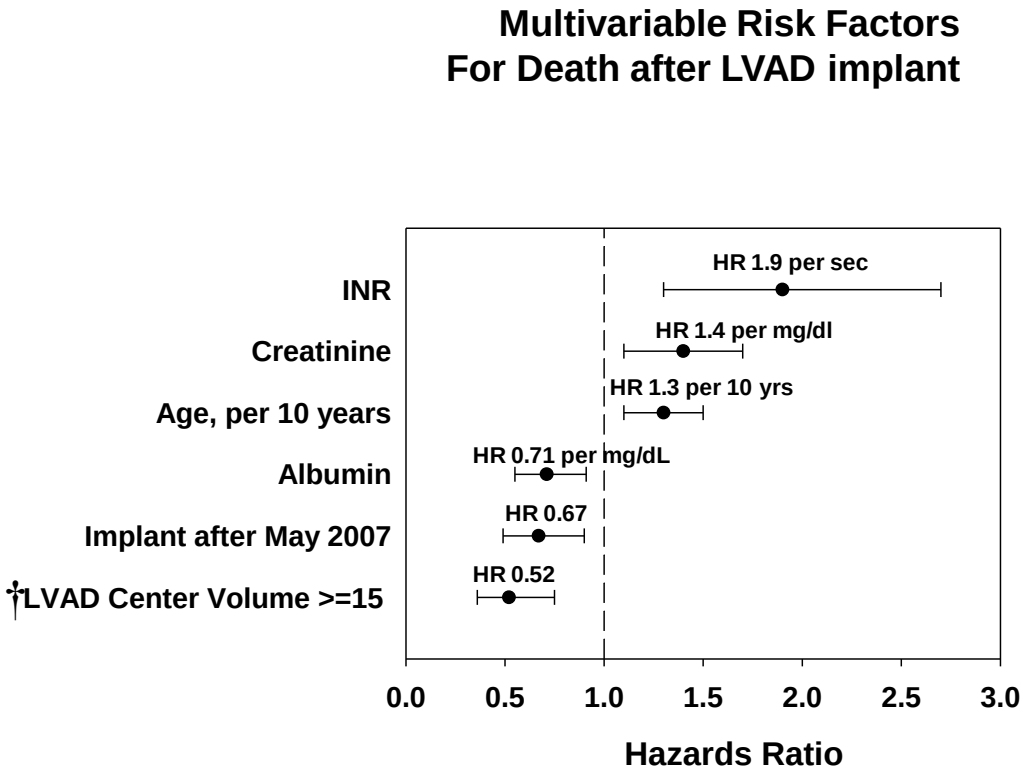
Note: Some devices may be disabled if CMS clinical criteria are not met

