UZ LEUVEN

70TH ESCVS CONGRESS & 7TH IMAD MEETING

20 I 23 JUNE 2022

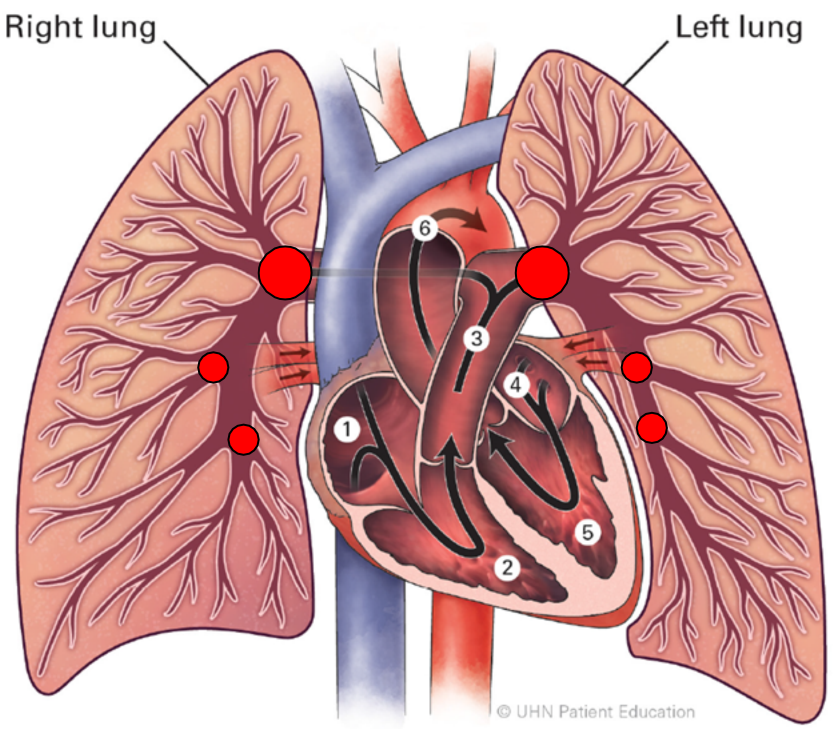
Pulmonary Endarterectomy for Chronic Thromboembolic Pulmonary Hypertension (CTEPH):

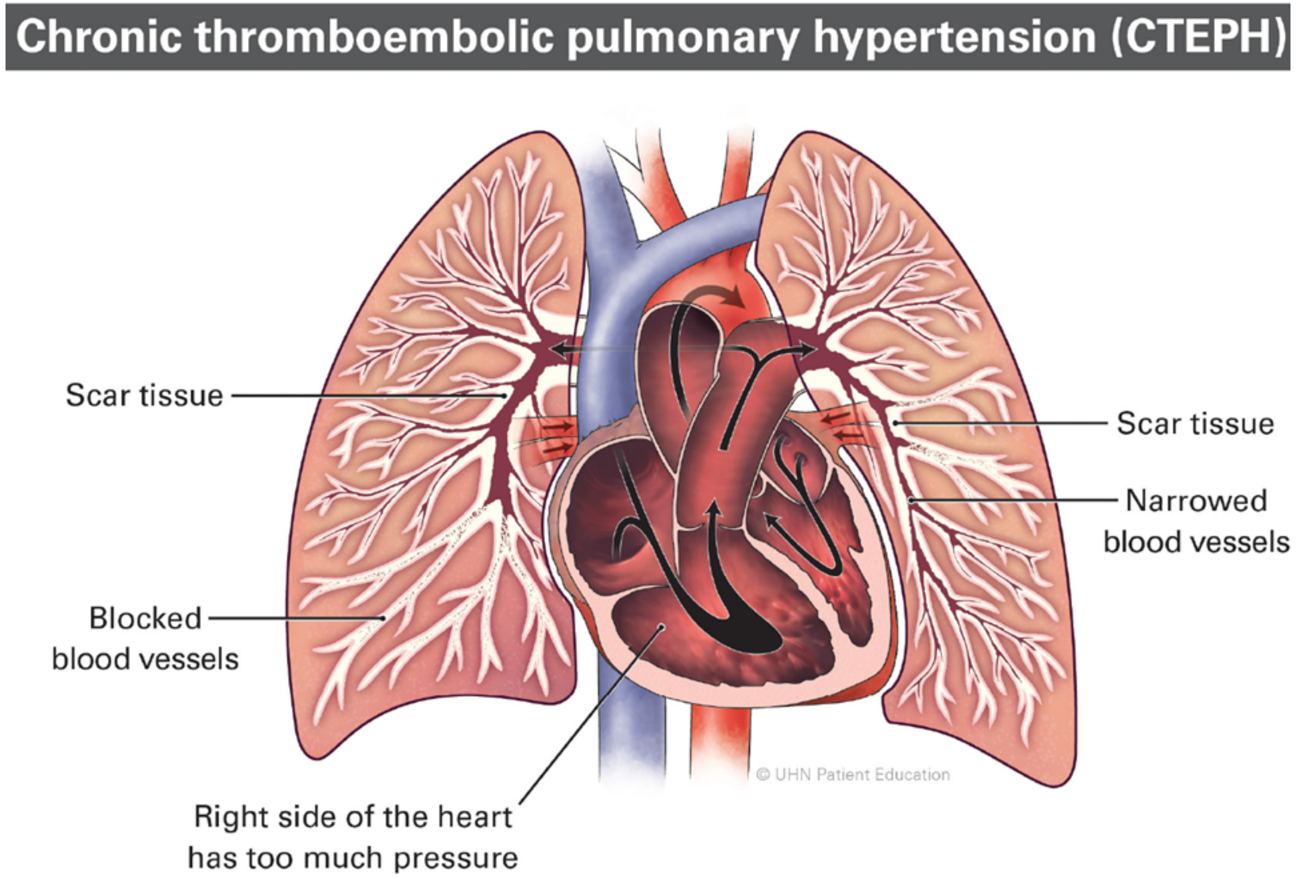
Tom Verbelen MD, PhD

Assistant Professor

Department of Cardiac Surgery, University Hospitals Leuven, Belgium

https://www.uhn.ca/PatientsFamilies/Health_Information/Health_Topics/Documents/What_is_Chronic_Thromboembolic_Pulmonary_Hypertension_CTEPH.pdf





- ~ 3.2% of acute PE survivors

- Incomplete resolution of pulmonary thromboemboli and fibrotic transformation

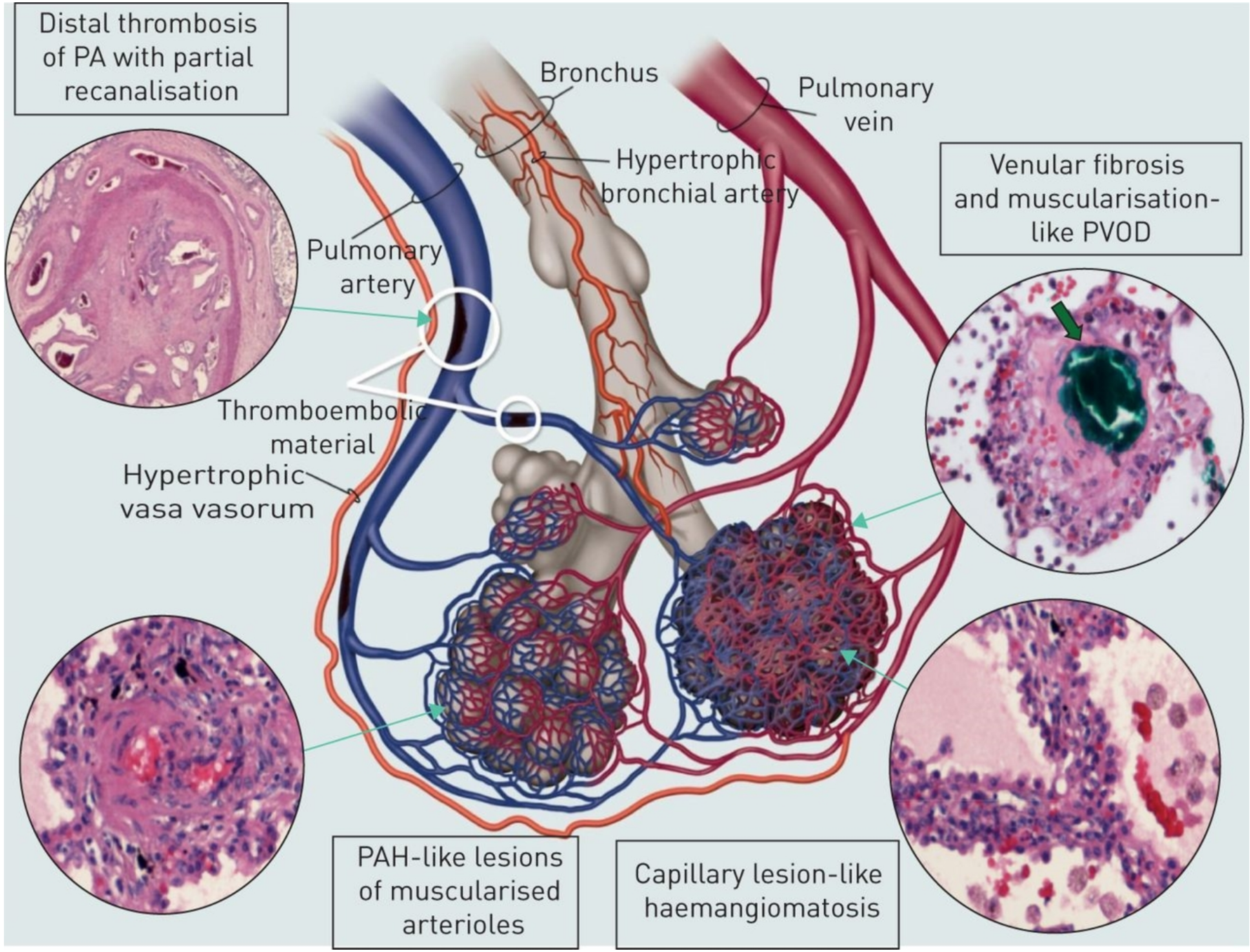
- Narrowing/occlusion proximal pulmonary arteries

- Pulmonary vascular resistance (PVR) ↑
    1. Proximal obstruction
    2. Secondary microvasculopathy

- Pulmonary Hypertension (PH)

- RV-failure

  5-year survival:
  - mPAP > 40 mmHg: 30%
  - mPAP > 50 mmHg: 10%



Simonneau G, Torbicki A, Dorfmüller P, et al. The pathophysiology of chronic thromboembolic pulmonary hypertension. Eur Respir Rev 2017; 26: 160112 [https://doi.org/10.1183/ 16000617.0112-2016].

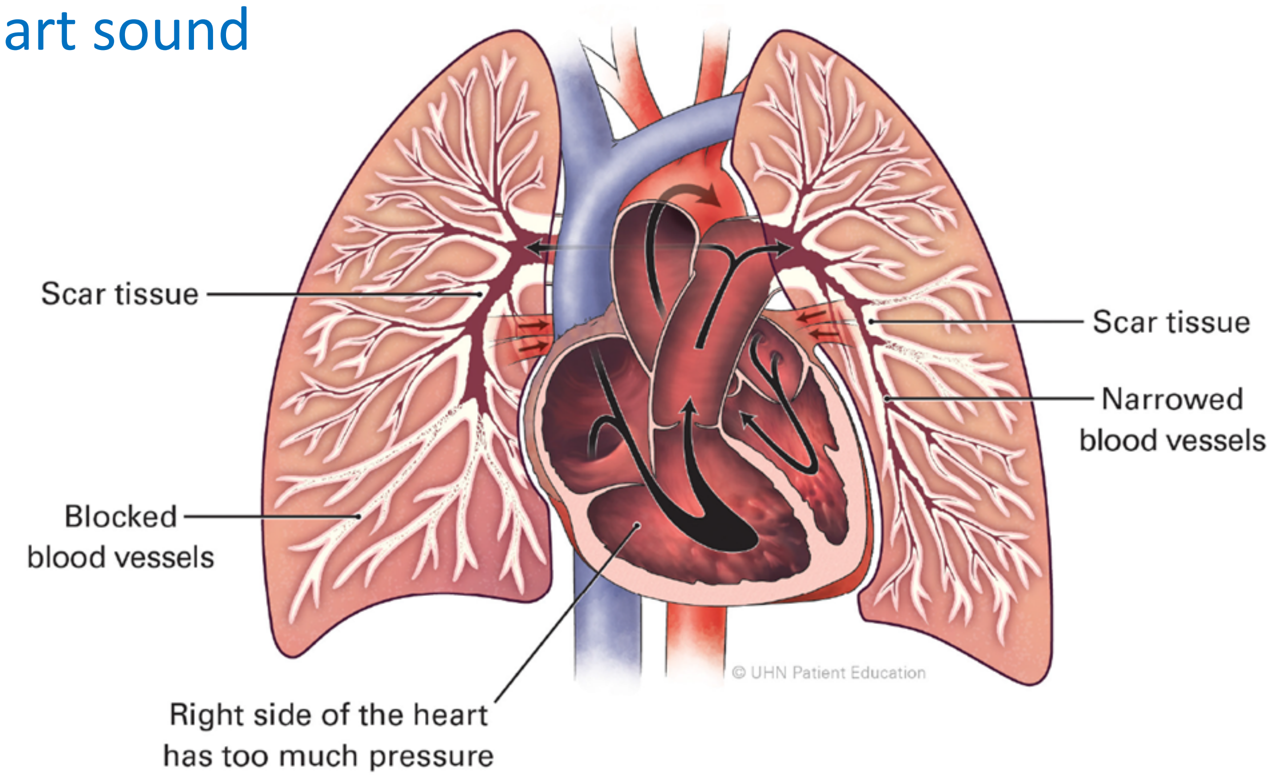
Clinical presentation CTEPH: not specific!

- Exercise intolerance and/or exertional dyspnea
  - Cardiac Output ↓
  - Dead space ventilation ↑

- Accentuated pulmonary component 2nd heart sound

- RV-dysfunction
  - Lower extremity swelling
  - Chest pain or pressure
  - Exertional light-headedness
  - Hepatomegaly and ascites
  - TI murmur

- Hemoptysis



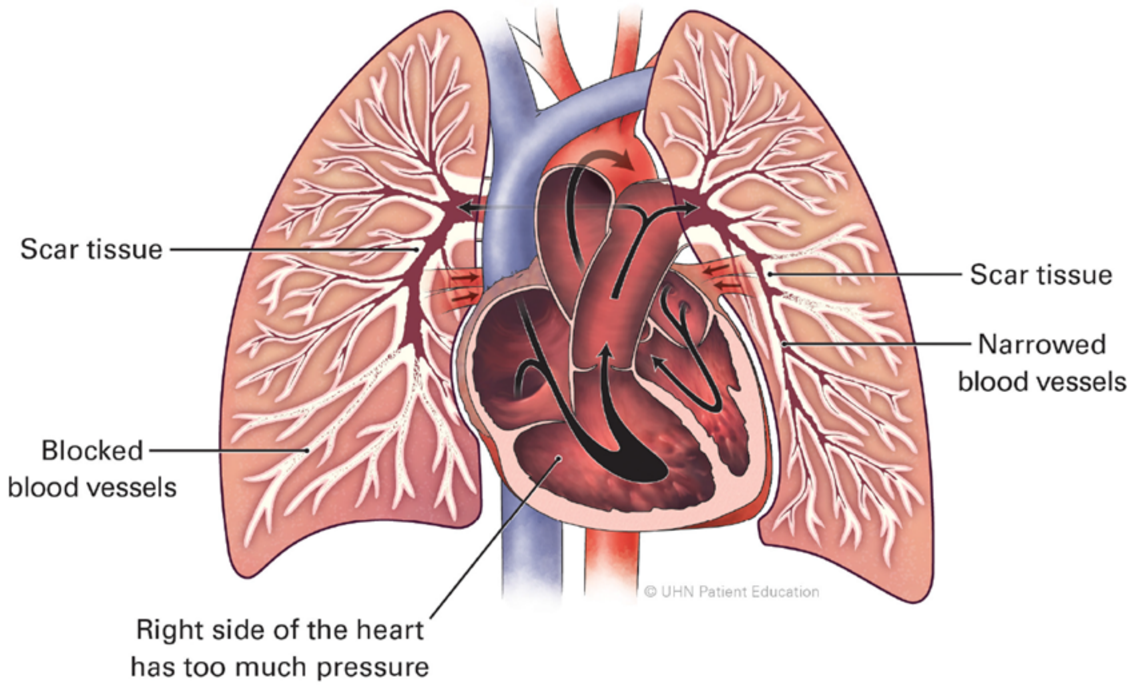
https://www.uhn.ca/PatientsFamilies/Health_Information/Health_Topics/Documents/What_is_Chronic_Thromboembolic_Pulmonary_Hypertension_CTEPH.pdf

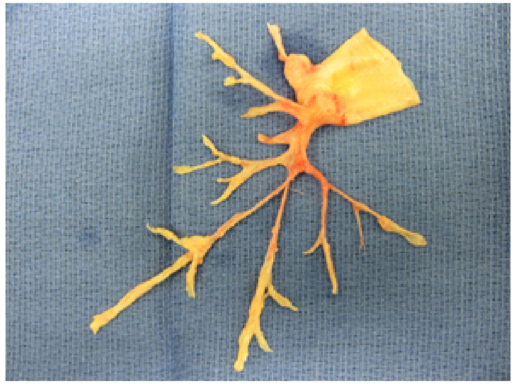
Risk factors CTEPH

- Acute pulmonary embolism
  - Recurrent
  - Large perfusion defect
  - High mPAP 1st PE
  - Idiopathic

- Hemostatic abnormalities
  - Increased factor VIII, von Willebrand factor, type 1 plasminogen activator inhibitor
  - Abnormal fibrinogen structure
  - Antiphospholipid antibodies en Lupus anticoagulant
  - Non-type-O blood group
  - Increased lipoprotein(a)

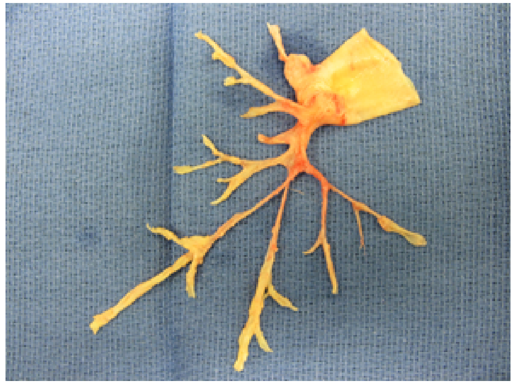
Associated medical conditions
- Splenectomy
- Ventriculo-atrial shunt
- Infected intravenous catheters/devices
- Chronic inflammatory diseases
- Hypothyroidy
- Malignancies





CTEPH

1. Diagnosis
2. PEA
3. Operability assessment
4. Patient selection
5. Results



Massive **UNDERDIAGNOSIS** of CTEPH

Chronic Thrombotic Obstruction of Major Pulmonary Arteries*

Report of a Case Successfully Treated by Thrombendarterectomy, and a Review of the Literature

LT. CMDR. VERNON N. HOUK, MC, USN, *Bethesda, Maryland*; CHARLES A. HUFNAGEL, M.D., *Washington, D. C.*
CMDR. JAMES E. McCLENATHAN, MC, USN *and* KENNETH M. MOSER, M.D. *Bethesda, Maryland*; *Washington, D. C.*

Houk et al. Am J Med 1963;35:269-82.

Pneumonol Alergol Pol. 1993;61(3-4):171-6.

