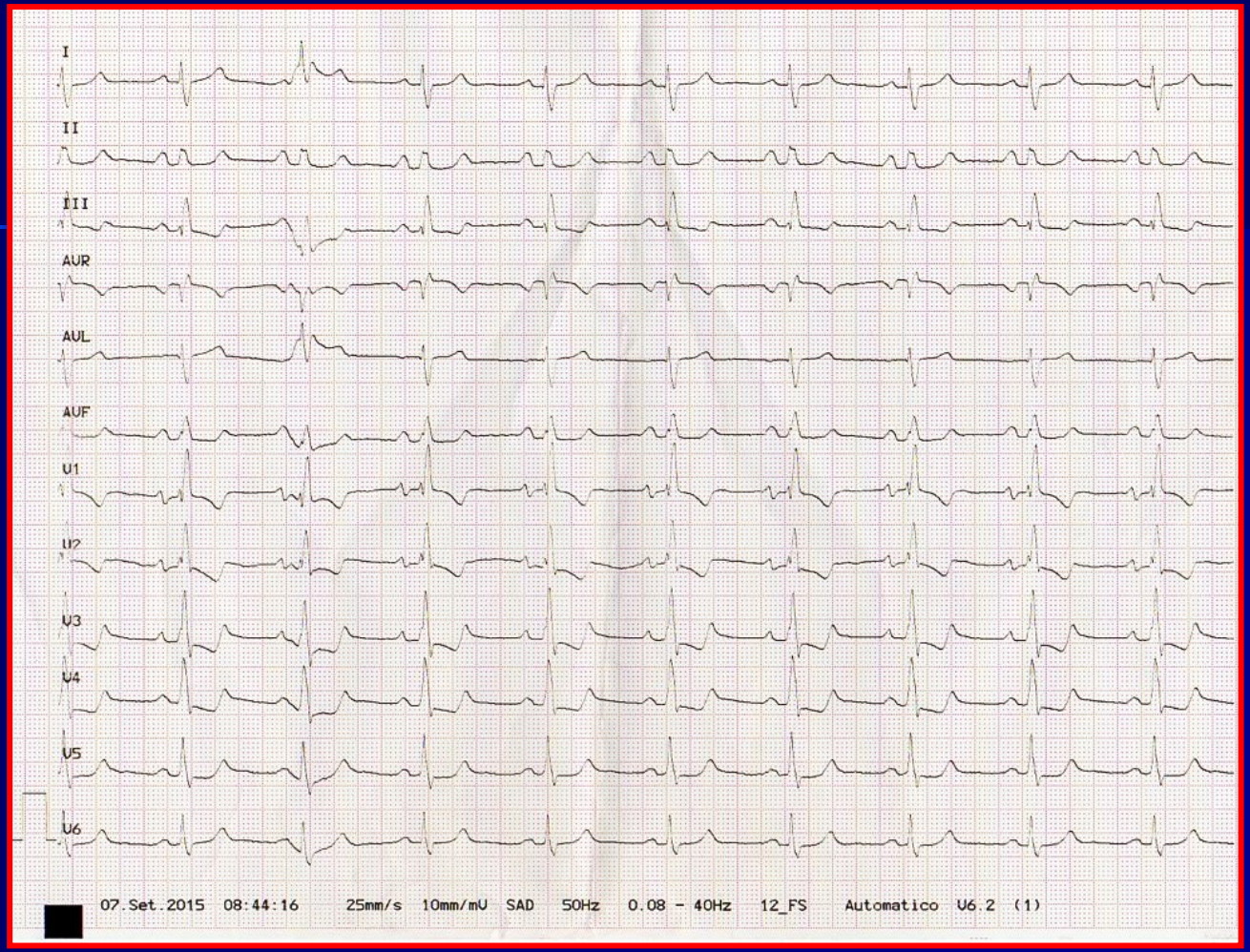
ECG nello screening dell'ipertensione polmonare: è ancora utile?

Emanuele Romeo

U.O.C. Cardiology– PH Unit,
Università degli Studi della Campania L. Vanvitelli,
A.O. "Dei Colli-CTO" - Napoli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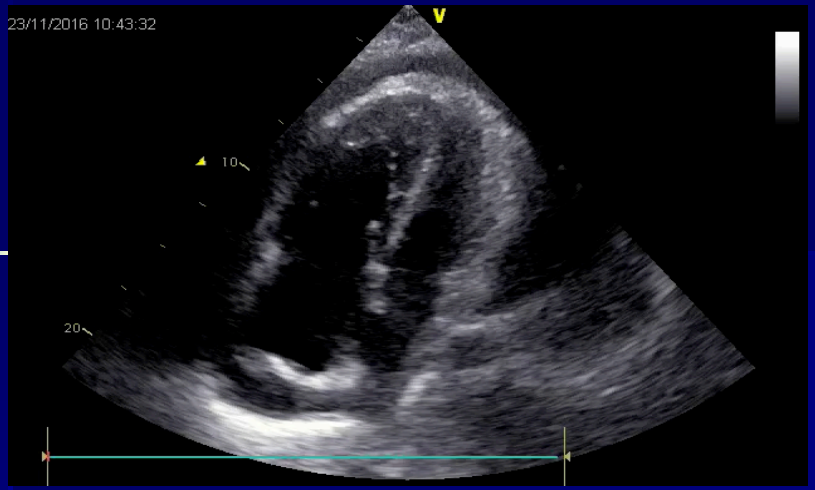
Case report

- Female, 56 yo
- Progressively worsening dyspnea on mild exertion for several months.
- ECG: Sinus rhythm at a heart rate of 60 bpm. Signs of right atrial enlargement. Signs of right ventricular overload/hypertrophy.

Pro-BNP 4.521 ng/ml (vn: 0-125).

Chest HR-CT:
Negative for lung disease.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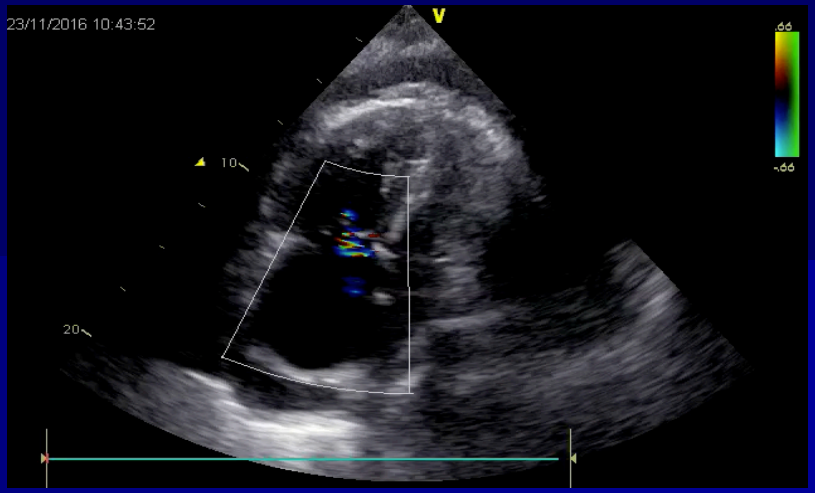
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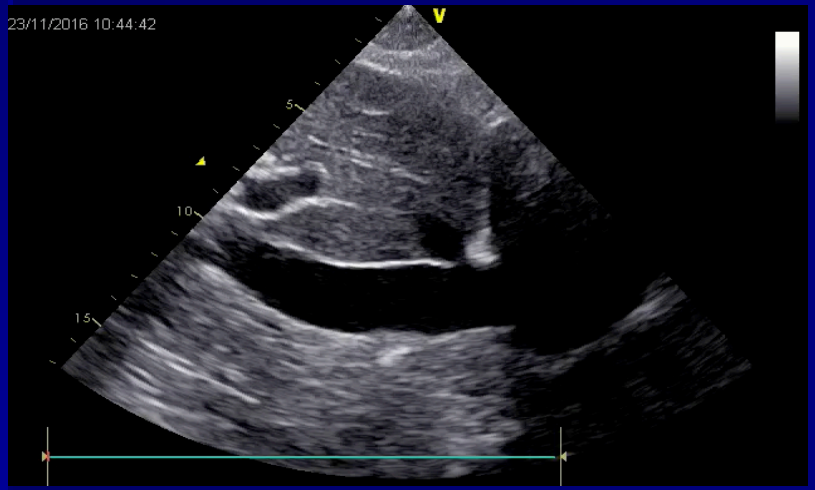
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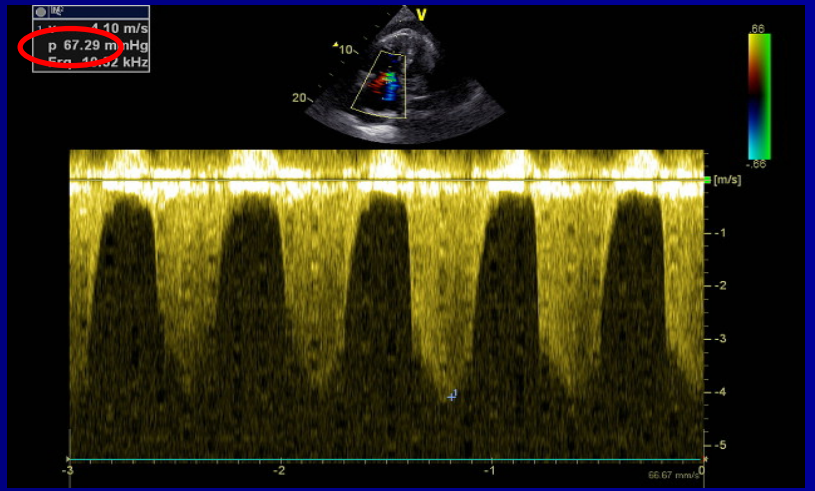
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Right heart catheterization

