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CASE REPORT
Heart failure

A young woman presenting with dyspnoea and diffuse T-wave inversions: a case report

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Background T-wave inversions on electrocardiograms (ECGs) indicate a variety of conditions, such as coronary artery disease, myocarditis, and cardiomyopathy. Pulmonary artery stenosis (PAS) and pulmonary hypertension (PH) may cause right ventricular enlargement and ischaemia, which are reflected as T-wave inversions on ECGs. Continuous ECG monitoring is crucial for detecting dynamic changes indicative of PAS progression and reversal in right heart remodelling.

Case summary This report presents the case of a young woman who experienced exertional dyspnoea for 5 years with ECG findings showing T-wave inversions across multiple leads. The patient was diagnosed with PAS and PH caused by Takayasu arteritis (TA). Following three successful balloon pulmonary angioplasty sessions, the patient exhibited significant clinical improvement, including the remission of PAS and PH. Throughout a 59-month cumulative follow-up period, the sustained effectiveness of the treatment was evidenced by the regression of right heart remodelling, as manifested in the normalization of the initially inverted T-waves on the ECG.

Discussion Electrocardiogram changes, including right axis deviation, right bundle branch block, a deep S wave in lead I ($R/S < 1$), and a prominent R wave in lead aVR ($R/Q > 1$), have been termed PAS syndrome, often linked to TA-associated PAS, especially in young East Asian females. Early diagnosis is crucial but challenging due to atypical symptoms. The non-invasive ECG is vital for detection, with balloon pulmonary angioplasty serving as an effective treatment for TA-induced PAS when surgery is not an option, improving outcomes and potentially reversing right heart remodelling.

Keywords Pulmonary hypertension WHO group 4 • Takayasu arteritis • Inverted T-wave • Pulmonary artery stenosis • Case report

ESC curriculum 6.7 Right heart dysfunction • 9.6 Pulmonary hypertension

Learning points

- The pulmonary artery stenosis (PAS) syndrome electrocardiogram signature enables early identification of PAS, including that associated with Takayasu arteritis.
- The electrocardiogram (ECG) is an important tool for detecting right heart reverse remodelling. Monitoring dynamic ECG changes during follow-up is essential for assessing treatment efficacy in patients with pulmonary artery stenosis after balloon pulmonary angioplasty.
- Balloon pulmonary angioplasty proves to be an effective treatment for Takayasu arteritis-related pulmonary artery stenosis.

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Introduction

T-wave inversions on electrocardiograms (ECGs) can manifest in various conditions, including coronary heart disease (CAD), myocarditis, and cardiomyopathy.[1] Additionally, pulmonary artery stenosis (PAS) and pulmonary hypertension (PH) can cause right ventricle (RV) dilatation and ischaemia, leading to T-wave inversions on ECGs. In this report, we present a case of PAS caused by Takayasu arteritis (TA), which was characterized by diffused T-wave inversions that reversed following the alleviation of PAS.

