Transthoracic Echocardiography Findings in an Adolescent With Late-Detection Subaortic Membrane and Patent Ductus Arteriosus: Impact of Surgical Intervention

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INTRODUCTION

Increased pulmonary blood flow from a patent ductus arteriosus (PDA) can lead to pulmonary hypertension (PH), increased pulmonary vascular resistance (PVR), and Eisenmenger syndrome. Campbell *et al.*[1] reported a 90% mortality rate by age 60 in patients with unrepaired PDA. However, both pediatric and adult patients with PDA often respond well to surgical or device closure, even in the presence of PH and increased PVR if reactive to vasoactive testing. We present the transthoracic echocardiography (TTE) findings before and after surgical intervention in an adolescent patient with late-detection PDA, PH, subaortic membrane (SAM), and aortic regurgitation (AR). After surgery, pulmonary artery pressure normalized and left ventricular and left atrial size returned toward normal.

CASE PRESENTATION

A 17-year-old woman presented to our outpatient clinic. At age 10 years she was diagnosed with a heart murmur. The patient complained of tiring more easily than her peers. Several days before the echocardiographic study, she reported new-onset nausea and dizziness. The patient denied any history of tobacco or intravenous drug use. Vital signs showed a heart rate of 80 beats per minute, a respiratory rate of 16 breaths per minute, and a body temperature of 37 °C. Systemic blood pressure was 96/50 mm Hg. COVID testing was negative. Physical examination revealed a bounding precordium, 4/6 systolic murmur that radiated to the neck and back, suprasternal notch thrill that radiated to the right neck, and 3+ arterial pulses. Body surface area was 1.38 m^2. Both height and weight were proportional and were less than the 10th percentile for age. The lungs were clear to auscultation. There were no dysmorphic features suggestive of genetic syndromes.

Results of complete blood count, renal function, and liver function analysis were normal. Electrocardiography revealed sinus rhythm and left ventricular hypertrophy with strain.

Echocardiographic images were recorded with a Siemens Sequoia C512 (Siemens Medical Solutions USA, Mountain View, CA). Transthoracic echocardiography showed left ventricular enlargement (LVE) and left atrial enlargement (LAE). The left ventricular end-diastolic diameter (LVEDD) measured 8.0 cm with severe eccentric left ventricular hypertrophy and an estimated left ventricular mass of 340 g/m^2 by M-mode echocardiography. Ejection fraction was 64% by two-dimensional (2D) biplane method of disks. Maximal left atrial volume measured by 2D biplane method of disks was 85.4 mL/m^2, right atrial area measured 7.5 cm^2/m^2, and right ventricular area measured 11.3 cm^2/m^2 from the apical 4-chamber view (A4CH; Figure 1, Video 1). Right ventricular fractional area change was 38%.

The peak tricuspid regurgitation gradient was 67 mm Hg. The end-diastolic pulmonary regurgitation gradient was 40 mm Hg. The inferior vena cava diameter was less than 1.5 cm and collapsed with inspiration, indicating an estimated right atrial pressure of 3 mm Hg. During the echocardiographic study, 3 episodes of nonsustained tachycardia were observed.

Apical 5-chamber (A5CH) imaging showed the SAM with a maximal length of 8.5 mm and a distance of 6.0 mm from the SAM to the aortic valve leaflets. Continuous-wave Doppler (CWD) recorded a peak gradient of 56 mm Hg and a mean gradient of 39 mm Hg from this window (Figure 2, Video 2).

Pulsed-wave Doppler interrogation of the PDA showed continuous left-to-right shunting with a peak gradient of 15 mm Hg. The 2D minimal ductal diameter was 1.5 cm (Figure 3, Videos 3 and 4).

When compared to systemic blood pressure (96/50 mm Hg), peak pulmonary artery pressure was estimated at 81 mm Hg. Shunt flow decreased in late diastole due to PH, which explains the absence of a continuous murmur. Holodiastolic blood flow reversal was noted in the abdominal aorta. There was mild tricuspid and mitral regurgitation and moderate AR with a jet diameter to left ventricular outflow tract (LVOT) diameter ratio of 45%.