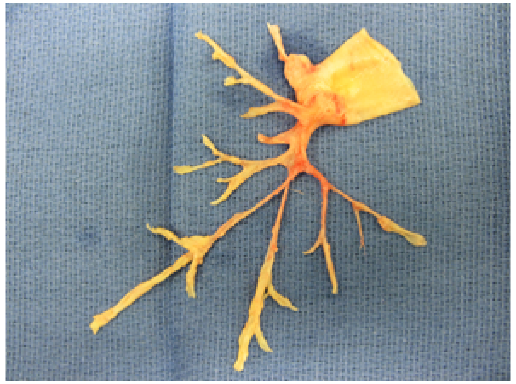
[Pulmonary thromboembolism--random analysis of autopsy material]

[Article in Polish]

A Panasiuk [1], J Dzieciol, H F Nowak, A Kemona, M Barwijuk-Machała

- 240 cases
- Only six correctly diagnosed before death

- 13,216 patients
- CTEPD in 5.5 % of autopsies (31.3% in elderly)



CTEPH – Underdiagnosis

Estimated incidence
of new CTEPH

17 per million inhabitant/year

Based on:

- PE incidence = 1 per 1000 inh/year[1]
- CTEPH incidence post-PE = 3%[2]
- 57% already have CTEPH, 43% not[3]
- 75% have a history of PE, 25% not[4]

- 1000 * 3% * 43% * 100/75 = 17 per million

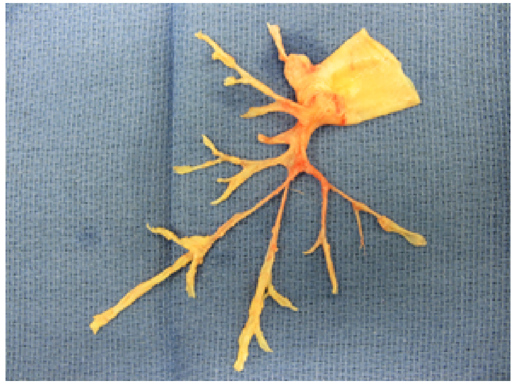
Observed incidence
of CTEPH

5-6 per million inhabitants/year

Based on:

Registry data[5-6]

1. Goldhaber SZ et al. Lancet. 1999;353:1386-9,
2. Ende-Verhaar YM *et al. Eur Respir J* 2017;49:1601792.
3. Guerin L *et al. Thromb Haemost* 2014;112:598–605.
4. Pepke-Zaba J et al, Circulation 2011;124:1973-81,
5. Kramm T *et al. Clin Res Cardiol* 2018;107:548-53,
6. Delcroix M et al. Ann Am Thorac Soc. 2016;13 Suppl 3:S201-6



Diagnostic Delay of CTEPH

AGORA
RESEARCH LETTER

CrossMark

Determinants of diagnostic delay in chronic thromboembolic pulmonary hypertension: results from the European CTEPH Registry

Klok FA et al. Eur Respir J.2018;52:1801687.

Chronic Thromboembolic Pulmonary Hypertension (CTEPH)
Results From an International Prospective Registry

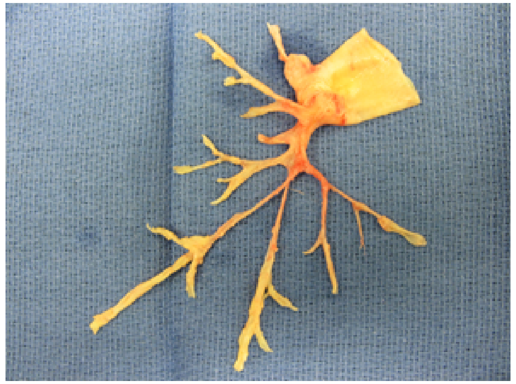
Pepke-Zaba J et al. Circulation. 2011;124:1973-81.

Early diagnosis and referral to CTEPH center = critical for optimal treatment

Diagnostic delay ↑
→ hemodynamic profile↓, survival↓

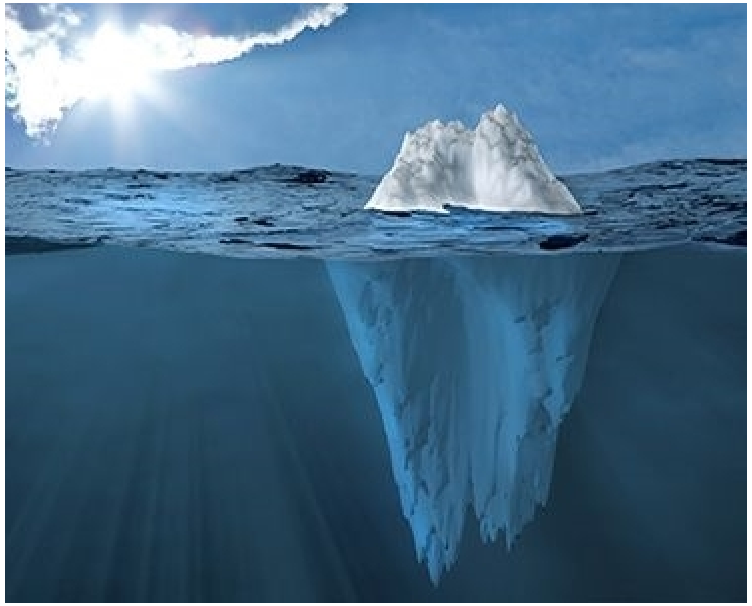
⟺

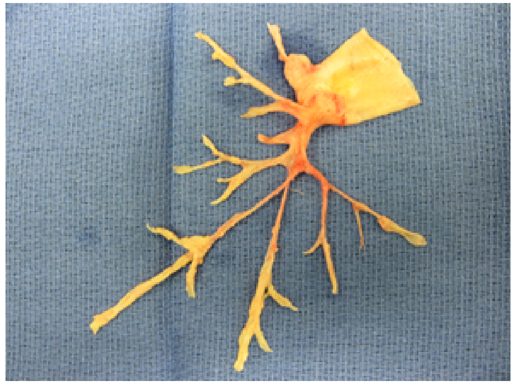
Median delay of 14 months between clinical presentation and diagnosis



Massive underdiagnosis and diagnostic delay of CTEPH

1. Nonspecific clinical presentation and subtle physical examination findings
2. Diagnostic misclassifications as acute PE or other conditions
3. Discount possibility of CTEPD in absence of history of VTE
4. Lack of awareness
5. Cumbersome diagnostic process





Screening after acute PE

European Heart Journal (2016) 37, 67–119
doi:10.1093/eurheartj/ehv317

ESC/ERS GUIDELINES

2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension

TTE = recommended screening tool

Original Articles

Prospective cardiopulmonary screening program to detect chronic thromboembolic pulmonary hypertension in patients after acute pulmonary embolism

Klok FA et al. Haemtatologica.2010;95:970-5.

TTE for all PE survivors:

- Low diagnostic yield
- Overdiagnosis
- Cost-ineffective

ESC European Society of Cardiology

European Heart Journal (2020) 41, 543–603
doi:10.1093/eurheartj/ehz405

ESC GUIDELINES

2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS)

TTE 3-6 months after PE if persistent dyspnea and/or predisposing conditions for CTEPH

Prevalence and potential determinants of exertional dyspnea after acute pulmonary embolism

Klok FA et al. Respir Med. 2010;104:1744-9,

CTEPH ~ 3.2% of acute PE survivors

↕

50% persistent dyspnea after PE

Based on the **InShape II study** results
Boon G et al. Thorax 2021

- Acurate and early exclusion of CTEPH after acute PE
- Avoids TTE in 81% of patients
- Vast ma
4 montl

DIAGNOSIS OF ACUTE PE

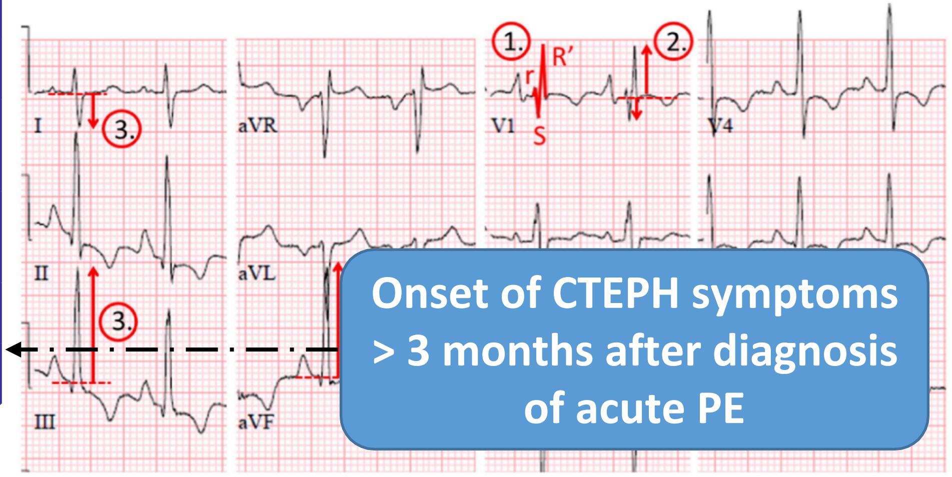
Anticoagulate

Findings of pre-existing CTEPH on CT pulmonary angiography to diagnose acute PE

CTEPH prediction sco	
Unprovoked PE	+ 6 points
Known hypothyro	+3 points
Symptom onset < 2 weeks before PE diagnosis	+ 3 points
Right ventricular dysfunction on CT or TTE	+ 2 points
Known diabetes mellitus	- 3points
Thrombolytic therapy or embolectomy for the acute PE event	- 3points

Findings of pre-existing CTEPH on computed tomography pulmonary angiography
Direct vascular signs
Eccentric wall-adherent filling defect(s), which may calcify; different from the central filling defects within a distended lumen, which are the hallmark of acute PE
Abrupt tapering and truncation
Complete occlusion and pouch defects
Intimal irregularity
Linear intraluminal filling defects (intravascular webs and bands)
Stenosis and post-stenotic dilatation
Vascular tortuosity
Indirect vascular signs
Significant RV hypertrophy, RA dilatation
Pericardial effusion
Dilatation of pulmonary artery (> 29 mm in men and > 27 mm in women) and/or calcifications of pulmonary artery
Systemic collateral arterial supply (bronchial arterial collaterals towards pulmonary post-obstructive vessels)
of the lung parenchyma resulting in geopgraphical variation in perfusion

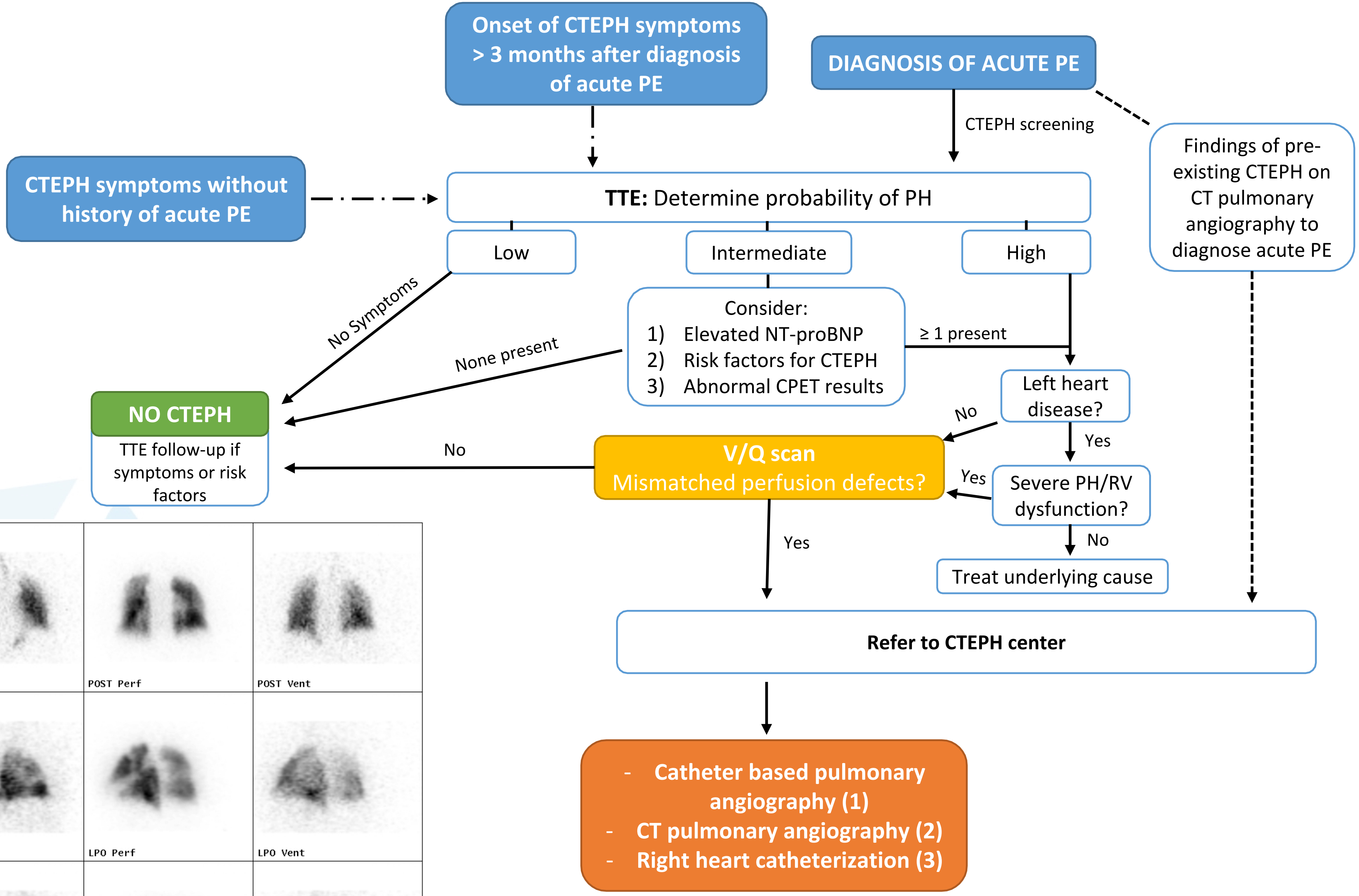
Refer to CTEPH center

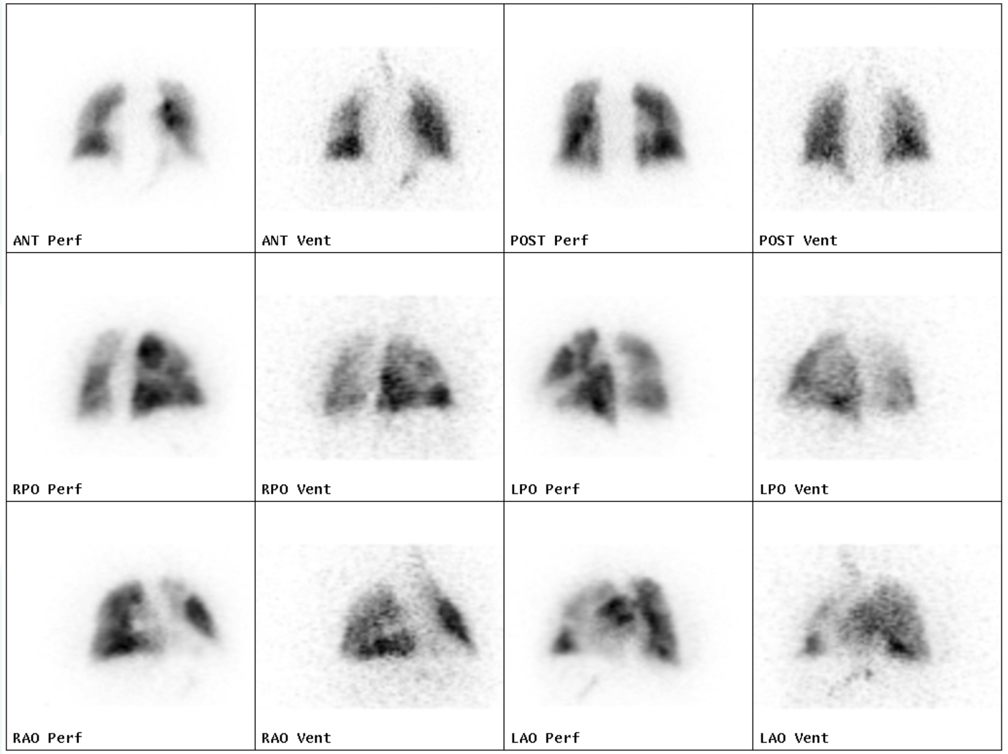


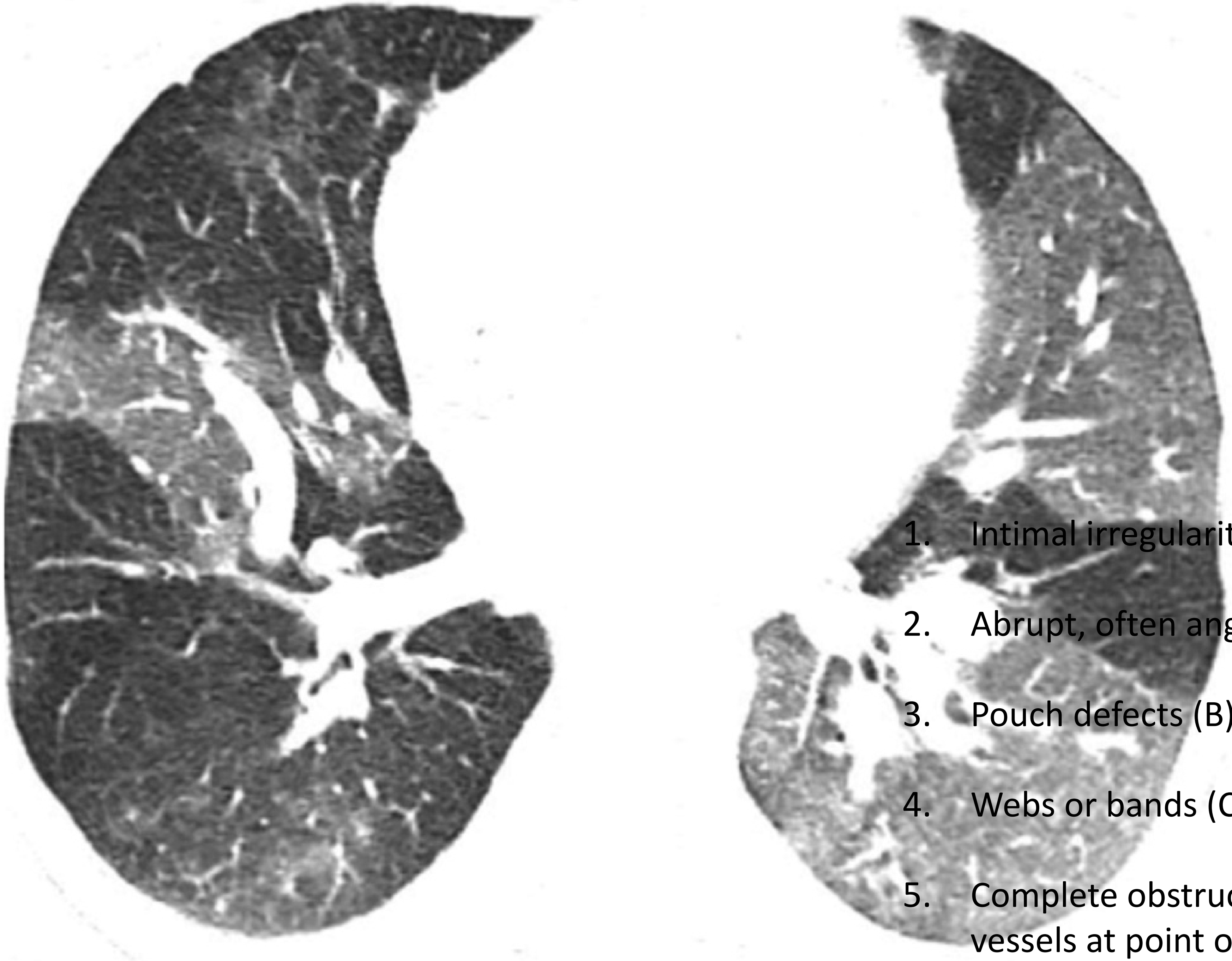
CTEPH symptoms without history of acute PE

Onset of CTEPH symptoms > 3 months after diagnosis of acute PE

Konstantinides SV et al. Eur Heart J. 2020;41:543-603, and Klok FA et al. Eur Respir J. 2020;55(6),


