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Il cateterismo destro resta irrinunciabile

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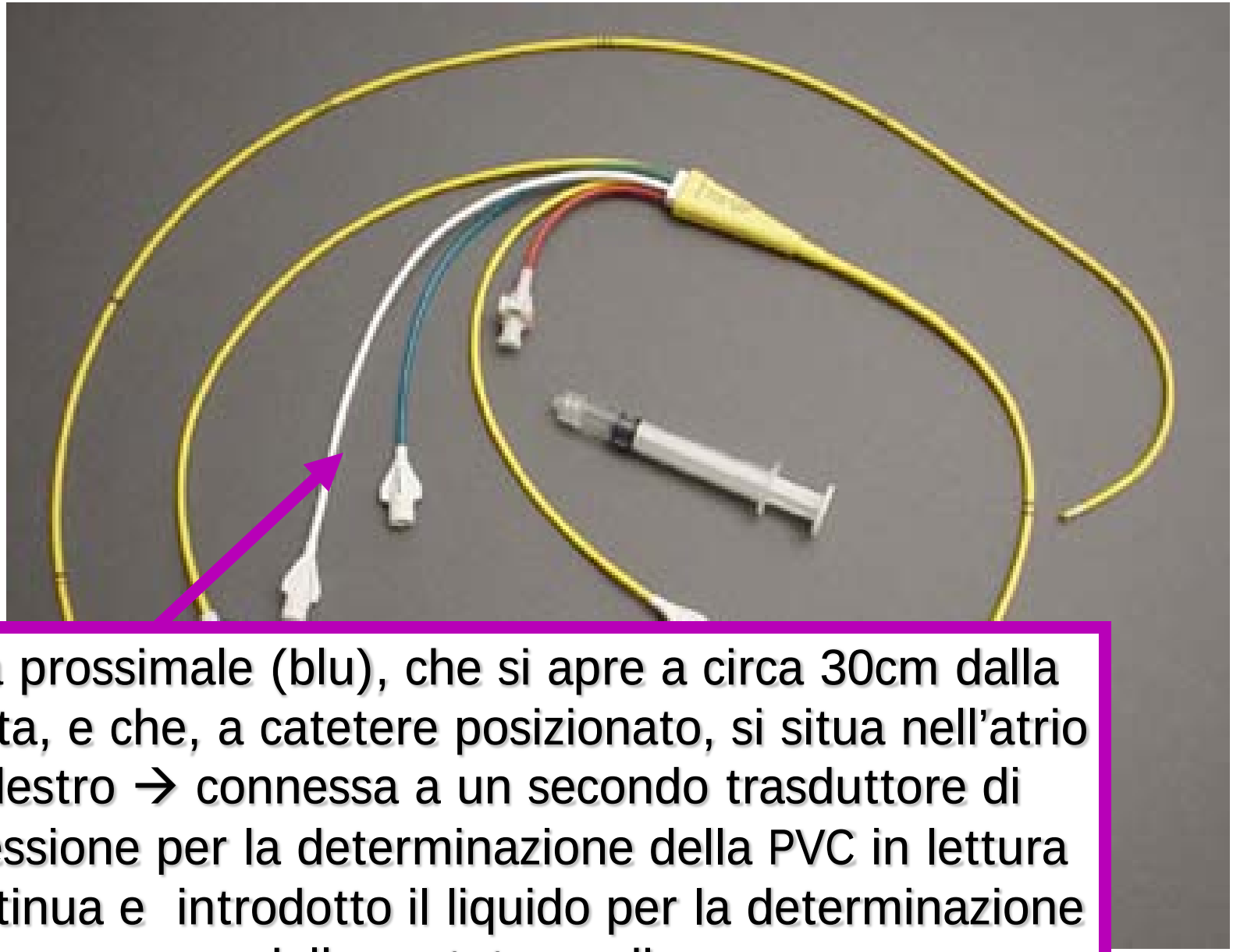
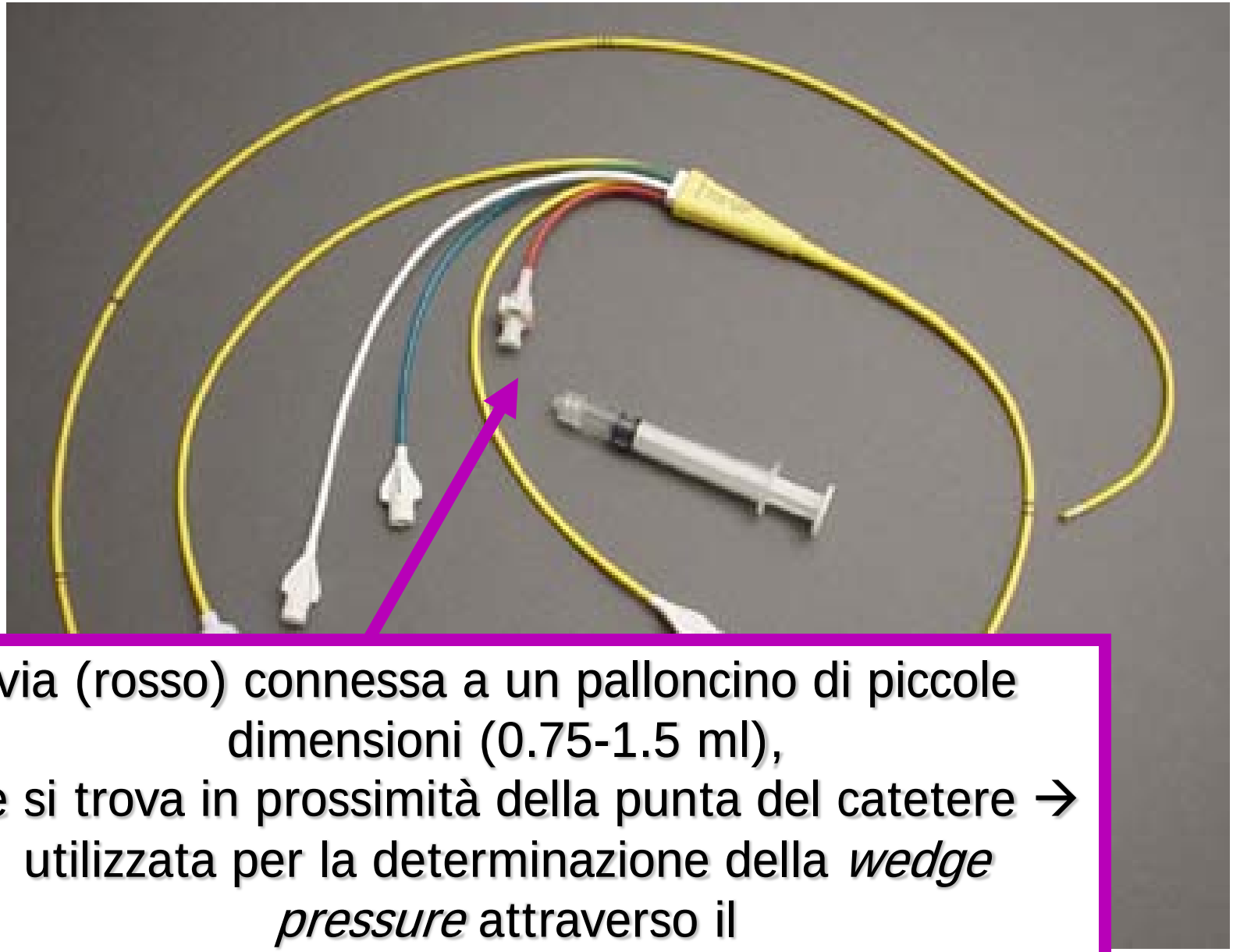
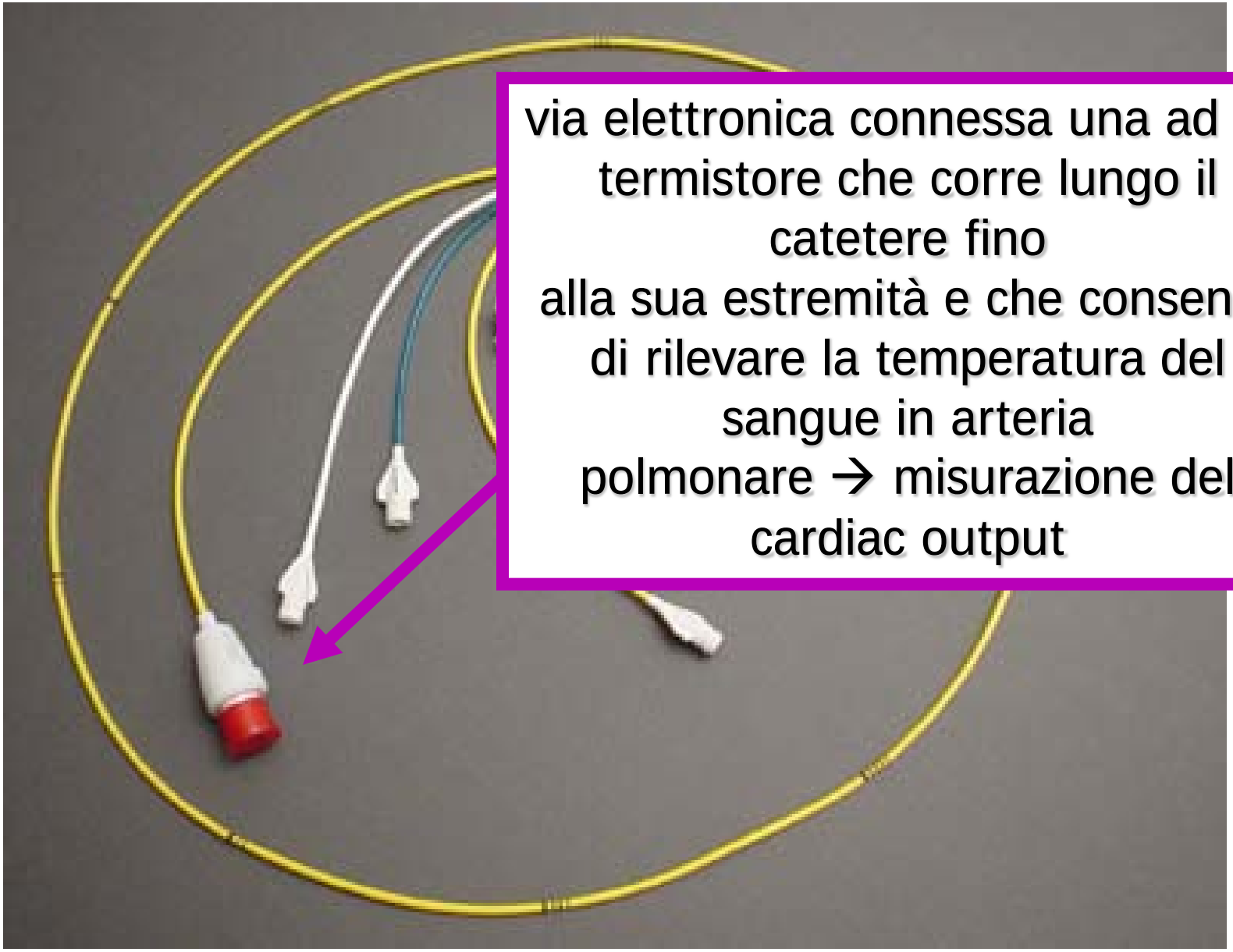
via distale (giallo), che si apre alla punta del catetere → connessa ad un trasduttore di pressione → pressioni delle camere cardiache destre e prelievo di sangue venoso misto



via prossimale (blu), che si apre a circa 30cm dalla punta, e che, a catetere posizionato, si situa nell'atrio destro → connessa a un secondo trasduttore di pressione per la determinazione della PVC in lettura continua e introdotto il liquido per la determinazione della portata cardiaca.