	Baseline	3 mo FU	12 mo FU
RAP (mmHg)	**21**	**12**	**7**
PAP (S/D/M) (mmHg)	72/31/**43**	65/30/**39**	46/21/**31**
PAWP (mmHg)	9	10	9
CI (L/min/m²)	**1.5**	**2.7**	**3.1**
PVR (WU)	**13.3**	**5.4**	**3.5**

CTPH: remodelling after PEA and Riociguat therapy

Before

After PEA

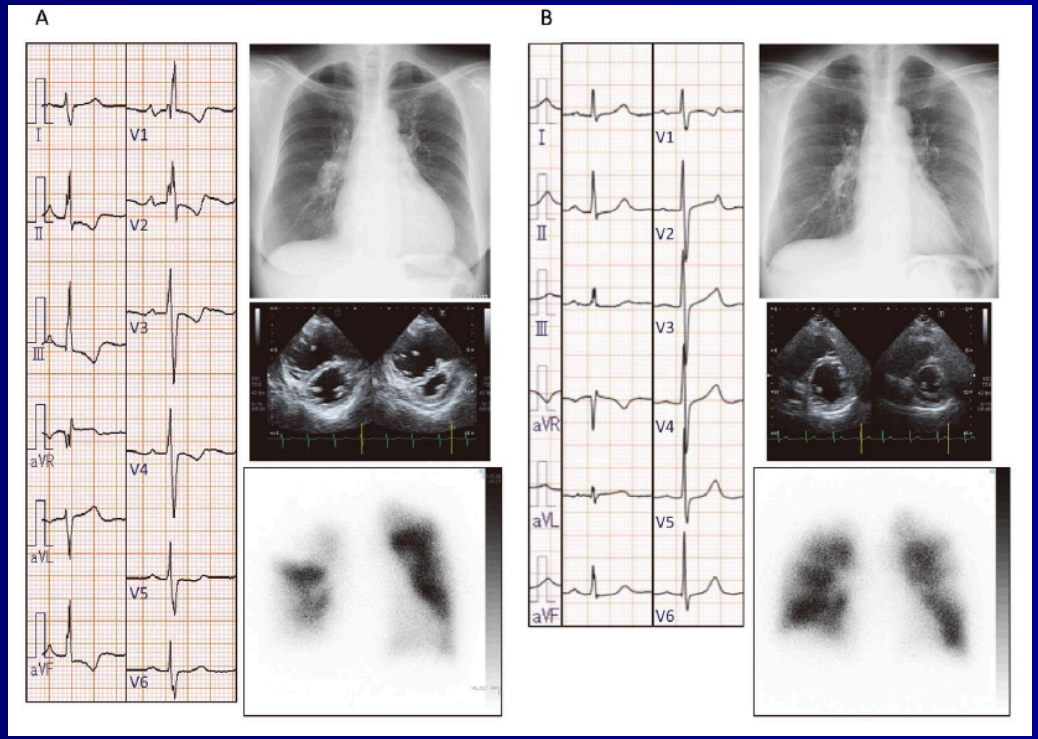

Table 8 Electrocardiogram abnormalities in patients with pulmonary hypertension

Typical ECG abnormalities in PH[66]
• P pulmonale (P >0.25 mV in lead II)
• Right or sagittal axis deviation (QRS axis >90° or indeterminable)
• RV hypertrophy (R/S >1, with R >0.5 mV in V1; R in V1 + S in lead V5 >1 mV)
• Right bundle branch block—complete or incomplete (qR or rSR patterns in V1)
• RV strain pattern[a] (ST depression/T-wave inversion in the right pre-cordial V1–4 and inferior II, III, aVF leads)
• Prolonged QTc interval (unspecific)[b]

ECG, electrocardiogram; PH, pulmonary hypertension; QTc, corrected QT interval; RV, right ventricular.

[a]Present in advanced PH.

[b]Patients with pulmonary arterial hypertension can present with a prolonged QTc interval (although non-specific), which may reflect RV dysfunction and delayed myocardial repolarization, and is an independent predictor of mortality.[67]

A normal ECG does not exclude the presence of PH, but a normal ECG in combination with normal biomarkers (BNP/ NT-proBNP) is associated with a low likelihood of PH in patients referred for suspected PH or at risk of PH (i.e. after acute PE).

2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension

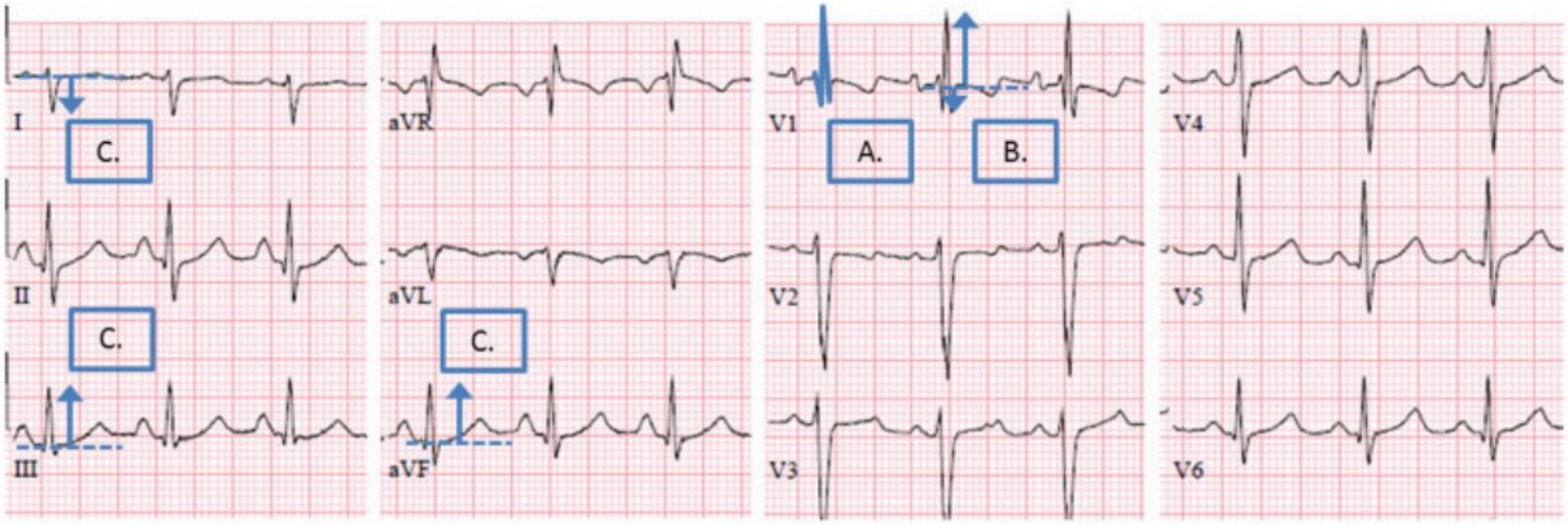

Fig. 2 ECG demonstrating the three electrocardiographic signs of the rule-out criteria. (**A**) In lead V1, a right bundle branch block: rSR′ or RSr′ pattern with a QRS duration $\geq$ 120 ms; (**B**) in lead V1, R:S $>$ 1 with R $>$ 0.5 mV; and (**C**) right QRS axis deviation QRS axis >90 degrees. CTEPH, chronic thromboembolic pulmonary hypertension; ECG, electrocardiography.

Non-invasive early exclusion of chronic thromboembolic pulmonary hypertension after acute pulmonary embolism: the InShape II study

Gudula J A M Boon ,[1] Yvonne M Ende-Verhaar ,[1] Roisin Bavalia ,[2] Lahassan H El Bouazzaoui,[3] Marion Delcroix ,[4] Olga Dzikowska-Diduch ,[5] Menno V Huisman ,[1] Katarzyna Kurnicka ,[5] Albert T A Mairuhu ,[6] Saskia Middeldorp ,[2] Piotr Pruszczyk ,[5] Dieuwertje Ruigrok ,[7] Peter Verhamme ,[8] Hubert W Vliegen ,[9] Anton Vonk Noordegraaf ,[7] Joris W J Vriend,[10] Frederikus A Klok ,[1] InShape II study group

ABSTRACT

Background The current diagnostic delay of chronic thromboembolic pulmonary hypertension (CTEPH) after pulmonary embolism (PE) is unacceptably long, causing loss of quality-adjusted life years and excess mortality. Validated screening strategies for early CTEPH diagnosis are lacking. Echocardiographic screening among all PE survivors is associated with overdiagnosis and cost-ineffectiveness. We aimed to validate a simple screening strategy for excluding CTEPH early after acute PE, limiting the number of performed echocardiograms.

Methods In this prospective, international, multicentre management study, consecutive patients were managed according to a screening algorithm starting 3 months after acute PE to determine whether echocardiographic evaluation of pulmonary hypertension (PH) was indicated. If the 'CTEPH prediction score' indicated high pretest probability or matching symptoms were present, the 'CTEPH rule-out criteria' were applied, consisting of ECG reading and N-terminalpro-brain natriuretic peptide. Only if these results could not rule out possible PH, the patients were referred for echocardiography.

Results 424 patients were included. Based on the algorithm, CTEPH was considered absent in 343 (81%) patients, leaving 81 patients (19%) referred for echocardiography. During 2-year follow-up, one patient in whom echocardiography was deemed unnecessary by the algorithm was diagnosed with CTEPH, reflecting an algorithm failure rate of 0.29% (95% CI 0% to 1.6%). Overall CTEPH incidence was 3.1% (13/424), of whom 10 patients were diagnosed within 4 months after the PE presentation.

