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Case Report

Endovascular transatrial stenting of pulmonary vein stenosis after lung transplantation

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ABSTRACT

Pulmonary vein stenosis (PVS) and pulmonary vein occlusion (PVO) represent rare complications after lung transplantation (LTx), with limited therapeutic options and a high risk of graft loss. We present 2 cases of successful endovascular transatrial stenting following double LTx. A 60-year-old woman with chronic obstructive pulmonary disease who underwent double lobar LTx was diagnosed at postoperative day 72 with a high-grade PVS on the left side. A 22-year-old woman with idiopathic pulmonary arterial hypertension who underwent double LTx was diagnosed 9 days later with PVO of the left upper lobe vein. To avoid surgical reintervention, endovascular transatrial dilatation and stenting were performed successfully in both cases. Transatrial endovascular stenting of PVS or PVO after LTx seems an effective and safe treatment option that should be considered for these life-threatening complications and executed with care.

1. Introduction

Pulmonary vein (PV) anastomosis in lung transplantation (LTx) can be complicated by pulmonary vein stenosis (PVS) or pulmonary vein occlusion (PVO) due to compression, kinking, or vascular wall injury. PVS and PVO may result in thrombosis with increased capillary congestion and ventilation/perfusion (V/Q) mismatch resulting in hypoxemia, edema, pleural effusion, or hemodynamic collapse.

PVS represents a rare but life-threatening complication after LTx, with a prevalence of 1.4% and mortality of up to 45%.[1] Diagnosing PVS remains challenging owing to its clinical presentation resembling primary graft dysfunction (PGD), infection, or acute rejection. Standard diagnostic modalities include transesophageal echocardiography (TEE), computed tomography angiography (CTA), or magnetic resonance imaging. Treatment options include open repair, lobectomy/pneumonectomy, or retransplantation. Although an endovascular approach for PVS following catheter ablation for atrial fibrillation is well-described,[2] angioplasty with stenting has rarely been reported after LTx.[3-8]

We present 2 cases of PVS and PVO following double LTx, successfully treated with endovascular transatrial stenting, and provide an overview of the reported experience after LTx. The ethics committee of University Hospitals Leuven approved reporting (S51577).

Abbreviations: CTA, Computed tomography angiography; LA, Left atrium; LL, Left lung; LTx, Lung transplantation; LULV, Left upper lobe vein; PGD, Primary graft dysfunction; PG, Peak instantaneous gradient; POD, Postoperative day; PV, Pulmonary vein; PVO, Pulmonary vein occlusion; PVS, Pulmonary vein stenosis; TEE, Transesophageal echocardiography; V/Q, Ventilation/perfusion.

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2. Case report

2.1. Case 1

A 60-year-old woman (height, 163 cm; weight, 58 kg) with chronic obstructive pulmonary disease underwent double lobar LTx (right lower/middle lobe and left lower lobe) in July 2020 under venoarterial extracorporeal membrane oxygenation support. The donor was a brain-dead 32-year-old man (height, 190 cm; weight, 95 kg).

PGD at 0, 24, 48, and 72 hours after LTx was 2, 2, 2, and 1, respectively.[9] The patient could not be weaned off the ventilator, requiring tracheostomy on the postoperative day (POD) 11. Frequent left lung (LL) aspiration was performed for impaction. On POD 53, bilateral thoracic drainage was required for pleural effusion, and TEE 5 days later revealed left PVS, confirmed using CTA (residual diameter: 3.7 mm over 6 mm) (Fig. A, B). Right/left perfusion scintigraphy was 88%/12%.

As the patient remained stable, the initial treatment was conservative. However, intermittent mechanical ventilation was continuously needed. Therefore, an endovascular approach was performed on POD 131. An 8<11-F sheath was placed in the right femoral vein. Through the right atrium, a transatrial puncture was performed. The solitary left PV was passed using a Progreat Micro Catheter (Terumo) and 4-F vertebral catheter. Interrogation with 12-mm balloon dilatation (4401204X Powerflex, Cordis) was performed; subsequently, a 26-mm stent (EV3 Intrastent-LDMAX; S18-26, Medtronic) was deployed up to 12 mm.

An immediate hemodynamic response was observed, and the peak pulmonary velocity over stenosis dropped from 147 cm/s (Fig. C) to 60 cm/s. A pressure Peak instantaneous gradient (PG) between PV and left atrium (LA) measured before stenting was 9 mmHg, evolving to laminar flow without significant pressure PG after stenting. Acetylsalicylic acid at 80 mg was initiated.

