Invasive exploration of heart failure: What does it bring?

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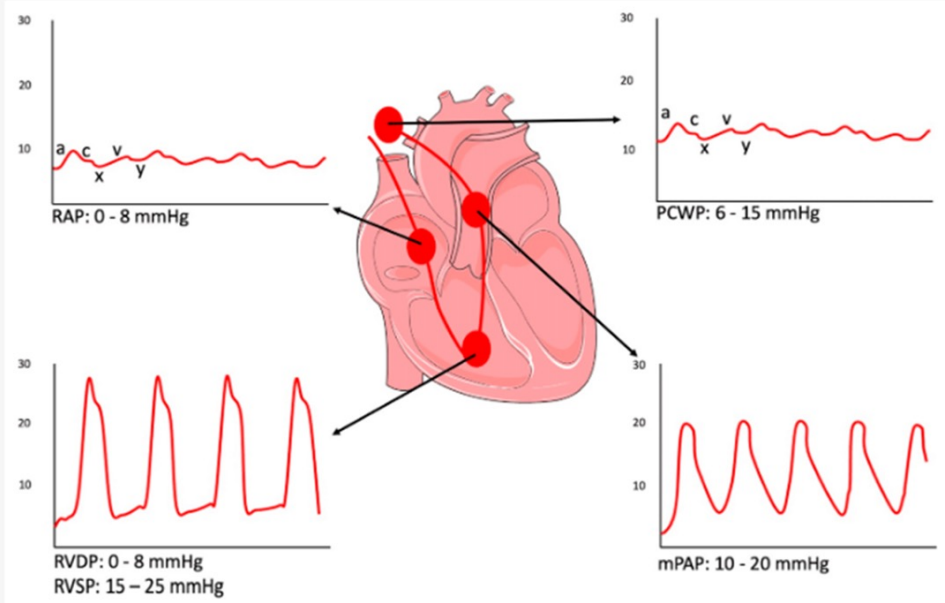
Introduction

- Right cardiac catheterization is crucial in assessing hemodynamics and optimizing patient management in end-stage heart failure.



Haemodynamic measures obtained during right heart catheterization

Measured variables	Normal value
Right atrial pressure, mean (RAP)	2–6 mmHg
Pulmonary artery pressure, systolic (sPAP)	15–30 mmHg
Pulmonary artery pressure, diastolic (dPAP)	4–12 mmHg
Pulmonary artery pressure, mean (mPAP)	8–20 mmHg
Pulmonary arterial wedge pressure, mean (PAWP)	≤15 mmHg
Cardiac output (CO)	4–8 L/min
Mixed venous oxygen saturation (SvO_2)[a]	65–80%
Arterial oxygen saturation (SaO_2)	95–100%
Systemic blood pressure	120/80 mmHg

Calculated parameters	
Pulmonary vascular resistance (PVR)[b]	0.3–2.0 WU
Pulmonary vascular resistance index (PVRI)	3–3.5 WU·m^2
Total pulmonary resistance (TPR)[c]	<3 WU
Cardiac index (CI)	2.5–4.0 L/min·m^2
Stroke volume (SV)	60–100 mL
Stroke volume index (SVI)	33–47 mL/m^2
Pulmonary arterial compliance (PAC)[d]	>2.3 mL/mmHg

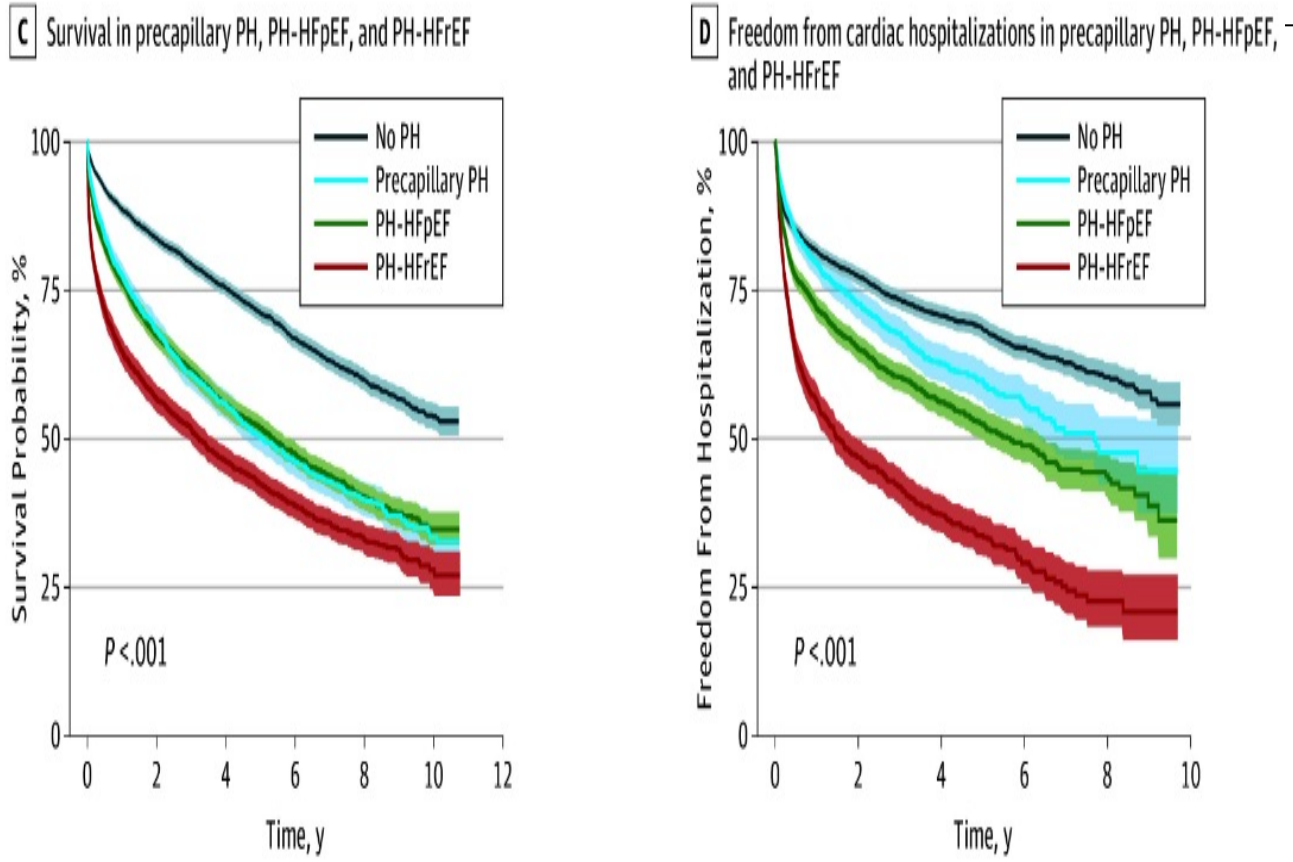
European Heart Journal, Volume 43, Issue 38, 7 October 2022