via (rosso) connessa a un palloncino di piccole dimensioni (0.75-1.5 ml),
che si trova in prossimità della punta del catetere → utilizzata per la determinazione della *wedge pressure* attraverso il gonfiaggio del palloncino.



via elettronica connessa una ad un termistore che corre lungo il catetere fino
alla sua estremità e che consente di rilevare la temperatura del sangue in arteria polmonare → misurazione del cardiac output

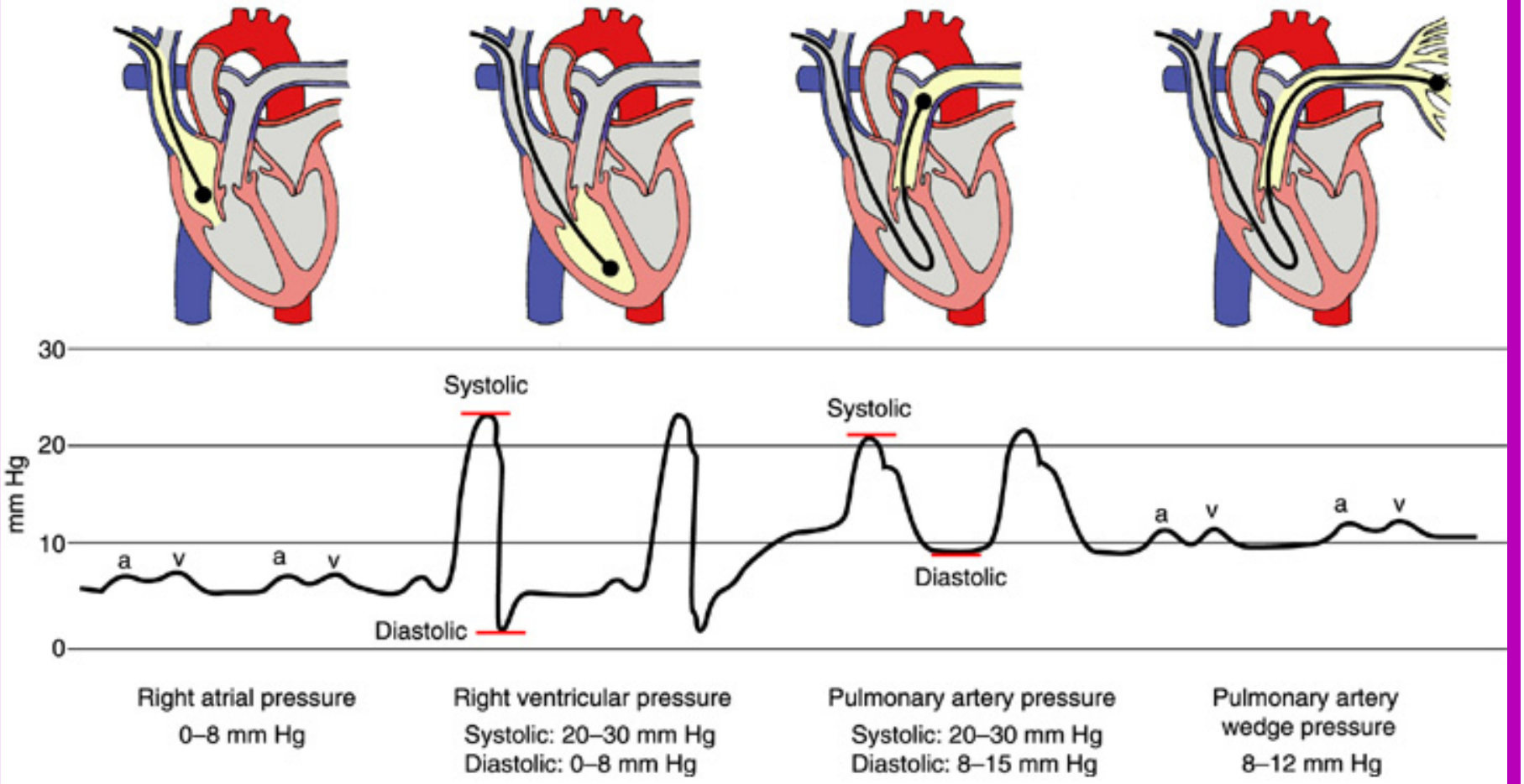


Figure 17-58 Normal values and wave configurations produced by the pulmonary artery catheter.

Indicazioni al Cateterismo Cardiaco Destro

- Confermare la diagnosi nelle forme di PAH e CTEPH
- Eseguire test di vasoreattività nei casi salezionati
- Determinare la severità
- Monitorare la risposta al trattamento
- Raccomandato nei gruppi 2 e 3 se vi indicazione al trapianto

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"PH/PAH should be suspected in any patient with otherwise unexplained dyspnea on exertion, syncope, and/or signs of right ventricular dysfunction. Transthoracic echocardiography continues to be the most important noninvasive screening tool to assess the possibility of PH, but RHC remains mandatory to establish the diagnosis"

Hoeper MM, et al. J Am Coll Cardiol 2013; 62:D42-50

Table 3 Haemodynamic definitions of pulmonary hypertension[a]