Summary figure

Date	Event
Week 1	Hospital admission due to exertional dyspnoea.
	Electrocardiogram (ECG): a deep S wave (R/S < 1) in lead Ⅰ and a prominent R wave (R/Q > 1) in lead avR, inverted T-waves in leads Ⅱ, Ⅲ, and V1–V4.
	Echocardiography (Echo): moderate TR, TRV of 4.6 m/s, sPAP of 99 mmHg, RVIDd of 40 mm, IVC of 21 mm.
Week 2	Right heart catheterization (RHC): pre-capillary pulmonary hypertension, mPAP of 65 mmHg, PAWP of 13 mmHg, SvO_2 of 59%, CI of 2.8 L/min/m^2, PVR of 11.3 WU.
	Ventilation–perfusion scintigraphy: no perfusion in the right lung.
	Computed tomography pulmonary angiography (CTPA): subtotal occlusion in the proximal right pulmonary artery, RV/LV dimension ratio of 1.06.
	Magnetic resonance angiography: subtotal occlusion of the right pulmonary artery, wall thickening, and delayed enhancement of both right and main pulmonary.
	Initiation of oral prednisone 10 mg once daily, oral bosentan 125 mg twice daily, and oral diuretic therapy.
Week 6	ESR: 2 mm/h; C-reactive protein: 1.1 mg/L.
	The first balloon pulmonary angioplasty (BPA) treatment.
Week 11	Echo: RVIDd of 40 mm, TAPSE of 18 mm, IVC of 21 mm.
	RHC: mPAP of 36 mmHg, PAWP of 8 mmHg, SvO_2 of 76%, CI of 2.5 L/min/m^2, PVR of 6.83 WU.
	The second BPA treatment.
Week 16	ECG: inverted T-waves in leads III, V1, and V2.
	Echo: RVIDd of 35 mm, RVA of 18.9 cm^2, RAA of 17 cm^2, TAPSE of 18 mm.
	RHC: mPAP of 28 mmHg, PAWP of 7 mmHg, SvO_2 of 75%, CI of 2.7 L/min/m^2, PVR of 4.67 WU.
	The third BPA treatment.
Week 44	ECG: normalized T-waves, a decrease in S-wave amplitude in lead I and R-wave amplitude in aVR (R/S > 1 in lead I, R/Q < 1 in lead aVR).
	Echo: RVIDd of 33 mm, RVA of 19 cm^2, RAA of 16 cm^2, TAPSE of 21 mm.
	RHC: mPAP of 27 mmHg, PAWP of 10 mmHg, SvO_2 of 74%, CI of 3.1 L/min/m^2, PVR of 3.54 WU.
	Continued oral prednisone 5 mg once daily and bosentan 62.5 mg twice daily.
Week 92	ECG: normal ECG.
	Echo: RVIDd of 33 mm, RVA of 17.7 cm^2, RAA of 16.6 cm^2, TAPSE of 21 mm.
	CTPA: no restenosis of the re-opened right pulmonary artery, RV/LV dimension ratio of 0.56.
	RHC: mPAP of 25 mmHg, PAWP of 6 mmHg, SvO_2 of 71%, CI of 4.0 L/min/m^2, PVR of 2.84 WU.
Week 167	ECG: normal ECG.
	Echo: RVIDd of 35 mm, RVA of 20.2 cm^2, RAA of 15 cm^2, TAPSE of 23 mm.
	6 min walk distance: 465 m.
	RHC: mPAP of 30 mmHg, PAWP of 12 mmHg, SvO_2 of 81%, CI of 3.2 L/min/m^2, PVR of 3.39 WU.
Week 271	ECG: normal ECG.
	Echo: RVIDd of 35 mm, RVA of 13 cm^2, RAA of 13 cm^2, TAPSE of 22 mm.

Case presentation

A 41-year-old woman was admitted with dyspnoea, with which she had been suffering for 5 years and had worsened over the past 6 months. The ECG showed normal sinus rhythm, with a QRS axis of 123°. Lead I had a deep S wave (R/S < 1) and lead aVR displayed a prominent R wave (R/Q > 1). Flattened or inverted T-waves were evident in leads II, III, aVF, and V1–V5 (*Figure 1*). The patient reported no significant past medical history or known familial history. Vital signs included a temperature of 36.4°C, a blood pressure of 104/70 mmHg, a pulse rate of 81 b.p.m., and a respiratory rate of 21/min. Physical examination showed decreased breath sounds in the right lung upon auscultation and a systolic murmur heard in the tricuspid area. Blood gas analysis on room air showed an O_2 saturation of 89%, a PO_2 of 58.4 mmHg, and a PCO_2 of 34.5 mmHg. High-sensitivity cardiac troponin T and D-dimer were normal, while the N-terminal pro-brain natriuretic peptide (NT-proBNP) level was elevated at 590 pg/mL (normal < 125 pg/mL). Echocardiography showed no left heart abnormalities with a left ventricular (LV) ejection fraction of 69%. Additional