Haemodynamic definitions of pulmonary hypertension

Definition	Haemodynamic characteristics
PH	mPAP >20 mmHg
Pre-capillary PH	mPAP >20 mmHg PAWP ≤15 mmHg PVR >2 WU
IpcPH	mPAP >20 mmHg PAWP >15 mmHg PVR ≤2 WU
CpcPH	mPAP >20 mmHg PAWP >15 mmHg PVR >2 WU
Exercise PH	mPAP/CO slope between rest and exercise >3 mmHg/L/min

2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension, Humbert M et al; European Repiratory Journal,

Predictive value of PH in HF:



- Vanderpool RR et al.; JAMA cardiol. 2018 Apr; 3(4): 298–306

Guidelines Overview

Right heart catheterization recommendations. 2013 ACCF/AHA and 2021 ESC HF management guidelines.

	Recommendations	COR	LOE
2013 ACCF/AHA HF Management Guideline	Invasive hemodynamic monitoring is recommended in patients with respiratory distress or impaired systemic perfusion when clinical assessment is inadequate	I	C
	Invasive hemodynamic should be considered for carefully selected patients with acute HF with persistent symptoms and/or when hemodynamics are uncertain	IIa	C
	Routine use of invasive hemodynamic monitoring is not recommended in normotensive patients with acute HF	III	B
2021 ESC HF Management Guideline	Right heart catheterization is recommended in patients with severe HF being evaluated for heart transplantation or MCS	I	C
	Right heart catheterization should be considered in patients where HF is thought to be due to constrictive pericarditis, restrictive cardiomyopathy, congenital heart disease, and high output states.	IIa	C
	Right heart catheterization should be considered in patients with probable pulmonary hypertension, assessed by echo in order to confirm the diagnosis and assess its reversibility before the correction of valve/structural heart disease.	IIa	C
	Right heart catheterization may be considered in selected patients with HFpEF to confirm the diagnosis.	IIb	C

ISHLT recommandations:

The 2016 International Society for Heart Lung Transplantation listing criteria for heart transplantation: A 10-year update

Mandeep R. Mehra, MD (Chair) • Charles E. Canter, MD • Margaret M. Hannan, MD • ...
Erik A.M. Verschuuren, MD, PhD • Andreas Zuckermann, MD
on behalf of the International Society for Heart Lung Transplantation (ISHLT) Infectious Diseases, Pediatric and Heart Failure and Transplantation Councils •

1.3. Role of diagnostic right-heart catheterization

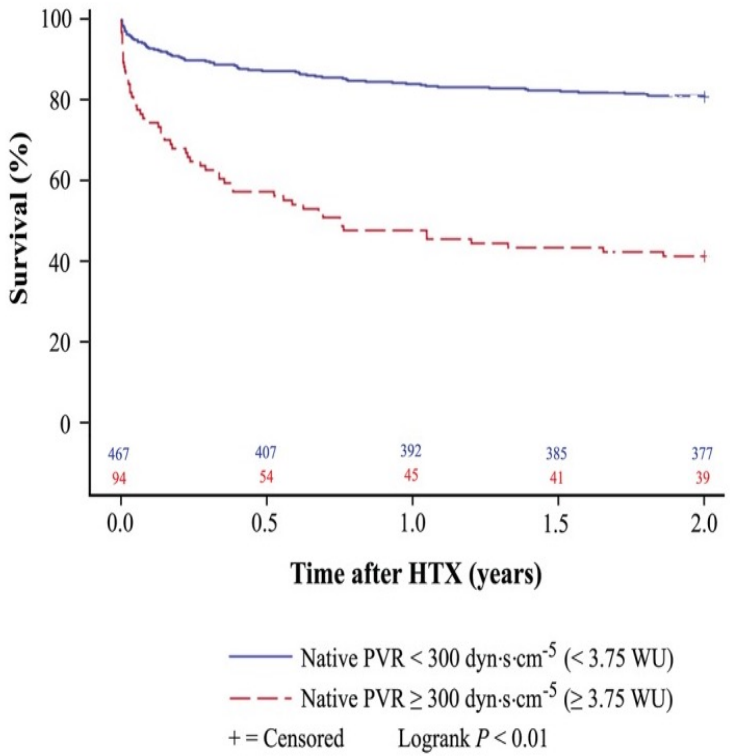
Right heart catheterization (RHC) should be performed on all **adult** candidates in preparation for listing for cardiac transplantation and **periodically** until transplantation (**Class 1, Level of Evidence: C**). **Periodic RHC is not advocated for routine surveillance in children (Class III, Level of Evidence: C).**

Continuing approval without change.