Seven days after intervention, the patient was definitely extubated and discharged from the intensive care unit on POD 152 and from the hospital on POD 176. Follow-up computed tomography and V/Q scans obtained 65 days after stenting showed an in-stent diameter of 10 mm (Fig. D) and right/LL perfusion of 59%/41%. At the last follow-up (POD 550), pulmonary function remained stable with a forced vital capacity of 1.86 L/60% and a forced 1-second expiratory volume of 1.67 L/68%.

2.2. Case 2

A 22-year-old woman (height, 163 cm; weight, 74 kg) with pulmonary hypertension underwent double LTx in October 2021 under venoarterial extracorporeal membrane oxygenation support. The donor was a brain-dead 27-year-old woman (height, 159 cm; weight, 63 kg). LL implantation was challenged by a hypertrophic heart, and the PV bifurcation was too proximal for atrial anastomosis, for which both recipient's veins were reunited to create a single cuff (Fig. E).[10]

Due to bilateral pulmonary edema and limited cardiac function, extracorporeal membrane oxygenation was continued for 2 days (PGD3 at all time points).[9] Although the right ventricle recuperated, the patient could not be weaned off ventilation and the LL remained consolidated, accompanied by pleural effusion (Fig. F). CTA on POD 5 revealed an LA thrombus but patent pulmonary veins. A V/Q scan obtained on POD 9 showed 22.5% LL perfusion with upper/lower lobe distribution of 5.6%/16.9%. On POD 10, right-side heart catheterization and transatrial puncture via a 6<11-F sheath in the right femoral vein was performed. Occlusion of the left upper lobe vein (LULV) was diagnosed (Fig. G).

After interrogation, a kink, distal of the anastomosis, was passed with a guidewire (Terumo), revealing a patent PV filled with thrombi (Fig. H). A 12-mm balloon (Tyshack, Braun) interrogation was performed, which revealed safe stretchability up to 10 mm; a 10/20-mm stent (Cook Medical) was implanted.

The peak pulmonary velocity over stenosis dropped from 172 cm/s before stenting to 77 cm/s after stenting. The PG between LULV and LA before stenting was 12 mmHg, which restored to laminar flow. Low-molecular-weight heparin (Enoxaparin 60 mg) was initiated and switched to oral anticoagulants (Edoxaban 30 mg) for deep venous thrombosis.

A tracheostomy was placed on POD 18, and the patient became ventilator independent on POD 36; she was discharged from the intensive care unit 5 days later and from the hospital on POD 61. Follow-up