Right parasternal CWD recorded a peak gradient of 123 mm Hg and a mean gradient of 75 mm Hg (Figure 4). Based on the high gradient, presence of PH, new onset of symptoms, and tachyarrhythmia, the patient was admitted for further evaluation and treatment.

To rule out elevated PVR we proceeded with invasive testing. Cardiac catheterization recorded mean systolic pulmonary artery pressure of 82% systemic pressure. Aortic pressure was 97/53 mm Hg, and pulmonary artery pressure was 69/44 mm Hg. Calculated PVR was 2.1 Woods units. The pulmonary to systemic flow ratio was 5.6 to 1. Right atrial pressure was 8 mm Hg. Left ventricular ejection fraction by cine-angiography was reduced at 47%, and the left

At surgery the SAM was resected from the LVOT, the PDA was ligated, and a commissuroplasty of the aortic valve was performed. The pathologic specimen of SAM was described as "fibromembranous tissue with myxoid changes without evidence of inflammation or malignancy measuring 2.0 cm × 0.4 cm." The patient was stable after surgery.
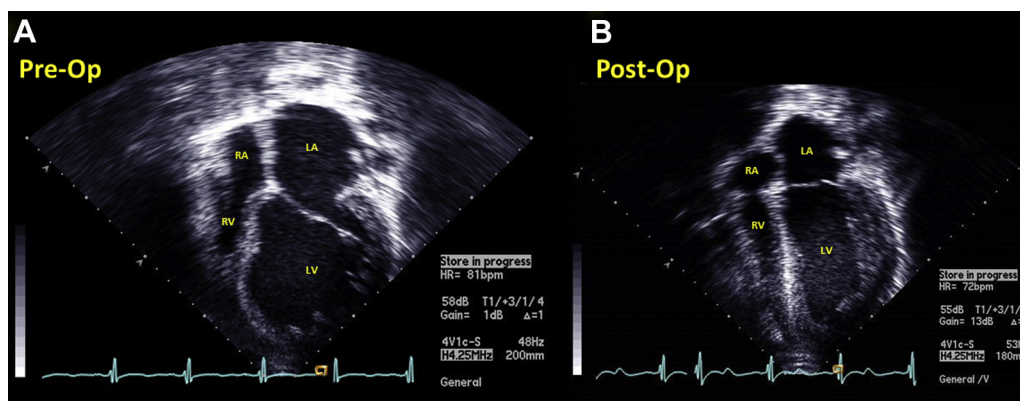
The 2-week postoperative physical exam revealed a heart rate of 70 beats per minute, respiratory rate of 12 breaths per minute, normal precordial activity, no heart murmur, normal pulses, and no evidence of a palpable suprasternal notch thrill.

A postoperative TTE recorded 2 weeks after intervention showed that the LVEDD had reduced in diameter from 8.0 to 5.9 cm; maximal left atrial volume, from 85.4 to 23.9 mL/m^2; tricuspid regurgitation peak pressure gradient, from 66 to 19 mm Hg; pulmonary regurgitation end-diastolic pressure gradient, from 45 to 6 mm Hg; and LVOT peak pressure gradient, from 123 to 19 mm Hg. The postoperative ejection fraction by 2D biplane method of disks was reduced at 46% (Video 5). After commissuroplasty of the aortic valve, AR jet diameter to LVOT diameter ratio was 22% (Figure 5, Videos 6 and 7).

DISCUSSION

The combination of SAM with PDA and associated PH and AR is rare. We report a case of an adolescent patient with late detection of a SAM and PDA. Consequently, our patient developed PH, LVE, LAE and AR. Moafa *et al.*[2] have reported a series of 7 pediatric patients who presented in early childhood (age 6 months to 7 years). They showed that a SAM distance to the aortic valve of less than 4 mm was associated with the need for surgical intervention and that ductal closure was not related to outcome.[2] In our case the distance from the SAM to the aortic valve was 6 mm, but moderate AR was still observed. The safety of ductal closure in the presence of PH, pathogenesis of AR, clinical manifestations of PDA, and the differential diagnosis of dilated cardiomyopathy (DCM) in an adolescent are discussed.