RHC should be performed at 3- to 6-month intervals in listed patients, especially in the presence of reversible pulmonary hypertension or worsening of heart failure symptoms (**Class I, Level of Evidence: C**).

A vasodilator challenge should be administered when the pulmonary artery systolic pressure is $\geq$ 50 mm Hg and either the transpulmonary gradient is $\geq$ 15 or the pulmonary vascular resistance (PVR) is $>$ 3Wood units while maintaining a systolic arterial blood pressure $>$ 85 mm Hg (**Class I, Level of Evidence: C**).

Elevated pre-transplant pulmonary vascular resistance is associated with early post-transplant mortality

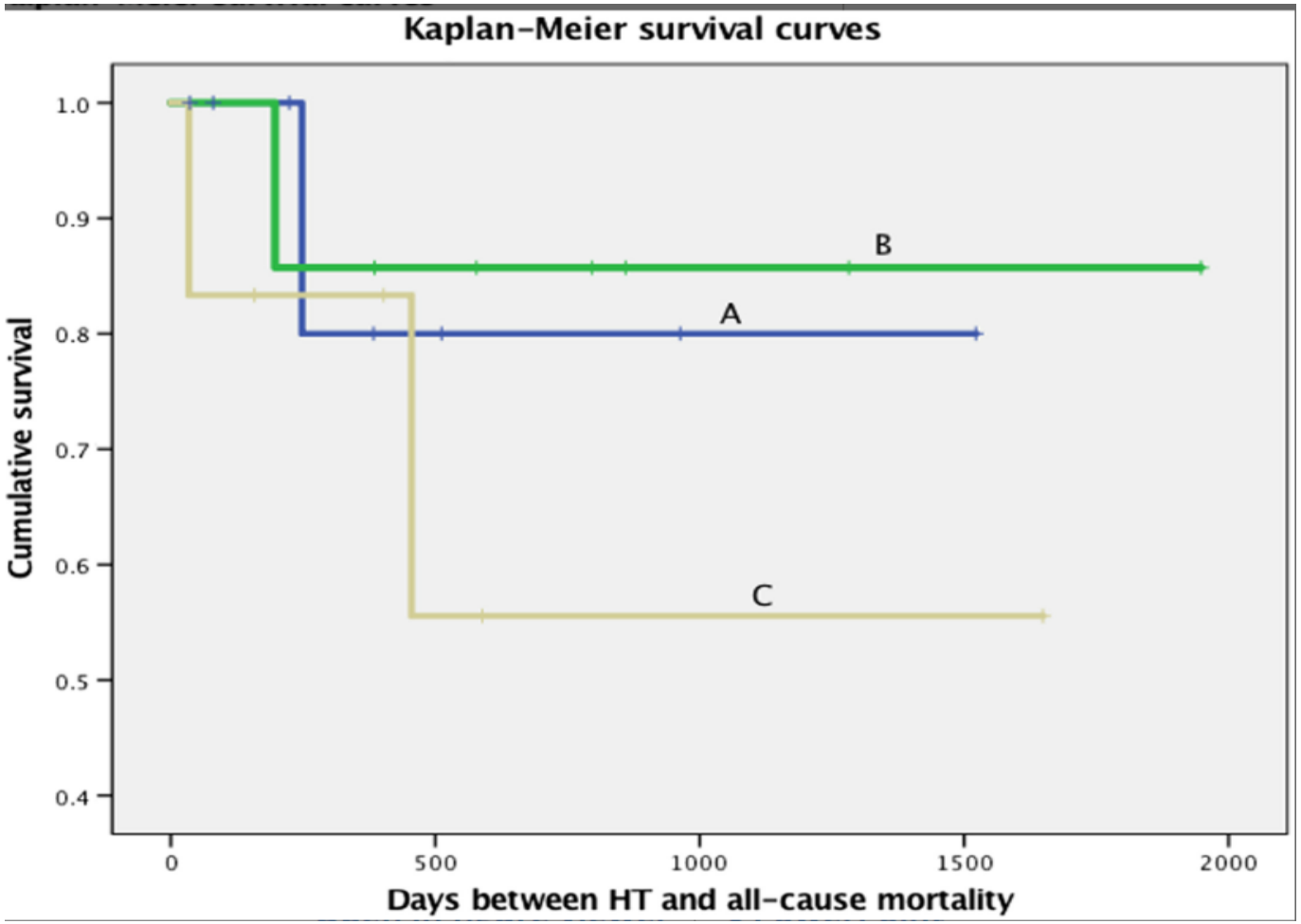


Outcomes after heart transplantation: primary outcome—causes of death within 30 days after heart transplantation

	PVR < 300	PVR ≥ 300	Difference	95% CI	*P*-value
	dyn·s·cm^{-5} (<3.75 WU) (n = 467)	dyn·s·cm^{-5} (≥3.75 WU) (n = 94)			
30 day all-cause mortality, n (%)	30 (6.4%)	24 (25.5%)	19.1%	10.0 to 28.2%	<0.01
Transplant failure, n (%)	19 (4.1%)	20 (21.2%)	17.1%	8.7 to 25.5%	<0.01