Onset of CTEPH symptoms > 3 months after diagnosis of acute PE
DIAGNOSIS OF ACUTE PE
CTEPH screening
Findings of pre-existing CTEPH on CT pulmonary angiography to diagnose acute PE
CTEPH symptoms without history of acute PE
TTE: Determine probability of PH
Low
Intermediate
High
No Symptoms
Consider:
1) Elevated NT-proBNP
2) Risk factors for CTEPH
3) Abnormal CPET results
≥ 1 present
None present
Left heart disease?
No
Yes
NO CTEPH
TTE follow-up if symptoms or risk factors
No
V/Q scan
Mismatched perfusion defects?
Yes
Severe PH/RV dysfunction?
No
Yes
Treat underlying cause
Refer to CTEPH center
- Catheter based pulmonary angiography (1)
- CT pulmonary angiography (2)
- Right heart catheterization (3)

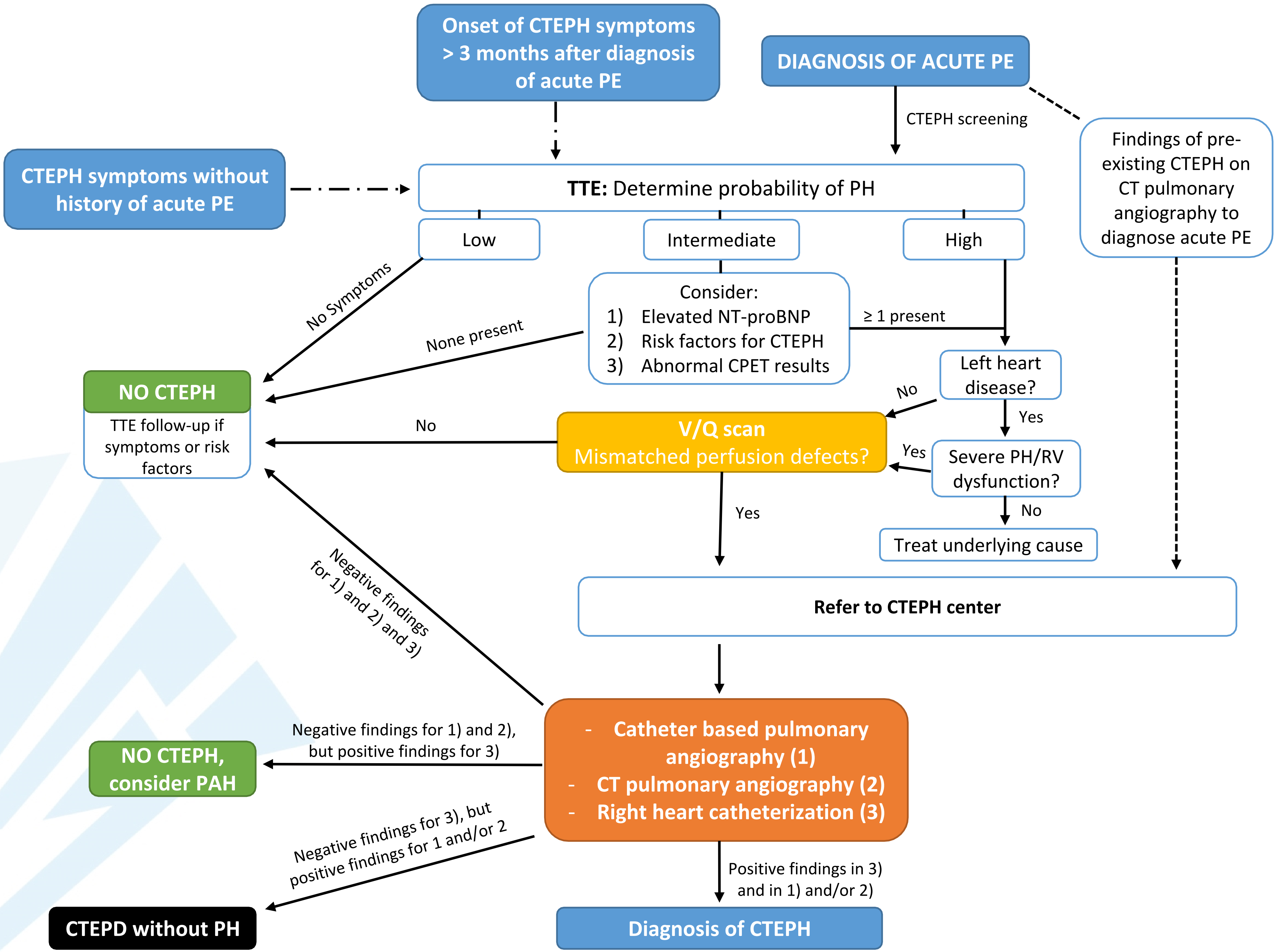

ANT Perf
ANT Vent
POST Perf
POST Vent
RPO Perf
RPO Vent
LPO Perf
LPO Vent
RAO Perf
RAO Vent
LAO Perf
LAO Vent

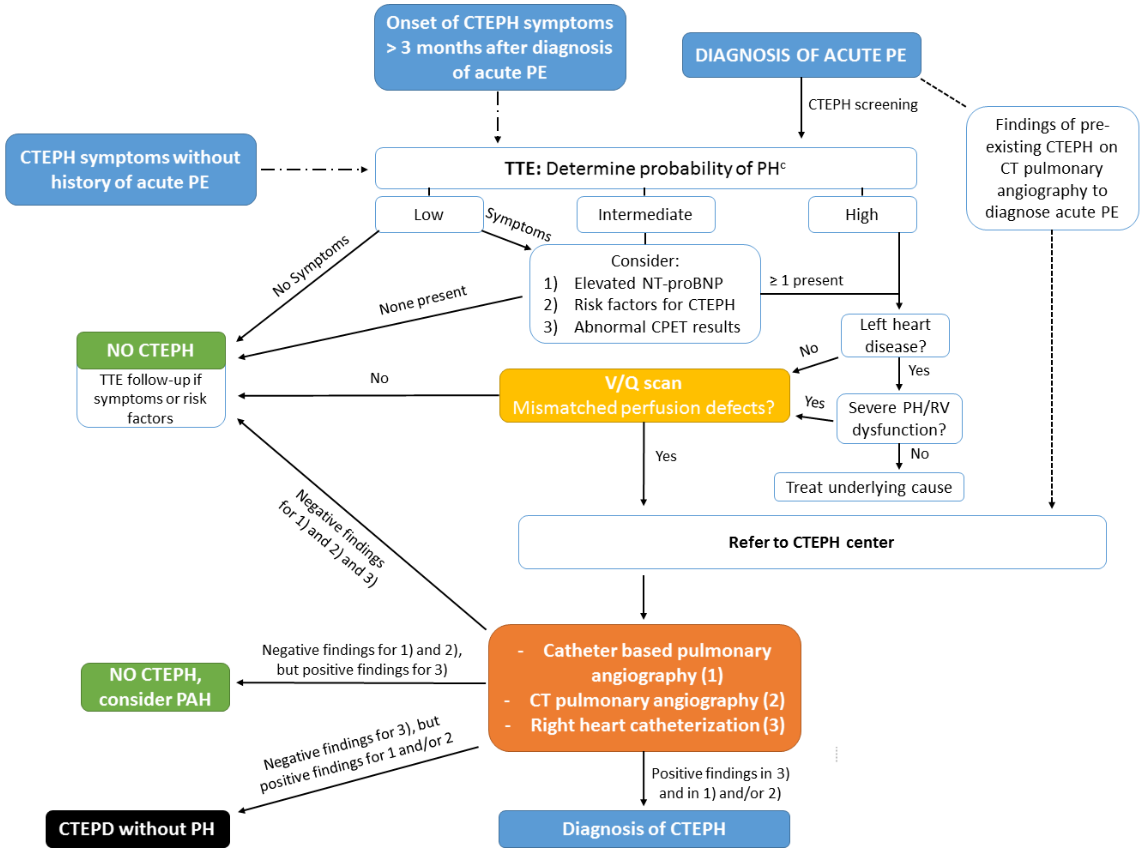


- Catheter based pulmonary angiography (1)
- CT pulmonary angiography (2)
- Right heart catheterization (3)

1. Intimal irregularities (A)
2. Abrupt, often angular narrowing (A)
3. Pouch defects (B)
4. Webs or bands (C)
5. Complete obstruction of main, lobar, or segmental vessels at point of origin (D)

Mahmud E et al. J Am Coll Cardiol. 2018;71:2468-86


Onset of CTEPH symptoms > 3 months after diagnosis of acute PE
DIAGNOSIS OF ACUTE PE
CTEPH screening
Findings of pre-existing CTEPH on CT pulmonary angiography to diagnose acute PE
CTEPH symptoms without history of acute PE
TTE: Determine probability of PH
Low
Intermediate
High
No Symptoms
Consider:
1) Elevated NT-proBNP
2) Risk factors for CTEPH
3) Abnormal CPET results
None present
≥ 1 present
Left heart disease?
No
Yes
NO CTEPH
TTE follow-up if symptoms or risk factors
No
V/Q scan
Mismatched perfusion defects?
Yes
Severe PH/RV dysfunction?
No
Treat underlying cause
Yes
Negative findings for 1) and 2) and 3)
Refer to CTEPH center
- Catheter based pulmonary angiography (1)
- CT pulmonary angiography (2)
- Right heart catheterization (3)
Negative findings for 1) and 2), but positive findings for 3)
NO CTEPH, consider PAH
Negative findings for 3), but positive findings for 1 and/or 2
CTEPD without PH
Positive findings in 3) and in 1) and/or 2)
Diagnosis of CTEPH



DISADVANTAGES

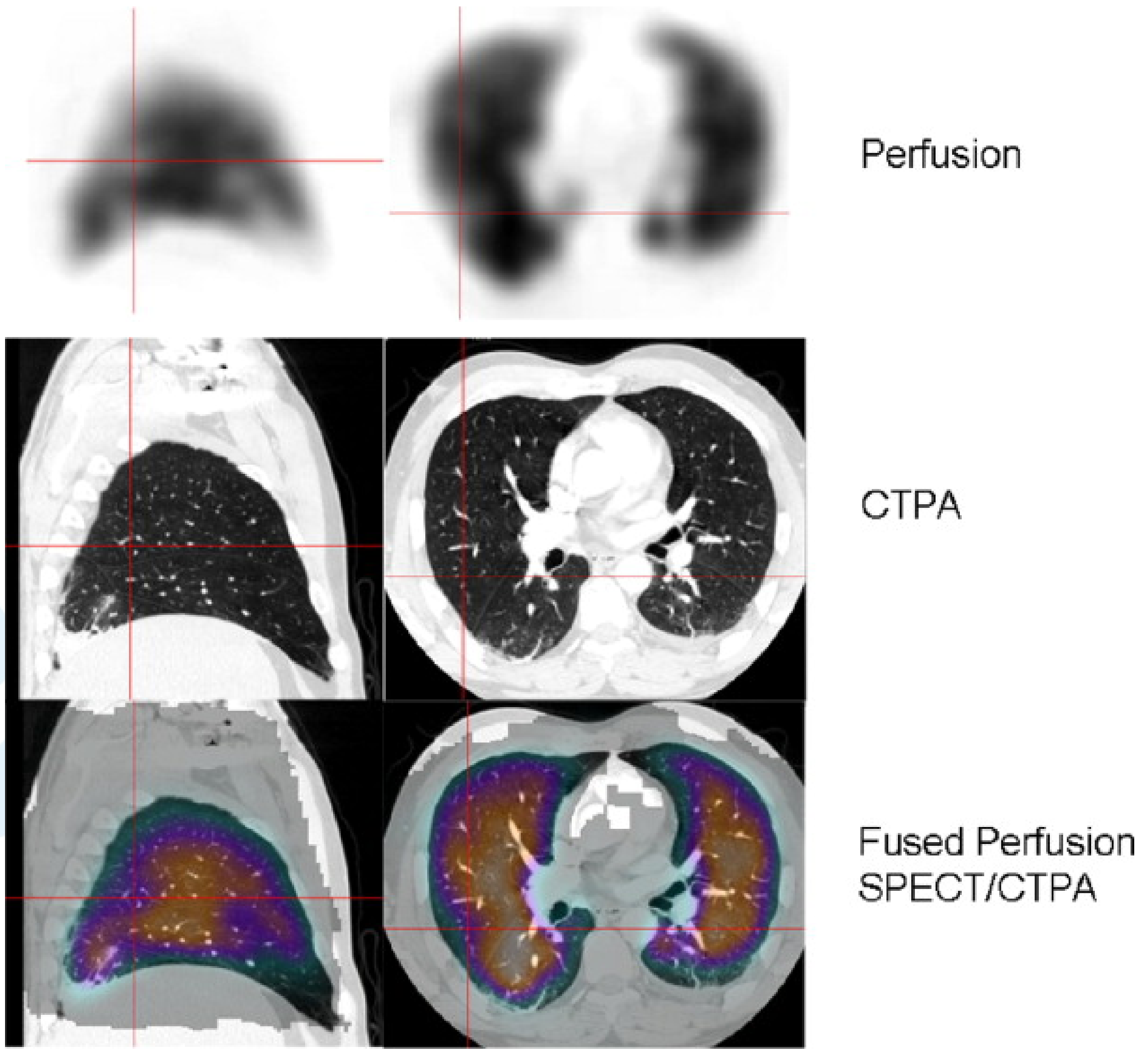
1. V/Q 2D images: segmental defects missed

2. V/Q + ≈ other etiologies of pulmonary malperfusion
   → Additional diagnostic imaging

3. Always Pulmonary angiography AND CTPA

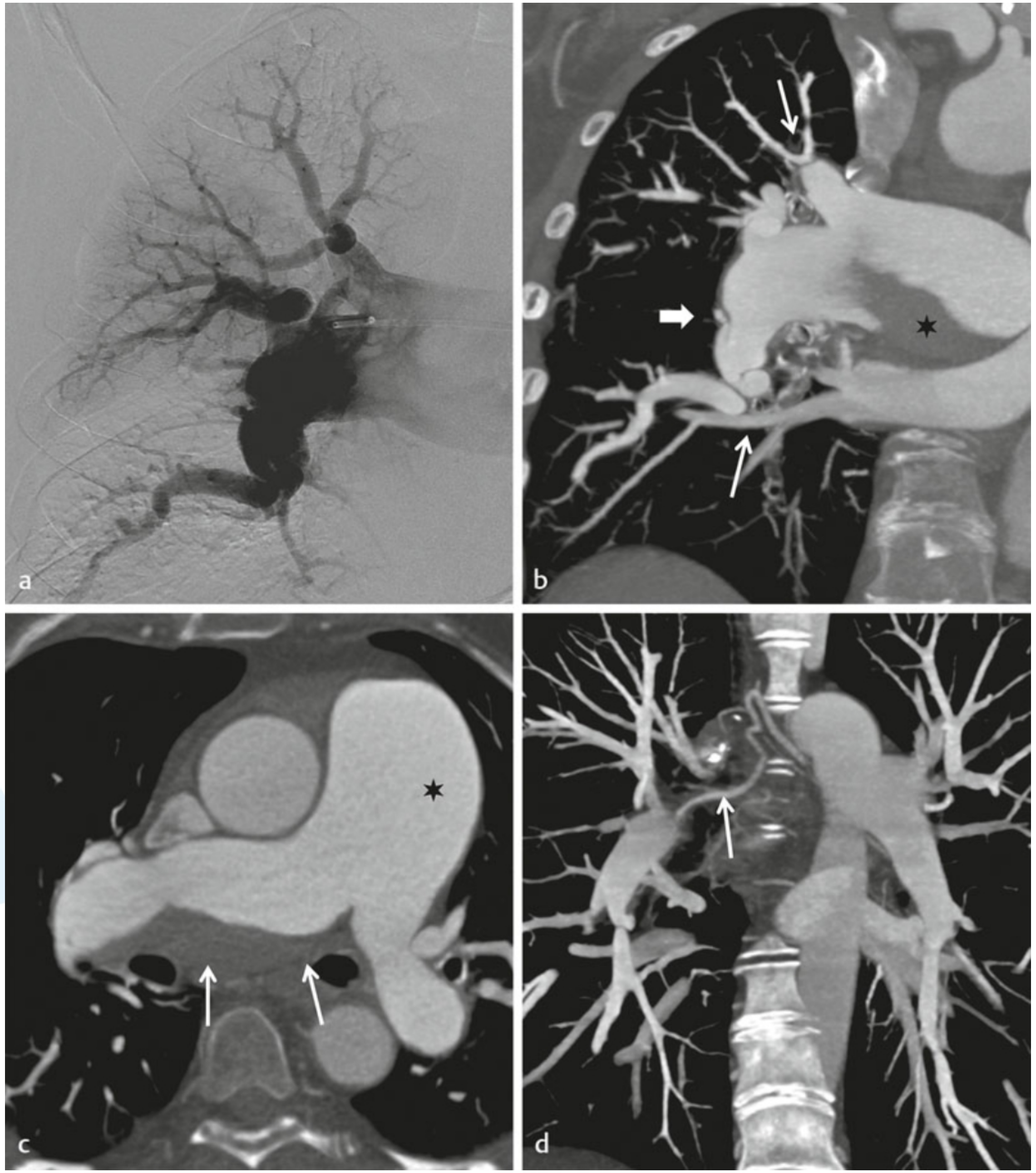
4. Radiation and contrast exposure and costs are high

Single-photon emission computed tomography (SPECT)



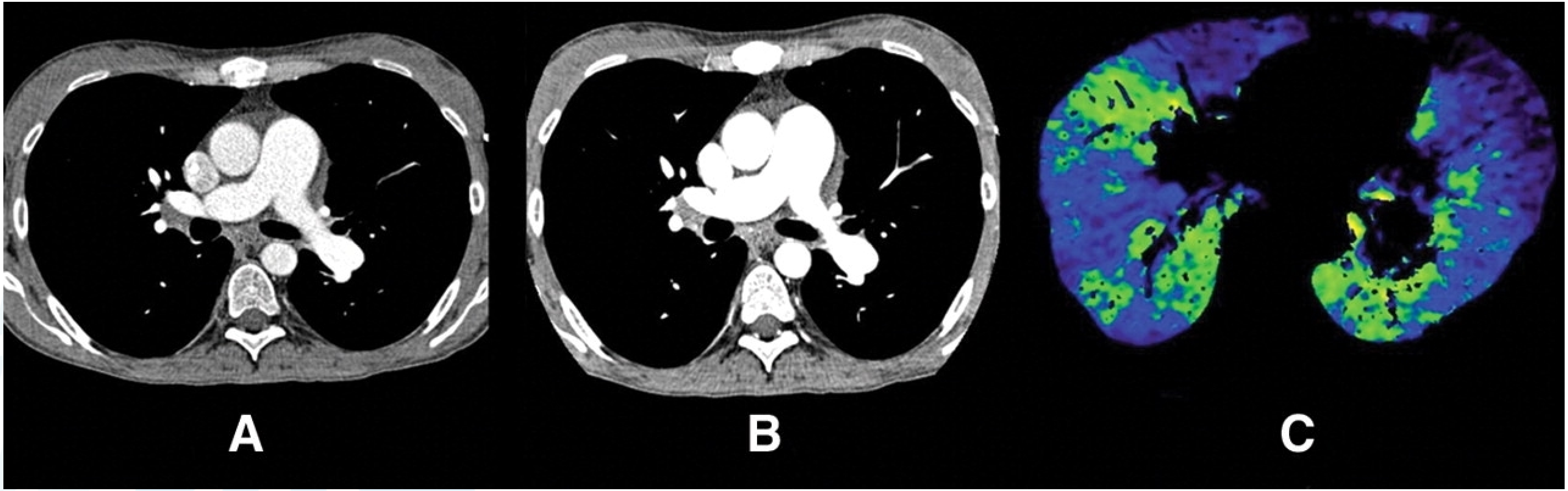
Roach PJ et al. Semin Nucl Med, 2010;40:455-466,