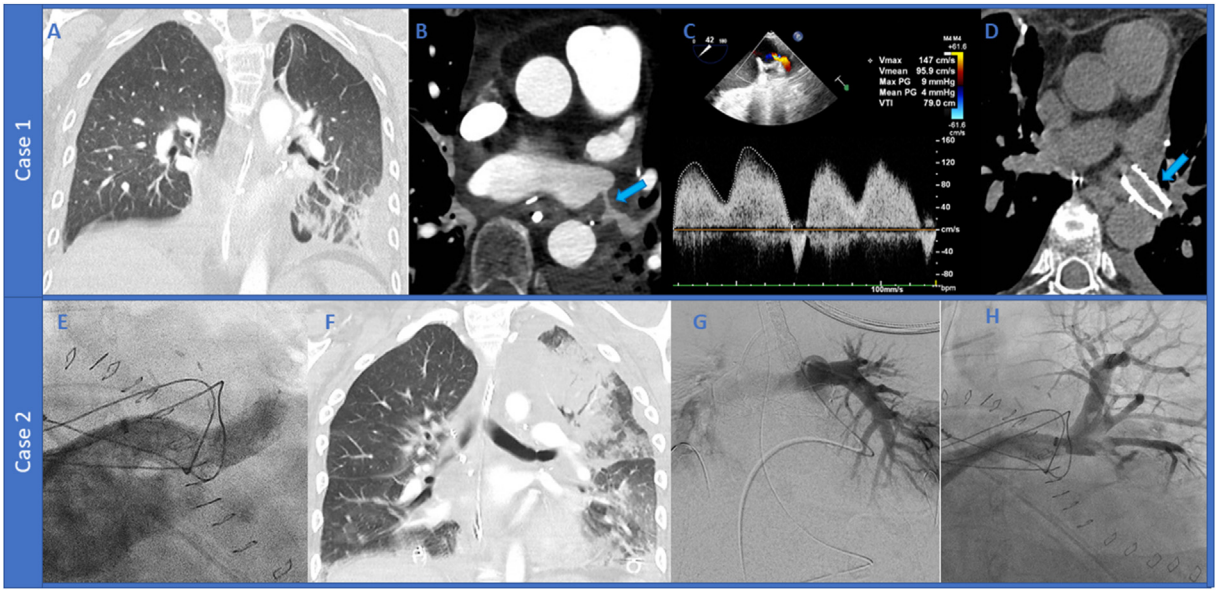

Fig. Case 1: ((A) Coronal plane CTA on the postoperative day 72, bilateral (Left more pronounced) lung consolidation and pleural effusion. (B) Transverse plane CTA, arrow: pulmonary vein stenosis. (C) Transesophageal echocardiography depicting increased pulmonary velocity over stenosis. (D) Transverse plane CTA performed 65 days after intervention, arrow: stent. Case 2: (E) Heart catheterization, visualization of side-to-side recipient venous anastomosis, creating a "donut-like" shape when anastomosed end-to-end with the donor atrial cuff. (F) Coronal plane CTA on the postoperative day 5, left lung consolidation, and pleural effusion concentrated in the left upper lobe. (G) Heart catheterization contrast injection visualized only lower pulmonary vein due to left upper lobe vein occlusion. (H) Heart catheterization contrast injection, visualization of left upper lobe vein with thrombi after pulmonary vein occlusion passing. CTA, computed tomography angiography; Vmax, maximum velocity; Vmean, mean velocity; PG, peak instantaneous gradient; VTI, velocity time integral.

computed tomography and V/Q scans obtained 83 days after stenting confirmed a patent LULV with 10.5-mm diameter and LL (upper/lower lobe distribution) perfusion of 42% (19%/23%), respectively. Pulmonary function at the last follow-up (POD 133) remained stable with a forced vital capacity of 1.72 L/45% and a forced 1-second expiratory volume of 1.46 L/44%.

3. Discussion

We describe 2 cases of successful transatrial endovascular stenting of the left PV after LTx, avoiding surgical reintervention.

Eight other cases of endovascular PVS treatment, all isolated LTx, have been reported (Table).[3-8,11,12] Most common clinical presentations were respiratory insufficiency, pulmonary edema, or pleural effusion. In 89% (8/9) of the cases, CTA confirmed PVS at a mean of 215 days after LTx. All reported PVS diameters were ≤4 mm. The mean pressure gradient over PVS was 18 mmHg. The diameter of all implanted stents was ≥10 mm. Stenting was performed in 78% (7/9) of the cases. Antithrombotic strategy ranged from monotherapy to triple therapy. Symptoms resolved in 78% (7/9) of the cases and recurred in 2 patients who died.

These findings suggest that single LTx might have a higher risk of developing symptomatic PVS than double LTx, owing to limited compensation by the contralateral diseased lung. Apart from optimization of caliber mismatch, surgical strategies to avoid PVS/PVO are stay sutures for orientation, prevention of kinking by limiting the vessel length, and techniques for resizing short atrial cuffs.[13,14]

According to the literature, PVS after LTx could be considered from a peak PV velocity of 100 to 120 cm/s (mean reported velocity, 208 ± 86 cm/s) and a diameter of <5 mm or 50% reduction in comparison to the contralateral PV.[1,15] Contributing factors to the development of PVS/PVO could be changing intrathoracic pressures, heart remodulation, edema, infection, or hemorrhagic complications. Likely, the PVO in case 2 occurred with right ventricle normalization after LTx.

Early PVS/PVO is challenging to diagnose because of its clinical presentation resembling PGD, infection, or acute rejection. Late post-transplant PVS can resemble infection or allograft rejection. Early imaging by CTA, TEE, magnetic resonance imaging, heart catheterization, or V/Q scan is critical.

Management ranges from conservative to open repair, graft removal, retransplantation, or endovascular stenting. A conservative approach (pharmaceutic management of edema, intensive rehabilitation, and

Table
Literature review.

	Reference	Sex, age (y)	Primary diagnosis	Type of Tx	Location of PVS	Clinical presentation[a]	Diagnosis modality	Time of diagnosis after surgery	PV diameter
PVS	Clark et al[3] (1996)	F, 32	FA	LSL	LPV	1	ANG	4 d	Information NA
	Zimmermann et al[4] (2009)	M, 42	IPF	RSL	URPV	1, 2	CTA	16 d	0.4 cm
	Pazos-López et al[5] (2010)	F, 31	IPF	LSL	LLPV	1	TEE, CTA	11 d	Information NA
	Loyalka et al[6] (2012)	M, 56	IPF	LSL	LLPV	1	CTA	Early postoperative period	0.17 cm^2 PVA
	Mohamed Mydin et al[11] (2012)	M, 63	IP	RSL	LRPV	1	CTA	12 mo	0.2 cm
	Rashad et al[12] (2015)	F, 64	IPF	RSL	URPV, LRPV	3	TEE, CTA	8 mo	Information NA
	Jobanputra et al[7] (2017)	F, 60	IPF	LSL	CLPV	1	TEE, CTA	14 mo	0.15 cm^2 SSA
	Jing et al[7] (2021)	M, 31	HP	LSL	ULPV, LLPV	1, 2, 3	CTA	19 mo	0.20 cm, 0.25 cm
	Orlitová et al, case 1	F, 60	COPD	BLL	LLPV	1, 2, 3	TEE, CTA	72 d	0.30 cm
PVO	Orlitová et al, case 2	F, 22	IPH	SSL	ULPV	1, 2, 3	TEE, CTA, ANG	10 d	PVO, microchannel