Rivinius R et al., ESC Heart Fail. 2020 Feb; 7(1): 176–187

Elevated pre-translant pulmonary vascular resistance



A- PVR < 3 UW

B-PVR > 3UW but reversible

C-PVR > 3 UW no reversible

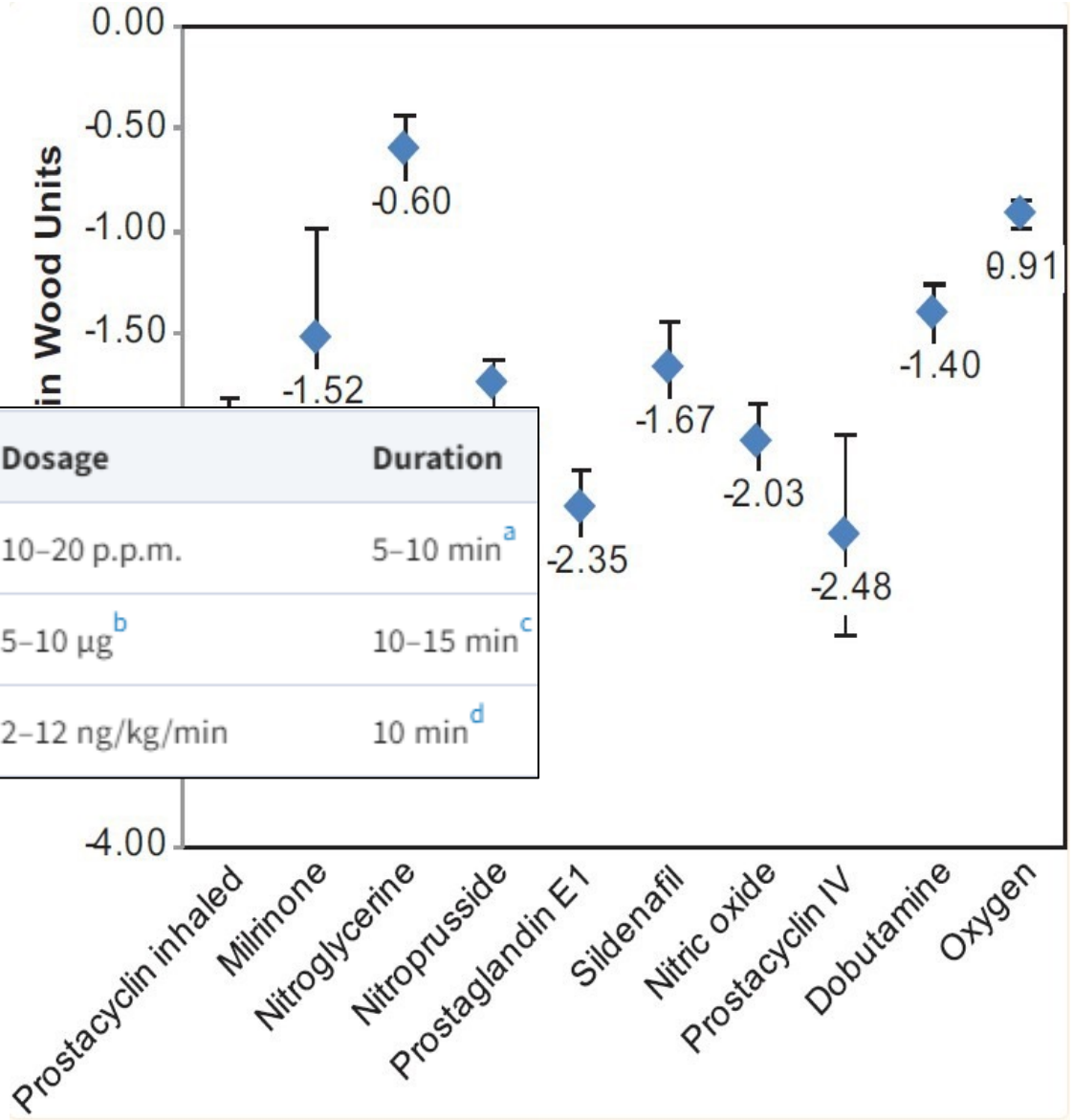
Strong C et al.; ESC Heart failure 2020

pulmonary hypertension reversibility test

Drug	Change in PVR	Lower confidence interval	Upper confidence interval	*P* value
Prostacyclin inhaled				
Prostacyclin IV				
Prostaglandin E1				
Sildenafil				
Milrinone				
Nitroglycerin				
Nitric oxide				
Nitroprusside				
Dobutamine	−1.40	−1.698	−1.102	<0.0001
Oxygen	−0.91	−1.047	−0.782	<0.0001