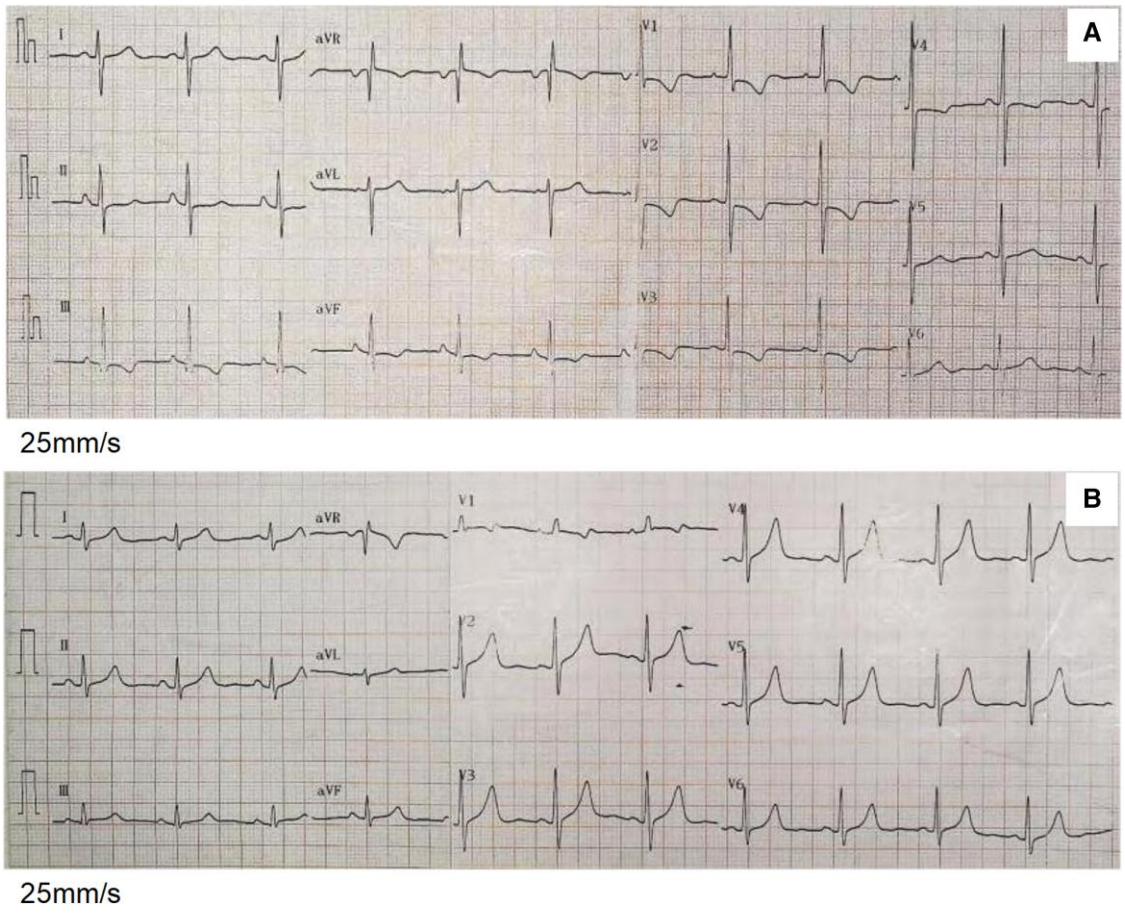

Figure 1 Initial electrocardiogram (*A*) shows a deep S wave in lead I (R/S < 1) and a prominent R wave in lead aVR (R/Q > 1), and flattened/inverted T-waves in the inferior leads and precordial leads V1–V6. Follow-up at week 44 (*B*) shows a reduction in the amplitude of the S wave in lead I and a diminished amplitude of the R wave in aVR (R/S > 1 in lead I, R/Q < 1 in lead aVR).

