A 22-year-old male presented with recurrent stroke, central cyanosis, and dyspnea. Transesophageal echocardiography and cardiac catheterization revealed bidirectional shunt flow through atrial septal defect (ASD) without pulmonary arterial hypertension. The orifice of inferior vena cava facing towards ASD opening led partially right to left shunt resulting in cyanosis with normal pulmonary arterial pressure.

**KEY WORDS:** Atrial septal defect - Cyanosis - Inferior vena cava.

**INTRODUCTION**

In patients with atrial septal defect (ASD), usually left to right shunt flow is predominant. However, long standing ASD with large defect can cause pulmonary arterial hypertension and therefore turn into right to left shunt. However, right to left shunt is also possible in ASD patients even with normal pulmonary arterial pressure. We present a case of cyanotic ASD with normal pulmonary arterial pressure caused by direct blood flow of inferior vena cava (IVC) through ASD to the left atrium (LA).

**CASE**

A 22-year-old male presenting with vertiginous dizziness was referred to cardiologic clinic for further evaluation of cyanosis from neurologic department. The patient was active, but complained of mild dyspnea on exertion. He was absent with any medical history.

On physical examination, clubbing fingers of both hands were detected (Fig. 1). Chest X-ray finding was normal with cardio-thoracic ratio of 0.4 (Fig. 2A). Electrocardiography revealed normal axis without evidence of cardiac chamber enlargement. Complete blood count showed polycythemia (hemoglobin 19.3 g/dL, hematocrit 56.4%) but JAK2 mutation was negative which suggests polycythemia was secondary change from hypoxemia. Brain magnetic resonance imaging (MRI) showed right cerebellar small embolic nature infarction. No intra- or extra-cranial vascular obstruction was detected. Interestingly, his initial blood gas analysis showed hypoxemia...
Atrial Septal Defect with Bidirectional Shunt

In-Cheol Kim, et al.

221

Without transesophageal echocardiography (TEE). After 6 months, he readmitted to neurology department with second attack of stroke. The brain MRI revealed acute embolic infarction on right thalamus without large vessel pathology. TTE with bubble test showed rapid filling of LA and left ventricle chambers with agitated bubble simultaneously within 3–4 cardiac cycles after filling right atrium (RA) and right ventricle chambers (Fig. 3, Supplementary movie 1). TEE showed ASD with bidirectional shunt flow (Fig. 4). Left to right shunt was dominant during most of the cardiac cycle, but right to left

(PaO₂ 58.1 mm Hg, O₂ saturation 90.7% at room air) with mild hypocapnea (PaCO₂ 27.3 mm Hg) which could not be corrected with oxygenation therapy (PaO₂ 70.8 mm Hg, O₂ saturation 93.6% at 4 L oxygenation by nasal cannula). Putting the laboratory tests together, intra- or extra-cardiac shunt was suspected. However, on initial transthoracic echocardiography (TTE), there were no signs of heart chambers enlargement and no definite intra-cardiac shunt flow was detected (Fig. 2B and C). After the initial work-up, he was on clopidogrel 75 mg daily medication and discharged from neurology department without transesophageal echocardiography (TEE). After 6 months, he readmitted to neurology department with second attack of stroke. The brain MRI revealed acute embolic infarction on right thalamus without large vessel pathology. TTE with bubble test showed rapid filling of LA and left ventricle chambers with agitated bubble simultaneously within 3–4 cardiac cycles after filling right atrium (RA) and right ventricle chambers (Fig. 3, Supplementary movie 1). TEE showed ASD with bidirectional shunt flow (Fig. 4). Left to right shunt was dominant during most of the cardiac cycle, but right to left

Fig. 2. Initial chest X-ray (A) and transthoracic echocardiography of parasternal long axis (B) and apical 4-chamber view (C). These tests showed that cardiac chambers were not enlarged and left ventricular ejection fraction was normal.

