Letter to the Editor

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

**Yunfei Pu[1,2#], Gaohua Li[2#], Teng Zhang[2#], Yuxuan Cui[2], Bin Li[2], Chunqiu Liu[2,3], Yeqing Li[1]**

[1]Department of Cardiology, Chongqing General Hospital, Chongqing, China; [2]Department of Internal Medicine, Changdu People's Hospital, Changdu, China; [3]Department of Nephrology, Chongqing University Three Gorges Hospital, Chongqing, China

[#]These authors contributed equally to this work.

*Correspondence to:* Yeqing Li, MD. Department of Cardiology, Chongqing General Hospital, No. 118, Xingguang Avenue, Liangjiang New Area, Chongqing 401147, China. Email: gungunlyq@126.com.

Submitted Sep 21, 2023. Accepted for publication Feb 15, 2024. Published online Mar 27, 2024.
doi: 10.21037/qims-23-1348
**View this article at:** https://dx.doi.org/10.21037/qims-23-1348

## 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; $SpO_2$, 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; $PaCO_2$, partial pressure of carbon dioxide; $PaO_2$, partial pressure of oxygen; $HCO_3^-$, 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.

 

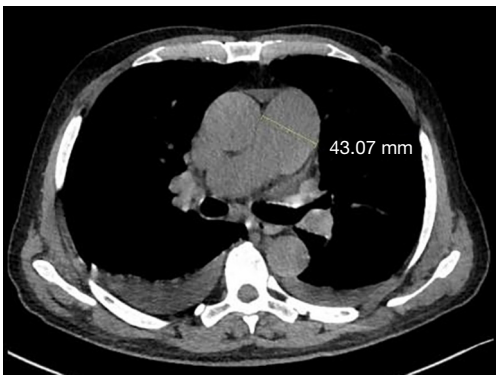


**Figure 1** The computed tomography image illustrates a significant dilation of the main pulmonary artery, with a diameter of 43.07 mm.

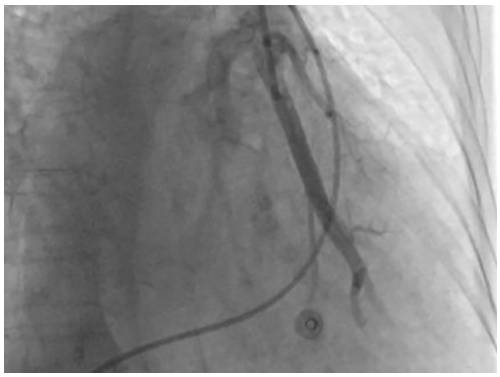

**Figure 2** This image displays the lower left pulmonary angiography. Angiography showed mild dilation of the left lower pulmonary artery, no stenosis, smooth intima, and normal blood flow.

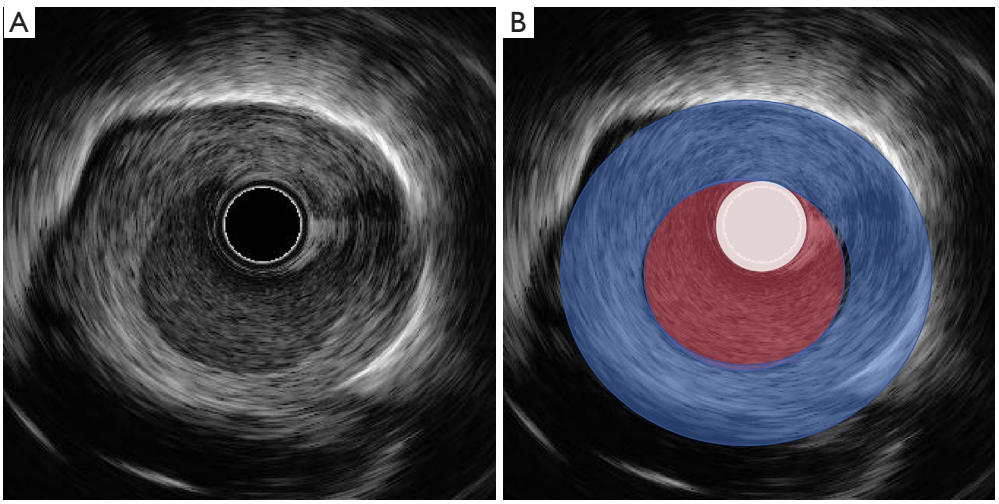


**Figure 3** The cross-sectional image of the lower left pulmonary arteriole. (A) Depicting the arteriole at a specific level of the arteriole with a lumen diameter of 2.62–3.06 mm, luminal area of 6.46 $mm^2$ and a thickened intima measuring 0.61–1.1 mm in the patient with HAPH. (B) Illustration of 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 $SaO_2$ 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 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.

## Acknowledgments

*Funding:* This study was supported by grants from the Chongqing Natural Science Foundation Project (No. CSTB2022NSCQ-MSX1563) and the Basic Research and Frontier Exploration Project of Yuzhong District, Chongqing (No. 20210167).