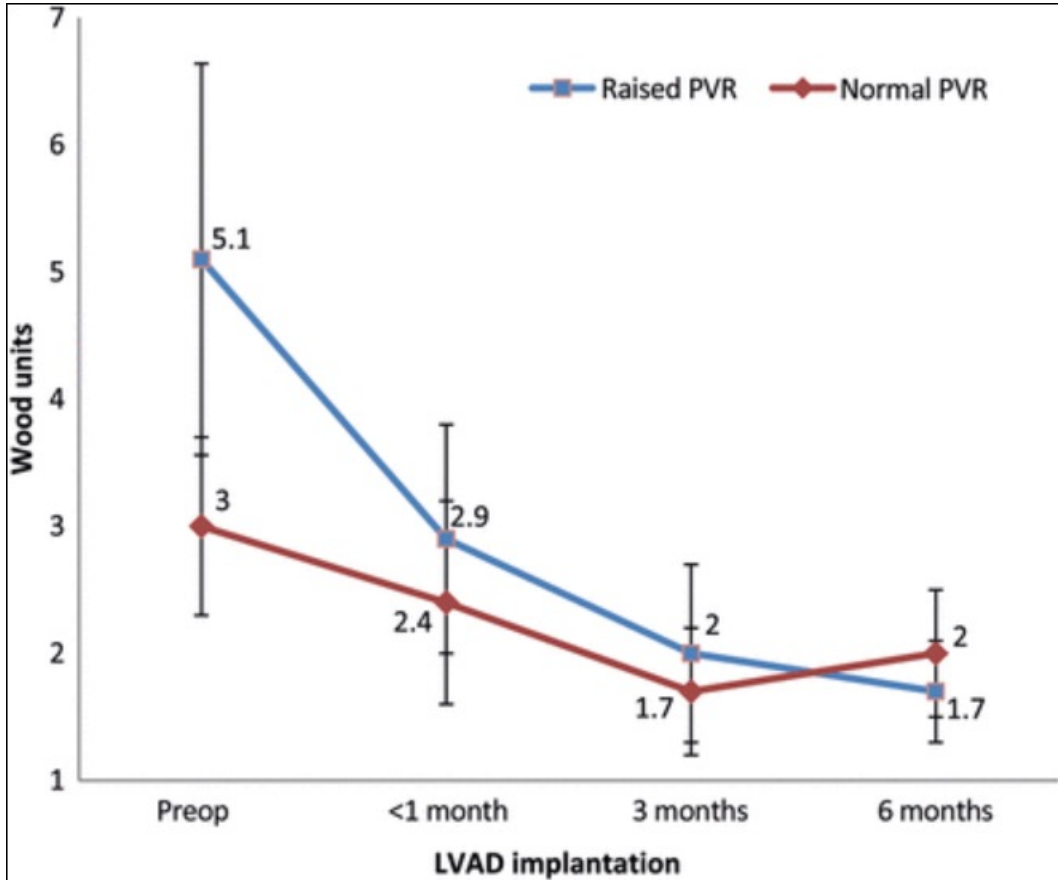
PVR: pulmonary vascular resistance

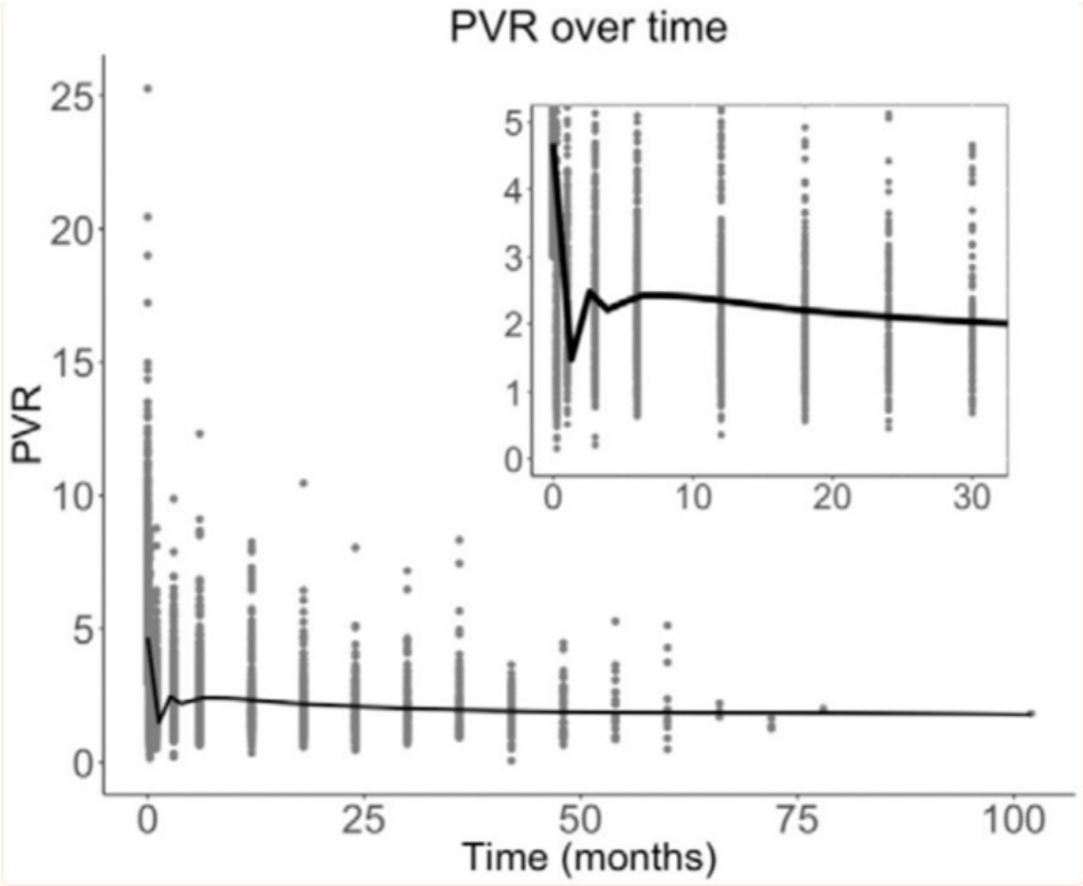
Compound	Route	Half-life	Dosage	Duration
Nitric oxide[129]	inh	15–30 s	10–20 p.p.m.	5–10 min[a]
Iloprost[130,131]	inh	30 min	5–10 µg[b]	10–15 min[c]
Epoprostenol[129]	i.v.	3 min	2–12 ng/kg/min	10 min[d]