Definition	Characteristics[a]	Clinical group(s)[b]
PH	PAPm >25 mmHg	All
Pre-capillary PH	PAPm ≥25 mmHg PAWP ≤15 mmHg	1. Pulmonary arterial hypertension 3. PH due to lung diseases 4. Chronic thromboembolic PH 5. PH with unclear and/or multifactorial mechanisms
Post-capillary PH	PAPm ≥25 mmHg PAWP >15 mmHg	2. PH due to left heart disease 5. PH with unclear and/or multifactorial mechanisms
Isolated post-capillary PH (Ipc-PH)	DPG <7 mmHg and/or PVR ≤3 WU[c]	
Combined post-capillary and pre-capillary PH (Cpc-PH)	DPG ≥7 mmHg and/or PVR >3 WU[c]	

DPG (diastolic pressure gradient) = diastolic PAP - mean PAWP

- PAWP non è un numero costante, ma una variabile biologica influenzata da numerosi fattori come il bilancio di liquidi e la pressione intratoracica

- In molti pazienti con patologie del cuore sinistro è possibile trovare temporaneamente dei valori di PAWP < 15 mmHg per riduzione del post-carico con la terapia diuretica (Abraham WT. Lancet 2011;377:658-666)

- la presenza di fattori di rischio (ipertensione arteriosa, età, obesità, diabete mellito, OSAS, patologia delle coronarie, FA) e segni ecocardiografici di ingrandimento atrio sx o ipertrofia VSx indicano con alta probabilità un quadro di patologia cardiaca con FE conservata (Hoeper MM. J Am Coll Cardiol 2009;54:S85-96)

Si può effettuare una prova di riempimento per smascherare una disfunzione diastolica del ventricolo sinistro?

un bolo di 500 cc di liquidi ev in 5-10 minuti potrebbe discriminare pazienti affetti da PAH da pazienti con IP secondaria a disfunzione diastolica dei Vsx

	Normal	PVH	OPVH	PAH	p-value
Subjects n	54	24	11	18	
Resting haemodynamics					
RAP mmHg	6±3	12±5	11±5	9±5	<0.0001[#,¶,+]
Mean PAP mmHg	18±4	40±11	35±10	44±8	<0.00001[#,¶,+]
PAWP mmHg	10±3	20±5	12±3	8±3	<0.00001[¶,+]
DWG mmHg	2±4	8±9	13±9	21±7	<0.00001[#,¶,+]
TPG mmHg	8±8	20±12	23±12	36±8	<0.00001[#,¶,+]
LVEDP mmHg	13±5	18±5	15±4	9±4	<0.00001[#,¶,+]
Cardiac output $L \cdot min^{-1}$	5.7±1.7	4.9±1.8	5.1±1.4	3.8±1.0	0.0006[#]
Cardiac index $L \cdot min^{-1} \cdot m^{-2}$	3.5±1.1	3.0±1.4	2.8±0.3	2.4±0.7	0.003[#]
PVR Wood units	1.5±0.9	5.2±4.3	5.3±4.0	10.1±4.5	<0.00001[#,¶,+]
CAD %	35	33	30	15	NS
Haemodynamics after fluid challenge					
Subjects n			6	18	
RAP mmHg			15±7	12±4	NS
Mean PAP mmHg			38±6	48±7	0.003[¶]
PAWP mmHg			17±5	12±2	0.03[¶]
TPG mmHg			21±9	36±7	0.001[¶]
DWG mmHg			10±8	20±6	0.001[¶]
LVEDP mmHg			21±2	12±3	<0.00001[¶]
Cardiac output $L \cdot min^{-1}$			5.6±1.9	4.1±1.2	NS
ΔRAP			4±5	3±2	NS
Δmean PAP			3±7	0±5	NS
ΔPAWP			4±4	3±3	NS
ΔTPG			-2±6	-3±4	NS
ΔDWG			-2±5	-3±5	NS
ΔLVEDP			6±3	2±2	0.01[¶]
Δcardiac output			0.4±0.4	0.1±0.3	NS

Fox BD. 2013

"The term PAH describes a group of PH patients characterized haemodynamically by the presence of pre-capillary PH, defined by a pulmonary artery wedge pressure (PAWP) ≤15 mmHg and a **PVR ≥3 Wood units** (WU) in the absence of other causes of precapillary PH such as PH due to lung diseases, CTEPH or other rare diseases"

Resistenze vascolari polmonari (PVR)

Sono espressione funzionale dell'alterazione anatomica del sistema vascolare polmonare risultante da

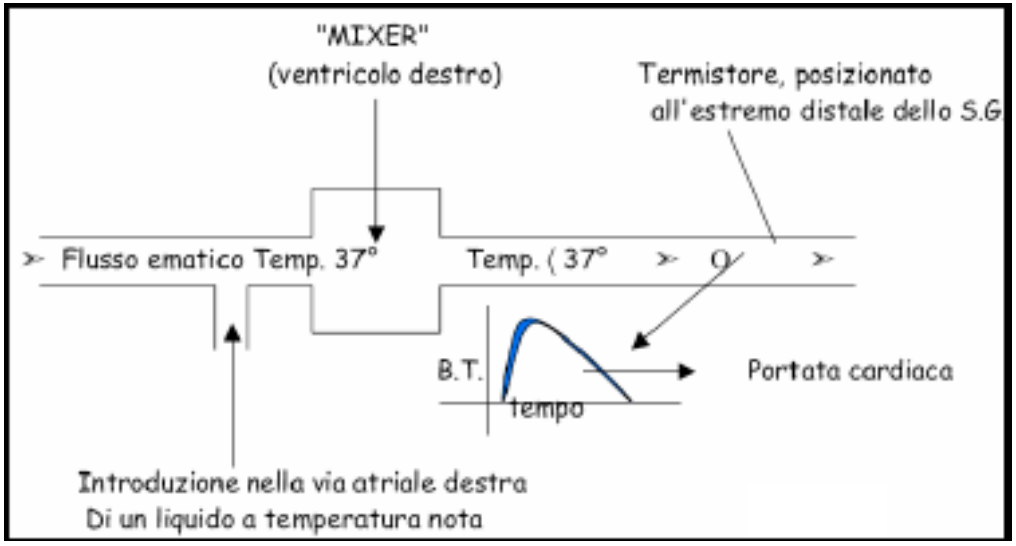
Vasocostrizione
Rimodellamento vascolare
Infiammazione
Trombosi