observations were RV dimensions of 40 mm in diastole, a notable interventricular septum leftward swing during diastole, the inferior vena cava diameter of 21 mm with a collapsibility index during inspiration of <50%, and moderate tricuspid regurgitation with a regurgitant jet velocity of 4.6 cm/s, indicating PH. Subsequent assessments, including pulmonary function tests and coronary computed tomography angiography, both were normal. Given these findings, right heart catheterization (RHC) was performed, revealing a pre-capillary PH with a mean pulmonary arterial pressure (mPAP) of 65 mmHg, pulmonary artery wedge pressure (PAWP) of 13 mmHg, mixed venous oxygen saturation (SvO_2) of 59%, cardiac index (CI) of 2.8 L/min/m^2, and pulmonary vascular resistance (PVR) of 11.3 Wood Units (WU). To explore the aetiologies of PH, subsequent examinations were conducted for the patient, including ventilation–perfusion scintigraphy, which revealed no perfusion in the right lung. Additionally, computed tomography pulmonary angiography (CTPA) demonstrated a subtotal occlusion in the proximal right pulmonary artery with the ratio of RV to LV (RV/LV) dimensions being 1.06 in the four-chamber view (*Figure 2*).

Initially, acute pulmonary embolism (PE) and chronic thromboembolic pulmonary hypertension (CTEPH) were considered but excluded due to negative D-dimer test, lack of prior PE episodes, and absence of PE risk factors. Further investigation including erythrocyte sedimentation rate (ESR) and C-reactive protein, both of which were normal, and magnetic resonance angiography (MRA) revealed subtotal occlusion of the right pulmonary artery, wall thickening, and delayed enhancement of both right and main pulmonary arteries, indicative of TA. No stenosis, aneurysmal dilatation, or delayed aortic wall enhancement was detected in the aorta and its branches (*Figure 3*). A multidisciplinary team, including immunology specialists, diagnosed the patient with PAS and PH caused by TA, which is currently in remission, based on the normalization of ESR, C-reactive protein levels, and MRA findings.

She was started on oral prednisone 10 mg daily, and oral bosentan 125 mg twice a day. Given the patient's refusal of surgical pulmonary endarterectomy, the patient underwent three sessions of balloon pulmonary angioplasty (BPA) over a period of 12 weeks. Following the final BPA session, the patient experienced substantial symptoms relief, and the NT-proBNP level returned to normal. Further, The RHC showed a mPAP of 28 mmHg, PAWP of 7 mmHg, SvO_2 of 75%, CI of 2.7 L/min/m^2 SvO2 and PVR of 4.67 WU (*Figure 4*; Supplementary material online, *Videos S1–S3*). The patient continued to receive oral prednisone 5 mg daily and oral bosentan 62.5 mg twice a day. Anticoagulation (rivaroxaban 20 mg) was initially administered due to the risk of thrombosis from subtotal pulmonary artery occlusion after the first BPA session. However, after 10 months, we replaced it with antiplatelet therapy as the patient's condition had stabilized with sustained vessel patency confirmed via follow-up imaging and the risk of increased menstrual bleeding outweighed the benefits of continued anticoagulation. At 7-month follow-up after the final BPA session, the