Gglin M et al.;Pulm Circ.2013 Apr-Jun; 3(2): 406–413

LVAD effect on PVR:

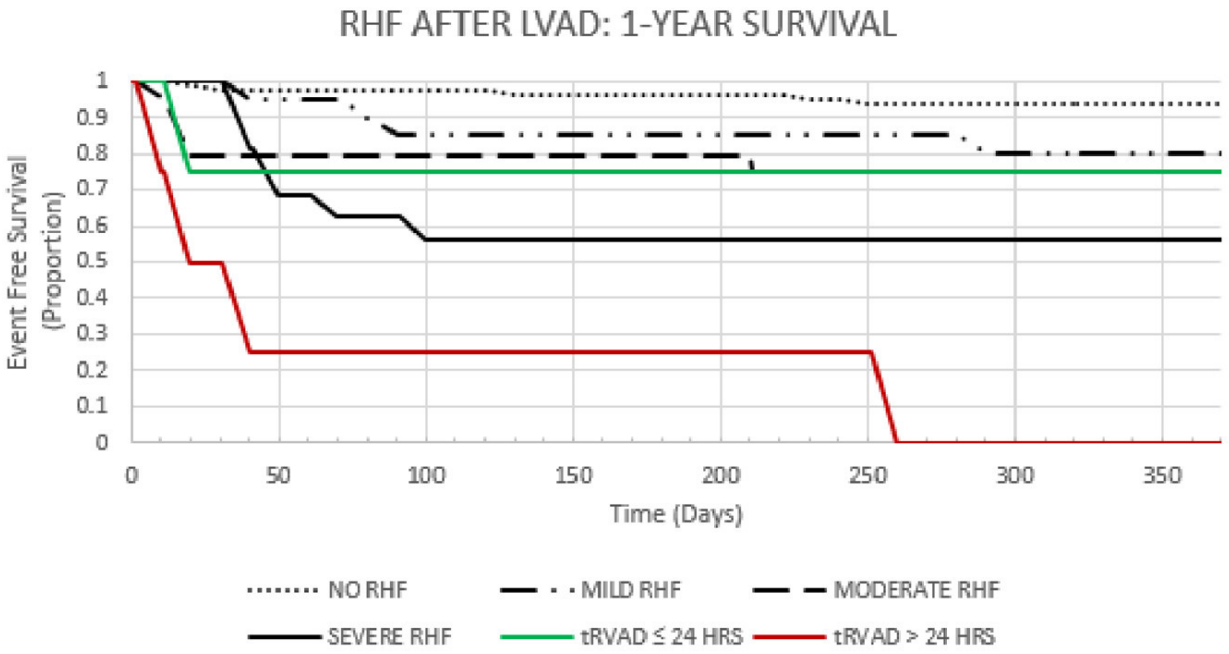


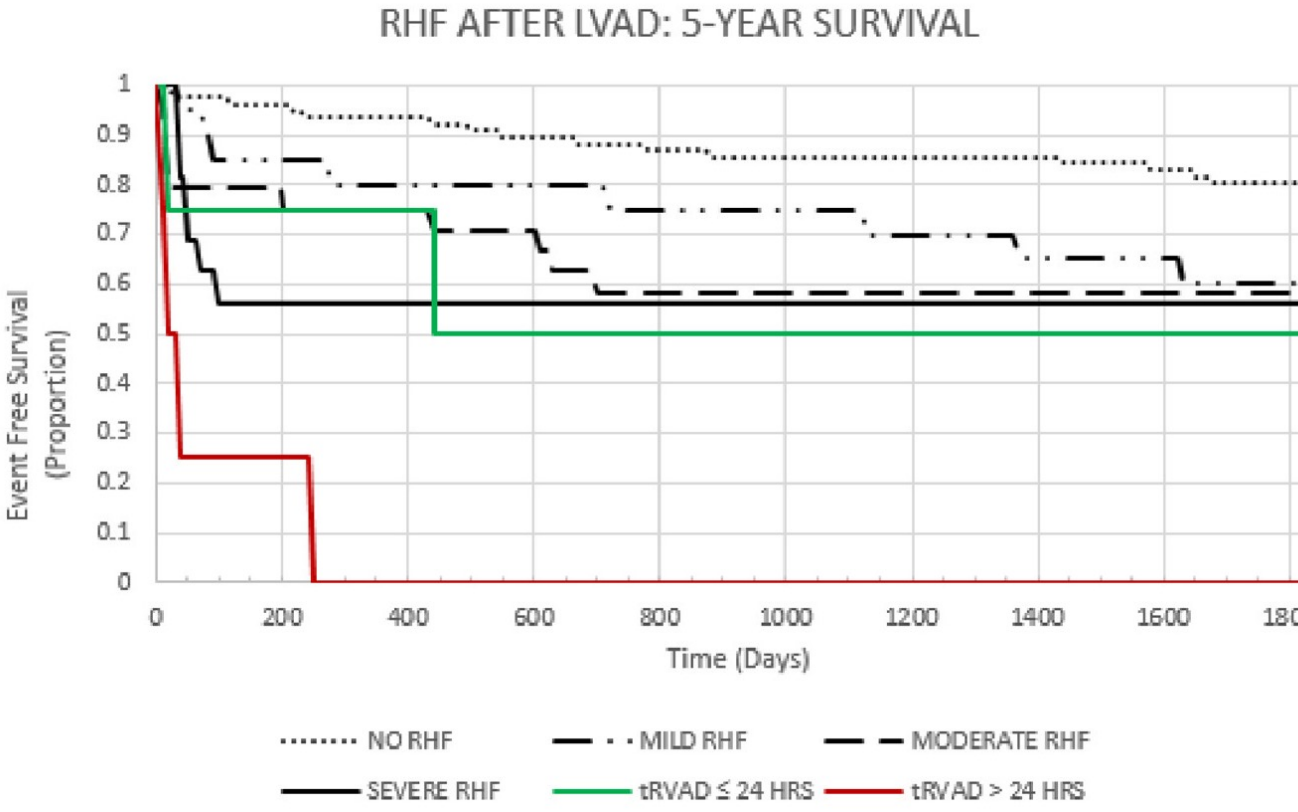


- Kutty RS et al., *European Journal of Cardio-Thoracic Surgery*, Volume 43, Issue 6, June 2013

Gulati et al.; J Card Fail. 2021 May; 27(5):552-559

RHF after LVAD





Garcia RA et al.;Journal of Cardiac Failure 26(10):S136 2020

ISHLT recommendations:

The 2023 International Society for Heart and Lung Transplantation Guidelines for Mechanical Circulatory Support: A 10- Year Update

Diyar Saeed, MD, PhD • David Feldman, MD, PhD • Aly El Banayosy, MD • ...