## 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.



## References

1. Humbert M, Kovacs G, Hoeper MM, Badagliacca R, Berger RMF, Brida M, et al. 2022 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension. Eur Respir J 2023;61:2200879.
2. Simonneau G, Galiè N, Rubin LJ, Langleben D, Seeger W, Domenighetti G, Gibbs S, Lebrec D, Speich R, Beghetti M, Rich S, Fishman A. Clinical classification of pulmonary hypertension. J Am Coll Cardiol 2004;43:5S-12S.
3. Wilkins MR, Ghofrani HA, Weissmann N, Aldashev A, Zhao L. Pathophysiology and treatment of high-altitude pulmonary vascular disease. Circulation 2015;131:582-90.
4. Maggiorini M, Léon-Velarde F. High-altitude pulmonary hypertension: a pathophysiological entity to different diseases. Eur Respir J 2003;22:1019-25.
5. Pasha MA, Newman JH. High-altitude disorders: pulmonary hypertension: pulmonary vascular disease: the global perspective. Chest 2010;137:13S-9S.
6. Aldashev AA, Sarybaev AS, Sydykov AS, Kalmyrzaev BB, Kim EV, Mamanova LB, Maripov R, Kojonazarov BK, Mirrakhimov MM, Wilkins MR, Morrell NW. Characterization of high-altitude pulmonary hypertension in the Kyrgyz: association with angiotensin-converting enzyme genotype. Am J Respir Crit Care Med 2002;166:1396-402.
7. Honda S, Kataoka Y, Kanaya T, Noguchi T, Ogawa H, Yasuda S. Characterization of coronary atherosclerosis by intravascular imaging modalities. Cardiovasc Diagn Ther 2016;6:368-81.
8. Pu Y, Wang F, Li Y, Cui K. Endovascular management and intravascular ultrasonography for spontaneous dissection of the internal carotid artery in acute stroke. Quant Imaging Med Surg 2023;13:4723-30.
9. Mirrakhimov AE, Strohl KP. High-altitude Pulmonary Hypertension: an Update on Disease Pathogenesis and Management. Open Cardiovasc Med J 2016;10:19-27.
10. Heath D, Williams D, Rios-Dalenz J, Calderon M, Gosney J. Small pulmonary arterial vessels of Aymara Indians from the Bolivian Andes. Histopathology 1990;16:565-71.
11. Moudgil R, Michelakis ED, Archer SL. Hypoxic pulmonary vasoconstriction. J Appl Physiol (1985) 2005;98:390-403.
12. Durmowicz AG, Stenmark KR. Mechanisms of structural remodeling in chronic pulmonary hypertension. Pediatr Rev 1999;20:e91-e102.
13. Remy-Jardin M, Ryerson CJ, Schiebler ML, Leung ANC, Wild JM, Hoeper MM, Alderson PO, Goodman LR, Mayo J, Haramati LB, Ohno Y, Thistlethwaite P, van Beek EJR, Knight SL, Lynch DA, Rubin GD, Humbert M. Imaging of pulmonary hypertension in adults: a position paper from the Fleischner Society. Eur Respir J 2021;57:2004455.
14. Porter TR, Mohanty PK, Pandian NG. Intravascular ultrasound imaging of pulmonary arteries. Methodology, clinical applications, and future potential. Chest 1994;106:1551-7.
15. Ishii M, Kato H, Kawano T, Akagi T, Maeno Y, Sugimura T, Hashino K, Takagishi T. Evaluation of pulmonary artery histopathologic findings in congenital heart disease: an in vitro study using intravascular ultrasound imaging. J Am Coll Cardiol 1995;26:272-6.
16. Scott PJ, Essop AR, al-Ashab W, Deaner A, Parsons J, Williams G. Imaging of pulmonary vascular disease by intravascular ultrasound. Int J Card Imaging 1993;9:179-84.
17. Rodés-Cabau J, Domingo E, Román A, Majó J, Lara B, Padilla F, Anívarro I, Angel J, Tardif JC, Soler-Soler J. Intravascular ultrasound of the elastic pulmonary arteries: a new approach for the evaluation of primary pulmonary hypertension. Heart 2003;89:311-5.
18. Bressollette E, Dupuis J, Bonan R, Doucet S, Cernacek P, Tardif JC. Intravascular ultrasound assessment of pulmonary vascular disease in patients with pulmonary hypertension. Chest 2001;120:809-15.
19. Shen JY, Cai ZY, Sun LY, Yang CD, He B. The Application of Intravascular Ultrasound to Evaluate Pulmonary

 

Vascular Properties and Mortality in Patients with Pulmonary Arterial Hypertension. J Am Soc Echocardiogr 2016;29:103-11.
20. Lau EM, Iyer N, Ilsar R, Bailey BP, Adams MR, Celermajer DS. Abnormal pulmonary artery stiffness in pulmonary arterial hypertension: in vivo study with intravascular ultrasound. PLoS One 2012;7:e33331.

**Cite this article as:** Pu Y, Li G, Zhang T, Cui Y, Li B, Liu C, Li Y. Intravascular ultrasound imaging of pulmonary artery with high-altitude pulmonary hypertension. Quant Imaging Med Surg 2024;14(4):3204-3209. doi: 10.21037/qims-23-1348

 