Salavitabar *et al.*[3] have studied the safety and outcomes of pediatric patients with PDA and PH undergoing transcatheter closure. They showed that transcatheter closure of PDA can be performed safely in many children with PH, even in those receiving pulmonary

ventricular to aortic pressure gradient was 68 mm Hg. The PDA measured 1.4 cm by angiography. The left ventricular end-diastolic pressure was elevated at 27 mm Hg.

Figure 1 Preoperative transthoracic echocardiography, 2D, A4CH view, end-diastolic frame shows LVE and LAE. **(A)** Although the mitral valve is open in this frame, the electrocardiogram confirms that this is an end-diastolic frame (possibly due to a large shunt resulting in delayed mitral valve closure). **(B)** Postoperative TTE, 2D, A4CH view, end-diastolic frame shows the change in heart size after surgery. The LVEDD was reduced in diameter from 8.0 to 5.9 cm, and maximal left atrial volume was reduced from 85.4 to 23.9 mL/m^2; the ventricle is less spherical.
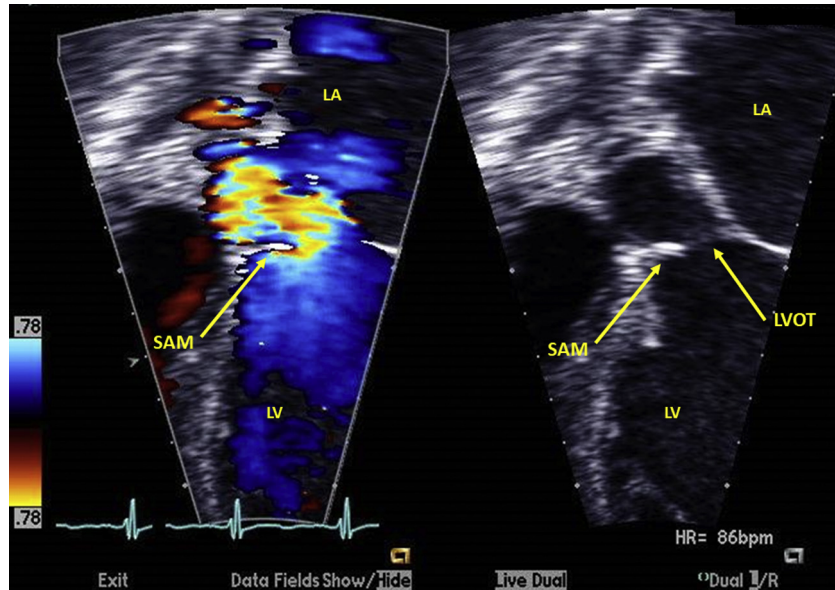
Figure 2 Transthoracic echocardiography, 2D and color Doppler, A5CH in color compare mode demonstrates the SAM (*arrows*). The SAM had a maximal length of 8.5 mm and a distance of 6.0 mm from the SAM to the aortic valve leaflets.
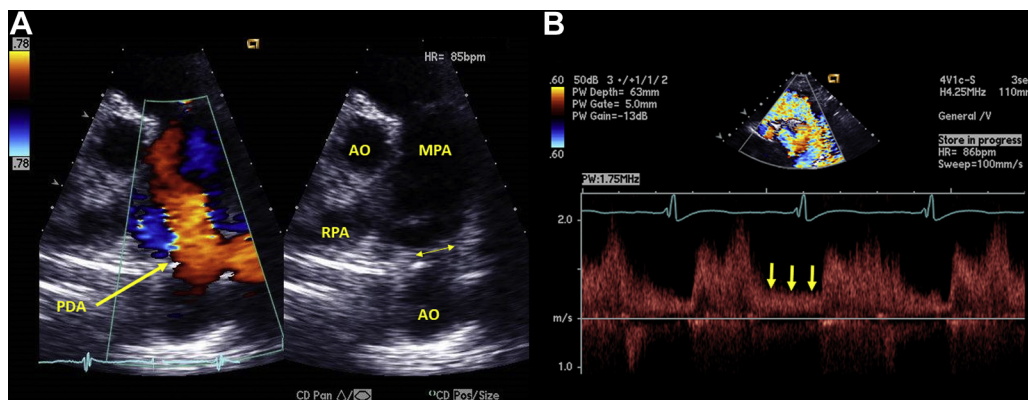
Figure 3 (A) Transthoracic echocardiography, 2D parasternal modified short-axis view in color compare mode shows a minimal ductal diameter of 1.5 cm (*double-headed arrow*). **(B)** Transthoracic echocardiography, pulsed-wave Doppler recorded from a high left parasternal view shows continuous left-to-right shunting with a peak PDA gradient of 15 mm Hg. Shunt flow decreased in late diastole due to PH (*yellow arrows*), which explains the absence of a continuous murmur. *Ao*, Aorta; *MPA*, main pulmonary artery; *RPA*, right pulmonary artery.