ECG-gated CT



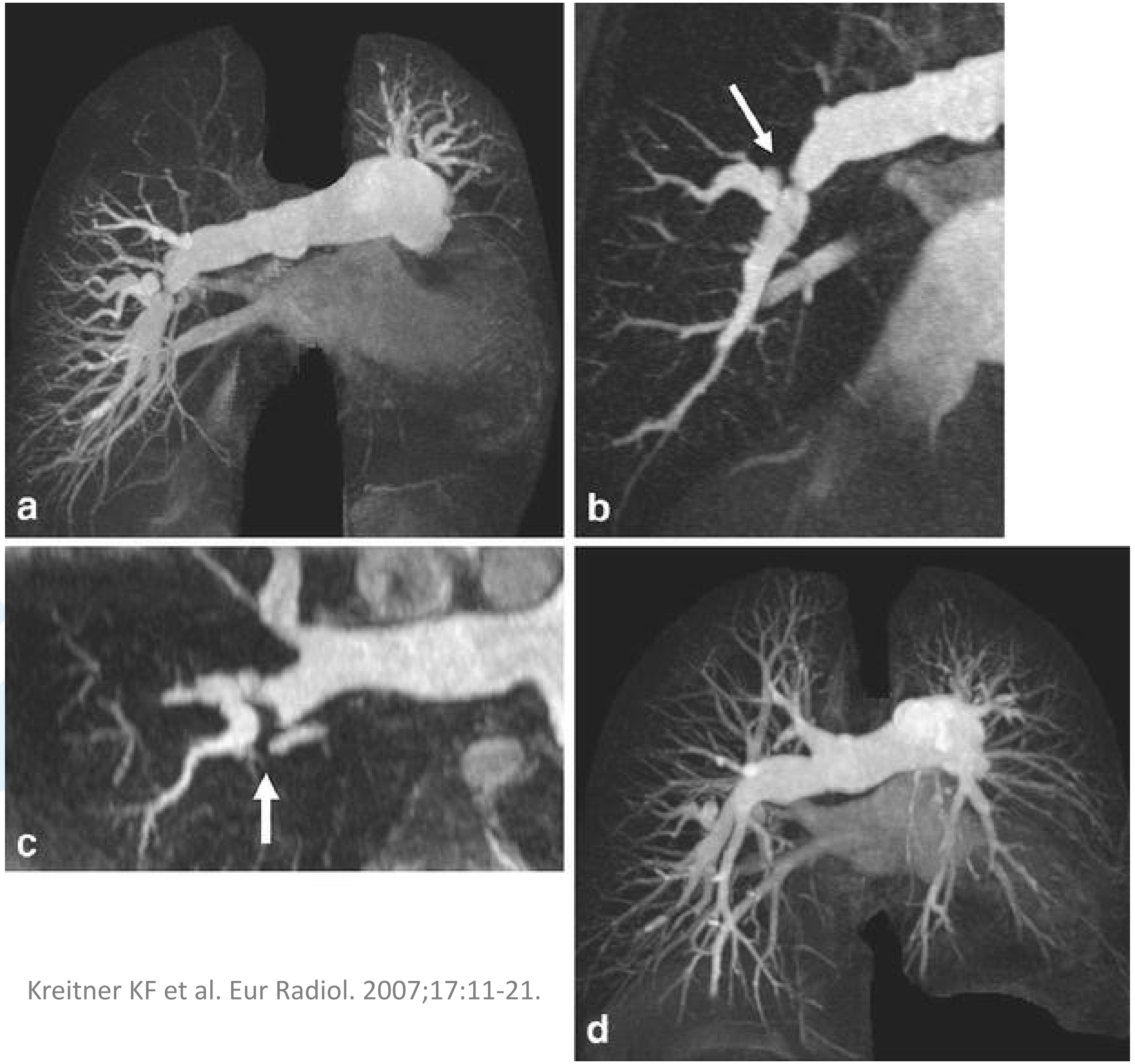
Wirth G et al. Rofo. 2014;186:751-61,

Dual Energy CT (DECT)



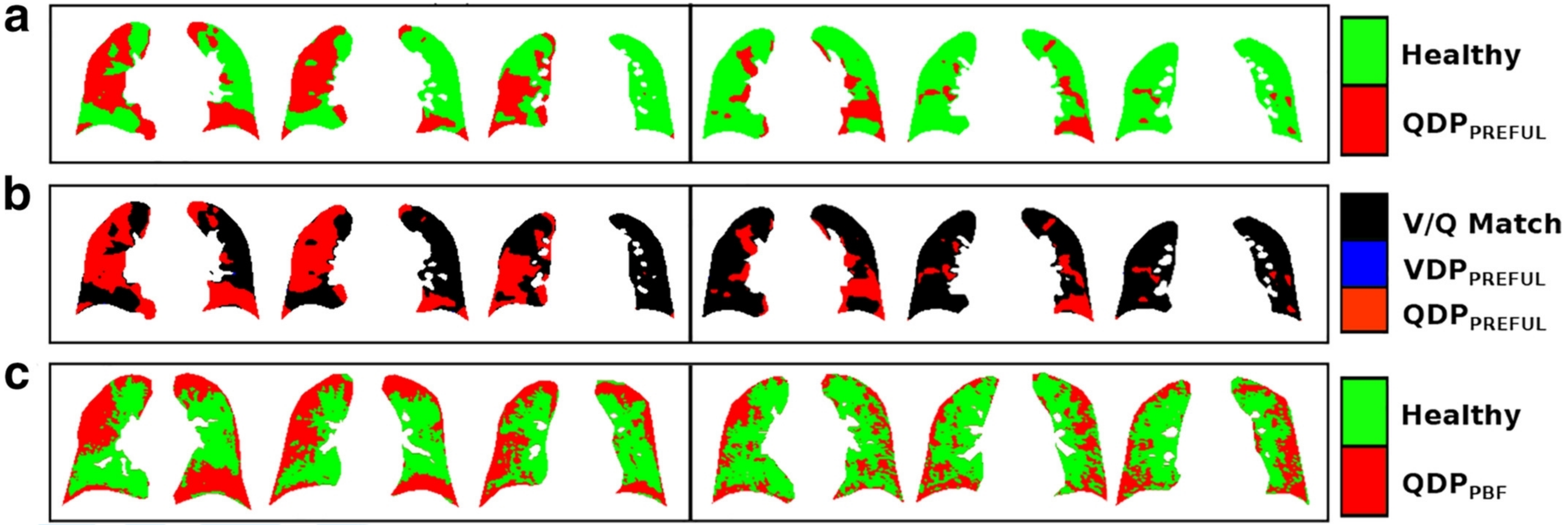
Hoey ET et al. AJR Am J Roentgenol.2011;196:524-32.

Contrast-enhanced MR angiography (ce-MRA)



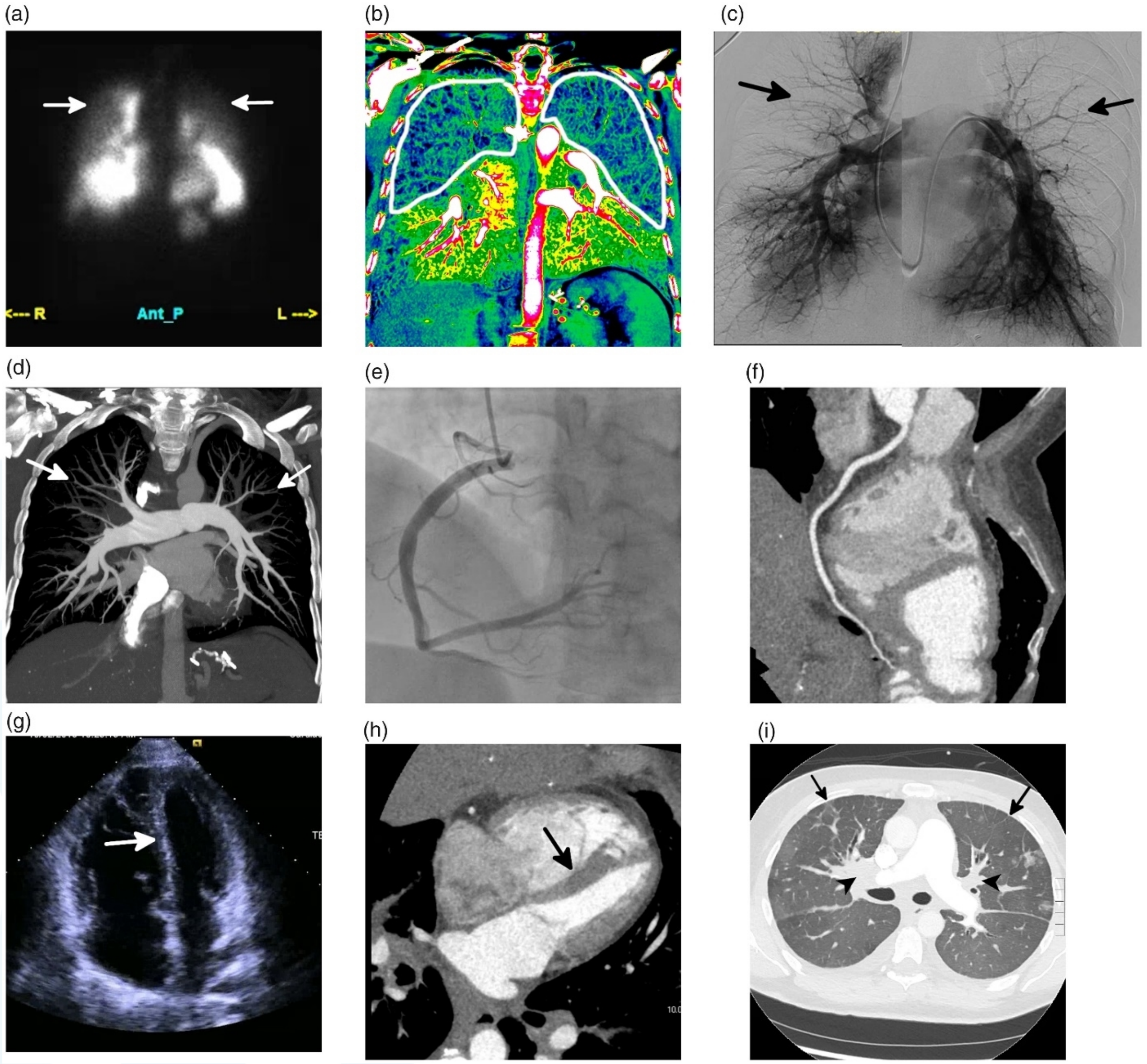
Kreitner KF et al. Eur Radiol. 2007;17:11-21.

Phase-Resolved Functional Lung (PREFUL)-MRI



Pöhler GH et al. J Magn Reson Imaging. 2020;52:610-9.

Ultimate goal: one single imaging tool to screen, diagnose and assess operability



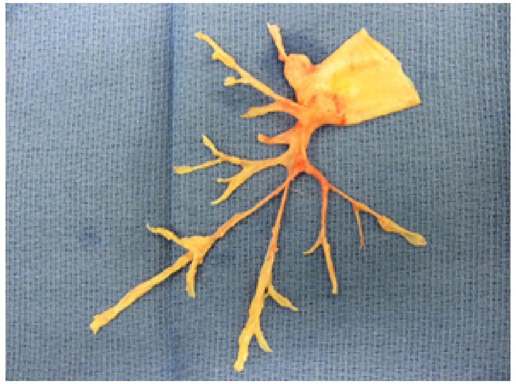
- Qualitative and quantitative assessment of pulmonary perfusion
- High spatial resolution assessment of pulmonary and coronary arteries
- Morphologic and quantitative assessement of heart
- Lower radiation exposure
- Lower cost

Review Article Pulmonary Circulation

Optimizing the diagnosis and assessment of chronic thromboembolic pulmonary hypertension with advancing imaging modalities

Seth Kligerman and Albert Hsiao
Cardiothoracic Imaging, University of California San Diego, La Jolla, CA, USA

Single ECG-gated dual energy CTPA and coronary CT angiography exam



CTEPH

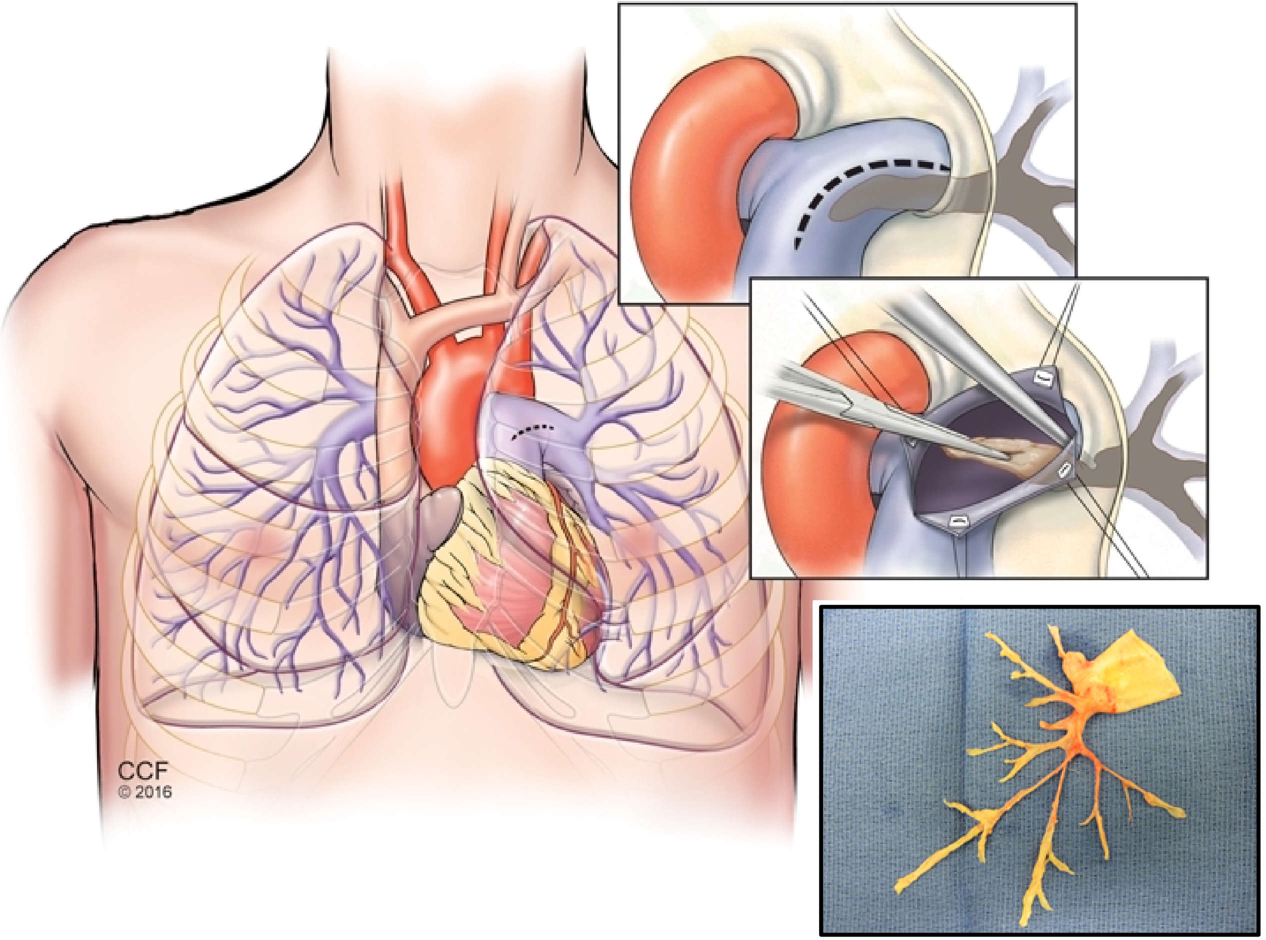
1. Diagnosis
2. PEA
3. Operability assessment
4. Patient selection
5. Results

Pulmonary (Thrombo)EndArterectomy **(PEA) (PTE)**

- ≠ Trendelenburg
- Removal of fibrotic transformed intima via a dissection plane

Why?

1. Hemodynamic: RV function ↑
2. Respiratory: death space ↓
3. Prophylactic: progressive RV-dysfunction ar retrograde extension of obstruction
4. Prophylactic: secondary arteriopathy

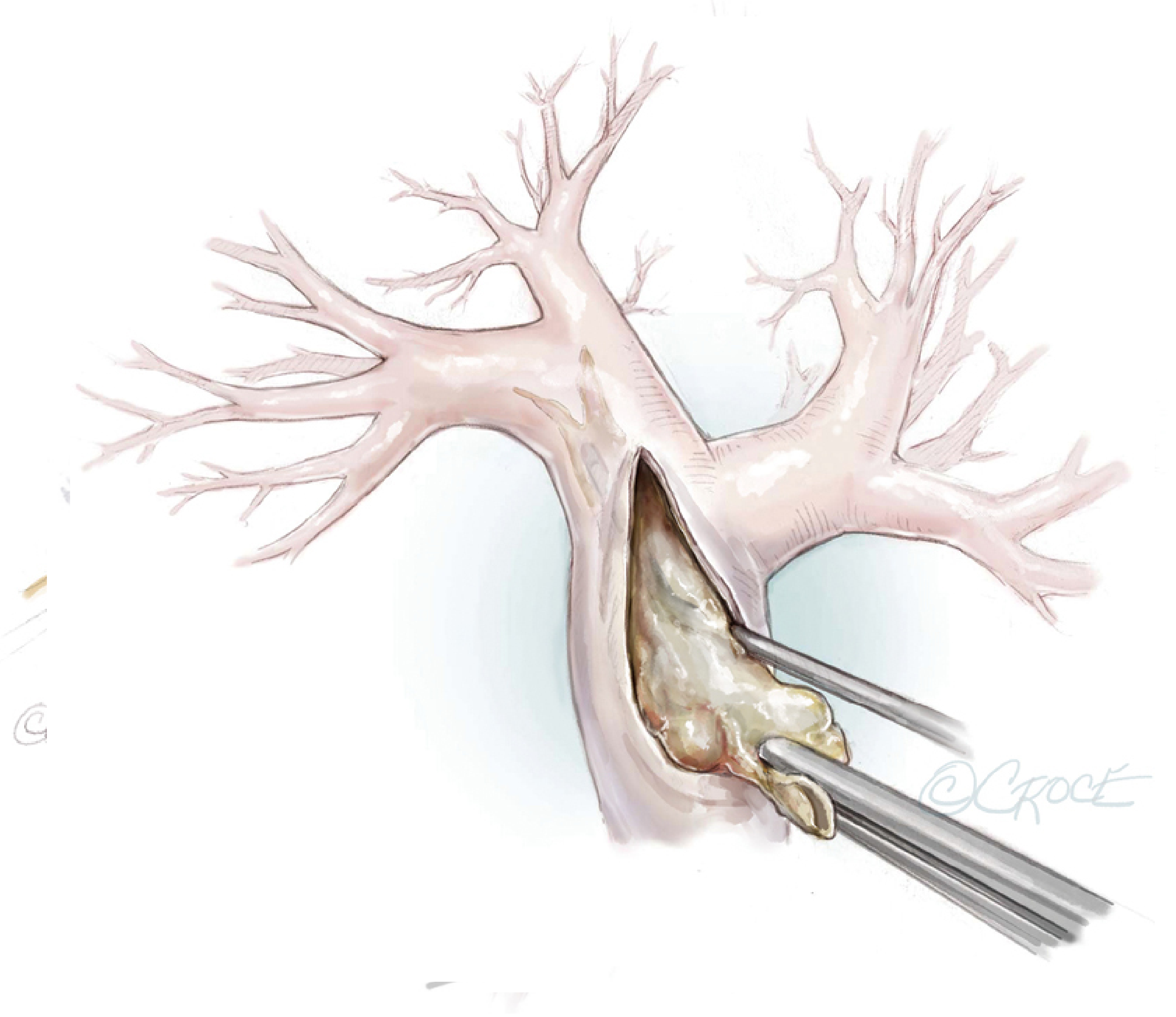


Pulmonary (Thrombo)EndArterectomy (PEA) (PTE)

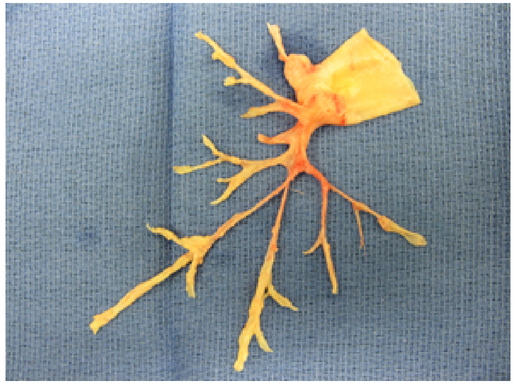
- ≠ Trendelenburg
- Removal of fibrotic transformed intima via a dissection plane

How? 4 basic principles

1. Bilateral: median sternotomy
2. Identification correct dissection plane
3. Complete endarterectomy
4. CPB + cooling (20°C) + circulatory arrest (max 20 min)



Guth S, et al. Ann Cardiothorac Surg 2022:11:180-188.



