



Intravascular ultrasound imaging of pulmonary artery with high-altitude pulmonary hypertension

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Introduction

High-altitude pulmonary hypertension (HAPH) arises from prolonged exposure to high altitudes. It is recognized as a distinct category of pulmonary hypertension (PH) according to the third clinical classification of PH, according to 2022 European Society of Cardiology (ESC) and European Respiratory Society (ERS) Guidelines (1). The population residing at altitudes exceeding 2,500 meters above sea level exceeds 140 million, with approximately 40 million temporary mountain visitors (2-4). Due to a significant population being exposed to the effects of high altitude, HAPH has emerged as a notable public health concern in mountainous regions worldwide (5). Data on the prevalence of HAPH are limited, which is likely to differ based on altitude and ethnic factors. For example, approximately 14% of Kyrgyz highlanders have shown electrocardiograph evidence of right ventricular hypertrophy (6).

A precise comprehension of the structural aspects of pulmonary artery tissue is valuable for clinical diagnosis, condition assessment, treatment, monitoring, and prognostic evaluation in HAPH (5). Intravascular ultrasound (IVUS) is an interventional imaging modality that can provide real-time cross-sectional images of blood vessels, offering clear visualization of the blood vessel wall structure (7). IVUS stands out as one of the most accurate methods for detecting vascular abnormalities. For example, IVUS has been used for spontaneous dissection of the internal carotid artery in acute stroke (8). There

are no studies to date that have used IVUS to evaluate the structure of pulmonary artery tissue in HAPH. Therefore, in this report, we present a case with a clinical diagnosis of HAPH, wherein the structure of the pulmonary artery was clearly examined using IVUS.

Case presentation

A 76-year-old man, a long-term resident of Xizang at an altitude of 3,200 meters, was a native to high altitudes. He had a medical history of HAPH, heart failure, and essential hypertension. At the time, he was admitted to the hospital (Changdu People's Hospital, Changdu, China) complaining of shortness of breath during activity for three months. Rough breathing and slight murmur can be heard by physical examination. The echocardiography revealed elevated pulmonary artery pressure of 48 mmHg. However, left ventricular function was within normal parameters with ejection fraction 58%. The patient was diagnosed as heart failure with preserved ejection fraction because of the N-terminal pro brain natriuretic peptide (NT-proBNP) was 2,034 pg/mL and cardiac ultrasound ejection fraction was 58%. The vital signs, laboratory examination and echocardiography of the patient are shown in *Tables 1-3*. Further evaluation through cardiac catheterization showed a pulmonary arterial pressure of 47/16 mmHg. The mean pulmonary pressure was 26.3 mmHg. Pulmonary wedge pressure was measured at

Table 1 Patient's characteristics and baseline hemodynamics

Patient's characteristics	Results
Age (years)	76
Weight (kg)	76
Height (cm)	172
BMI (kg/m ²)	26.7
Blood pressure (mmHg)	154/80
Heart rate (beats/min)	81
Respiratory rate (times/min)	21
SpO ₂ (%)	91

BMI, body mass index; SpO₂, saturation of pulse oxygen.

Table 2 Basic laboratory examination results from the patient

Laboratory tests	Results
NT-proBNP (pg/mL)	2,034
Blood routine examination	
RBC (10 ⁹ /L)	6.12
WBC (10 ⁹ /L)	4.4
PLT (10 ⁹ /L)	161
Hemoglobin (g/L)	182
Arterial blood gas analysis	
pH	7.39
PaCO ₂ (mmHg)	44
PaO ₂ (mmHg)	64
HCO ₃ ⁻ (mmol/L)	25
O _{2sat} (%)	86
BE (mmol/L)	-1

NT-proBNP, N-terminal pro brain natriuretic peptide; RBC, red blood cell; WBC, white blood cell; PLT, platelets; pH, power of hydrogen; PaCO₂, partial pressure of carbon dioxide; PaO₂, partial pressure of oxygen; HCO₃⁻, bicarbonate anion; O_{2sat}, oxygen saturation; BE, base excess.