Conclusions The InShape II algorithm accurately excluded CTEPH, without the need for echocardiography in the overall majority of patients. CTEPH was identified early after acute PE, resulting in a substantially shorter diagnostic delay than in current practice.

Key messages

What is the key question?

- Since the current unacceptably long diagnostic delay of chronic thromboembolic pulmonary hypertension (CTEPH) after acute pulmonary embolism (PE) leads to decreased quality of life and excess mortality, we aimed to prospectively validate a simple strategy for evaluating the presence of CTEPH early in the course of acute PE.

What is the bottom line?

- The simple non-invasive InShape II algorithm accurately ruled out CTEPH early after acute PE without the need for echocardiography in 81% of patients with PE, resulting in a substantially faster CTEPH diagnosis than in current routine practice.

Why read on?

- The InShape II study is the first management study to successfully validate a dedicated CTEPH screening strategy after acute PE.

INTRODUCTION

Chronic thromboembolic pulmonary hypertension (CTEPH) is characterised by persistent obstruction of the pulmonary arteries by organised fibrotic thrombi with secondary microvascular remodelling, leading to increased pulmonary vascular resistance, pulmonary hypertension (PH), right heart failure and ultimately, if proper and timely treatment is not initiated, death.[1–5] While this rare disease is the most feared long-term complication of acute pulmonary embolism (PE), its early diagnosis remains an important clinical challenge.[6 7] Indeed, the current diagnostic delay of CTEPH after PE is unacceptably long exceeding 1 year, causing loss of quality-adjusted life years and excess mortality.[8–11]

Until recently, there were no clear recommendations for specific follow-up programmes after PE for early detection of CTEPH.[12 13] Subjecting all acute PE survivors to transthoracic echocardiography, which is the recommended screening tool for suspected PH, has been shown to have a low diagnostic yield, results in overdiagnosis and is cost-ineffective.[14] An active screening algorithm was suggested for the first time in the 2019 Guidelines

Sensitivity of a Simple Noninvasive Screening Algorithm for Chronic Thromboembolic Pulmonary Hypertension after Acute Pulmonary Embolism

Yvonne M. Ende-Verhaar[1] Dieuwertje Ruigrok[2] Harm Jan Bogaard[2] Menno V. Huisman[1]
Lilian J. Meijboom[3] Anton Vonk Noordegraaf[2] Frederikus A. Klok[1]

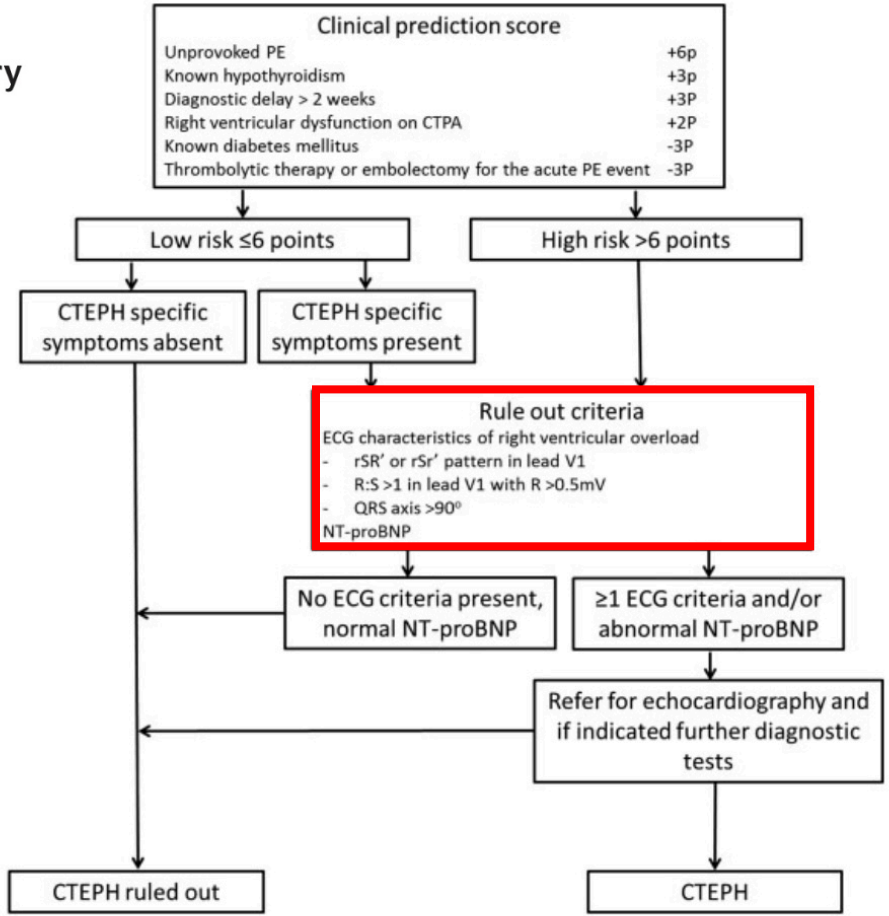

Fig. 1 Screening algorithm for CTEPH after acute PE consisting of the CTEPH prediction score, CTEPH-specific symptoms, and the rule-out criteria. CTEPH, chronic thromboembolic pulmonary hypertension; PE, pulmonary embolism; ECG, electrocardiography; NT-proBNP, N-terminal pro-brain natriuretic peptide.

Non-invasive early exclusion of chronic thromboembolic pulmonary hypertension after acute pulmonary embolism: the InShape II study

Gudula J A M Boon [1], Yvonne M Ende-Verhaar [1], Roisin Bavalia [2], Lahassan H El Bouazzaoui [3], Marion Delcroix [4], Olga Dzikowska-Diduch [5], Menno V Huisman [1], Katarzyna Kurnicka [5], Albert T A Mairuhu [6], Saskia Middeldorp [2], Piotr Pruszczyk [5], Dieuwertje Ruigrok [7], Peter Verhamme [8], Hubert W Vliegen [9], Anton Vonk Noordegraaf [7], Joris W J Vriend [10], Frederikus A Klok [1], InShape II study group

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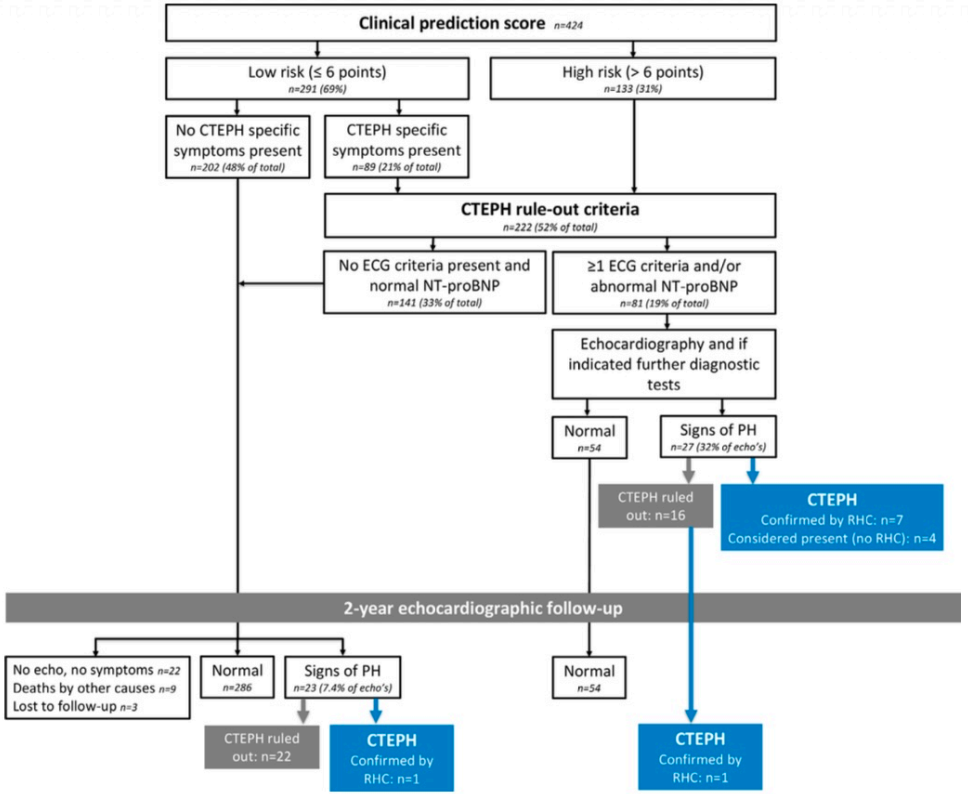


Figure 1 Results of 2-year follow-up after completing the InShape II study algorithm. Note: The ECG criteria of RV pressure overload are as follows: (1) rSR′ or rSr′ pattern in lead V1, (2) R:S>1 in lead V1 with R>0.5 mV and (3) QRS axis >90°. 'Signs of PH' relate to echocardiographically determined intermediate or high probability of PH according to the 2015 ESC/ERS guidelines for the diagnosis and treatment of PH.[12] CTEPH, chronic thromboembolic pulmonary hypertension; NT-proBNP, N-terminal pro-brain natriuretic peptide; PE, pulmonary embolism; PH, pulmonary hypertension; RHC, right heart catheterisation; RV, right ventricle.