PVR (wood units) = (PAP-PCWP)*80/CO
PVRI = (PAP-PCWP)*80/CI

Le **PVR** sono incluse nella definizione della PAH per le seguenti ragioni:

- sottolineare l'importanza di avere una conferma diagnostica emodinamica
- ridurre la possibilità che pazienti con patologia del cuore sinistro vengano classificati come pazienti affetti da PAH
- Calcolare il CO

Tecnica della **TERMODILUIZIONE**



- 10 cc di soluzione fredda in circa 5 sec a pressione costante
- Tre misurazioni riproducibili
- Affidabile anche in pz con CO molto ridotto e/o insufficienza tricuspidalica severa
- Inaccurato in pazienti con shunt cardiaci

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Test di Vasoreattività

Drug	Route	Half-life	Dose range[d]	Increments[e]	Duration[f]	Class[a]	Level[b]	Ref[c]
Nitric oxide	Inh	15–30 sec	10–20 ppm	-	5 min[g]	I	C	4, 5
Epoprostenol	i.v.	3 min	2–12 ng/kg/min	2 ng/kg/min	10 min	I	C	4, 6
Adenosine	i.v.	5–10 sec	50–350 µg/kg/min	50 µg/kg/min	2 min	IIa	C	7
Iloprost	Inh	30 min	5–20 µg	-	15 min	IIb	C	8

- Positivo: riduzione della PAP media ≥10 mmHg che raggiunge un valore assoluto ≤40 mmHg associata ad incremento o ad assenza di variazione della gittata cardiaca (solo il 10% di pz rispecchia questi criteri)

- Indicato in pazienti con IAPI, IAP ereditaria e IAP associata all'assunzione di anoressizzanti per individuare coloro che possono essere trattati con CCB ad alte dosi

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Determinants of prognosis[a] (estimated 1-year mortality)	Low risk <5%	Intermediate risk 5–10%	High risk >10%
Clinical signs of right heart failure	Absent	Absent	Present
Progression of symptoms	No	Slow	Rapid
Syncope	No	Occasional syncope[b]	Repeated syncope[c]
WHO functional class	I, II	III	IV
6MWD	>440 m	165–440 m	<165 m
Cardiopulmonary exercise testing	Peak VO_2 >15 ml/min/kg (>65% pred.) VE/VCO_2 slope <36	Peak VO_2 11–15 ml/min/kg (35–65% pred.) VE/VCO_2 slope 36–44.9	Peak VO_2 <11 ml/min/kg (<35% pred.) VE/VCO_2 slope ≥45
NT-proBNP plasma levels	BNP <50 ng/l NT-proBNP <300 ng/l	BNP 50–300 ng/l NT-proBNP 300–1400 ng/l	BNP >300 ng/l NT-proBNP >1400 ng/l
Imaging (echocardiography, CMR imaging)	RA area <18 cm^2 No pericardial effusion	RA area 18–26 cm^2 No or minimal, pericardial effusion	RA area >26 cm^2 Pericardial effusion
Haemodynamics	RAP <8 mmHg CI ≥2.5 l/min/m^2 SvO_2 >65%	RAP 8–14 mmHg CI 2.0–2.4 l/min/m^2 SvO_2 60–65%	RAP >14 mmHg CI <2.0 l/min/m^2 SvO_2 <60%

Predictive significance of hemodynamic parameters measured at rest

Study	N*	mRAP	mPAP	Cardiac Output	Cardiac Index	PVR	SVI	Compliance
NIH registry[11]	194	✓†	✓†	NA	✓†	NA	NA	NA
French PAH registry[13]	354	✓‡	NS	✓†	✓‡	NS	NA	NA
REVEAL[18]	2,716	✓†	✓‡	NA	✓‡	✓†	NA	NA
French epoprostenol cohort[2]	178	✓†	✓‡	NA	NS	NA	NA	NA
US epoprostenol study[19]	162	✓‡	NS	NA	NS	NS	NA	NA
PAH-CTD cohort[20]	429	✓‡	✓‡	NA	✓‡	✓‡	NA	NA
IPAH study[22]	104	✓‡	NS	NA	✓‡	✓‡	NA	✓‡
SSc-PAH[21]	76	NS	NS	NA	✓‡	✓†	✓†	✓†

IPAH = idiopathic PAH; mPAP = mean pulmonary arterial pressure; NA = not assessed; NIH = National Institutes of Health; NS = not significant; PAH = pulmonary arterial hypertension; PAH-CTD = PAH associated with connective tissue disease; PVR = pulmonary vascular resistance; mRAP = mean right atrial pressure; SSc-PAH = PAH associated with systemic sclerosis; SVI = stroke volume index.

✓ = significant.

*Not all patients had data for all variables.

†Univariate and multivariate.

‡Univariate only.