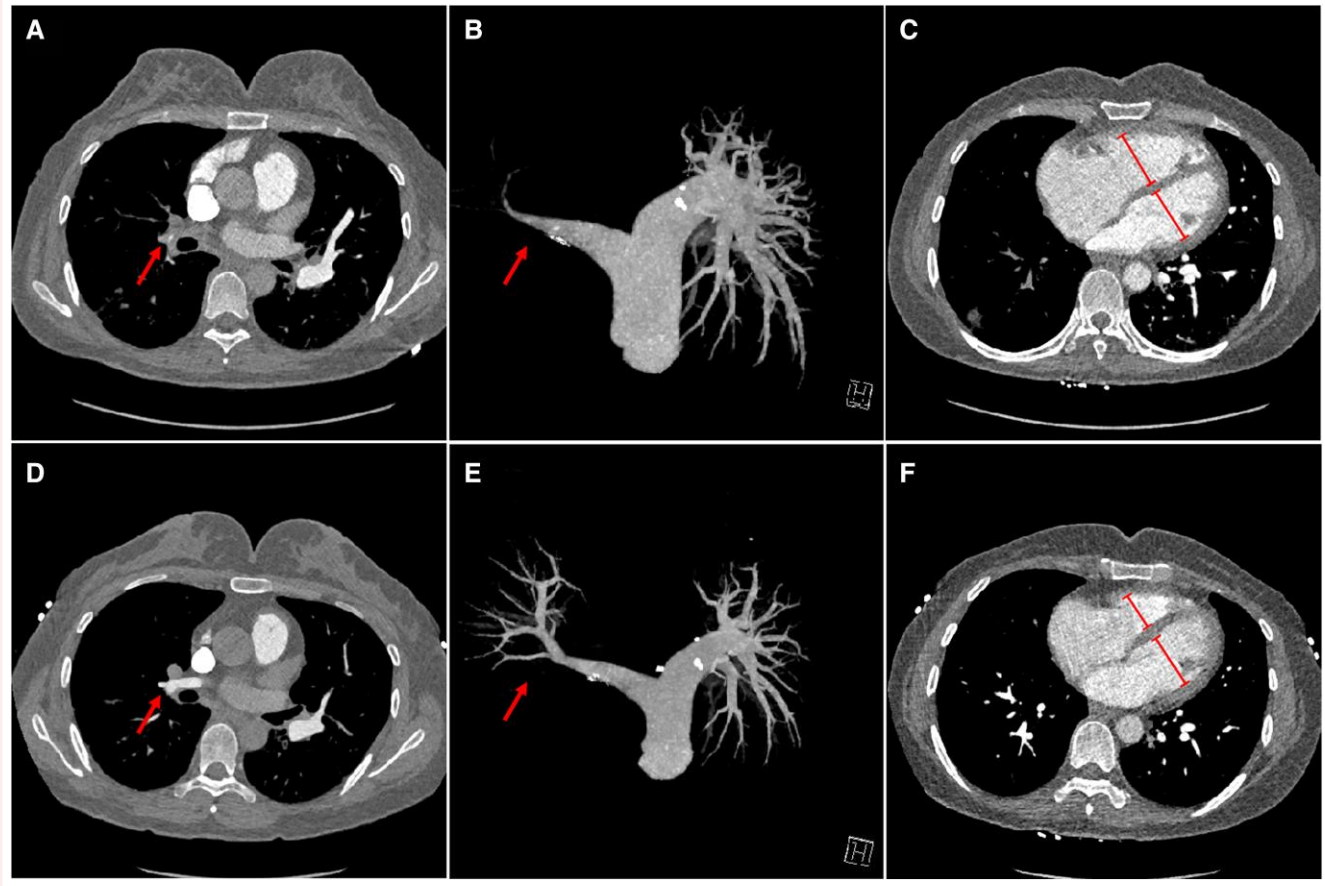

Figure 2 Initial computed tomography pulmonary angiography demonstrates subtotal occlusion in the proximal right pulmonary artery (*A*, *B*) and right ventricle to left ventricle dimension ratio is 1.06 in the four-chamber view (*C*). Follow-up at week 92 demonstrates re-opened right pulmonary artery (*D*, *E*) and right ventricle to left ventricle dimension ratio is 0.56 in the four-chamber view (*F*).

ECG showed a decrease in S-wave amplitude in lead I and R-wave amplitude in aVR (R/S > 1 in lead I, R/Q < 1 in lead aVR). The inverted T-waves reverted to an upright position (except for V1) (*Figure 1*). By the 18-month follow-up, the CTPA demonstrated no restenosis of the right pulmonary artery and a notable reduction in RV/LV dimensions ratio to 0.56 *(Figure 2*). At 35-month follow-up, RHC showed mPAP of 30 mmHg, and PAWP of 12 mmHg, CI of 3.2 L/min, and PVR of 3.39 WU. She maintained good exercise capacity with WHO functional class Ⅰ and 6 min walk distance of 465 m. At 59-month follow-up, echocardiography showed normal RV with a RV area of 13 cm^2 and normal NT-proBNP level and ECG. The patient is being followed up regularly, including ECG and echocardiography every six months and RHC every year.