Boon GJAM, *et al*. *Thorax* 2021;**0**:1–8. doi:10.1136/thoraxjnl-2020-216324

Optimisation of detecting chronic thromboembolic pulmonary hypertension in acute pulmonary embolism survivors: the InShape IV study

Dieuwke Luijten, Luca Valerio, Gudula J.A.M. Boon, Stefano Barco, Harm Jan Bogaard, Marion Delcroix, Yvonne Ende-Verhaar, Menno V. Huisman, Luis Jara-Palomares, Karl-Friedrich Kreitner, Lucia J. M. Kroft, Albert TA Mairuhu, Anna C. Mavromanoli, Lilian J. Meijboom, Thijs E. van Mens, Maarten K. Ninaber, Esther J. Nossent, Piotr Pruszczyk, Stephan Rosenkranz, Hubert Vliegen, Anton Vonk Noordegraaf, Stavros V. Konstantinides, Frederikus A. Klok

Introduction

InShape II algorithm	Safely rules out CTEPH in acute PE survivors
Detailed CTPA reading of index PE	Signs on CTPA are highly specific for future CTEPH diagnosis

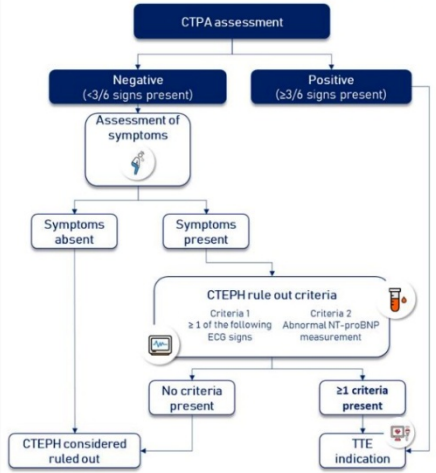
Can the InShape II algorithm be improved by adding detailed reading of the CTPA diagnosing index PE?

Methods

Design	12 new algorithms incorporating the CTEPH prediction score, ECG reading, NT-proBNP levels and dedicated CTPA
	Evaluated in two prospective cohorts: ➢ InShape II cohort (n=341) ➢ FOCUS cohort (n=171)
Evaluation of	Failure rate (%) incidence of confirmed CTEPH in PE patients in whom echocardiography was deemed unnecessary by the algorithm
	Netto reclassification index (NRI) Evaluates shifts in risk categories for both CTEPH and non-CTEPH patients compared to the InShape II algorithm

Results

InShape IV resulted in the most beneficial change compared to InShape II



InShape II cohort
- Failure rate of 0%
- Need for echocardiography in 20%
- NRI of +3.5

FOCUS cohort
- Failure rate of 0%
- Need for echocardiography in 24%
- NRI of +6.0

Conclusion:

Dedicated CTPA reading of the index PE incorporated in the new InShape IV algorithm improved the performance of the InShape II algorithm and may improve the selection of PE survivors who require echocardiography to rule out CTEPH

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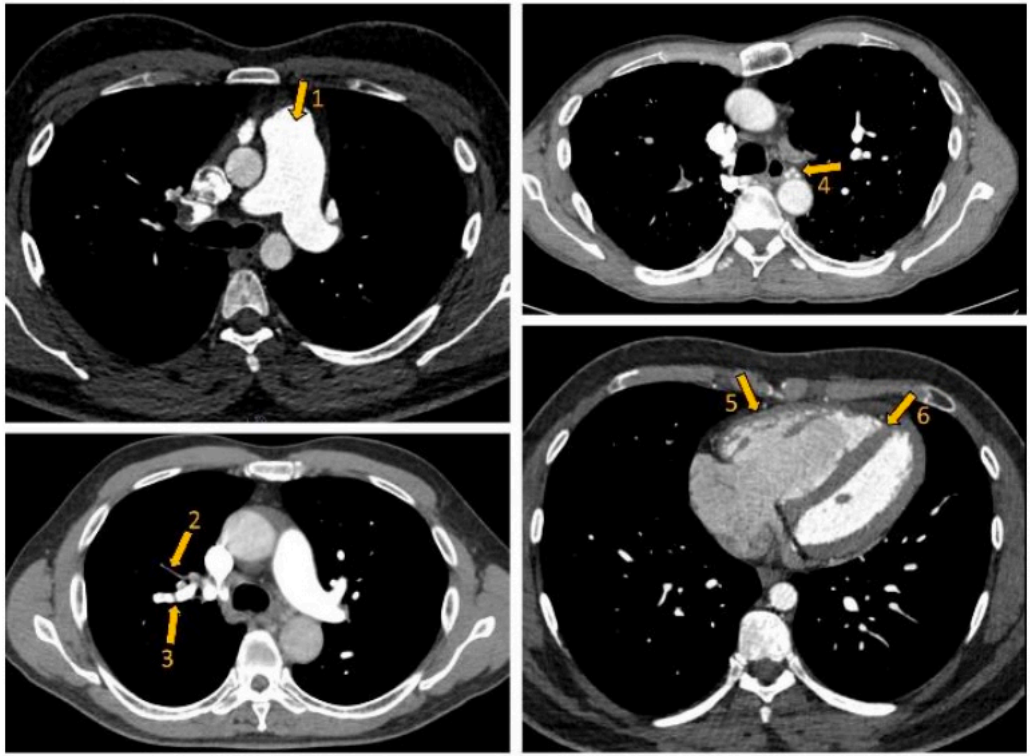
Appendix A: Chronic thromboembolic pulmonary hypertension signs on CT pulmonary angiography



1. Dilated pulmonary trunk
2. Arterial retraction
3. Intravascular web
4. Dilated bronchial arteries
5. RV wall hypertrophy
6. Flattening of the interventricular septum

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Diagnostic efficacy of ECG-derived ventricular gradient for the detection of chronic thromboembolic pulmonary hypertension in patients with acute pulmonary embolism

Dieuwke Luijten [a], Fleur M.M. Meijer [b], Gudula J.A.M. Boon [a], Yvonne M. Ende-Verhaar [a], Roisin Bavalia [c], Lahassan H. El Bouazzaoui [d], Marion Delcroix [e], Menno V. Huisman [a], Albert T. A. Mairuhu [f], Saskia Middeldorp [c], Piotr Pruszcyk [g], Dieuwertje Ruigrok [h], Peter Verhamme [i], Anton Vonk Noordegraaf [h], Joris W.J. Vriend [j], Hubert W. Vliegen [b], Frederikus A. Klok [a,*]

[a] Department of Medicine – Thrombosis and Hemostasis, Leiden University Medical Center, Leiden, the Netherlands
[b] Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands
[c] Department of Vascular Medicine, Amsterdam Cardiovascular Sciences, Amsterdam UMC, University of Amsterdam, Amsterdam, the Netherlands
[d] Department of Pulmonology, Haga Teaching Hospital, The Hague, the Netherlands
[e] Department of Pneumology, KU Leuven University Hospitals Leuven, Leuven, Belgium
[f] Department of Internal Medicine, Haga Teaching Hospital, The Hague, the Netherlands
[g] Department of Internal Medicine and Cardiology, Medical University of Warsaw, Warszawa, Poland
[h] Department of Pulmonology, Amsterdam UMC, VU University Medical Centre, Amsterdam, the Netherlands
[i] Department of Cardiovascular Sciences, Centre for Molecular and Vascular Biology, University Hospitals Leuven, Leuven, Belgium
[j] Department of Cardiology, Haga Teaching Hospital, The Hague, the Netherlands

ARTICLE INFO

Keywords:
Pulmonary hypertension
Algorithm
Pulmonary embolism
Vectorcardiography
Diagnosis

ABSTRACT

Introduction: Application of the chronic thromboembolic pulmonary hypertension (CTEPH) rule out criteria (manual electrocardiogram [ECG] reading and N-terminal pro-brain natriuretic peptide [NTproBNP] test) can rule out CTEPH in pulmonary embolism (PE) patients with persistent dyspnea (InShape II algorithm). Increased pulmonary pressure may also be identified using automated ECG-derived ventricular gradient optimized for right ventricular pressure overload (VG-RVPO).

Method: A predefined analysis of the InShape II study was performed. The diagnostic performance of the VG-RVPO for the detection of CTEPH and the incremental diagnostic value of the VG-RVPO as new rule-out criteria in the InShape II algorithm were evaluated.

Results: 60 patients were included; 5 (8.3%) were ultimately diagnosed with CTEPH. The mean baseline VG-RVPO (at time of PE diagnosis) was −18.12 mV·ms for CTEPH patients and − 21.57 mV·ms for non-CTEPH patients (mean difference 3.46 mV·ms [95%CI −29.03 to 35.94]). The VG-RVPO (after 3–6 months follow-up) normalized in patients with and without CTEPH, without a clear between-group difference (mean Δ VG-RVPO of −8.68 and − 8.42 mV·ms respectively; mean difference of −0.25 mV·ms, [95%CI −12.94 to 12.44]). The overall predictive accuracy of baseline VG-RVPO, follow-up RVPO and Δ VG-RVPO for CTEPH was moderate to poor (ROC AUC 0.611, 0.514 and 0.539, respectively). Up to 76% of the required echocardiograms could have been avoided with VG-RVPO criteria replacing the InShape II rule-out criteria, however at cost of missing up to 80% of the CTEPH diagnoses.

Conclusion: We could not demonstrate (additional) diagnostic value of VG-RVPO as standalone test or as on top of the InShape II algorithm.