Juliane Vierecke, MD • Daniel Zimpfer, MD, PhD • David D'Alessandro, MD • Show all authors

Recommendations to assess pre-VAD RV function

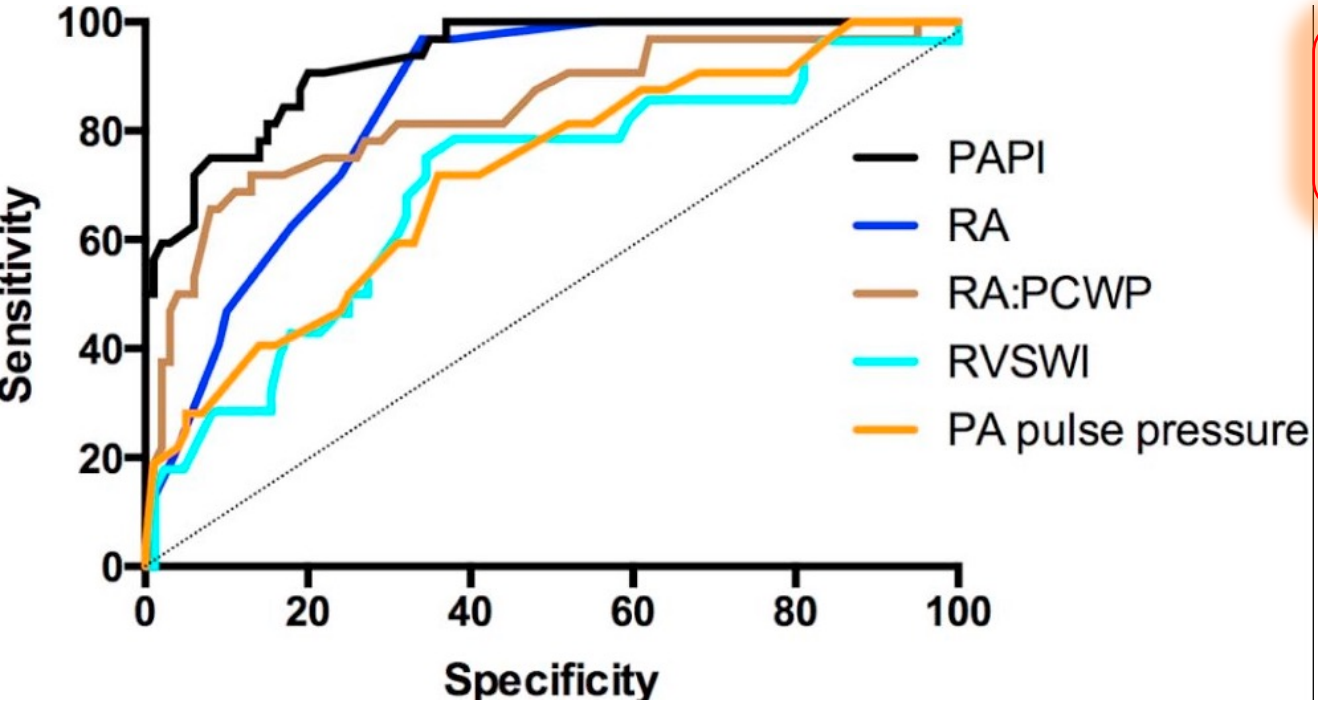
Class I: All patients should have invasive focused hemodynamic evaluation of the right heart unit before DMCS implantation. Low Pulmonary artery pulsatility index is a prognostic indicator for right ventricular failure after durable LVAD.

Level of Evidence: B.

Class I: All patients should have invasive hemodynamic evaluation before DMCS integrated with multimodality imaging with echocardiography and/or cardiac MRI focused quantitative parameters of right heart function and tricuspid valve integrity.

Level of Evidence: B.