CTEPD with or without PH

1. Diagnosis
2. PEA
3. Operability assessment
4. Patient selection
5. Results

Diagnosis of CTEPH

↓ Coronary angiography and other preoperative investigations

Operability assessment by multidisciplinary CTEPH team

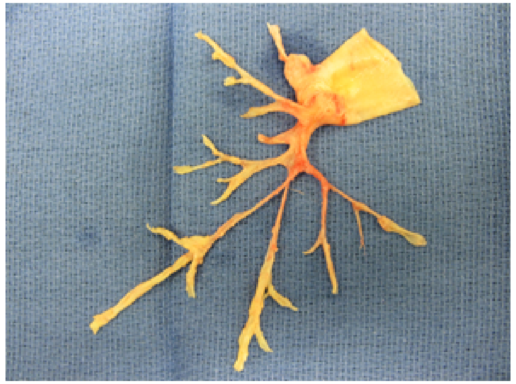
Technically Operable

Technically Non-Operable

Acceptable surgical risk/benefit ratio

Unacceptable surgical risk/benefit ratio

= patient selection



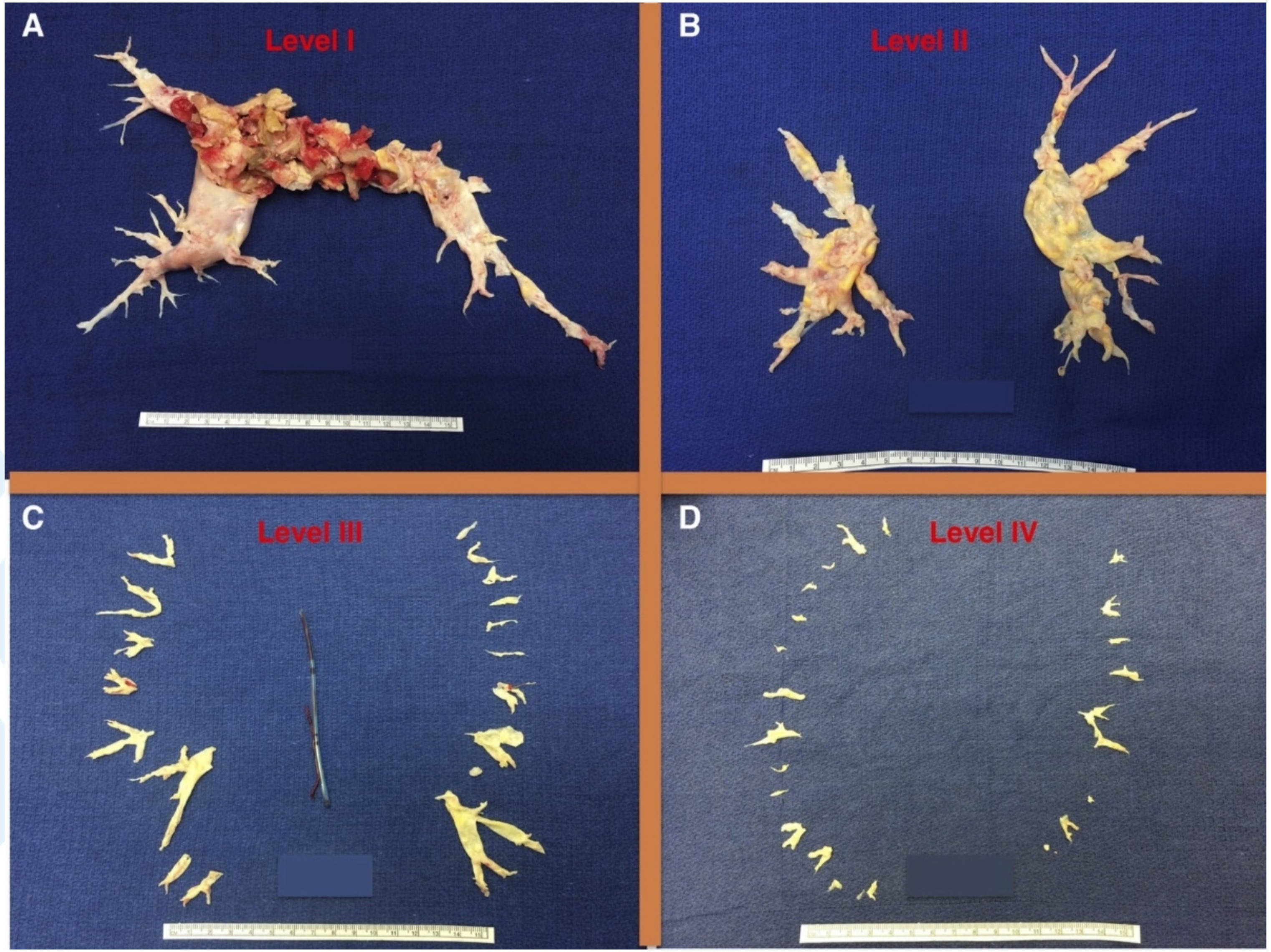
Operability assessment for PEA

1. Technical operability

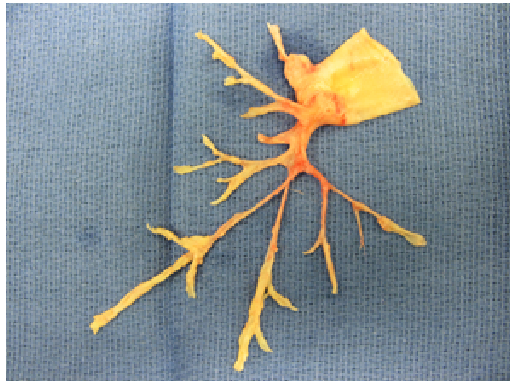
    - Anatomic location of CTEPD
    - Skill and experience of surgeon

Surgically accessible and ≈ PVR

Operability assessment for PEA
UCSD classification



Madani M et al. Ann Am Thorac Soc. 2016;13 Suppl 3:S240-7.



Operability assessment for PEA

Experienced PTE surgeon:

- > 20 in year starting to assess study cases
- > 20 in the year before starting to assess study cases
- > 40 in 3 years before starting to assess study cases

Jenkins D et al. J Thorac Cardiovasc Surg. 2016;152:669-74.e3.

Expertise of a CTEPH center:

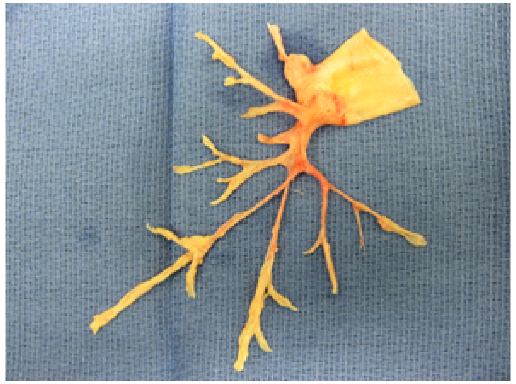
- Surgical mortality < 5% (level I)
- Surgical volume ≥ 50 PTE's/year (level II)
- Ability to operate on distal disease and to provide PTE, BPA and medical therapy (level III)

Jenkins D et al. Eur Respir Rev. 2017;26 (143),

One experienced CTEPH center

- 40-50 million population
- ≥ 50 PTE's/year
- In-hospital mortality rates < 5%

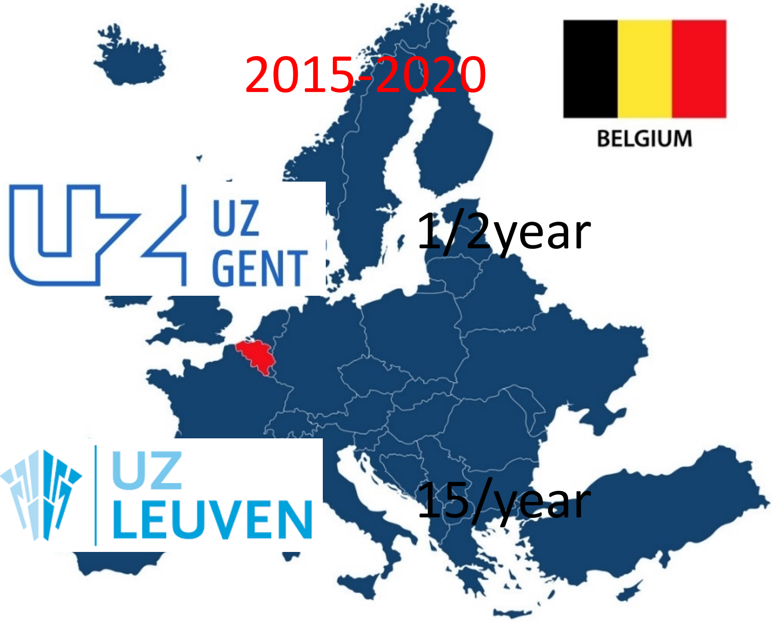
Jenkins D et al. Eur Respir Rev. 2017;26 (143),



Operability assessment for PEA

UZ LEUVEN

2017-2021: in-hospital mortality 3.6%

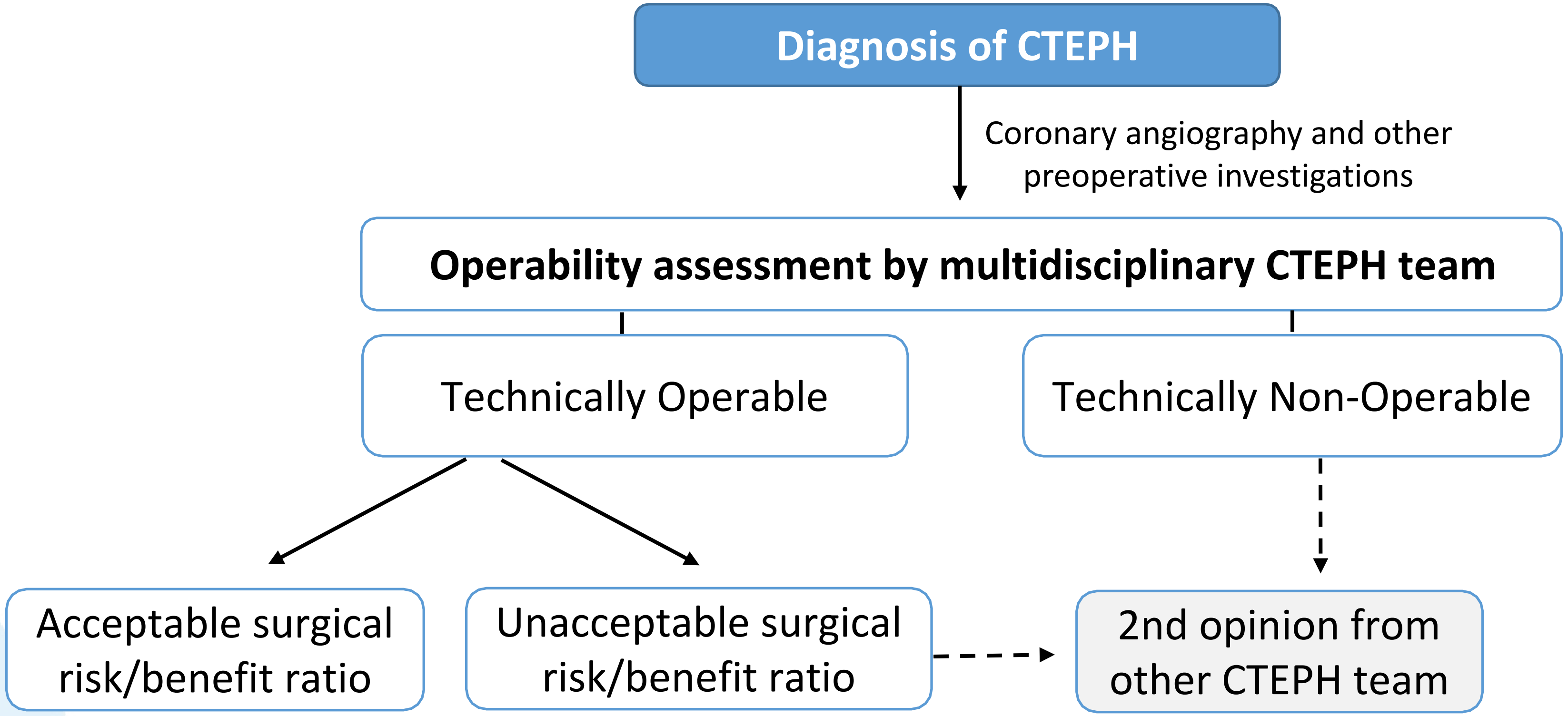


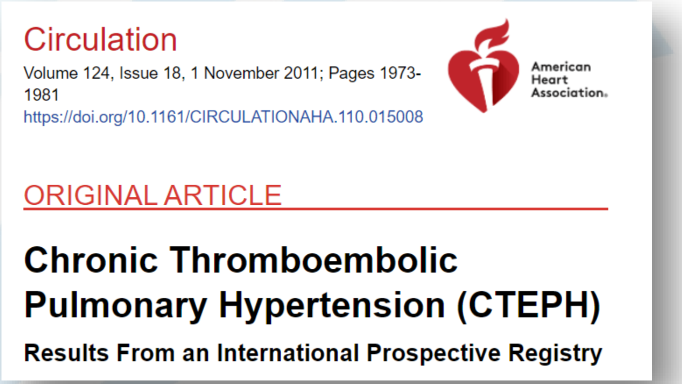
11.521.238 inhabitants

Hōpital Erasme ULB

5/year

CTEPH care in a single center !



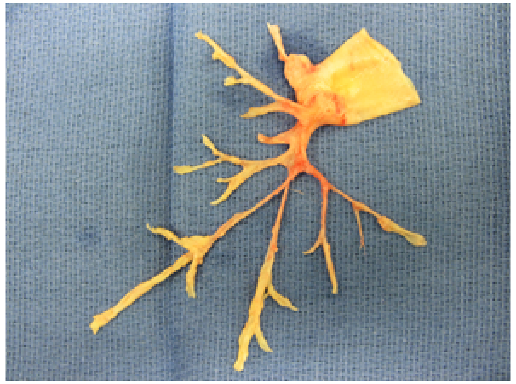

Circulation
Volume 124, Issue 18, 1 November 2011; Pages 1973-1981
https://doi.org/10.1161/CIRCULATIONAHA.110.015008

ORIGINAL ARTICLE

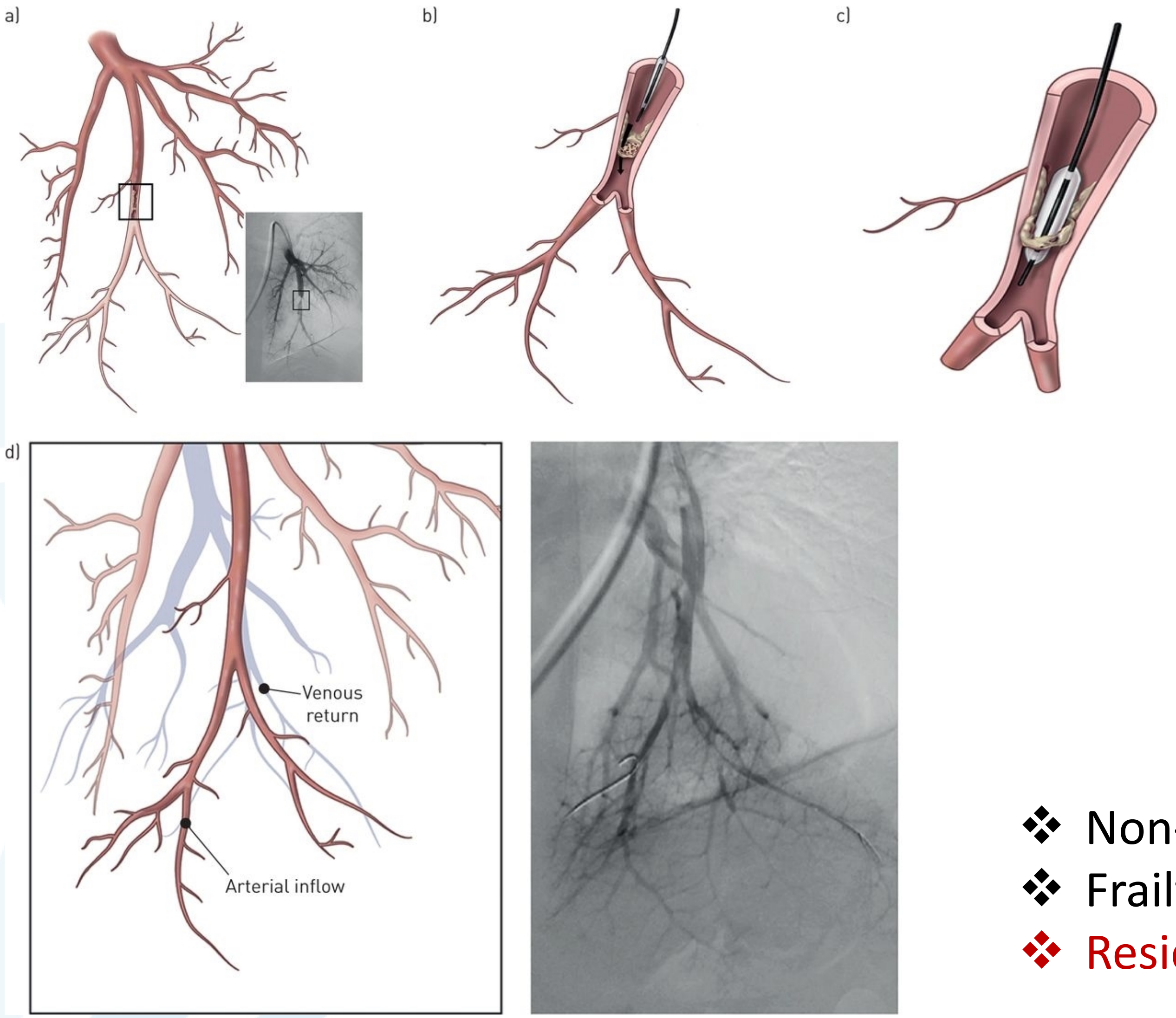
Chronic Thromboembolic Pulmonary Hypertension (CTEPH)