12 mmHg. The computed tomography imaging displayed dilation of the main pulmonary artery (*Figure 1*). Therefore, the patient was diagnosed with HAPH based on the patient's residence at an altitude of more than 2,500 meters, chronic exposure to hypoxia, clinical manifestations of shortness of breath, and elevated mean pulmonary artery pressure by the right heart catheter (more than 20 mmHg is considered PH according to 2022 ESC/ERS Guidelines for the diagnosis

Table 3 Echocardiography examination results from the patient

Echocardiography	Results
Echocardiographic examination	
Aortic root (mm)	29
Aortic valve calcification	None
Left atrium (mm)	29
Left ventricle	
EDD (mm)	52
ESD (mm)	38
FS (%)	26
IVS (mm)	12
PW (mm)	8
EF (%)	58
Right atrium (mm)	40
Right ventricle (mm)	25
Pericardial effusion	None
Doppler examination	
Aortic valve	
Peak flow (m/s)	0.79
Gradient (mmHg)	3
Regurgitation	None
Mitral valve	
E wave velocity (m/s)	0.2
A wave velocity (m/s)	0.4
E/A ratio	0.5
Regurgitation	Mild
Tricuspid valve	
Regurgitation	Mild
V max (m/s)	3.28
RAP (mmHg)	8
Pulmonic valve	
Regurgitation	Mild
PAsP (mmHg)	48

EDD, end-diastolic diameter; ESD, end-systolic diameter; FS, fractional shortening; IVS, inter-ventricular septum; PW, post wall; EF, ejection fraction; RAP, right atrial pressure; PAsP, pulmonary artery systolic pressure.

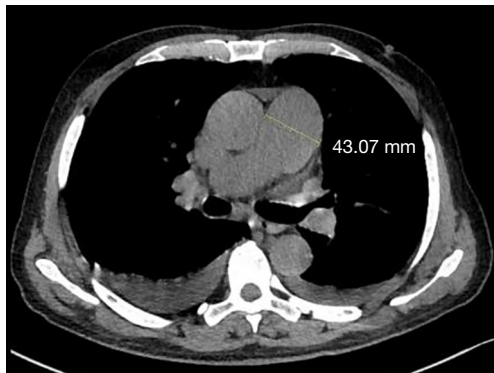


Figure 1 The computed tomography image illustrates a significant dilation of the main pulmonary artery, with a diameter of 43.07 mm.



Figure 2 This image displays the lower left pulmonary angiography. Angiography showed mild dilation of the left lower pulmonary artery, no stenosis, smooth intima, and normal blood flow.

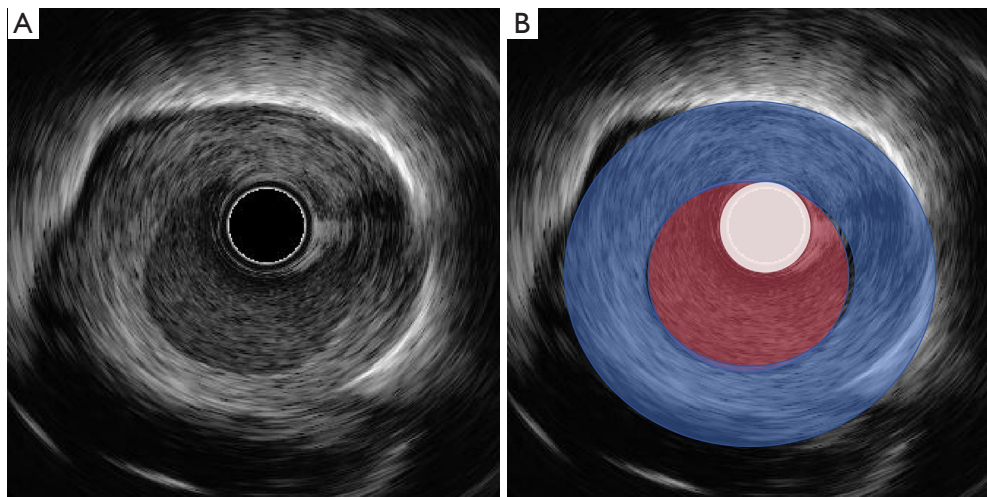


Figure 3 The cross-sectional image of the lower left pulmonary arteriole. (A) Depicting the arteriole at a specific level of the arteriole with a lumen diameter of 2.62–3.06 mm, luminal area of 6.46 mm² and a thickened intima measuring 0.61–1.1 mm in the patient with HAPH. (B) Illustration of the structure diagram corresponding to (A), where the white area represents the IVUS catheter, the red area represents the lumen filled with blood, and the blue area indicates the thickened inner membrane of the pulmonary artery. HAPH, high-altitude pulmonary hypertension; IVUS, intravascular ultrasound.