Pulmonary Artery Pulsatility Index Is Associated With Right Ventricular Failure After Left Ventricular Assist Device Surgery



Parameter	AUC (95% CI)	SE	Sensitivity	Specificity	PPV	NPV
PAPi < 1.85	0.942 (0.904, 0.980)	0.0195	0.938	0.810	0.832	0.928
RA > 11.5 mm Hg	0.846 (0.781, 0.911)	0.0326	0.968	0.650	0.735	0.954
RA:PCWP > 0.59	0.837 (0.749, 0.925)	0.0195	0.719	0.870	0.847	0.756
PA pulse pressure < 22.5 mm Hg	0.742 (0.613, 0.817)	0.0520	0.718	0.640	0.663	0.695
RVSWI < 0.57 mm Hg L^{-1} m^{-2}	0.692 (0.576, 0.809)	0.0595	0.786	0.631	0.680	0.747
Moderate-severe TR	0.678 (0.571, 0.783)	0.0542	0.743	0.446	0.603	0.680

Morine KJ et al., J Card Fail.2016;Feb;22(2):110-6

Hemodynamic predictors of right heart failure after LVAD placement

RAP/PCWP *ratio> 0,63*

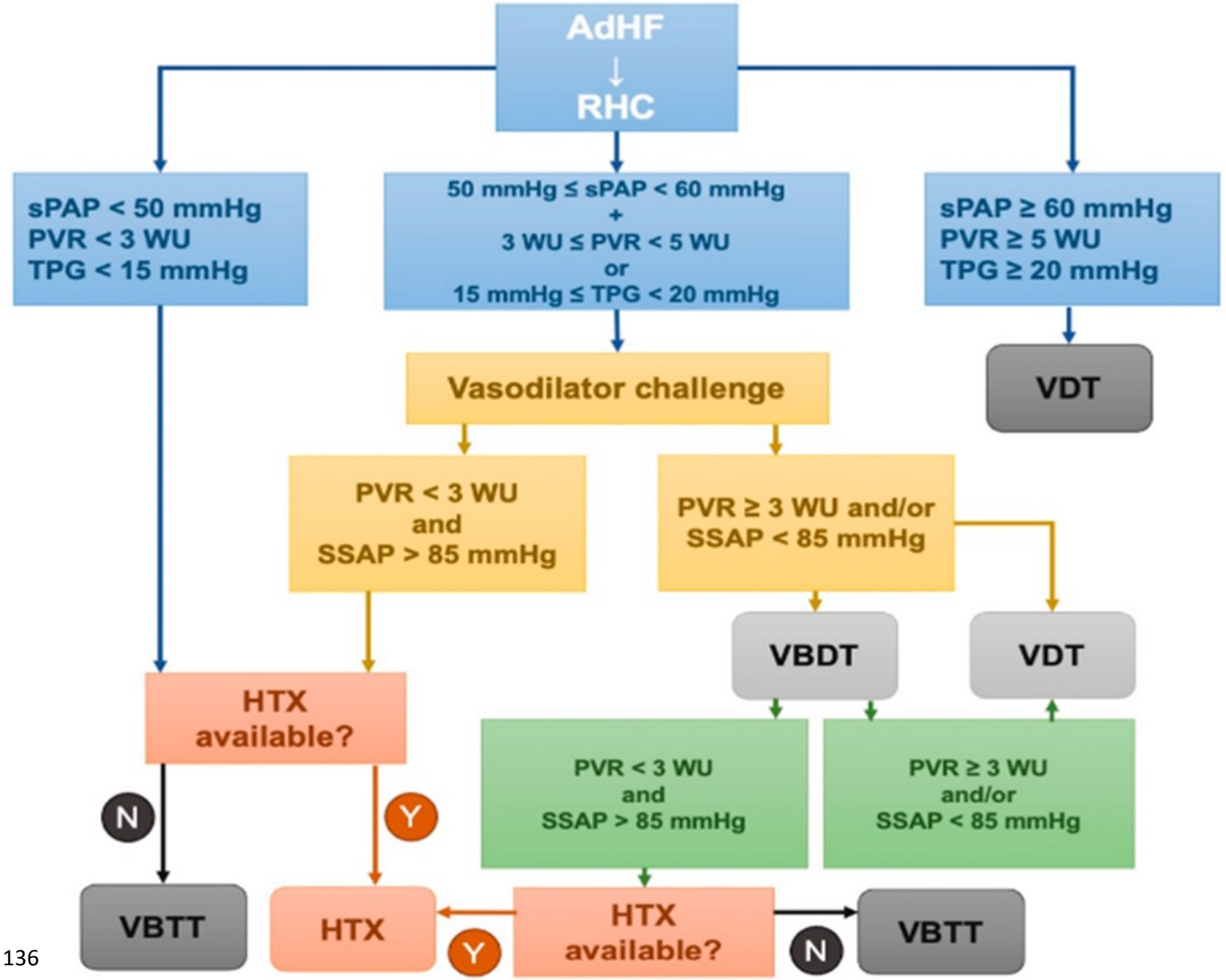
Pulmonary artery pulsatility index (PAPi) <1,85

PAPi= (PAPs- PAPd)/ RAP

RV stroke work index (RVSWI) <0,25

RVSWi= PAPm-RAP x (CI/HR)

RHC to support diagnosis and decision-making:



Manzi l et al;.*Diagnostics* **2024**, *14*(2), 136

Conclusion

Right cardiac catheterization plays a pivotal role in the management of advanced heart failure to guide treatment in heart transplant and heart assist device recipients