Results From an International Prospective Registry

- Low-volume centers reported more non-operable patients

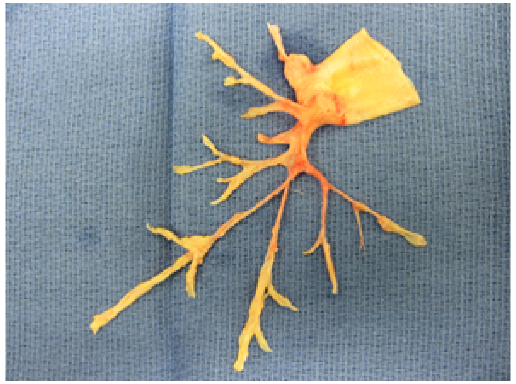


CTEPH – Multimodality treatment

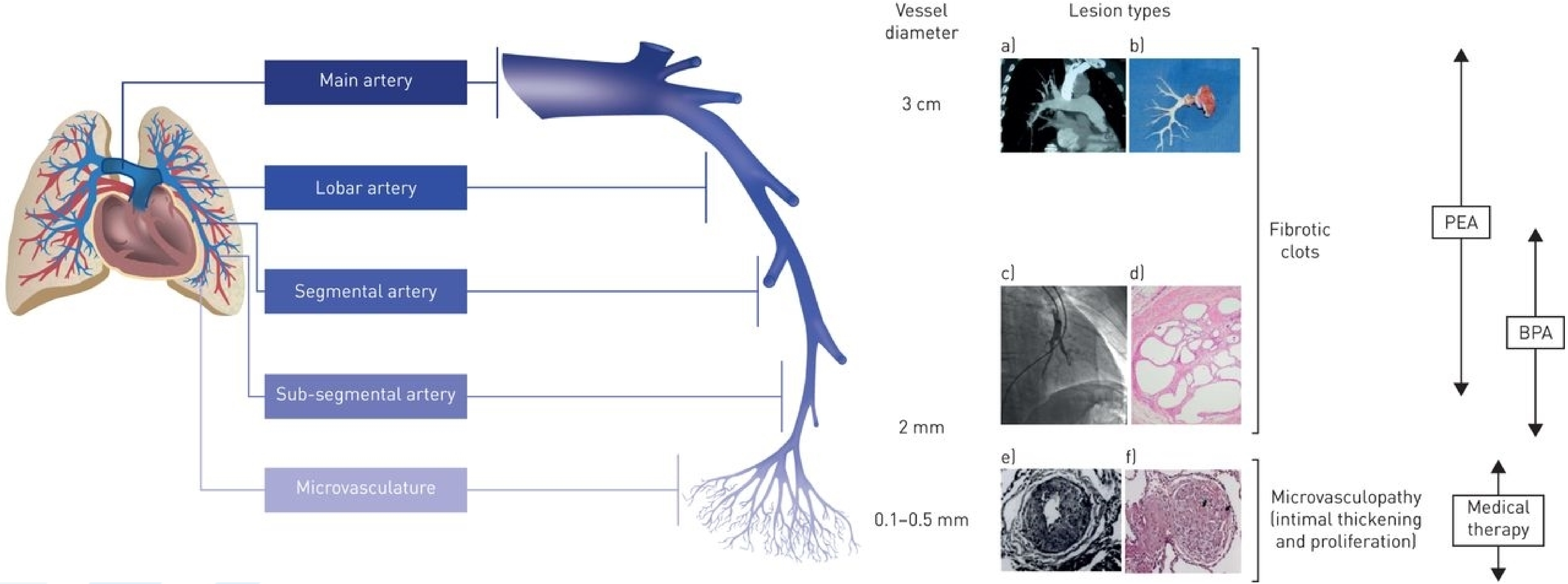


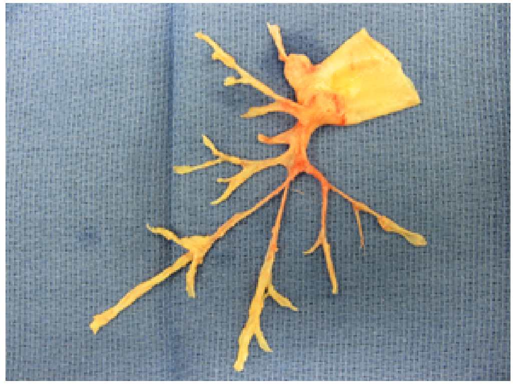
1. PEA
2. BPA (Balloon Pulmonary Angioplasty)
3. Medicatie

- ❖ Non-operable
- ❖ Frailty
- ❖ Residual lesions after PEA



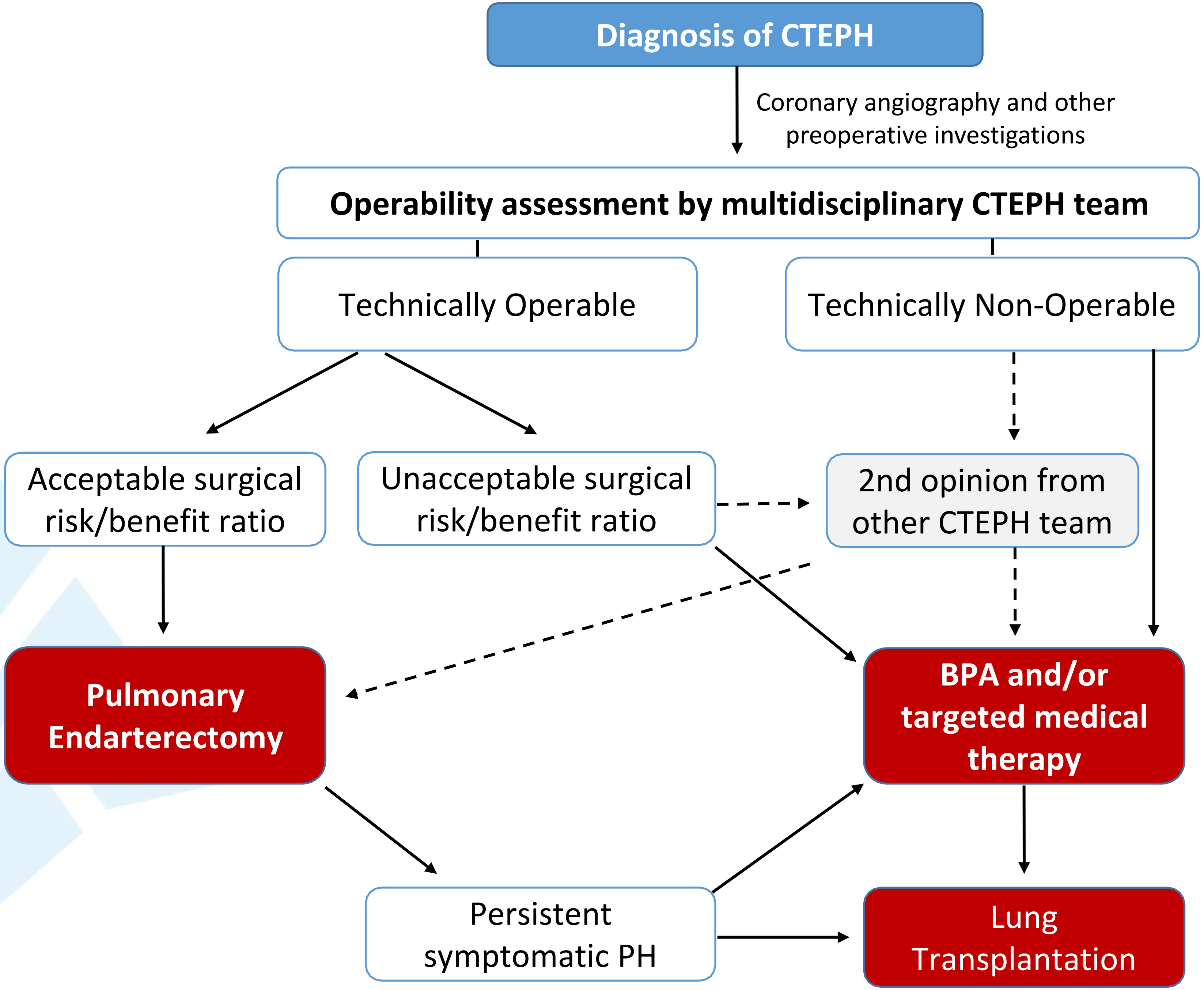
CTEPH – Multimodality treatment

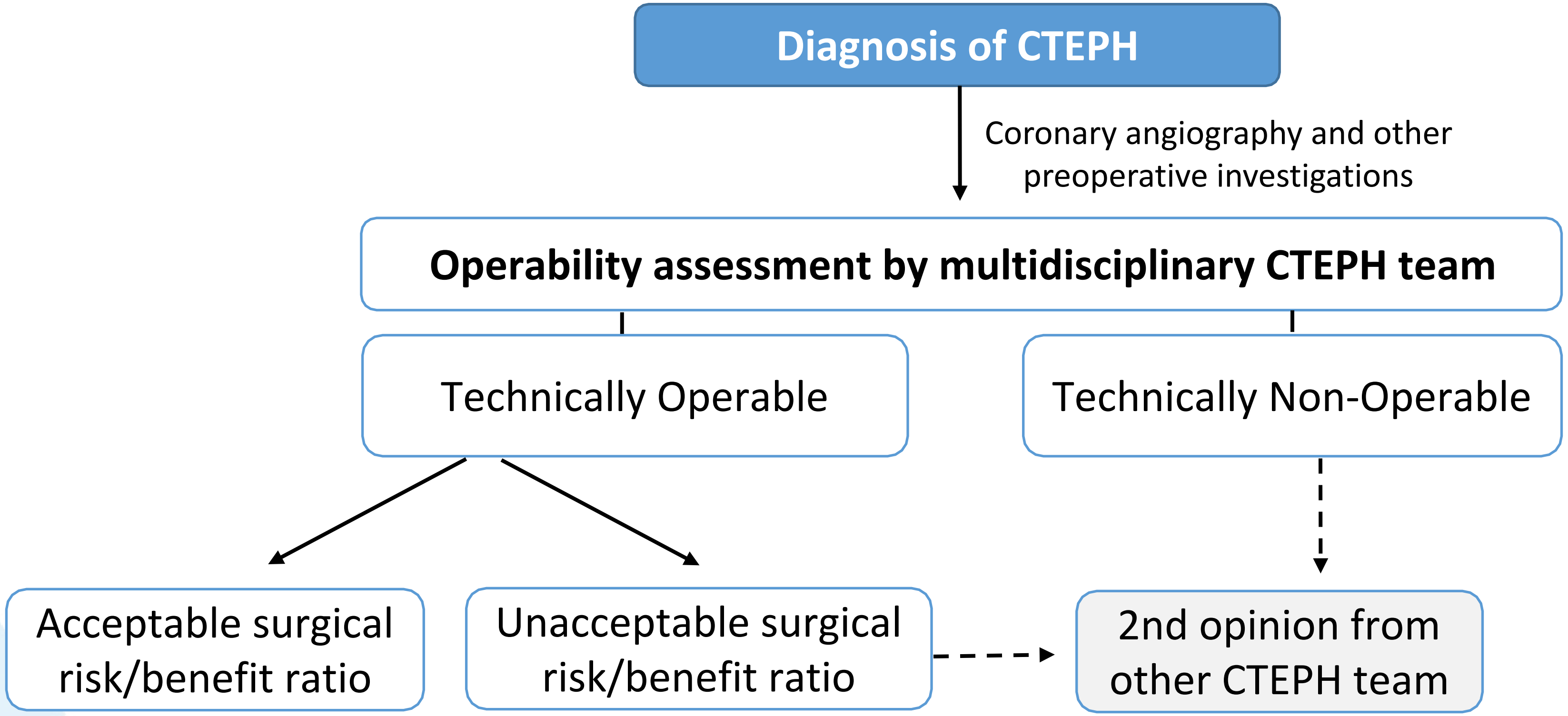




CTEPD with or without PH

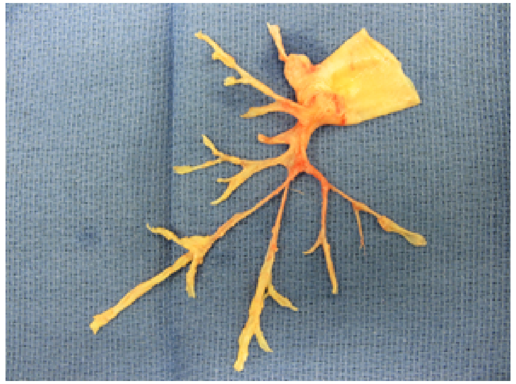
1. Diagnosis
2. PEA
3. Operability assessment
4. Patient selection
5. Results


Diagnosis of CTEPH
Coronary angiography and other preoperative investigations
Operability assessment by multidisciplinary CTEPH team
Technically Operable
Technically Non-Operable
Acceptable surgical risk/benefit ratio
Unacceptable surgical risk/benefit ratio
2nd opinion from other CTEPH team
Pulmonary Endarterectomy
BPA and/or targeted medical therapy
Persistent symptomatic PH
Lung Transplantation



Risk/benefit ratio: likelihood of

- Symptomatic improvement > individual patient expectations
- Hemodynamic improvement > correlation of accessible surgical disease and severity of PH and RV dysfunction



Patient selection for PEA

Severe parenchymal lung disease = only absolute contraindication

Case Report

Pulmonary Circulation

Pulmonary endarterectomy in a 12-year-old boy with multiple comorbidities

Tom Verbelen[1], Bjorn Cools[2], Zina Fejzic[3], R Marion Delcroix[6] and Bart Meyns[1]

RESEARCH ARTICLES: HEART FAILURE

Pulmonary endarterectomy in the octogenarian population: safety and outcomes

Grazioli, Valentina[a]; Ghio, Stefano[b]; Pin, Maurizio[a]; Sciortino, A Anna[a]; Silvaggio, Giuseppe[a]; Monterosso, Cristian[a]; Turco, Ann Catherine[c]; Merli, Vera N.[a]; Vanini, Benedetta[a,d]; D'Armini, And

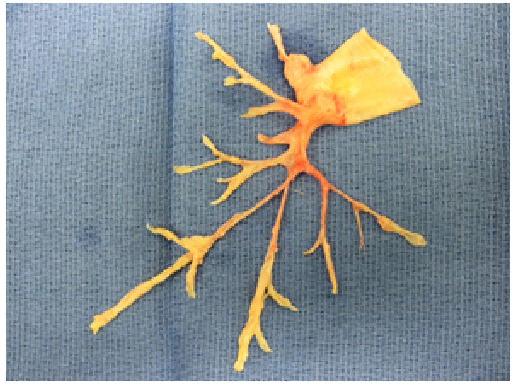
Author Information

Journal of Cardiovascular Medicine: July 2021 - Volume 22 - Iss

Baseline Body Mass Index Does Not Significantly Affect Outcomes After Pulmonary Thromboendarterectomy

Timothy M. Fernandes, MD, MPH, William R. Auger, MD, Peter F. Fedullo, MD, Nick H. Kim, MD, David S. Poch, MD, Michael M. Madani, MD, Victor G. Pretorius, MD, Stuart W. Jamieson, MD, and Kim M. Kerr, MD

Divisions of Pulmonary and Critical Care Medicine and Cardiothoracic Surgery, University of California, San Diego, San Diego, California



Patient selection for PEA

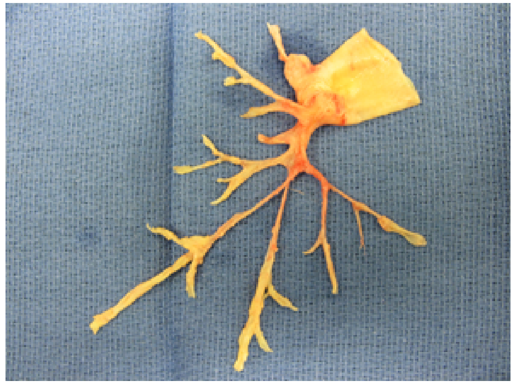
Severe parenchymal lung disease = only absolute contraindication

Relative contraindications:

- Absent history of DVT or PE
- Signs of RV-failure
- Significant pulmonary or left heart disease
- WHO functional class IV
- Inconsistency on imaging modalities
- Absence of appreciable lower lobe disease
- PVR > 1,200 dynes.s/cm^5 (> 15 WU) out of proportion to imaging
- Higher diastolic PAP

Kim NH et al. Eur respir J. 2019;53 (1).

vs potential benefits by multidisciplinary CTEPH team



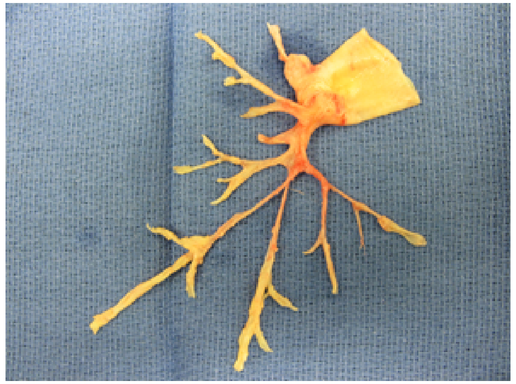
Patient refusal for PEA = 20%

Gall H et al. Pulm Circ. 2016;6:472-82.

- ≈ need for ongoing education and better understanding of CTEPH treatment
- ≈ delay or lack of referral

→ Refer to CTEPH center as early as possible!

- After each TTE with high PH probability
- After V/Q scan with mismatched perfusion defects, the latest.



Patient refusal for PEA = 20%

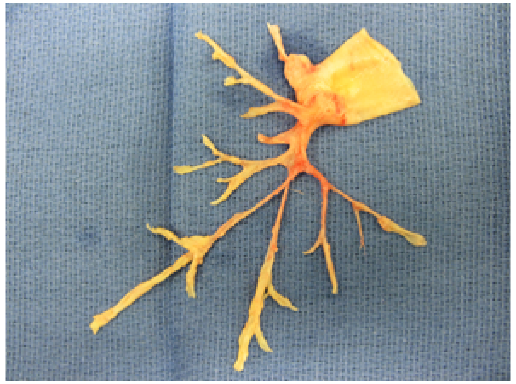
Gall H et al. Pulm Circ. 2016;6:472-82.

- ≈ need for ongoing education and better understanding of CTEPH treatment
- ≈ delay or lack of referral

→ Consultation regarding decision to surgery by member of CTEPH team

- Preferably by performing surgeon
- Information about
  - Improvement of exercise capacity and QoL
  - Low mortality rates (4.7% international CTEPH registry, 2.2% UCSD)
  - 5-year survival = 53% for PEA refusers vs 83% for patients that underwent PEA

Quadery SR et al. Eur Respir J. 2018;52(3)

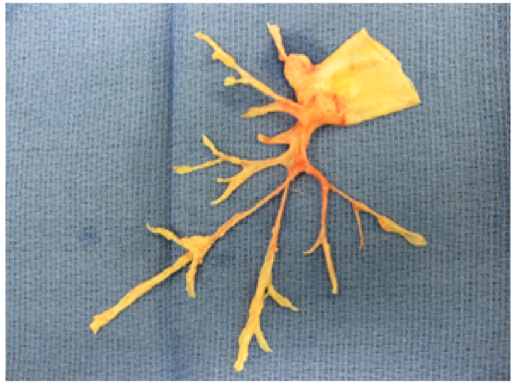


CTEPH operability assessment and patient selection

- Subjective
  - CHEST-1 study: 22% initially inoperable → operable   Jenkins D et al. J Thorac Cardiovasc Surg. 2016;152:669-74.e3.