Discussion

When discussing dyspnoea accompanied by T-wave inversions on an ECG, conditions such as CAD, myocarditis, cardiomyopathy, and PE are often considered.[1] Pulmonary artery stenosis can also lead to T-wave inversion or flattening in multiple leads. Other characteristic ECG findings include right axis deviation, right bundle branch block, deep S wave in lead I (R/S < 1) and prominent R wave in lead aVR (R/Q > 1), which have been termed as PAS syndrome.[2] These changes may be indicative of RV pressure overload and potential endocardial ischaemia.[3]

Takayasu arteritis is a chronic idiopathic granulomatous large-vessel vasculitis that primarily affects the aorta and its major branches, leading to vascular stenosis or occlusion.[4] In young East Asian females, TA-associated PH is not uncommon, with a significant proportion of TA cases developing PH as a consequence of PAS.[5,6] Owing to the atypical symptoms, early diagnosis is challenging and often overlooked or misdiagnosed.[6,7] The ECG, a staple in clinical diagnostics, offers a non-invasive, cost-effective, and timely method for detecting such conditions. Particular attention should be given to young Asian females, where PAS may be linked to TA. In addition, conditions like CTEPH, fibrosing mediastinitis-induced PAS, mediastinal tumours can also lead to PAS,[2,8,9] presenting with similar ECG alterations. Dynamic ECG changes may also indicate the reversal of right heart remodelling, underscoring the importance of continuous monitoring.

For patients with TA-induced PAS where surgical is not feasible, BPA offers a promising alternative.[10,11] This case report emphasizes the normalization of ECG findings following BPA treatment, indicating the reversal of right heart remodelling. The long-term efficacy of the interventions has been confirmed by sustained improvements observed during a 59-month follow-up period. Hence, early detection and prompt treatment are vital for improving outcomes in patients with PAS and PH associated with TA. It is worth noting that the selection of anti-thrombotic strategies after BPA in patients with TA-induced PAS is mostly empirical, and there is no consensus among centres, which needs further study in the future.