Diagnostic efficacy of ECG-derived ventricular gradient for the detection of chronic thromboembolic pulmonary hypertension in patients with acute pulmonary embolism

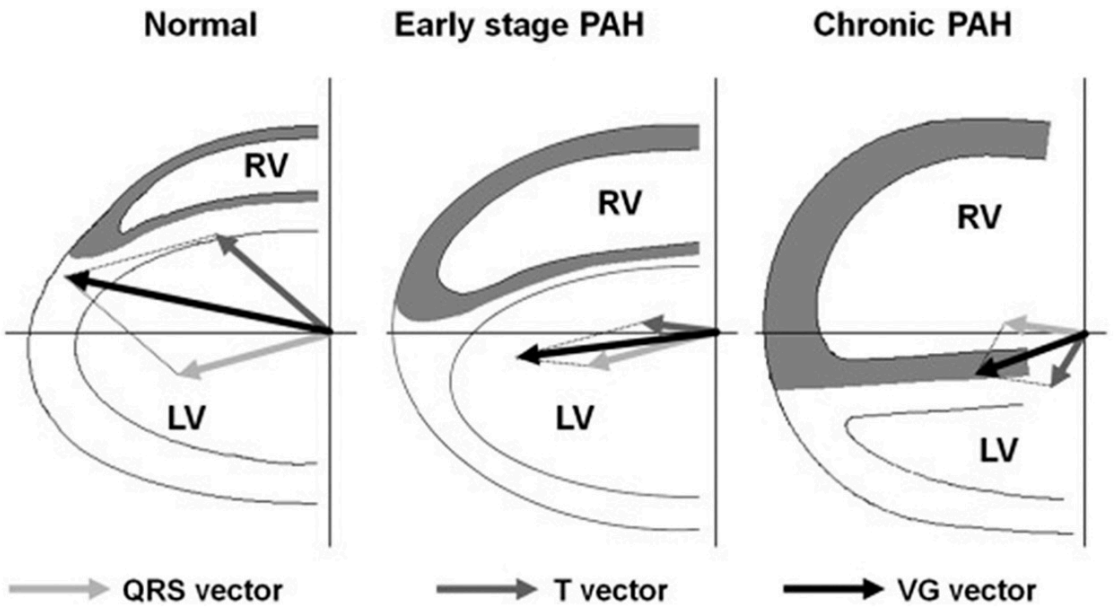

Fig. 1. Change in cardiac vectors from the normal physiologic situation to respectively early stage and chronic PH. Reprinted from Couperus et al. with permission [24]. Pulmonary arterial hypertension PAH.

Diagnostic efficacy of ECG-derived ventricular gradient for the detection of chronic thromboembolic pulmonary hypertension in patients with acute pulmonary embolism

Table 2
VG-RVPO measurements in the study patients.

ECG parameters	All patients (n = 60)	No CTEPH (*n* = 55)	CTEPH (*n* = 5)	Mean difference (95%CI)
VG-RVPO at baseline (mV . ms), mean ± SD	−21.28 ± 14.70	−21.58 ± 13.56	−18.12 ± 26.33	3.46 (−29.03 to 35.94)
VG-RVPO during follow-up (mV . ms), mean ± SD	−29.73 ± 17.26	−30.00 ± 17.41	−26.80 ± 17.00	3.20 (−13.05 to 19.46)
Δ VG-RVPO (mV . ms), mean ± SD	−8.45 ± 13.46	−8.42 ± 12.76	−8.68 ± 21.70	−0.25 (−12.94 to 12.44)
Change in VG-RVPO, n (%)[a]				
Normal-normal	39 (65.0)	36 (65.5)	3 (60.0)	
Abnormal-abnormal	8 (13.3)	7 (12.7)	1 (20.0)	
Aabnormal-normal	9 (15.0)	8 (14.5)	1 (20.0)	
Normal-abnormal	4 (6.7)	4 (7.3)	0 (0.0)	

[a] [baseline VG-RVPO]-[follow-up VG-RVPO]. The cut-off value for a normal value of the VG-RVPO set at − 13 mV ms, with < −13 mV ms being considered normal and ≥ −13 mV ms as abnormal. CTEPH, chronic thromboembolic pulmonary hypertension; ECG, electrocardiogram; VG-RVPO ventricular gradient optimized for right ventricular pressure overload.

Results: 60 patients were included; 5 (8.3%) were ultimately diagnosed with CTEPH. The mean baseline VG-RVPO (at time of PE diagnosis) was −18.12 mV·ms for CTEPH patients and − 21.57 mV·ms for non-CTEPH patients (mean difference 3.46 mV·ms [95%CI −29.03 to 35.94]). The VG-RVPO (after 3–6 months follow-up) normalized in patients with and without CTEPH, without a clear between-group difference (mean Δ VG-RVPO of −8.68 and − 8.42 mV·ms respectively; mean difference of −0.25 mV·ms, [95%CI −12.94 to 12.44]). The overall predictive accuracy of baseline VG-RVPO, follow-up RVPO and Δ VG-RVPO for CTEPH was moderate to poor (ROC AUC 0.611, 0.514 and 0.539, respectively). Up to 76% of the required echocardiograms could have been avoided with VG-RVPO criteria replacing the InShape II rule-out criteria, however at cost of missing up to 80% of the CTEPH diagnoses.

Conclusion: We could not demonstrate (additional) diagnostic value of VG-RVPO as standalone test or as on top of the InShape II algorithm.

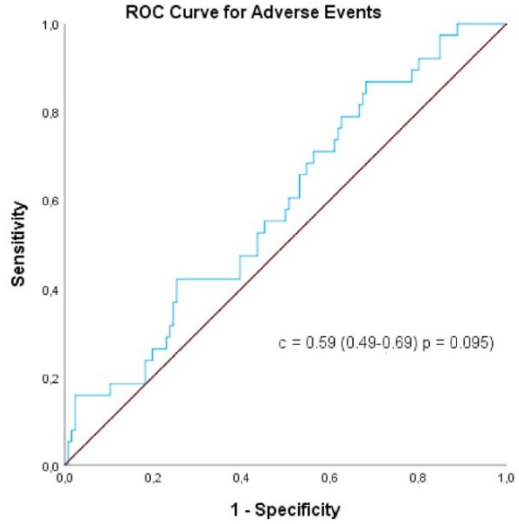

Fig. 2. ROC curve of the VG-RVPO based on occurrence of the 30-day composite endpoint for adverse events.
Abbreviations: VG-RVPO, ECG derived ventricular gradient optimized for right ventricular pressure overload; ROC; receiver operator curve
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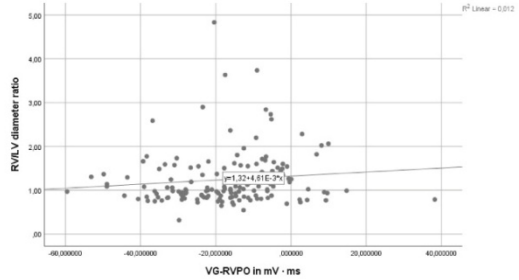

Fig. 3. Correlation between VG-RVPO and RV/LV diameter ratio.
Abbreviations: VG-RVPO, ECG derived ventricular gradient optimized for right ventricular pressure overload; RV, right ventricular; LV, left ventricular.

The value of vector ECG in predicting residual pulmonary hypertension in CTEPH patients after pulmonary endarterectomy

Dieuwke Luijten[1*], Tamara Rodenburg[2,3], Harm-Jan Bogaard[2,3], Azar Kianzad[2,3], Dieuwertje Ruigrok[2], Philip Croon[4], Patrick Smeele[2,3], Hubert W. Vliegen[5], Anton Vonk Noordegraaf[2,3], Lilian J. Meijboom[3,6], Frederikus A. Klok[1]

Although there was an association between the change in VG-RPVO and changes in mPAP or indexed RV mass, our study demonstrated that VG-RPVO has limited value in excluding the presence of residual PH post-PEA as up to 36% of the CTEPH patients with residual PH would have been missed if residual PH would have been excluded based on a normal VG-RVPO.

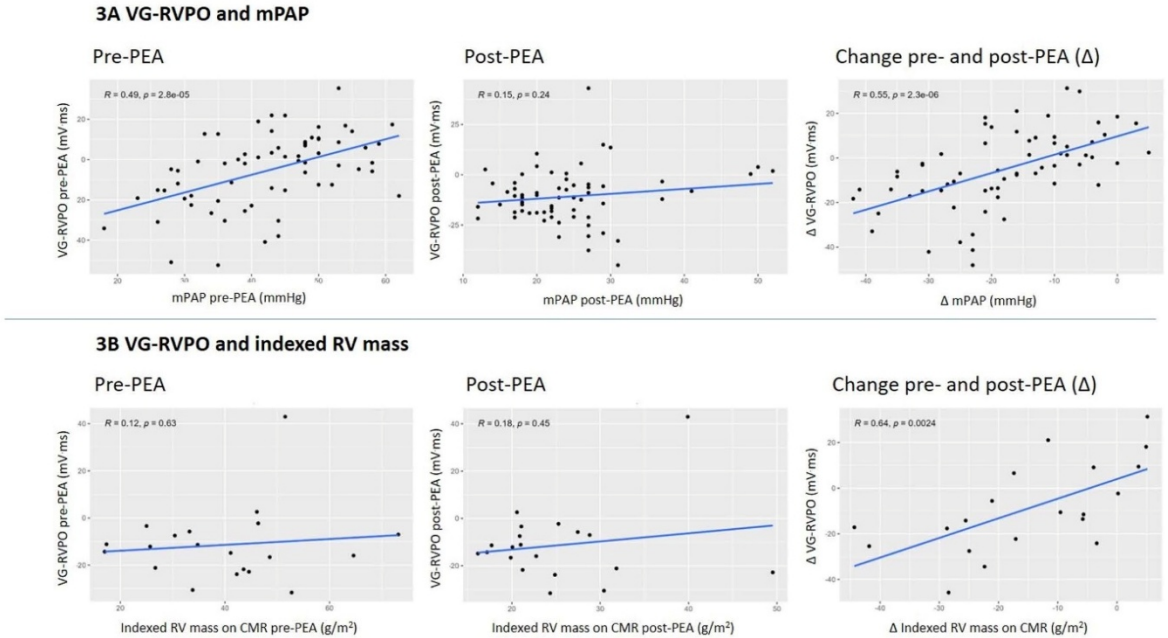

Fig 3. Relationship between VG-RVPO and mPAPor indexed RV mass. Abbreviations: CMR, cardiac magnetic resonance; mPAP, mean pulmonary artery pressure; PEA, pulmonary endarterectomy; RV, right ventricle; VG-RVPO, ventricular gradient optimized for right ventricular pressure overload.