    → 60% CTEPH patients operable (international CTEPH registry): ↑

- 10-15% of CTEPH cases ultimately undergo PEA   Gall H et al. Pulm Circ. 2016;6:472-82.
  - Delay in and/or lack of referral to CTEPH centers
  - Subjective operability assessment
  - Refusal of surgery by suboptimal informed patients



CTEPH operability assessment and patient selection

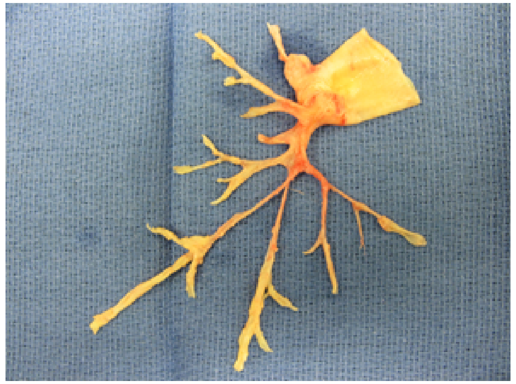
Highest PEA a year: 2.7/million inhabitants (Papworth 2017)

↕

Estimated incidence CTEPH = 17/million inhabitants a year
at least 60% operable

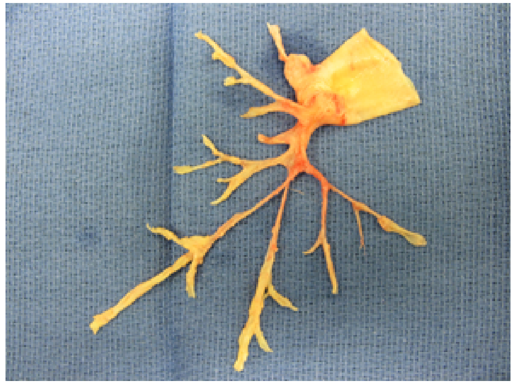
→ 10 PEA/million inhabitants a year

Belgium: 113/year ↔ ***20/year***



CTEPD with or without PH

1. Diagnosis
2. PEA
3. Operability assessment
4. Patient selection
5. Results

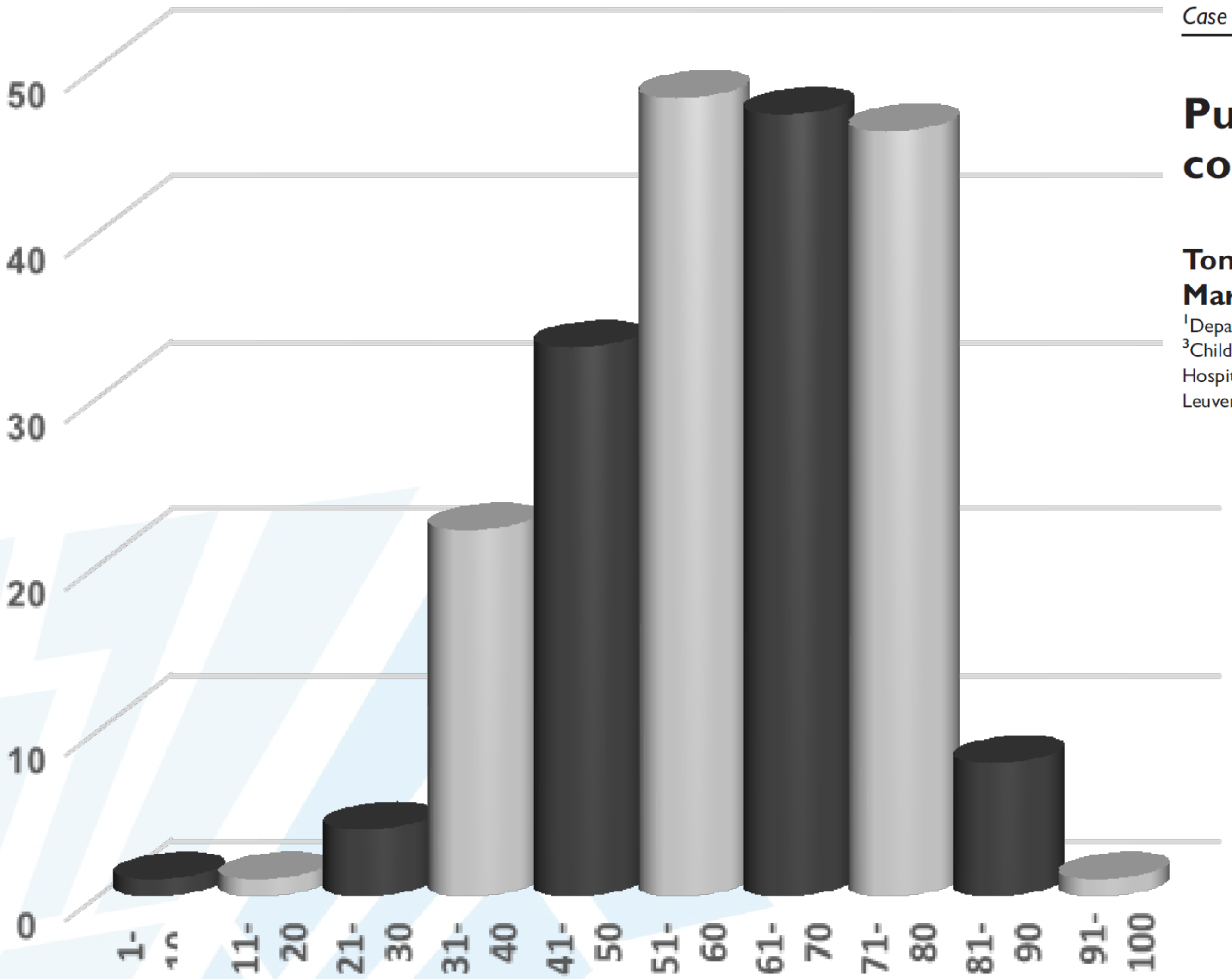


PEA – Patients

Mean ± SD Median (range) Median [Q1, Q2]	UZL 2018	Papworth, UK Cannon, 2016	Pavia, Italy D'Armani, 2016		San Diego, USA Madani, 2012		CTEPH Registry Pepke-Zaba 2011
Period	1999-2018	1997-2012	2008-2013		1999-2006	2006-2010	2007-2009
			Prox	Dist			
n	209	880	221	110	1,000	500	427
Age, y	60 (10-92)	57±15	61±15	60±14	52±15	51±15	63 [51-72]
Gender, % male	47	53	46	33	NA	NA	53
NYHA (I-II-III-IV), %	3-32-47-6	0-9-68-23	0-12-53-35	0-15-54-31	2-11-79-8	1-7-83-10	1-19-68-12
6MWD, m	341±138	260±126	277±118	289±112	-	-	329 [245, 427]
PAP, mmHg	46±11	47±11	44±10	46±10	46±11	46±11	47 [38, 55]
CI, L/min/m2	2.13±0.53	-	2.1±0.6	2.2±0.6	3.9±1.3*	4.3±14*	2.2 [1.8, 2.7]
PVR, dsc-5	810±380	830±382	876±392	926±337	861±446	719±383	717 [495,963]

* Cardiac output

PEA- Age-distribution



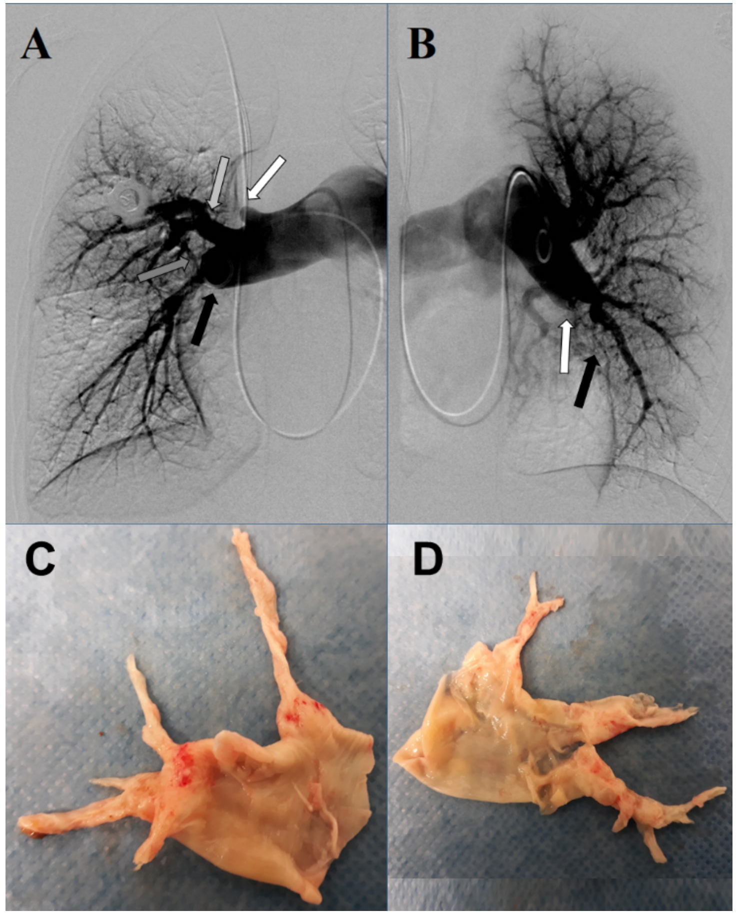
Case Report

Pulmonary Circulation

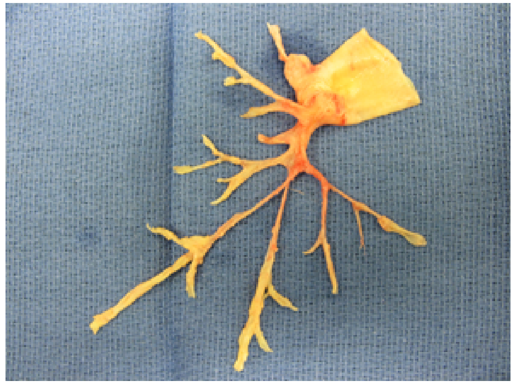
Pulmonary endarterectomy in a 12-year-old boy with multiple comorbidities

Tom Verbelen[1], Bjorn Cools[2], Zina Fejzic[3], Raf Van Den Eynde[4], Geert Maleux[5], Marion Delcroix[6] and Bart Meyns[1]

[1]Department of Cardiac Surgery, University Hospitals Leuven, Leuven, Belgium; [2]Department of Pediatric Cardiology, University Hospitals Leuven, Leuven, Belgium; [3]Children's Heart Center, Amalia Children's Hospital, Radboud University Medical Center, Nijmegen, the Netherlands; [4]Department of Anesthesiology, University Hospitals Leuven, Leuven, Belgium; [5]Department of Radiology, University Hospitals Leuven, Leuven, Belgium; [6]Department of Pneumology, University Hospitals Leuven, Leuven, Belgium



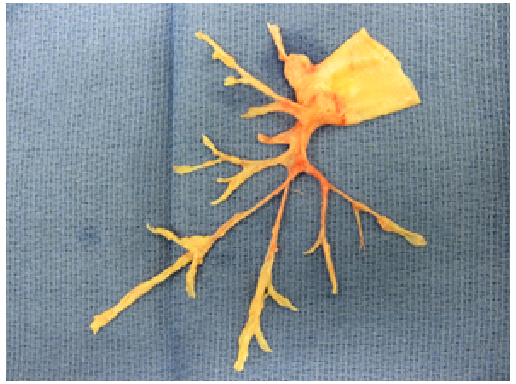
UZ LEUVEN



PEA – In-hospital outcome

Median (mean±SD) Median (range)	UZL 2018	Papworth, UK Cannon 2016	Pavia, Italy D'Armini, 2014		UCSD, USA Madani, 2012	
Period	1999-2018	1997-2012	2008-2013		1999-2006	2006-2010
			Proximal	Distal		
n	209	880	221	110	1,000	500
DHCA total, min	40 ± 17	-	84±32	102±28	35±12	36±12
MV, days	3 (1-75)	1 (2.5±4)	2 (1-3)	2 (1-4)	-	-
ICU, days	6 (1-75)	3 (7±9)	4 (3-7)	4 (3-8)	-	-
Hospitalization, days	19 (1-117)	16 (20±14)	13 (10-16)	13 (11-17)	-	-
ECMO, n	19 (†9)	-	-	-	-	-
Mortality, %	7.6	10.5	6.9	6.9	5.2	2.2

ECMO: 58% survival

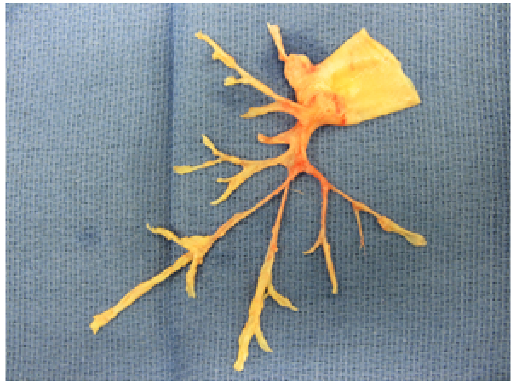


PEA = 253 - In-hospital death = 17 (6.7%)

#	Year	Day	Cause	Age	PVRpre	PVRpostOT
1	1999	D1	RHF	51	1125	847
2	2000	D0	RHF	69	1752	1852
3	2003	D15	bleeding	28	824	840
4	2003	D14	RHF	56	705	357
5	2003	D75	mediastinitis	92	671	412
6	2004	D19	RHF	68	1890	754
7	2005	D4	RHF? Inflamm reaction	33	472	476
8	2006	D9	RHF	71	1213	711
9	2008	D29	ARDS	55	1906	855
10	2008	D7	bleeding	46	1231	NA
11	2010	D14	MOF	68	692	NA
12	2011	D13	Sepsis	75	1233	NA
13	2014	D30	unknown	71	929	NA
14	2015	D14	RHF	72	1502	565
15	2017	D57	sepsis	63	519	309
16	2018	D69	unknown	38	852	NA
17	2021	D11	RHF	79	713	NA
				61 ± 17	1072 ± 464	725 ± 425

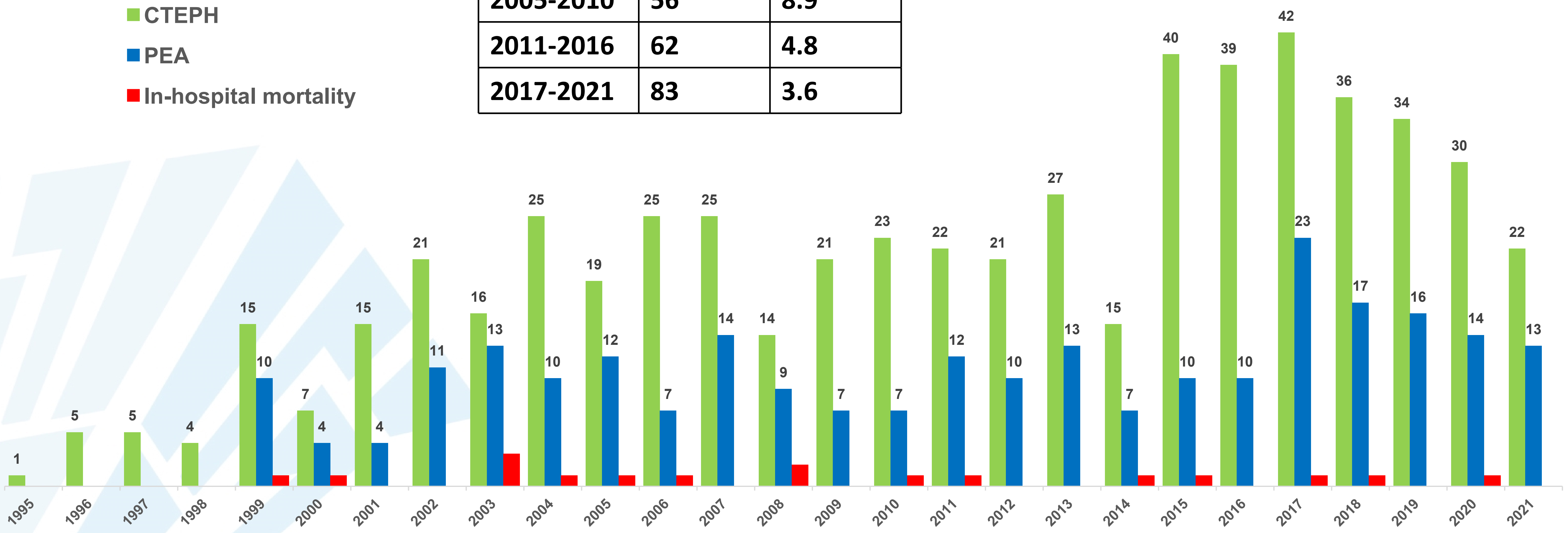
1365 ± 438 848 ± 521

UZ LEUVEN

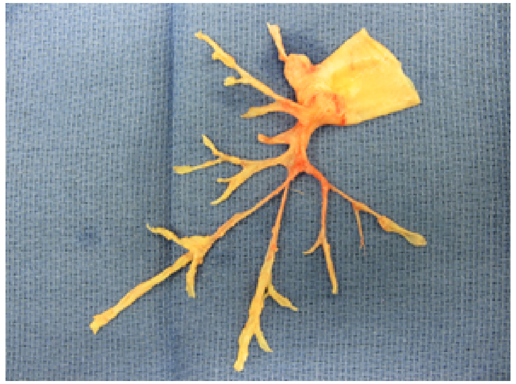


PEA = 253 - In-hospital death = 17 (6.7%)

	n	%
1999-2004	52	11.5
2005-2010	56	8.9
2011-2016	62	4.8
2017-2021	83	3.6



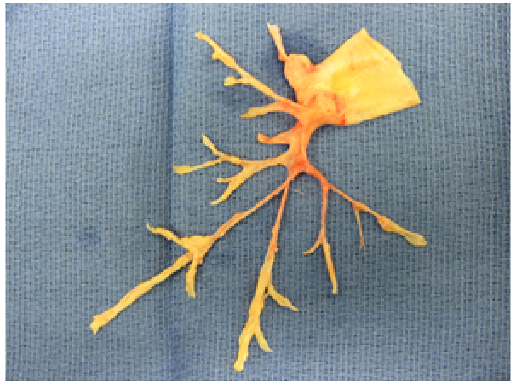
UZ LEUVEN



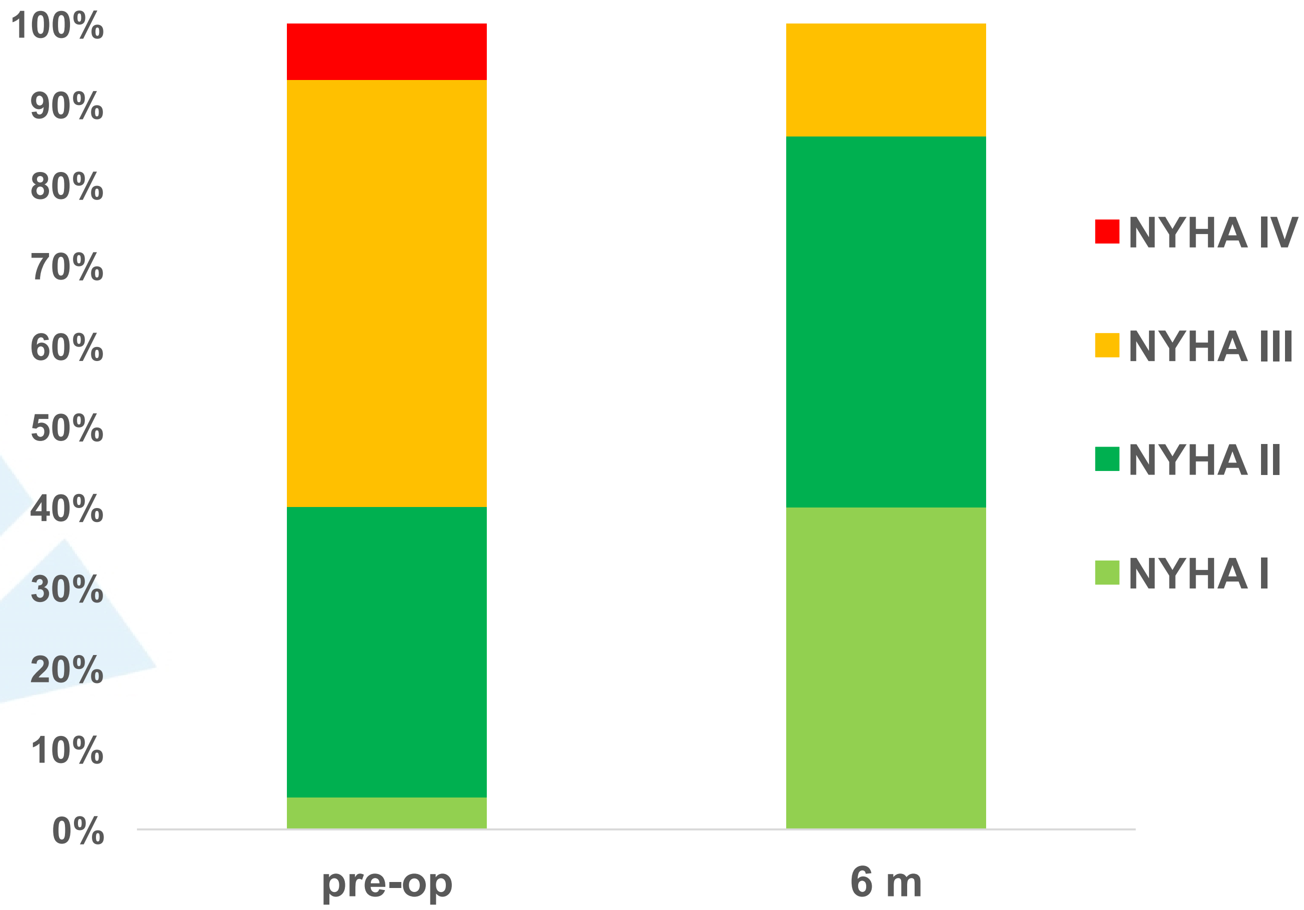
PEA – Results

mean±SD	UZ LEUVEN		Papworth, UK Cannon, 2016		Pavia, Italy D'Armani, 2016			
					Proximal		Distal	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
n	209	143	880	748	221	198	110	99
6MWD, m	341 ± 138	434 ± 134	260±126	353±118	277±118	-	289±112	-
PAP, mmHg	46 ± 11	28 ± 10	47±11	27±10	44±10	24±9	46±10	
CI, $L/min/m^2$	2.13 ± 0.53	2.55 ± 0.52	-	-	3.9±1.3*	5.2±1.1*	3.7±1.2*	5.0±1.2*
PVR, dsc^{-5}	810 ± 380	342 ± 214	830±382	317±239	876±392	270±175	926±337	300±139