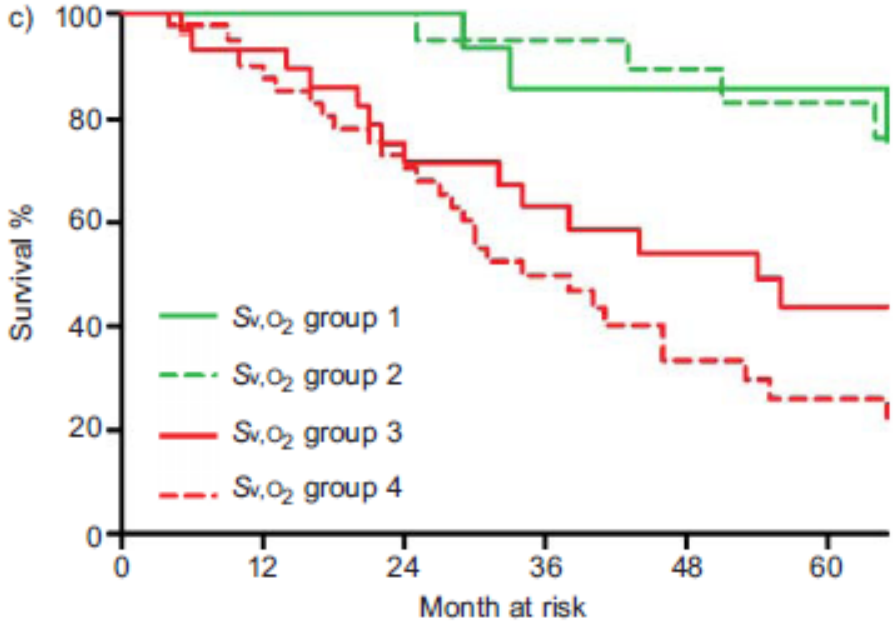
Adapted from *J Am Coll Cardiol*,[2,22] *Ann Intern Med*,[11] *Circulation*,[13,18,19] and *Am J Respir Crit Care Med*.[20,21]

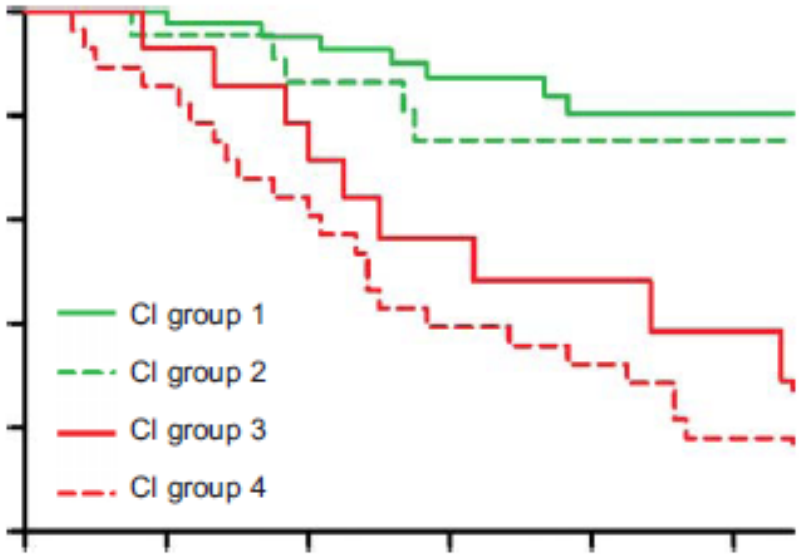
Saggar. Am J Cardiol 2012;110[suppl]:9S–15S

Eur Respir J 2012; 39: 589–596
DOI: 10.1183/09031936.00092311

The prognostic impact of follow-up assessments in patients with idiopathic pulmonary arterial hypertension

N. Nickel, H. Golpon, M. Greer, L. Knudsen, K. Olsson, V. Westerkamp, T. Welte and M.M. Hoeper





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Incremental prognostic value of cardiopulmonary exercise testing and resting haemodynamics in pulmonary arterial hypertension

Roland Wensel [a,b,*], Darrel P. Francis [a], F. Joachim Meyer [c], Christian F. Opitz [d], Leonhard Bruch [e], Michael Halank [f], Jörg Winkler [g], Hans-Jürgen Seyfarth [h], Sven Gläser [i], Friedrich Blumberg [j], Anne Obst [i], Michael Dandel [k], Roland Hetzer [k], Ralf Ewert [i]

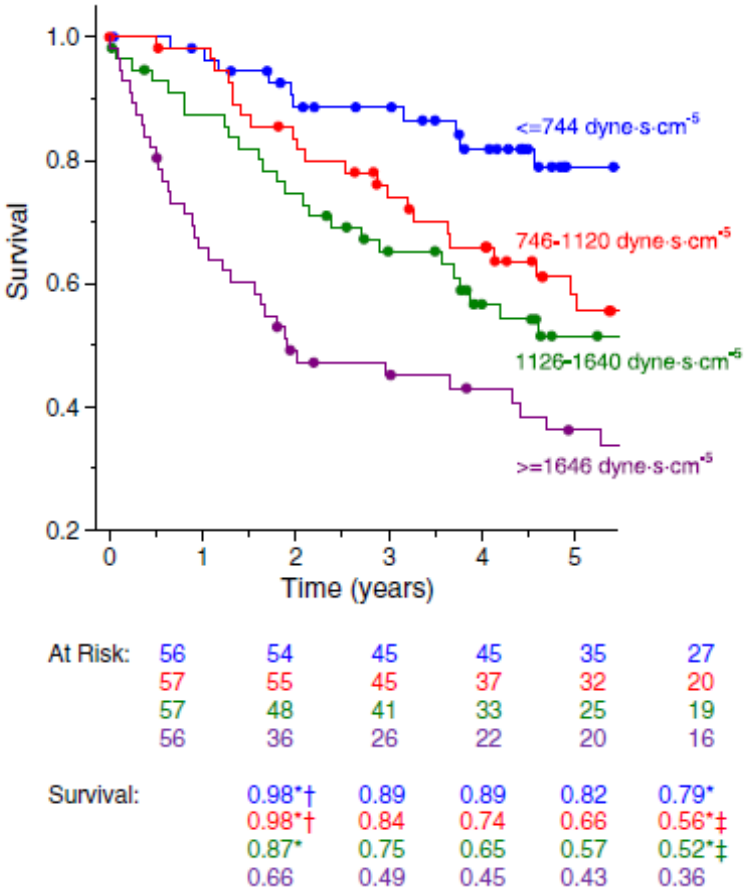

Fig. 3. Cumulative survival according to PVR quartile. *Adjusted $p<0.05$ vs. 4th quartile (>1646 dyn·s·cm^{-5}). †adjusted $p<0.05$ vs.3rd quartile. ‡adjusted $p<0.05$ vs. 1st quartile.