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A simple electrocardiographic model for an improved detection of chronic thromboembolic pulmonary hypertension after pulmonary embolism

Lukas Ley, MD [a], Christoph B. Wiedenroth, MD [b], Stefan Guth, MD [b], Christian Gold, MD [c], Athiththan Yogeswaran, MD [d], Hossein Ardeschir Ghofrani, MD [d,e,f], Dirk Bandorski, MD, PhD [g,*]

[a] Campus Kerckhoff, Justus-Liebig-University Giessen, Bad Nauheim, Germany
[b] Kerckhoff Heart and Thorax Center, Department of Thoracic Surgery, Bad Nauheim, Germany
[c] Department of Cardiology and Vascular Medicine, University Hospital Frankfurt, Frankfurt am Main, Germany
[d] Department of Internal Medicine, Justus-Liebig-University Giessen, Universities of Giessen and Marburg Lung Center (UGMLC), Giessen, Germany
[e] Kerckhoff Heart and Thorax Center, Department of Pneumology, Bad Nauheim, Germany
[f] Department of Medicine, Imperial College London, London, United Kingdom
[g] Faculty of Medicine, Semmelweis University Campus Hamburg, Hamburg, Germany

ARTICLE INFO

Keywords:
Screening
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ECG
Chronic thromboembolic pulmonary hypertension
CTEPH

ABSTRACT

Introduction: Chronic thromboembolic pulmonary hypertension (CTEPH) is considered a late sequelae of a preceding pulmonary embolism (PE). There is reasonable suspicion that the majority of CTEPH patients are currently not detected. The aim of the present study was to evaluate the potential utility of a simple electrocardiographic (ECG) model for an improved detection of CTEPH after PE.

Material and methods: The present study was conducted as a bicentric, retrospective cross-sectional study in two German high volume referral centres for pulmonary hypertension (PH) between February 2011 and September 2023. A total of 100 patients with CTEPH and 100 patients with excluded PH were included. An ECG model for detecting CTEPH consisting of a screening test and confirmatory test was developed and subsequently tested on the present CTEPH cohort and a hypothetical cohort of PE survivors from Germany.

Results: Applying this ECG model to the present CTEPH cohort, 79 % of CTEPH patients were correctly identified (sensitivity: 79 %) and only 8 % of non-PH patients were incorrectly identified as PH patients (specificity: 92 %). When theoretically applying this model in CTEPH screening of a hypothetical cohort of persistently symptomatic PE survivors, a total 70 % of CTEPH patients could potentially be detected (sensitivity: 70 %) and right heart catheterisations (RHC) without pathological findings would only be performed on 2.5 % of non-CTEPH patients (specificity: 97.5 %) without the application of echocardiography. Compared to the current estimated CTEPH detection rate this would be about a threefold increase (from 24 % to 70 %).

Conclusion: Electrocardiographic CTEPH screening could potentially increase the CTEPH detection rate significantly, without the application of echocardiography and with performance of only very few RHCs without pathological findings, if all persistently symptomatic PE survivors were given a simple ECG as standard follow-up. However, the present approach remains largely hypothetical for now and must be validated externally.

A simple electrocardiographic model for an improved detection of chronic thromboembolic pulmonary hypertension after pulmonary embolism

Lukas Ley, MD [a], Christoph B. Wiedenroth, MD [b], Stefan Guth, MD [b], Christian Gold, MD [c], Athiththan Yogeswaran, MD [d], Hossein Ardeschir Ghofrani, MD [d,e,f], Dirk Bandorski, MD, PhD [g,*]

- Screening test:
- R V1, V2 +S I, aVL - S V1≥− 0.40 mV.
- Confirmatory test:
- ≥1 of the following parameters:
- QRS axis associated with right heart strain (QRS axis > 90◦, SI QIII type, SI SII SIII type)
- P dextroatriale or P biatriale
- R/S in V1 >1.0
- R V1, V2 +S I, aVL - S V1 >0.6 mV
- R V1 +S V5, V6 >1.05 mV

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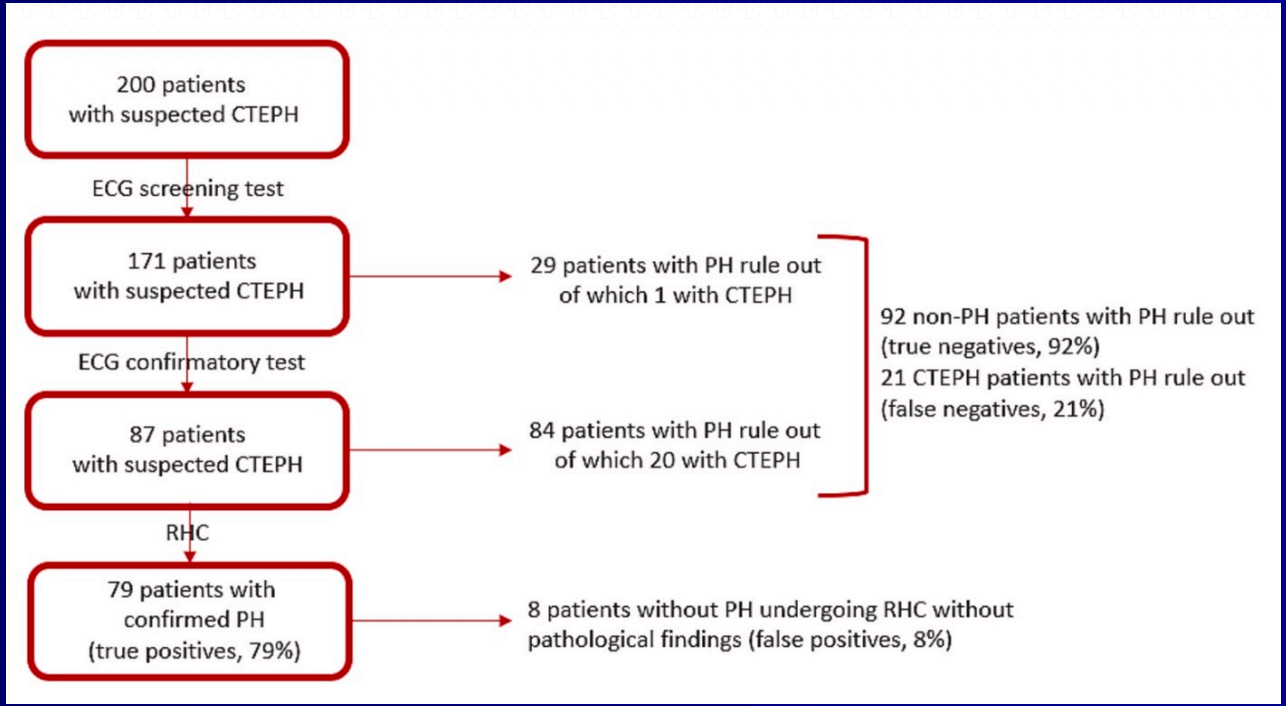

sensitivity: 79%

specificity: 92%

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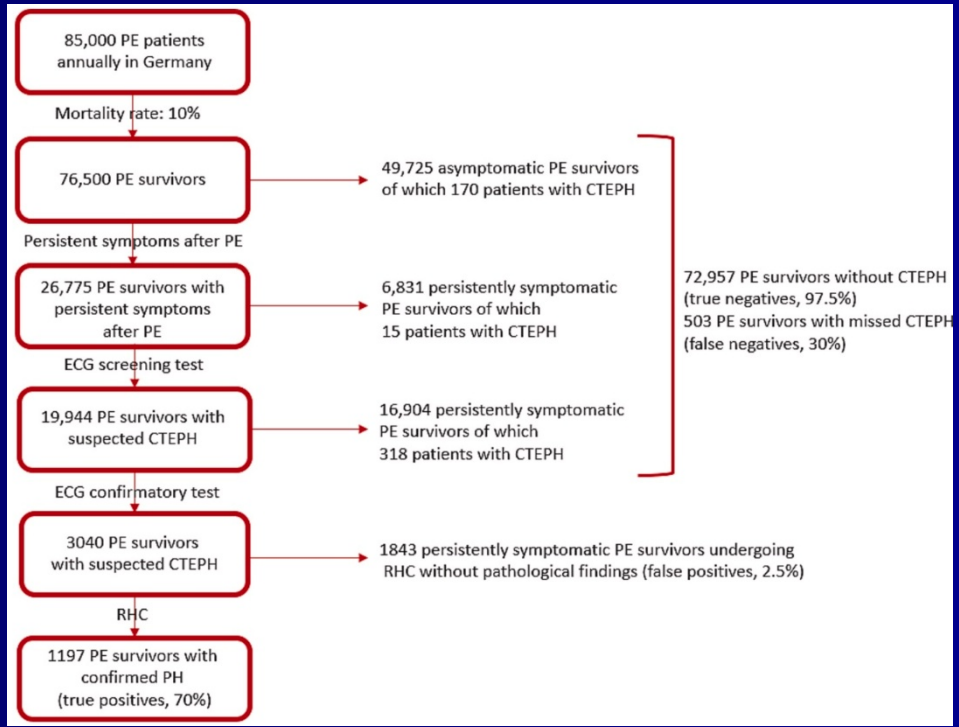

specificity: 97.5%

sensitivity: 70%

A simple electrocardiographic model for an improved detection of chronic thromboembolic pulmonary hypertension after pulmonary embolism