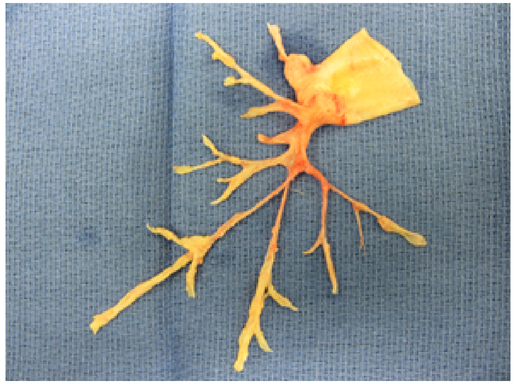
Post: measured after 3-6 months; *cardiac output



PEA – Long-term results

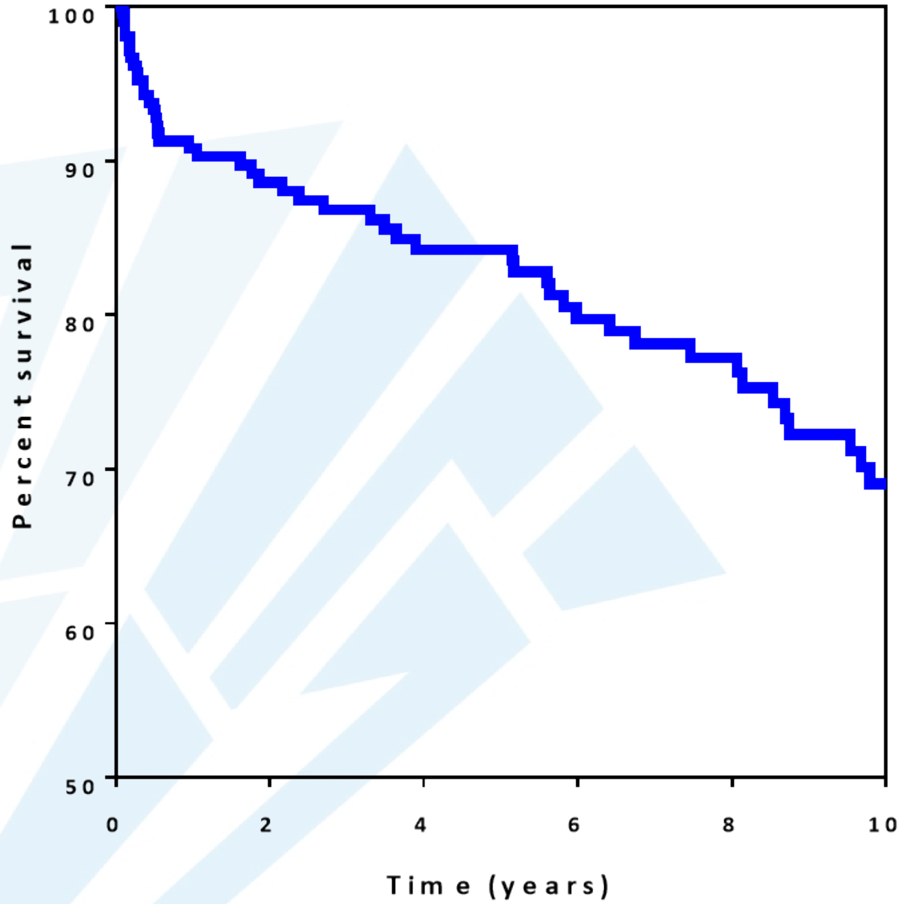


Pre-op (n=188), 6m (n = 168)

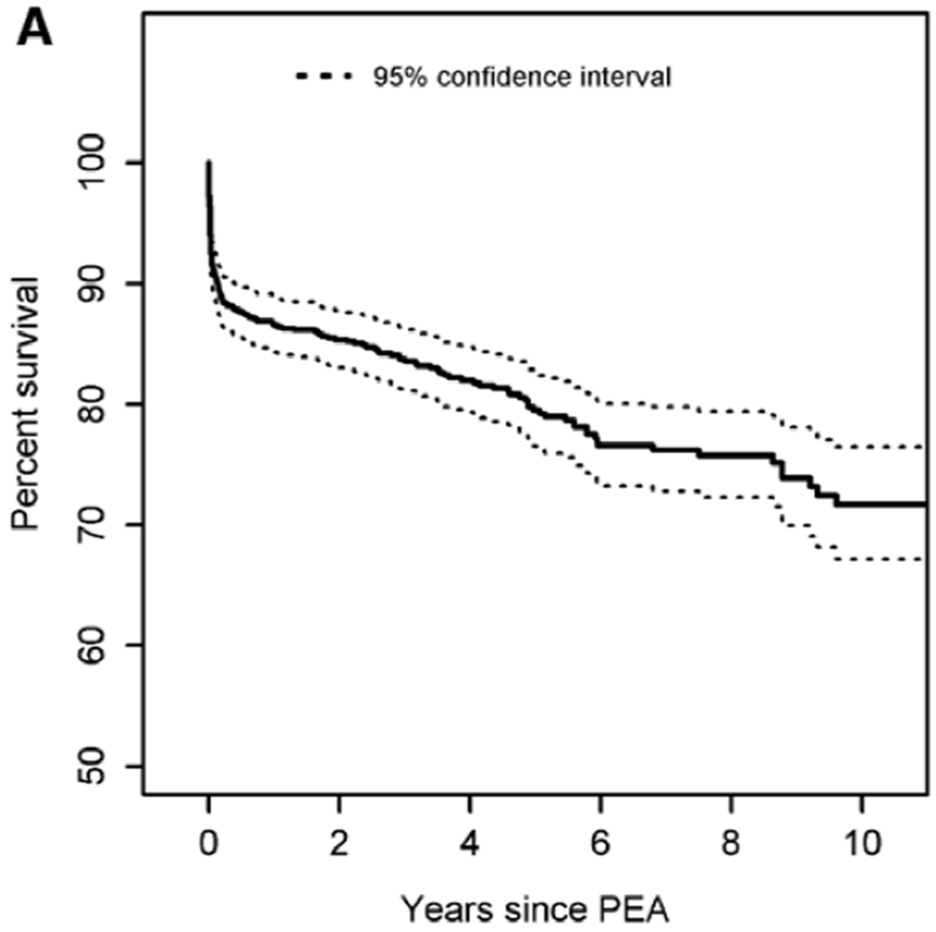


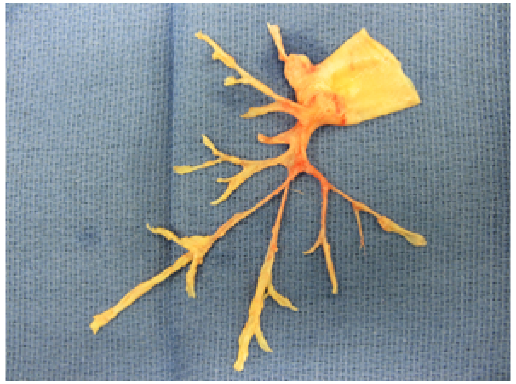
PEA – Long-term survival

UZ Leuven, 2018



Papworth, UK; Cannon 2016





PEA – Long-term survival

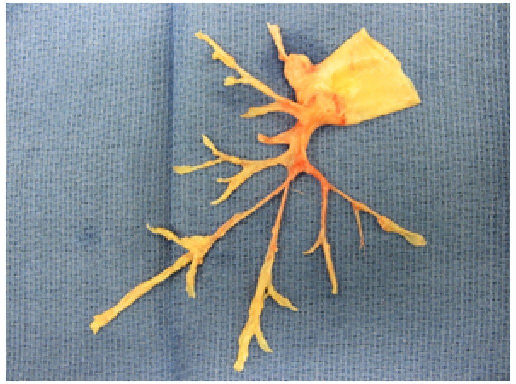
center	n	1-year	3-year	5-years	10-years
San Diego Madani, 2012	1410	-	-	82%	75%
Papworth Cannon, 2016	880	86%	84%	79%	72%
Pavia D'Armani, 2016	331	-	-	-	-
CTEPH Registry Delcroix, 2016	404	93%	89%	-	-
UZ Leuven	209	90%	86%	84%	69%

Circulation. 2016 Mar 1;133(9):859-71. doi: 10.1161/CIRCULATIONAHA.115.016522. Epub 2016 Jan 29.

Long-Term Outcome of Patients With Chronic Thromboembolic Pulmonary Hypertension: Results From an International Prospective Registry.

Delcroix M[1], Lang I[2], Pepke-Zaba J[2], Jansa P[2], D'Armini AM[2], Snijder R[2], Bresser P[2], Torbicki A[2], Mellemkjaer S[2], Lewczuk J[2], Simkova I[2], Barberà JA[2], de Perrot M[2], Hoeper MM[2], Gaine S[2], Speich R[2], Gomez-Sanchez MA[2], Kovacs G[2], Jaïs X[2], Ambroz D[2], Treacy C[2], Morsolini M[2], Jenkins D[2], Lindner J[2], Dartevelle P[2], Mayer E[2], Simonneau G[2].

- Mortality ↑
  - Operative complications
  - Postop residual PH
  - Additional cardiac procedures
  - History of cancer
  - High NYHA class, high RAP, dialysis dependent
- **PEA: strongest independent predictor for survival!**



PEA – Key Message

5-year survival untreated CTEPH:

- mPAP > 40 mmHg: 30%
- mPAP > 50 mmHg: 10%

↔

5-year survival PEA UZ Leuven (mPAP 46±11 mmHg)

84%

Significant ↑ 6MWD & NYHA

Consider CTEPH as possible cause of dyspnea
→ quick diagnosis and PEA

→ avoidance of multiple deaths a year

PEA = only <u>curative</u> treatment: best chance on ↑ survival and ↑ functional status

08/06/2022: first reported PEA via ministernotomy

UZ LEUVEN


ISSN 2225-319X
Volume 11 No.2
March 2022
www.annalscts.com

ACS
ANNALS OF CARDIOTHORACIC SURGERY

FOCUSED ISSUE

PTE in Chronic Thromboembolic Pulmonary Hypertension and Disease

Guest Editors: Sofia Martin-Suarez and Antonio Loforte, Bologna, Italy

SYSTEMATIC REVIEW
Pulmonary thromboendarterectomy for chronic thromboembolic pulmonary hypertension: a systematic review
John D. L. Brookes, *et al.*

KEYNOTE LECTURE SERIES
Chronic thromboembolic pulmonary hypertension: diagnosis, operability assessment and patient selection for pulmonary endarterectomy
Tom Verbelen, *et al.*

FEATURED ARTICLES
Pulmonary thromboendarterectomy—the Royal Papworth experience
David P. Jenkins, *et al.*

EDITORIAL
End-stage chronic thromboembolic pulmonary hypertension: is there still room for lung transplantation?—the past, the present and the future
Eleonora Faccioli, *et al.*

ART OF OPERATIVE TECHNIQUES
Pulmonary endarterectomy: technique and pitfalls
Stefan Guth, *et al.*

MASTERS OF CARDIOTHORACIC SURGERY
Surgical management of "ab-extrinseco" main stem left coronary compression during pulmonary thromboendarterectomy
Sofia Martin-Suarez, *et al.*

Indexed in PubMed, SCIE

AME

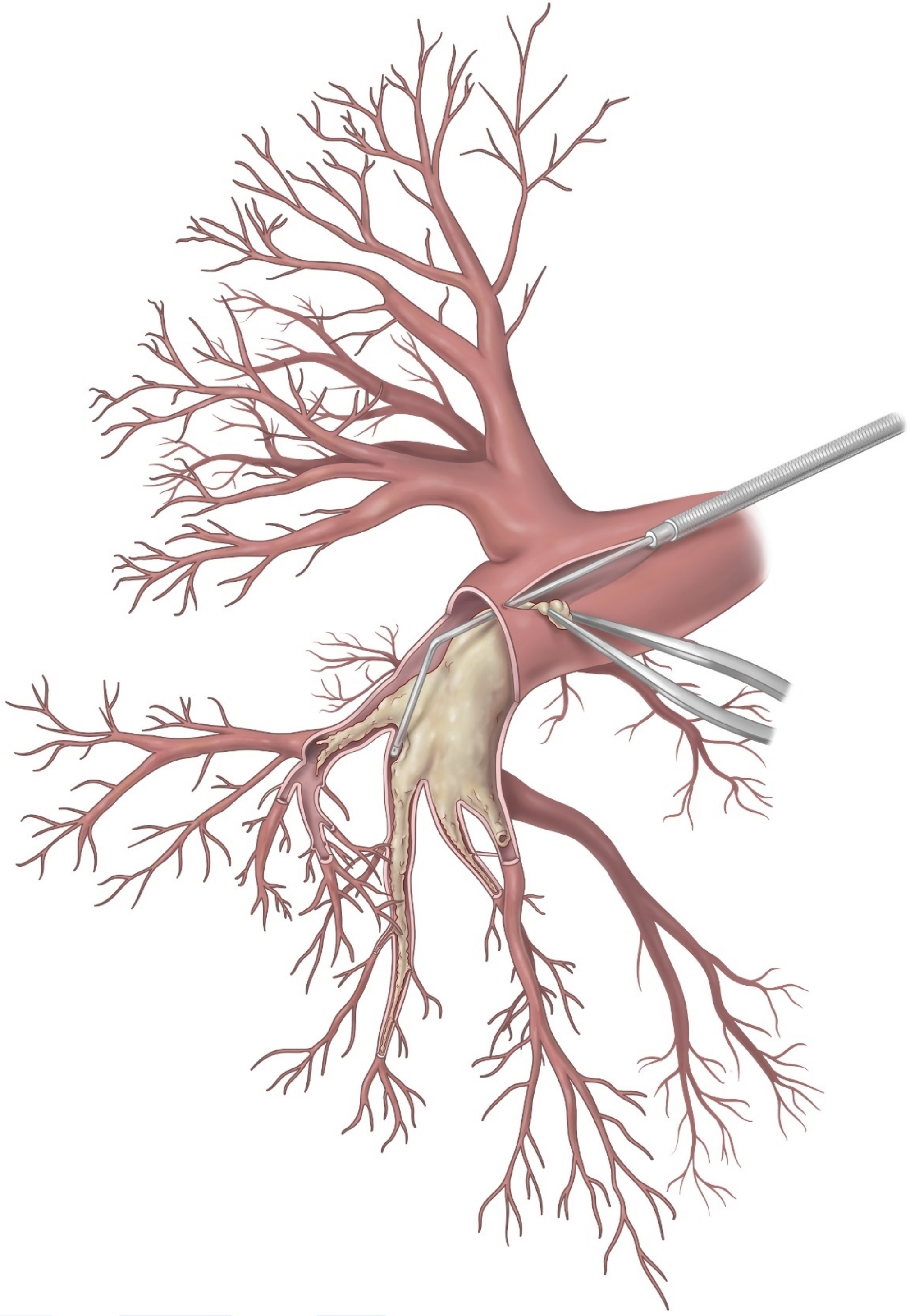
Keynote Lecture Series

Chronic thromboembolic pulmonary hypertension: diagnosis, operability assessment and patient selection for pulmonary endarterectomy

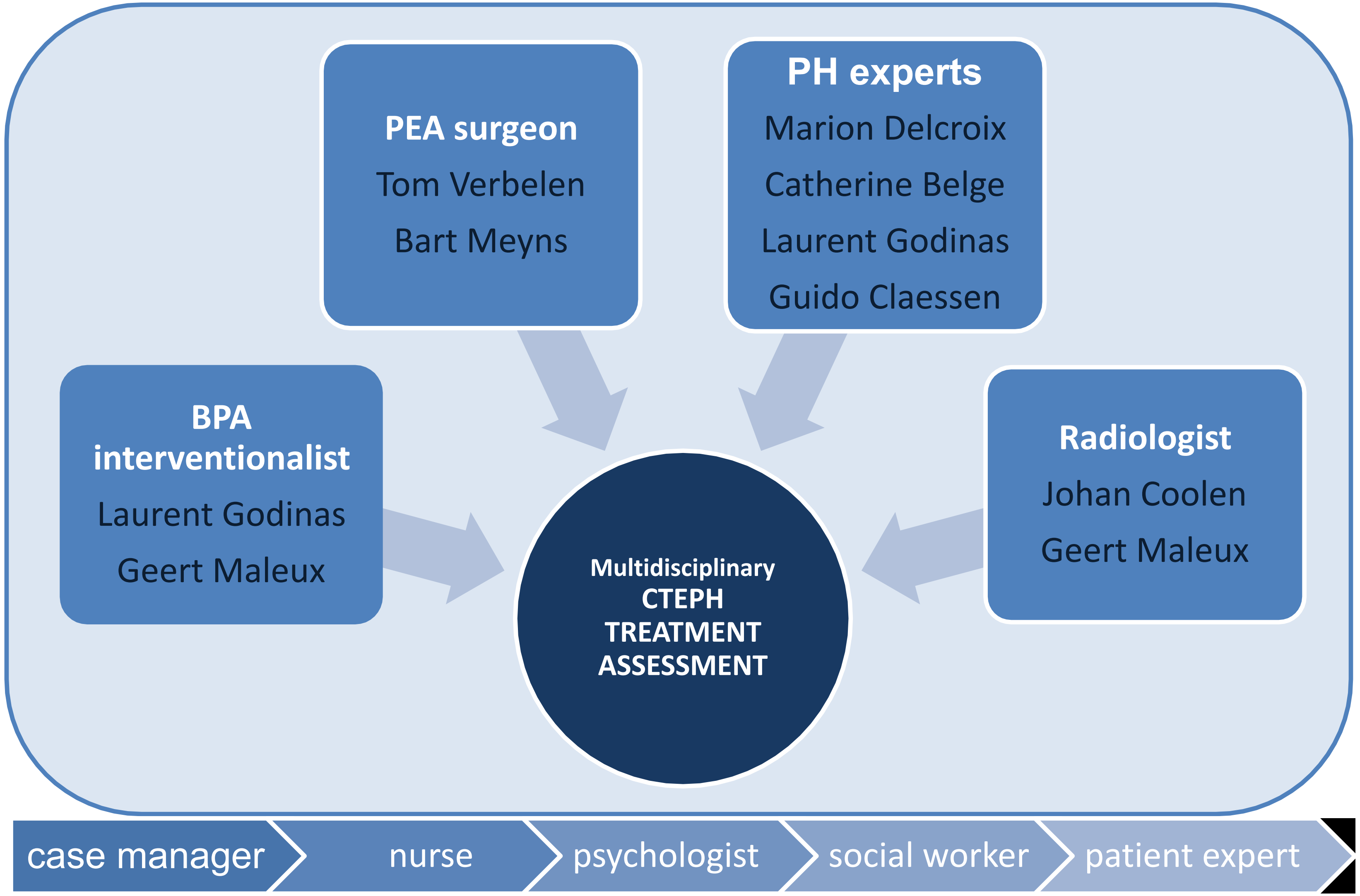
Tom Verbelen[1], Laurent Godinas[2], Geert Maleux[3], Johan Coolen[3], Guido Claessen[4], Catharina Belge[2], Bart Meyns[1], Marion Delcroix[2]

[1]Department of Cardiac Surgery, University Hospitals Leuven, Leuven, Belgium; [2]Department of Pneumology, University Hospitals Leuven, Leuven, Belgium; [3]Department of Radiology, University Hospitals Leuven, Leuven, Belgium; [4]Department of Cardiology, University Hospitals Leuven, Leuven, Belgium

Correspondence to: Tom Verbelen, MD, PhD. Department of Cardiac Surgery, University Hospitals Leuven, Herestraat 49, 3000 Leuven, Belgium. Email: tom.verbelen@uzleuven.be.



© Maren Hötten, Master Thesis in Scientific Illustration “Chronic Thromboembolic Pulmonary Hypertension: Diagnosis and Treatment”, University of Maastricht, 2016.



Tom Verbelen, MD, PhD
Assistant Professor
Deputy head of clinic Cardiac Surgery

tom.verbelen@uzleuven.be
tel. +32 16 34 40 96
tel. secr. +32 16 34 42 60
UZ Leuven | campus Gasthuisberg | Herestraat 49 | 3000 Leuven - Belgium | btw BE 0419 052 173 | www.uzleuven.be

UZ LEUVEN