Peak VO2, PVR and ΔHR independently predict prognosis in patients with PAH. Low peak VO2, high PVR and low ΔHR refer to poor prognosis. Combined use of peak VO2 and PVR provides accurate risk stratification underlining the complementary prognostic information from cardiopulmonary exercise testing and resting invasive haemodynamic data.

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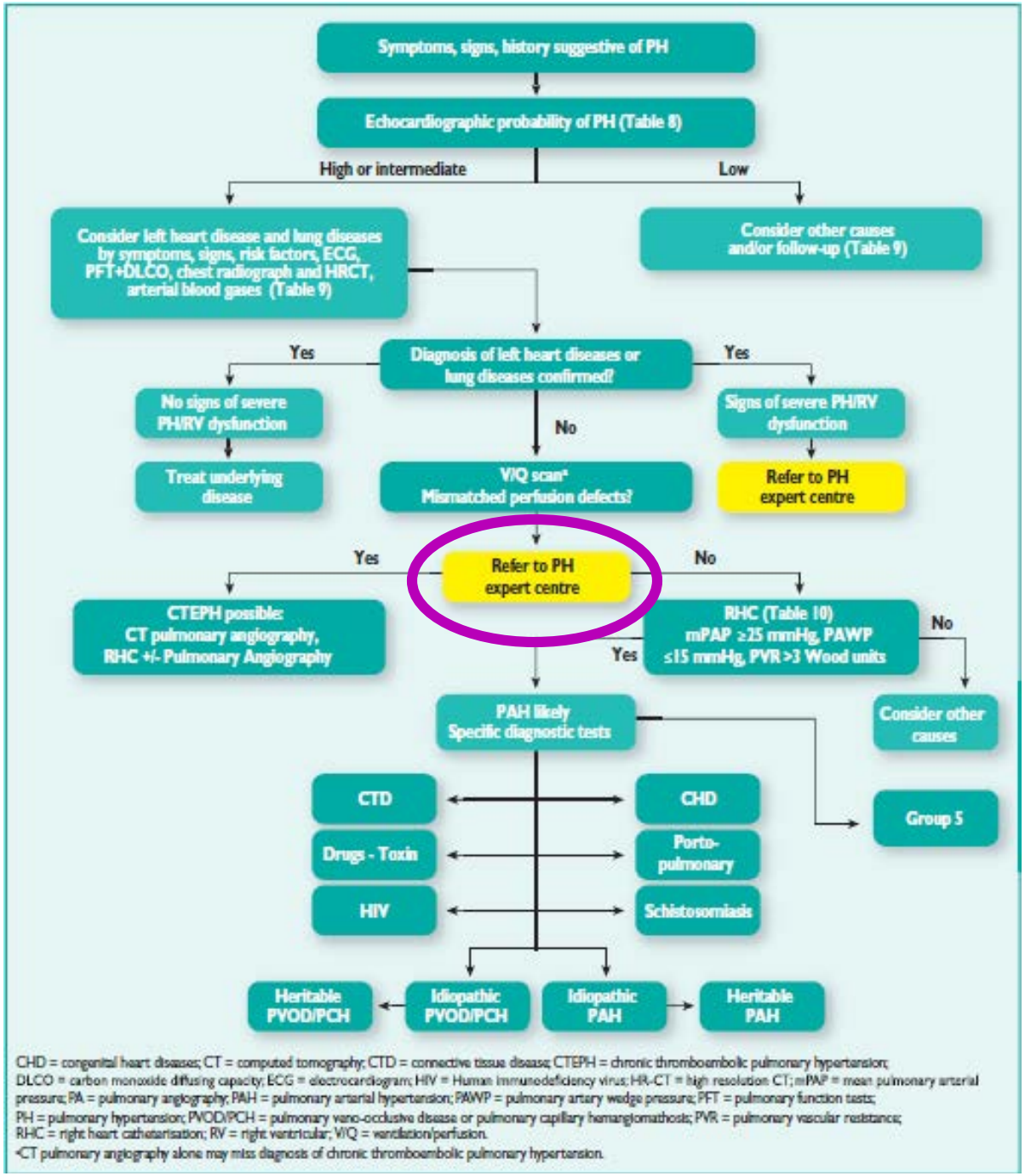
Macitentan and Morbidity and Mortality in Pulmonary Arterial Hypertension

Table S5. Treatment effect of macitentan on cardiac hemodynamic variables from baseline to month 6