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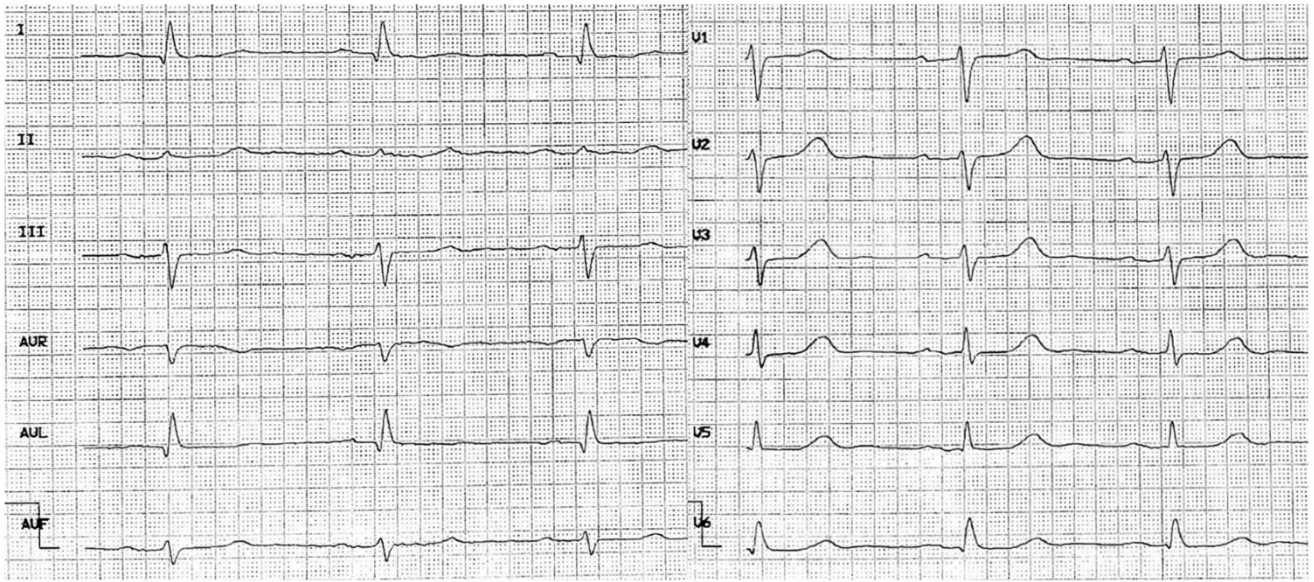

Fig. 4. ECG sample 2: Patient with confirmed PH exclusion (true negative).
Legend: 79 year old female patient with mean pulmonary artery pressure of 16 mmHg and pulmonary vascular resistance of 123 dyn*sec*cm^{-5}, screening test negative ("R V1, V2 + S I, aVL - S V1": −0.65 mV), confirmatory test not needed but also negative (total score: 0, no QRS axis associated with right heart strain, no P dextroatriale or P biatriale, R/S in V1: 0.3, "R V1, V2 + S I, aVL - S V1": −0.65 mV, "R V1 + S V5, V6": 0.3 mV); paper speed: 50 mm/s, sensitivity: 10 mm/mV.

Vero negativo

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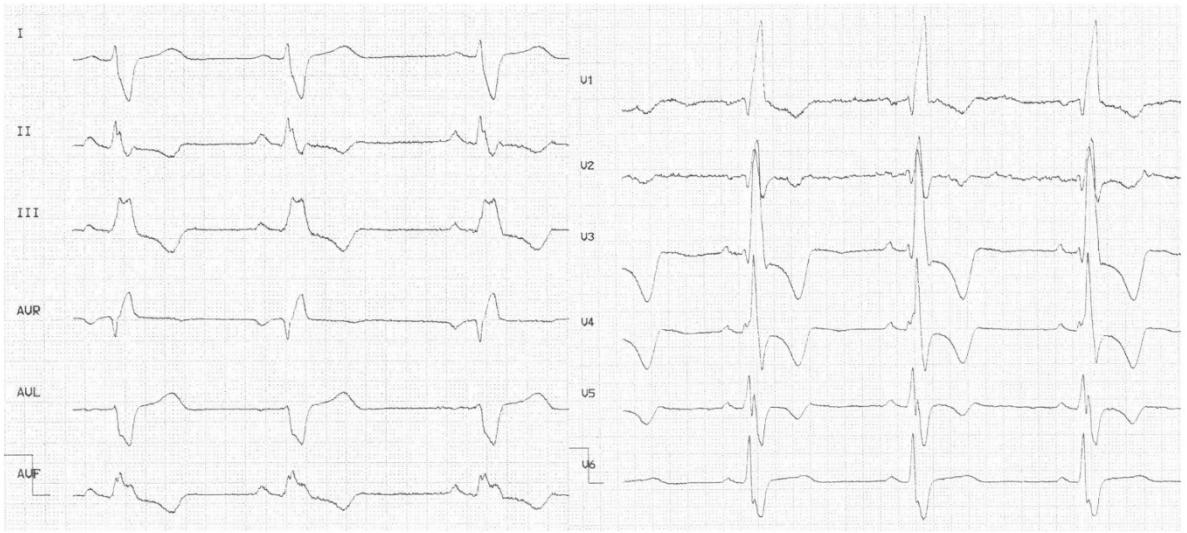


Fig. 3. ECG sample 1: Patient with confirmed CTEPH (true positive).
Legend: 36 year old male patient with mean pulmonary artery pressure of 44 mmHg and pulmonary vascular resistance of 571 dyn*sec*cm^{-5}; screening test positive ("R V1, V2 + S I, aVL - S V1": 3.00 mV), confirmatory test positive (total score: 5, QRS axis > 120°, P dextroatriale (P wave amplitude in V3: 0.25 mV), R/S in V1: 6.0, "R V1, V2 + S I, aVL - S V1": 3.00 mV, "R V1 + S V5, V6": 3.45 mV); additional signs: complete right bundle branch block (QRS duration: 150 ms), ST depressions in leads III, aVF and V1-V4, T wave inversions in leads II, III, aVF and V1-V5; paper speed: 50 mm/s, sensitivity: 10 mm/mV.

Vero positivo

DETECT Algorithm

Screening della PAH nella sclerosi sistemica

La PAH è una delle principali cause di mortalità nella sclerosi sistemica.
La diagnosi precoce migliora prognosi e possibilità terapeutiche.

RAZIONALE

- Identificare precocemente la PAH nei pazienti con sclerosi sistemica.
- Integrare parametri clinici, biomarcatori, ECG ed ecocardiografici.
- Algoritmo ad alta sensibilità per minimizzare i falsi negativi.
- Selezionare i pazienti da sottoporre a cateterismo cardiaco destro (RHC).

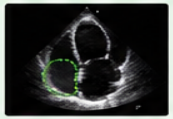
STEP 1 — Valutazione di 6 variabili non ecocardiografiche

- FVC/DLCO
- Telangectasie
- Anticorpi anticentromero
- NT-proBNP
- Acido urico
- Deviazione assiale destra all'ECG

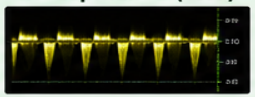
Calcolo dello SCORE 1 (punteggio ponderato)
Se SCORE 1 positivo → Step 2

STEP 2 — Ecocardiografia

Area atriale destra (RAA)



Velocità del rigurgito tricuspidalico (TRV)



Calcolo dello SCORE 2 (punteggio ponderato)
Se SCORE 2 elevato → Cateterismo cardiaco destro (RHC)

CATETERISMO CARDIACO DESTRO (RHC)

Gold standard per la diagnosi di PAH

PERFORMANCE DIAGNOSTICA

- **SENSIBILITÀ** ≈96%
- **SPECIFICITÀ** ≈48%
- **VALORE PRINCIPALE**
  Riduce al minimo i falsi negativi
- **POPOLAZIONE**
  Pazienti con sclerosi sistemica a rischio di PAH