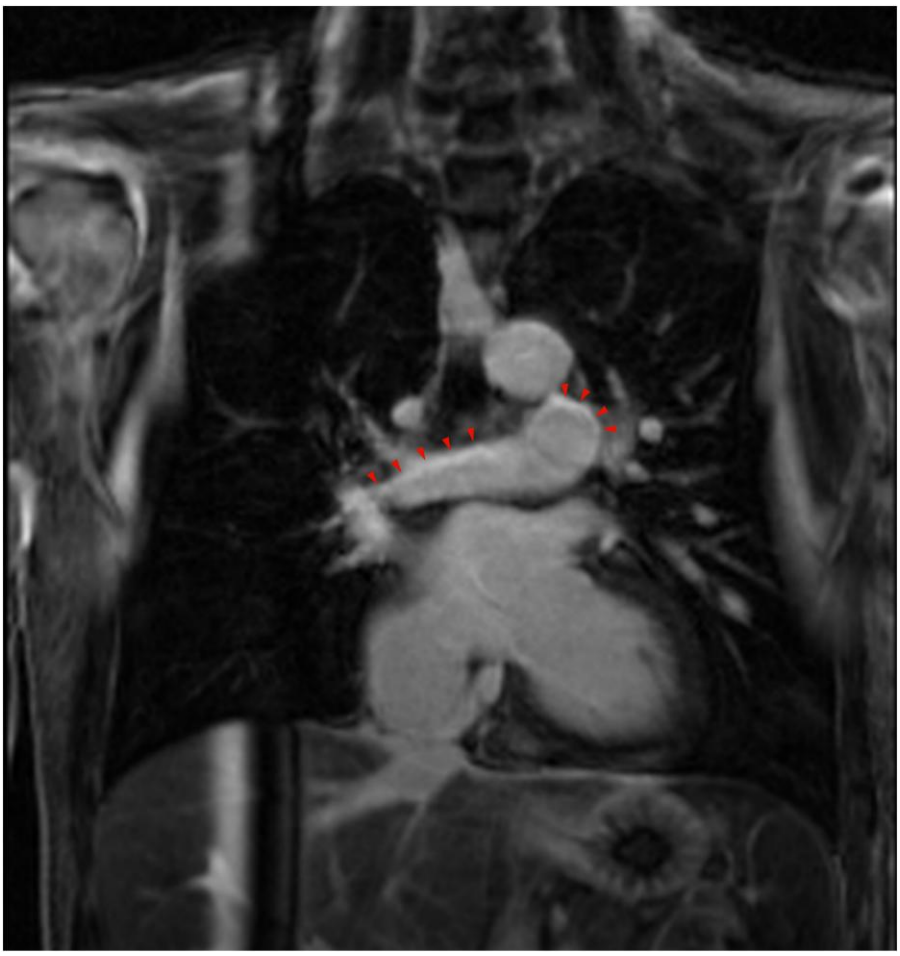

Figure 3 Magnetic resonance angiography demonstrates subtotal occlusion of the right pulmonary artery, wall thickening, and delayed enhancement of both right and main pulmonary arteries.

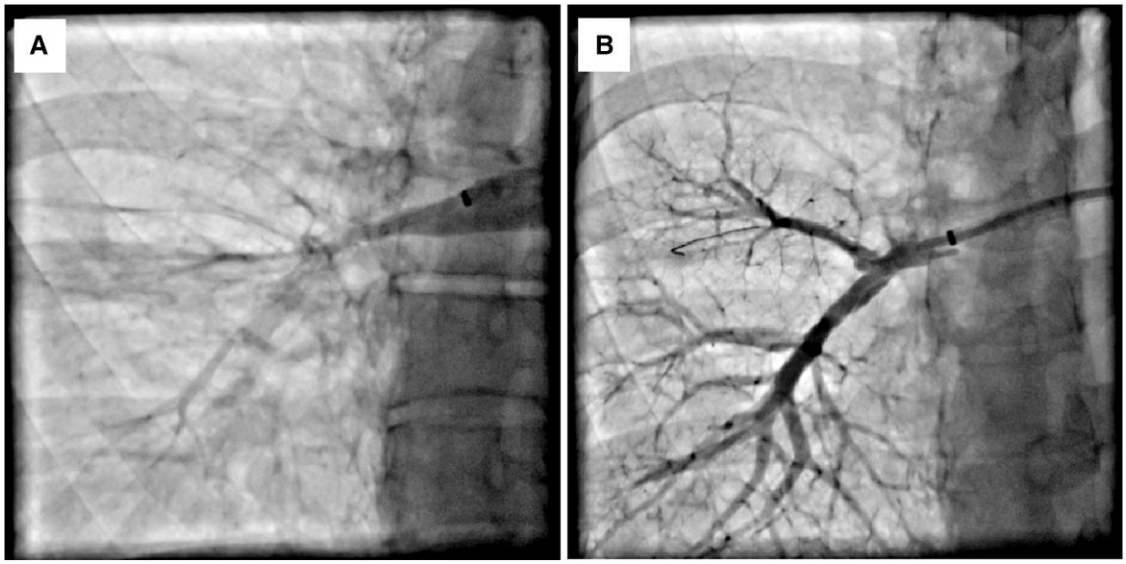

Figure 4 Pulmonary angiography at admission (*A*) and after three sessions of balloon pulmonary angioplasty (*B*).

Lead author biography

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Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports* online.

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Data availability

The data underlying this article are available in the article and in its online supplementary material.

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