	Placebo N=50	Macitentan 3 mg N=47	Macitentan 10 mg N=48
Pulmonary vascular resistance			
Baseline – dyn·sec/cm^5 Mean value (min, max)	886 (259, 3390)	945 (250, 2317)	907 (254, 2779)
Month 6 – dyn·sec/cm^5 Mean value (min, max)	1042 (164, 3409)	736 (71, 2308)	680 (158, 2813)
Ratio month 6/baseline (%) Geometric mean (95% CI)	115.8 (104.7, 128.1)	76.9 (69.8, 84.6)	71.3 (62.4, 81.4)
Treatment effect versus placebo Ratio of geometric mean (%) (97.5% CI)	-	66.4 (56.6, 77.8)	61.5 (51.0, 74.3)
Cardiac index			
Baseline – L/min/m^2 Mean value (min, max)	2.54 (1.31, 4.54)	2.34 (1.13, 5.15)	2.63 (1.20, 6.24)
Month 6 – L/min/m^2 Mean value (min, max)	2.21 (1.06, 3.89)	2.69 (1.26, 5.59)	2.93 (1.46, 5.11)
Change from baseline – L/min/m^2 Arithmetic mean (min, max)	-0.33 (-2.53, 0.44)	0.36 (-0.81, 1.76)	0.30 (-2.97, 1.99)
Treatment effect versus placebo Mean (97.5% CI)	-	0.69 (0.40, 0.97)	0.63 (0.28, 0.97)

CI: confidence interval

Pulido et al. N Engl J Med 2013; 369:809-818



CHD = congenital heart diseases; CT = computed tomography; CTD = connective tissue disease; CTEPH = chronic thromboembolic pulmonary hypertension; DLCO = carbon monoxide diffusing capacity; ECG = electrocardiogram; HIV = Human immunodeficiency virus; HR-CT = high resolution CT; mPAP = mean pulmonary arterial pressure; PA = pulmonary angiography; PAH = pulmonary arterial hypertension; PAWP = pulmonary artery wedge pressure; PFT = pulmonary function tests; PH = pulmonary hypertension; PVOD/PCH = pulmonary veno-occlusive disease or pulmonary capillary hemangiomathosis; PVR = pulmonary vascular resistance; RHC = right heart catheterisation; RV = right ventricular; V/Q = ventilation/perfusion.

*CT pulmonary angiography alone may miss diagnosis of chronic thromboembolic pulmonary hypertension.

Minori complicanze

Meno diagnosi errate

Corretta interpretazione parametri emodinamici

Complicanze

In <u>centri esperti</u>: morbilità = 1.1%, mortalità = 0.055%

J Am Coll Cardiol 2006; 48: 2546-52

TABLE 2 Contraindications and complications associated with right heart catheterisation

Contraindications [36–38]	Absolute: mechanical tricuspid or pulmonic valve, right heart masses (thrombus or tumour), and right-sided endocarditis Relative: coagulopathy, pacemaker, bioprosthetic tricuspid or pulmonic valve, left bundle branch block, arrhythmias, and skin site infections
Complications[#] [34]	Haematoma at puncture sites, pneumothoraces, arrhythmias, vasovagal episodes, hypotensive episodes, and pulmonary haemorrhage

[#]: the complications listed are those that occur most frequently.

Perforazione cardiaca per puntura miocardica, trombosi, tromboembolismi, infezioni, fistole artero-venose, perforazione arteria polmonare, infarto polmonare, annodamento del catetere

Contemporary Trends in the Diagnosis and Management of Pulmonary Arterial Hypertension

An Initiative to Close the Care Gap

Recommended Test	Test Not Done at Enrollment[a] (n=791), No. (%)	Additional Test Done at 6 Mo, Patients With Test Done/Patients With Data (%)	Additional Test Done at 12 Mo, Patients With Test Done/Patients With Data (%)
Essential blood work			
CBC	74 (9.4)	17/53 (32.1)	7/48 (14.6)
LFT	73 (9.2)	21/52 (40.4)	20/48 (41.7)
CTD screening	396 (50.1)	4/310 (1.3)	5/286 (1.8)
HIV screening	562 (71.1)	3/456 (0.7)	1/420 (0.2)
Chest radiograph	93 (11.8)	7/66 (10.6)	8/61 (13.1)
ECG	146 (18.5)	2/108 (1.9)	7/100 (7.0)
Echocardiogram	25 (3.2)	2/20 (10.0)	4/19 (21.1)
PFT	137 (17.3)	8/108 (7.4)	5/104 (4.8)
Oximetry	464 (58.7)	9/373 (2.4)	9/342 (2.6)
V̇/Q̇ lung scan	338 (42.7)	2/270 (0.7)	2/256 (0.8)
Exercise capacity	167 (21.1)	14/122 (11.5)	14/112 (12.5)
RHC	77 (9.7)	0/59 (0.0)	2/56 (3.6)
Contingent blood work[b]	241 (30.5)	26/192 (13.8)	45/182 (24.7)

Referral of Patients With Pulmonary Hypertension Diagnoses to Tertiary Pulmonary Hypertension Centers

The Multicenter RePHerral Study

JAMA Intern Med. 2013

- 25 (42%) of the 59 patients who underwent RHC at the tertiary centre were found to have a diagnosis that differed from the initial diagnosis of PH received prior to referral.

- Among the 56 patients diagnosed with PAH before referral, PAH was confirmed in 41 (73%) while 7 (12%) had no evidence of PH after tertiary care evaluation.

- 42 (30%) patients from the total study population had begun PAH treatments before referral, but, following tertiary centre evaluation, 57% of these patients were found to have been prescribed medications that are not supported by guideline recommendations.

PAH compensata

PAPm (mmHg)	52	14±3
P wedge (mmHg)	12	≤15
P atriale dx (mmHg)	10	≤6
CI (L/min/m2)	3,2	2,5 – 4,2
PVR (woods unit)	8	0,25 – 1,6

PAH scompensata

PAPm (mmHg)	72
P wedge (mmHg)	18
P atriale dx (mmHg)	20
CI (L/min/m2)	2,4
PVR (woods unit)	13,5
DPG (mmHg)	42

End-stage PAH

PAPm (mmHg)	40
P wedge (mmHg)	20
P atriale dx (mmHg)	25
CI (L/min/m2)	2
PVR (woods unit)	10
DPG (mmHg)	15