vasodilator therapy. Sudhakar *et al.*[4] showed similar findings in adolescent and adult patients. In our case, Doppler indices of PH normalized soon after surgical closure of the PDA.

Discrete subaortic stenosis has 3 forms: (1) fibromembranous and (2) fibromuscular (which together account for 90% of cases), and (3) tunnel (10% of cases). This lesion represents 6.5% of all congenital heart disease.[5] Lopes *et al.*[5] have described the natural history of SAM. They found that patients with a history of an LVOT gradient greater than 50 mm Hg are more likely to experience aortic valve disease. In our case, the combination of SAM and PDA produced a high gradient and moderate AR was present requiring commissuroplasty. The mechanism for this damage to the aortic valve was likely repetitive turbulent blood flow.[5]

Patent ductus arteriosus has many associated genetic syndromes such as CHARGE syndrome; Holt-Oram, Di George, and Noonan syndromes; trisomy 13, 18, and 21; and familial PDA.[6] Maternal conditions consisting of congenital rubella, maternal diabetes, and

exposure to magnesium, cocaine, and calcium channel blockers may also contribute to the development of PDA.[6] However, in this case there were no syndromic features or known history of maternal conditions. Many factors may contribute to the development of PDA. Prematurity is the most common cause, while birth at high altitudes and female gender (2.29:1 risk[1]) have been reported.[6] In at least 10% of other congenital heart diseases (CHDs), a PDA may be present. These lesions include hypoplastic left heart, coarctation of the aorta, and critical aortic stenosis which can depend on ductal blood flow to maintain systemic perfusion.[6] In our patient, PDA was associated with SAM, a similar obstruction to systemic blood flow. As in all CHDs it is important to search for associated lesions, and referral to a heart center with expertise in complex CHD is recommended.