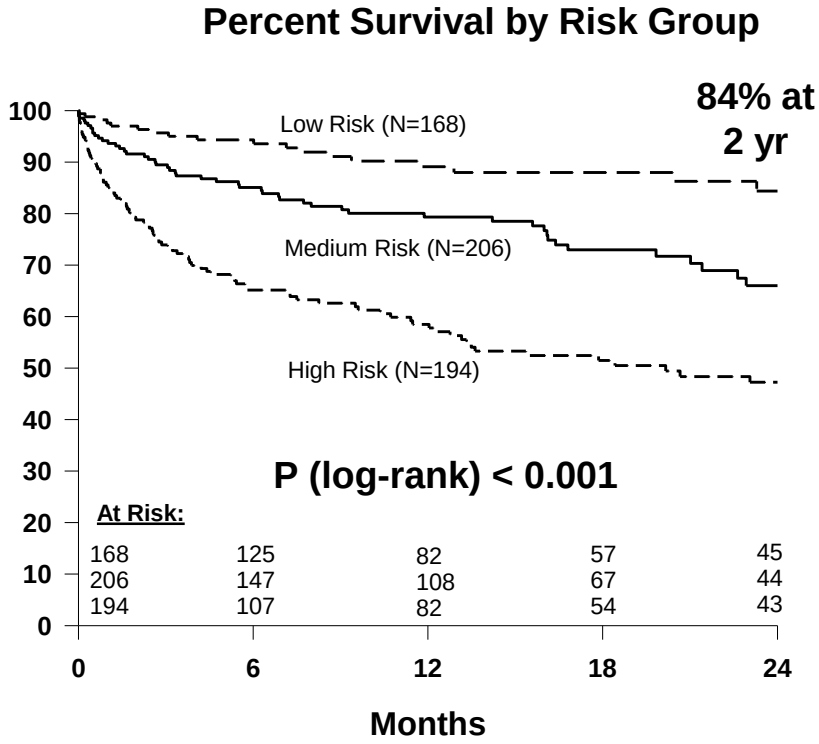
HF and Rehospitalizations



J Am Coll Cardiol 2013;61:1209–21

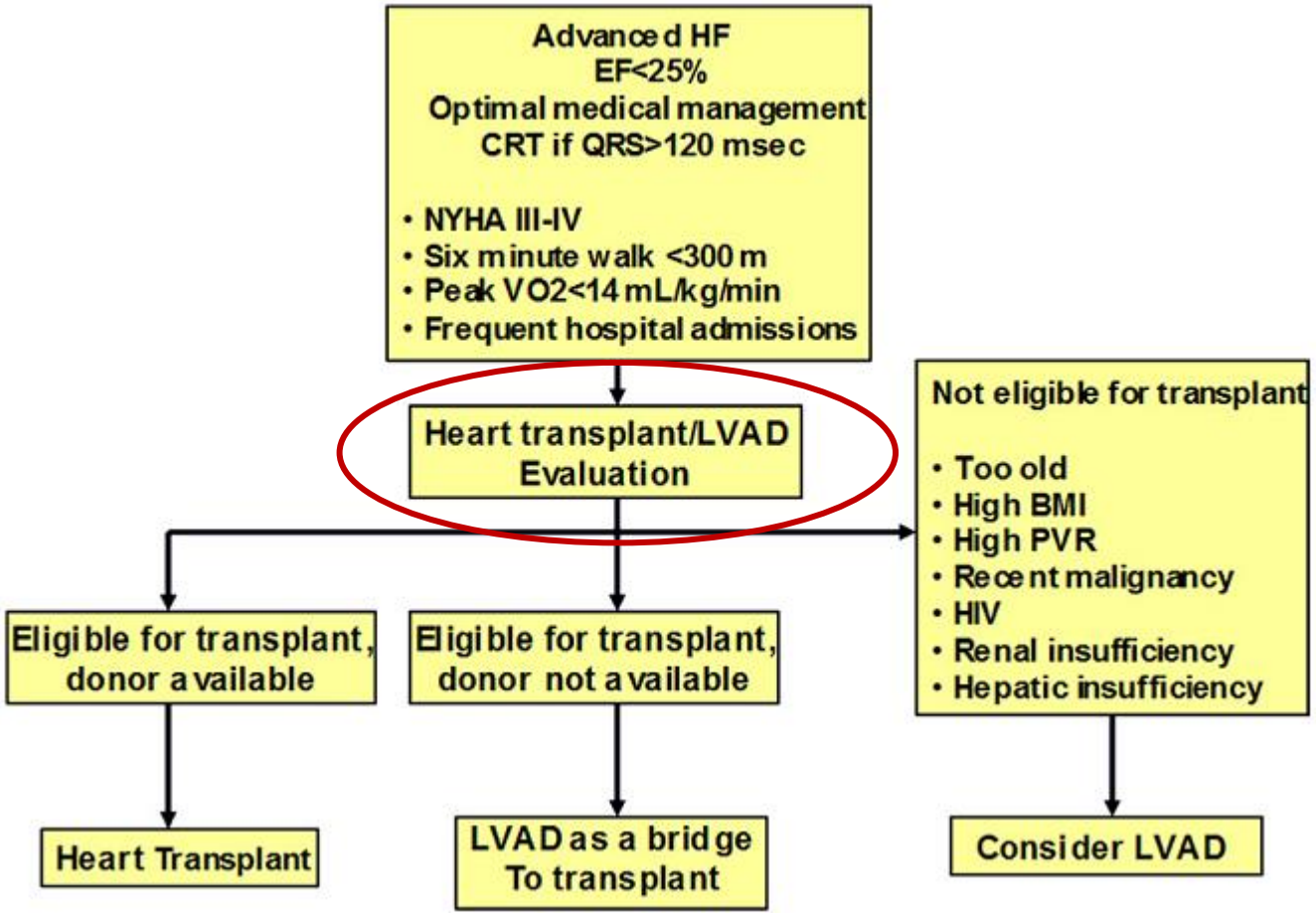
Estimated Survival on LVAD Support HeartMate II Risk Score





Cowger et al, J Am Coll Cardiol. 2013;61(3):313-321

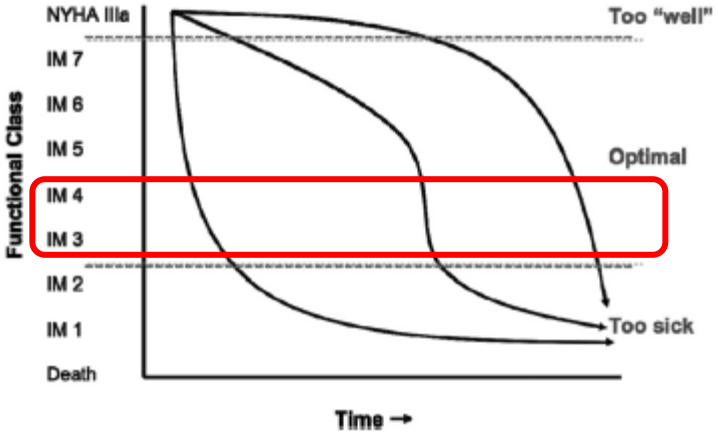
Suggested Algorithm



Miller and Guglin: J Am Coll Cardiol 2013;61:1209–21

Timing of VAD

- Stable, but inotrope dependent
- Recurrent advanced heart failure



Better "too" early than too late !