MESSAGGIO CHIAVE

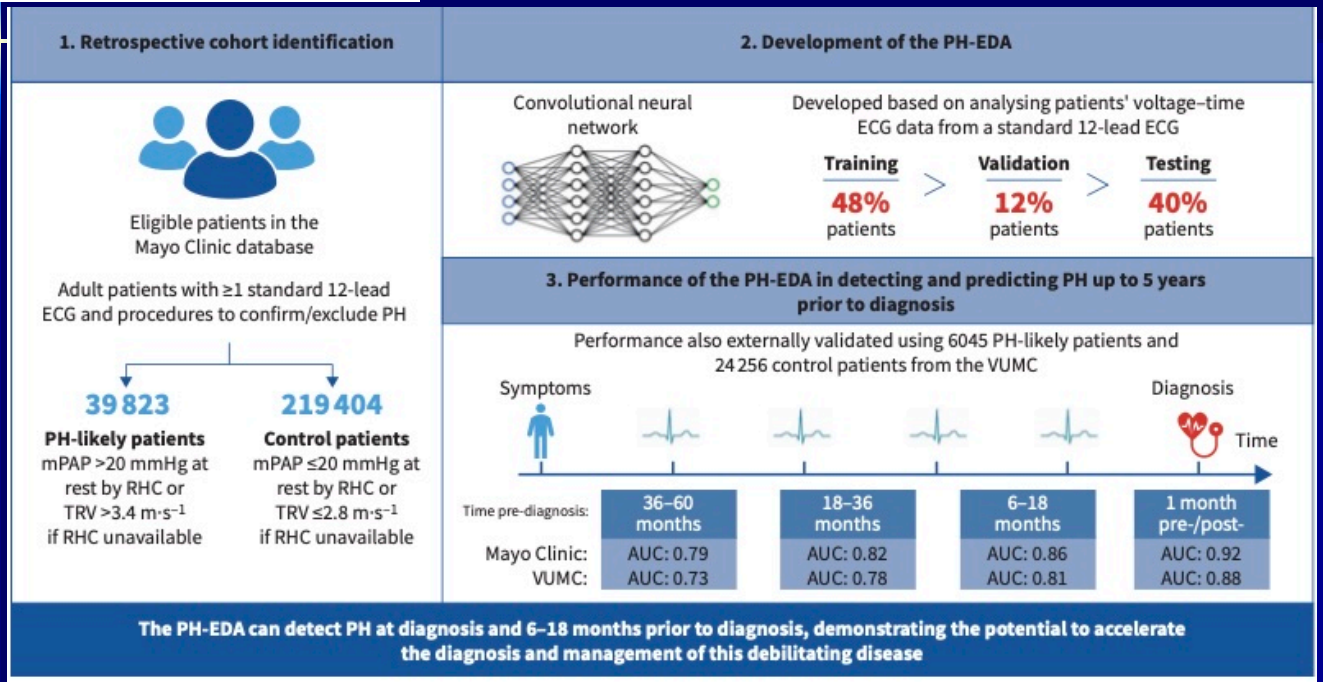
DETECT integra ECG, biomarcatori ed ecocardiografia per selezionare i pazienti con sclerosi sistemica da sottoporre a RHC, garantendo un'**elevata sensibilità** nella diagnosi precoce della PAH.

Coghlan JG et al. Ann Rheum Dis. 2014;73:1340-1349.

EUROPEAN RESPIRATORY JOURNAL
ORIGINAL RESEARCH ARTICLE
H.M. DUBROCK ET AL.

An electrocardiogram-based AI algorithm for early detection of pulmonary hypertension

Hilary M. DuBrock, Tyler E. Wagner, Katherine Carlson, Corinne L. Carpenter, Samir Awasthi, Zachi I. Attia, Robert P. Frantz, Paul A. Friedman, Suraj Kapa, Jeffrey Annis, Evan L. Brittain, Anna R. Hemnes, Samuel J. Asirvatham, Melwin Babu, Ashim Prasad, Unice Yoo, Rakesh Barve, Mona Selej, Peter Agron, Emily Kogan, Deborah Quinn, Preston Dunnmon, Najat Khan and Venky Soundararajan



GRAPHICAL ABSTRACT Summary of the development and validation of the Pulmonary Hypertension (PH) Early Detection Algorithm (PH-EDA) based on analysis of a standard 12-lead ECG. mPAP: mean pulmonary arterial pressure; RHC: right heart catheterisation; TRV: tricuspid regurgitation velocity; VUMC: Vanderbilt University Medical Center; AUC: area under the curve.

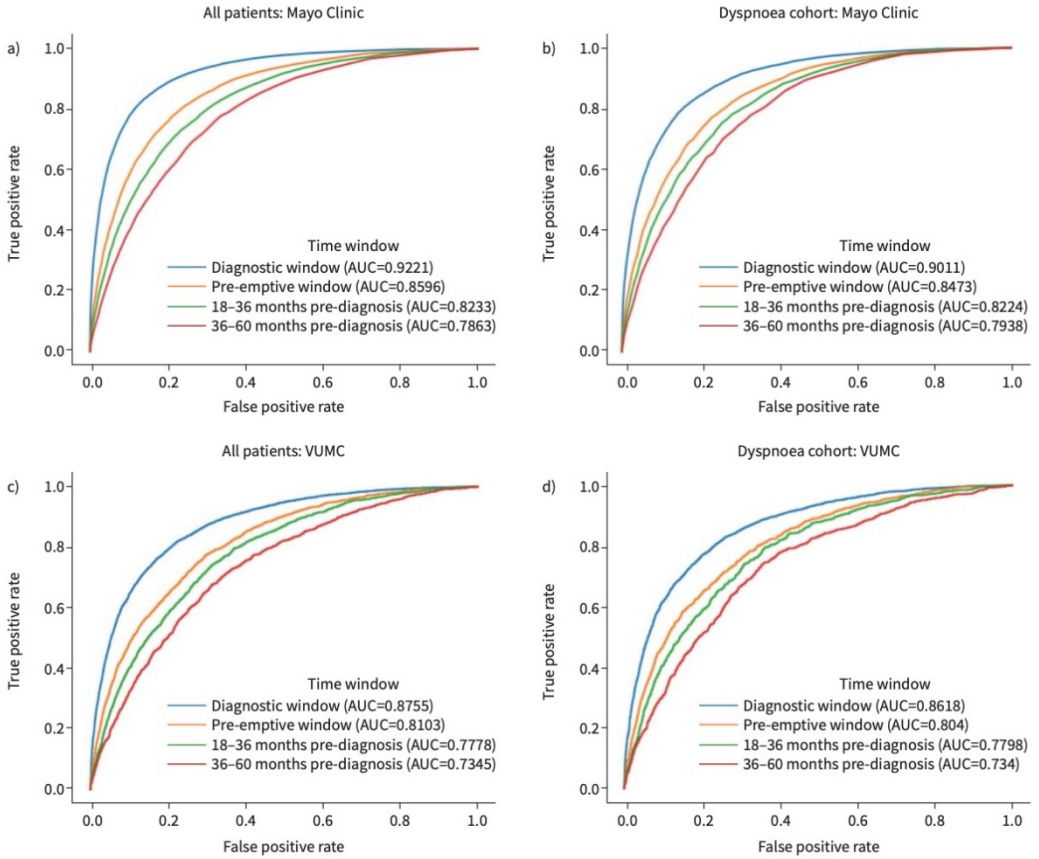


FIGURE 3 Receiver operating characteristic curves for the performance of the pulmonary hypertension (PH) early detection algorithm (PH-EDA) to identify patients with PH in ECGs across all four time windows of interest in a, c) all patients and b, d) patients with dyspnoea filter using the test datasets from a, b) Mayo Clinic and c, d) Vanderbilt University Medical Center (VUMC). AUC: area under the curve.

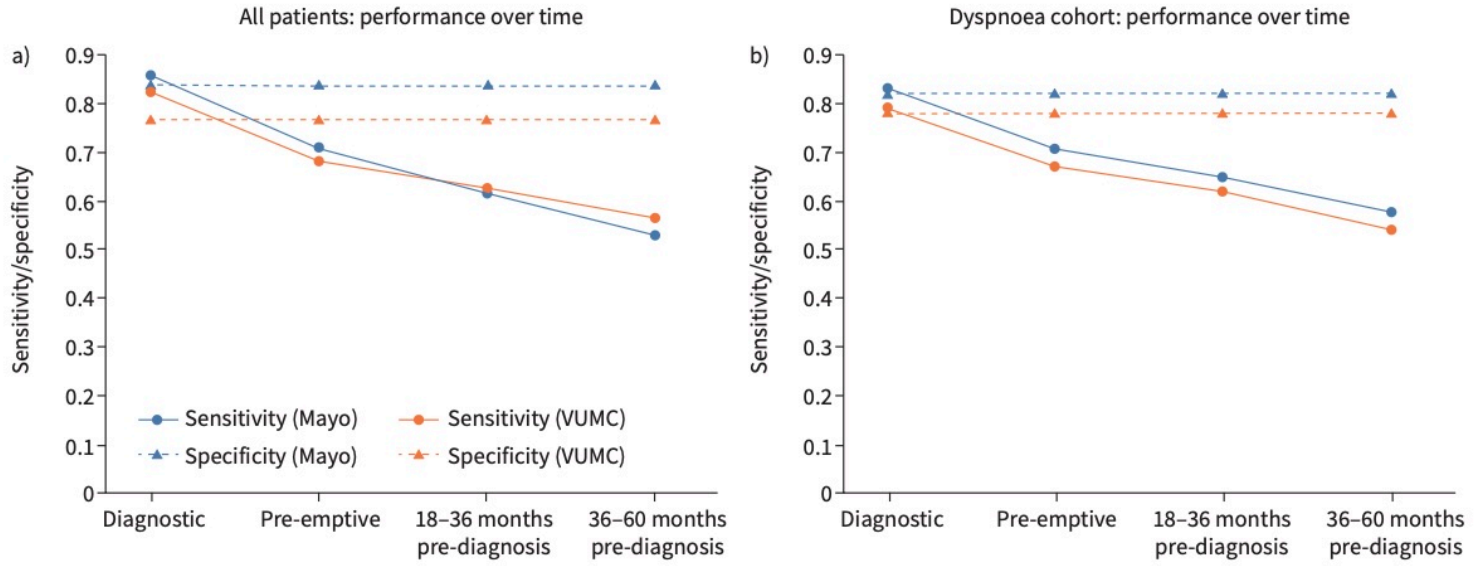


FIGURE 4 Sensitivity and specificity of the pulmonary hypertension (PH) early detection algorithm (PH-EDA) to detect PH across all four time windows of interest, in a) all patients and b) patients with dyspnoea, using test sets from Mayo Clinic and Vanderbilt University Medical Center (VUMC).

Take-home messages

- ECG alone cannot diagnose pulmonary hypertension.
- ECG remains an important first-line screening tool because it is inexpensive, rapid and universally available.
- Integrated algorithms combining ECG, biomarkers and echocardiography improve diagnostic accuracy.
- Early identification of high-risk patients is essential to shorten time to diagnosis.
- Artificial intelligence is likely to redefine the future role of ECG screening.

The future of pulmonary hypertension screening will not rely on a single test, but on the integration of