As a result of a large shunt, our patient presented with LVE and LAE giving the appearance of DCM. A large PDA should be included in the wide differential for a severely DCM in an adolescent or young
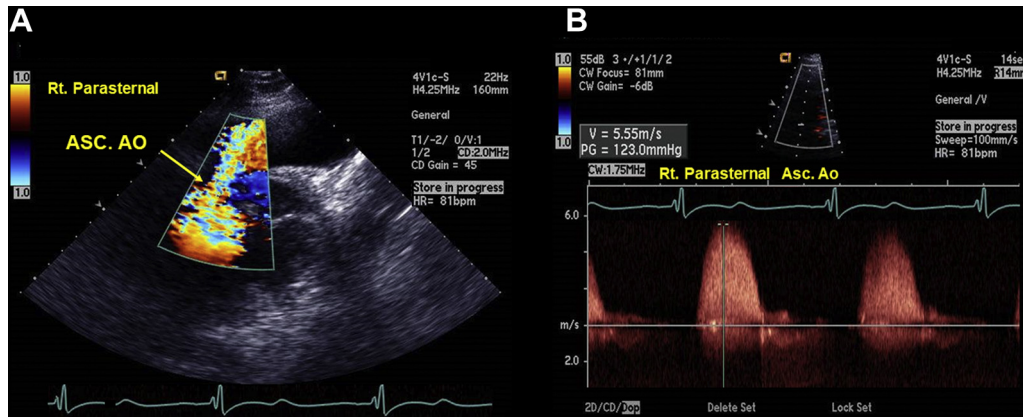
Figure 4 (A) Transthoracic echocardiography, 2D and color-flow Doppler parasagittal view of the ascending aorta (*yellow arrow*) recorded from the right parasternal window demonstrates a narrow jet near peak systole. **(B)** Transthoracic echocardiography, CWD imaged from the right parasternal window shows a high gradient (peak gradient, 123 mm Hg; mean gradient, 75 mm Hg) associated with SAM and a large shunt from a PDA. *ASC AO*, Ascending aorta.
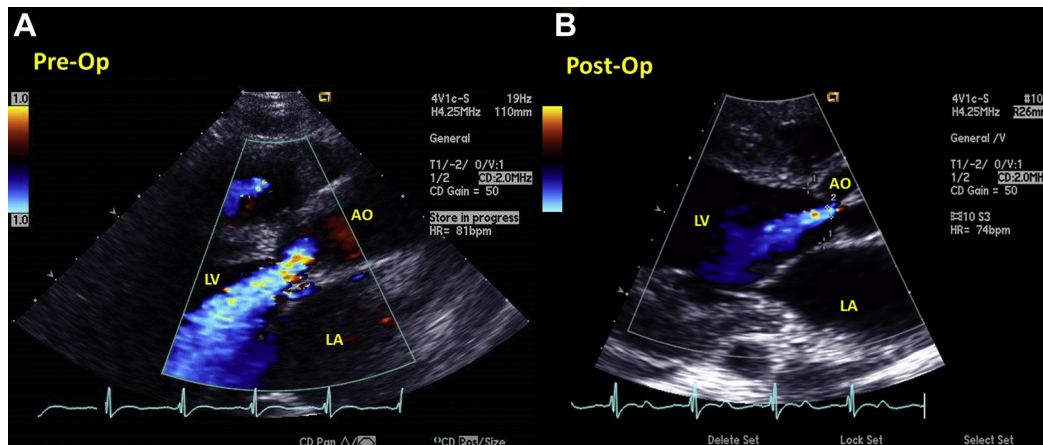
Figure 5 Transthoracic echocardiography, 2D and color Doppler from the left parasternal window. **(A)** The preoperative AR jet diameter to LVOT diameter ratio was 45% (moderate AR). **(B)** The postoperative AR jet diameter to LVOT diameter ratio was improved at 22% (mild AR).

adult.[7] More than 50% of DCM cases in children are less than 1 year old. The incidence of DCM peaks again in adolescents. The differential diagnosis of DCM in young adults is heterogeneous and includes genetic and environmental factors.[8] Genetic types include hypertrophic cardiomyopathy, familial DCM, and neuromuscular disorders.[8] Environmental factors such as viral myocarditis, bacterial infection, and nutritive-toxin influences comprise the majority of cases in adolescents.[8] Echocardiographic inspection for a PDA with or without a high-velocity jet should be pursued. It is important to note that in the presence of PH the typical continuous murmur of PDA may be absent. Moreover, shunt lesions that mimic the pathophysiology of PDA including cameral fistula to the left atrium and aortopulmonary window should be excluded.

CONCLUSION

A continuous murmur from a PDA is not present in patients with moderate PH. In this case, TTE provided hemodynamic data similar to cardiac catheterization and demonstrated normalization of PH after surgery. Patent ductus arteriosus should be considered in the differential diagnosis of an adolescent with DCM.

SUPPLEMENTARY DATA

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