	Reference	PPCFV (cm/s)	PV PG (mmHg)	Time of stenting	Type of stent (mm)	Antithrombotic therapy	Outcome
PVS	Clark et al[3] (1996)	Information NA	Information NA	Several mo post-LTx	Wall stent	Information NA	21 mo after LTx: RF, GIT bleed
	Zimmermann et al[4] (2009)	Information NA	Information NA	16 d after LTx	⊖ 10 × 16	100 mg/d A + 75 mg/d C for 6 mo + P 3 mo	No symptoms at 6 mo
	Pazos-López et al[5] (2010)	240	20	15 d after LTx	⊖ 10 × 19	150 mg/d A + 75 mg/d C for 6 mo + Ac 3 mo	No symptoms at 20 d
	Loyalka et al[6] (2012)	Information NA	8	Information NA	⊖ 10 × 25	325 mg/d A, 75 mg/d C	No symptoms at 1 mo
	Mohamed Mydin et al[11] (2012)	Information NA	7	No stent, only dilatation	Information NA	Information NA	Recurrence after 2 mo, died 6 wk later
	Rashad et al[12] (2015)	Information NA	Information NA	No stent, only dilatation	Information NA	Information NA	No residual symptoms
	Jobanputra et al[7] (2017)	Information NA	12-16	>1 y after LTx	⊖ 10 × 29	A + C + W for 1 mo, after A + W	No symptoms at 3 mo
	Jing et al[7] (2021)	Information NA	40	>1 y after LTx	⊖ 10 × 25	LMWH + W for 20 d, after W + C	No symptoms at 10 mo
	Current study, case 1	147	9	131 d after LTx	⊖ 12 × 26	A 80 mg/d	No symptoms at 10 mo
PVO	Current study, case 2	172	12	10 d after LTx	⊖ 10 × 20	LMWH 60 mg, after Ed 30 mg	No symptoms at 4 mo

A, acetylsalicylic acid; Ac, acenocoumarol; ANG, angiography; BLL, bilateral lobar lung; C, Clopidogrel; CLPV, common left pulmonary vein; COPD, chronic obstructive pulmonary disease; CTA, computed tomography angiography; Ed, edoxaban; F, female; FA, fibrosing alveolitis associated with rheumatoid arthritis; GIT, gastrointestinal tract; HP, hypersensitivity pneumonitis; IP, interstitial pneumonitis; IPF, idiopathic pulmonary fibrosis; IPH, idiopathic pulmonary hypertension; LLPV, lower left pulmonary vein; LMWH, low-molecular-weight heparin; LPV, left pulmonary vein; LSL, left single lung; LTx, lung transplantation; M, male; NA, not available; P, phenprocoumon; PG, pressure gradient; PPCFV, peak pulmonary cuff velocity; PV, pulmonary vein; PVA, pulmonary vein surface area; PVO, pulmonary vein occlusion; PVS, pulmonary vein stenosis; RF, respiratory failure; RSL, right single lung; SSA, stenotic segment area; SSL, sequential single lung; TEE, transesophageal echocardiography; Tx, transplantation; ULPV, upper left pulmonary vein; URPV, upper right pulmonary vein; W, warfarin; ⊖, diameter.

[a] Clinical presentation: 1, respiratory insufficiency; 2, pulmonary edema; 3, pleural effusions.

watchful waiting) has been described in patients with mild PVS after atrial fibrillation ablation. It can lead to symptom improvement due to collateral formation or recruitment.[2] In the case of PVO, immediate treatment is required.

Surgical revision after transplantation can be challenging because of adhesions and the risk of graft loss, requiring retransplantation. An endovascular approach offers a valuable alternative with limited risk of complications, including LA perforation, PV dissection, stent embolization, or thrombosis.[2] However, endovascular balloon dilatation of a fresh anastomosis can lead to rupturing and uncontrollable bleeding. In our experience, the best approach is interrogation with a soft compliant balloon (20% larger than the surrounding vessel) to assess the stretchability of the anastomosis, followed by stent implantation at the assessed size, which can be further dilated at a later stage.

In conclusion, transatrial endovascular treatment of PVS/PVO after LTx seems an effective and safe treatment that should be considered in the surgical LTx armamentarium and executed carefully to tackle these challenging complications.

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Data availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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