Fig. 3. Transthoracic echocardiography with agitated saline bubble test in modified apical 4-chamber view. Filling of LV cavity with bubble starts at the same time when RV cavity is filled (A and B), LV fulfillment is finished within 4 beats immediately after appearance of RV bubble (C and D). Arrow indicates each cardiac cycle of the image. RV: right ventricle, LV: left ventricle, RA: right atrium, LA: left atrium.
Patients with long standing ASD are in the risk of pulmonary arterial hypertension. Pulmonary hypertension in ASD patient results in elevation of RA pressure and consequently develops predominant right to left shunt. Deoxygenated systemic venous blood flow directly passes through the defect and ejected again during left ventricular systole to systemic arterial circulation. These findings make the patient cyanotic and show minimal response to supplemental oxygen. Pulmonary hypertension with right to left shunting at rest is the principal contraindication to ASD closure. In this case, the patient showed cyanosis with normal pulmonary arterial pressure. Godart et al. suggested two theories to explain the development of a right to left shunt with normal pulmonary artery pressure: 1) hemodynamic phenomenon with an interatrial pressure gradient such as RA myxoma, right ventricular infarction, and mechanical ventilation; 2) preferential blood flow streaming from the IVC to the LA through the defect without pressure gradient. Overdeveloped Eustachian valve can guide blood flow from the IVC through the ASD. Distortion and tilting of heart structure by aortic aneurysm, pneumonectomy or abdominal surgery is another reason for preferential blood flow from the IVC to the ASD. In the present case, anterolateral deviation of the IVC led direct flow through ASD opening to the LA. Presence of right to left shunt is an important cause of paradoxical embolism. In polycythemia, cerebral blood flow can decrease up to 50% due to increased blood viscosity. In this patient, right to left shunt and decreased cerebral flow due to polycythemia might have contributed to recurrent stroke event.

We present an interesting case of ASD with normal pulmonary arterial pressure manifesting with recurrent stroke in young adult. Right to left shunt was due to the unique IVC position directly facing ASD opening. Position of IVC and ASD opening should be considered in cyanotic ASD patients with normal sized heart chambers and pulmonary arterial pressure.
**SUPPLEMENTARY MOVIE LEGEND**

Movie 1. Modified apical 4-chamber view of the transthoracic echocardiography showing agitated saline bubble fully filled in the left ventricle within 4 beats immediately after appearance of the right ventricle.

**REFERENCES**

1. Sommer RJ, Hijazi ZM, Rhodes JF Jr. Pathophysiology of congenital heart disease in the adult: part I: Shunt lesions. Circulation 2008;117:1090-9.
2. Godart F, Rey C, Prat A, Vincentelli A, Chmaït A, Francart C, Porte H. Atrial right-to-left shunting causing severe hypoxemia despite normal right-sided pressures. Report of 11 consecutive cases corrected by percutaneous closure. Eur Heart J 2000;21:483-9.
3. Frost AE, Quiñones MA, Zoghbi WA, Noon GP. Reversal of pulmonary hypertension and subsequent repair of atrial septal defect after treatment with continuous intravenous epoprostenol. J Heart Lung Transplant 2005;24:501-3.
4. Steele PM, Fuster V, Cohen M, Ritter DG, McGoon DC. Isolated atrial septal defect with pulmonary vascular obstructive disease—long-term follow-up and prediction of outcome after surgical correction. Circulation 1987;76:1037-42.
5. Thomas JD, Tabakin BS, Irtleman FP. Atrial septal defect with right to left shunt despite normal pulmonary artery pressure. J Am Coll Cardiol 1987;9:221-4.
6. Nazzal SB, Bansal RC, Fitzmorris SJ, Schmidt CA. Platypnea-orthodeoxia as a cause of unexplained hypoxemia in an 82-yr-old female. Cathet Cardiovasc Diagn 1990;19:242-5.
7. Bakris NC, Siddiqi AJ, Fraser CD Jr, Mehta AC. Right-to-left interatrial shunt after pneumonectomy. Ann Thorac Surg 1997;63:198-201.
8. Smeeenk FW, Postmus PE. Interatrial right-to-left shunting developing after pulmonary resection in the absence of elevated right-sided heart pressures. Review of the literature. Chest 1993;103:528-31.
9. Kizer JR, Devereux RB. Clinical practice. Patent foramen ovale in young adults with unexplained stroke. N Engl J Med 2005;353:2361-72.
10. Frizzell JP. Acute stroke: pathophysiology, diagnosis, and treatment. AACN Clin Issues 2005;16:421-40; quiz 597-8.