and treatment of PH) (1), and it is essential that the left-sided cardiac disease, chronic lung disease and pulmonary embolism were excluded. Following pulmonary angiography (Figure 2), IVUS was performed. A 40 MHz IVUS catheter (TRUEVISION, Insight Lifetech, China) was sent to the lower left pulmonary artery. The IVUS images of the distal pulmonary artery are presented in Figure 3A,3B. Centripetal thicker intimal layers were clearly observed, while no evidence of mural thrombus was found. These findings aligned with the pathological changes associated

with HAPH. Low-flow oxygen inhalation at 1 L/min was administered for eight hours every day to maintain SaO₂ 95%. The blood pressure was reduced to the normal range after oral administration of Irbesartan 150 mg once daily. The patient reported that the symptom of shortness of breath was significantly relieved after one week. After oxygen inhalation and symptomatic treatment, the patient experienced an improvement in symptoms.

All procedures performed in this study were in accordance with the ethical standards

of the Changdu People's Hospital research committee and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient for publication of this article and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

Discussion

PH is a hemodynamic and pathophysiological condition characterized by a mean pulmonary artery pressure increase of over 20 mmHg, resulting in right heart failure (9). PH is a prevalent and often progressive condition associated with a high rate of disability and mortality, requiring careful attention and management.

HAPH is characterized by elevated pulmonary vascular resistance, resulting from hypoxia-induced pulmonary vasoconstriction and remodeling of pulmonary arterioles (10). The partial pressure of oxygen at 3,000 meters above sea level is only 69% of that on the plain. Many people who live at high altitude for a long time suffer from high altitude heart disease and high-altitude PH. The vascular modifications encompass several components of the vessel wall, including endothelial dysfunction, smooth muscle expansion in previously non-muscular vessels, and intimal thickening (11,12). An accurate comprehension of the structure of pulmonary artery tissue is valuable for clinical diagnosis, condition assessment, treatment improvement, monitoring, and prognosis determination in HAPH.

Previous imaging modalities have included chest radiography, echocardiography, right heart catheterization, and pulmonary artery computed tomography angiography (CTA). However, none of them are capable of adequately revealing the thin structure of the pulmonary artery (13). IVUS provides real-time cross-sectional images of blood vessels, presenting a clear view of the thin structure of the blood vessel wall (7,8). There were two studies reported that changes of PH observed with IVUS imaging correlated well with histopathologic grade (14,15). Thus, IVUS may have significant utility in the evaluation of pulmonary vascular morphology in patients with PH.

IVUS has been used to detect other forms of PH; however, the resulting images are often unclear (16-18). IVUS measurements of 20 consecutive patients with primary PH showed that they had thickened pulmonary artery walls. However, the vascular lining cannot be clearly shown because of the poor IVUS image quality (17). It was reported that the total vessel dimensions of the vessels

studied in patients with mitral stenosis and in those with PH of other etiologies are not significantly different (18). IVUS is useful in PH assessment by evaluating pulmonary vascular properties and predicting mortality (19). Lau *et al.* used IVUS to evaluate the mechanical properties of the elastic pulmonary arteries in subjects with PH, and assessed the effects of PH-specific therapy on indices of arterial stiffness (20).

Furthermore, there are no prior studies using IVUS to detect HAPH. Given the distinct pathological manifestations, hemodynamic features, and clinical approaches to diagnosis and treatment of HAPH compared to other forms of PH, accurate detection of the arterial tissue structure in HAPH using IVUS has significant clinical relevance. In this particular case, IVUS was employed for the first time to clearly evaluate the structural characteristics of pulmonary artery tissue in HAPH.

Conclusions

In summary, IVUS has been demonstrated to be safe and feasible, providing a clear visualization of the structural characteristics of the pulmonary artery tissue in HAPH. This technique holds significant promise in aiding the diagnosis and treatment of HAPH.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-1348/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All the study procedures were in accordance with the ethical standards of the Changdu People's Hospital research committee and with the Helsinki Declaration (as revised in 2013). Written

informed consent was obtained from the patient for publication of this article and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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