

A 54-Year-Old Man With Shortness of Breath and Irregular Pulse

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CLINICAL VIGNETTE

A 54-year-old man was admitted with worsening swelling of both legs for one month. The patient also had progressively increasing exertional dyspnea, orthopnea, and paroxysmal nocturnal dyspnea for the preceding month and an unquantified weight loss for the prior three months without any loss of appetite. He denied chest pain or dietary indiscretion.

The patient's history included atrial fibrillation and hyperthyroidism secondary to Graves' disease, for which the patient had undergone radioactive iodine ablation two months earlier. There was also an undocumented history of a stroke approximately 20 years ago with transient right hemiparesis, from which the patient had completely recovered. At the time of presentation the patient was not

taking his prescribed medications, which included warfarin and diltiazem.

Vital signs at presentation were a temperature of 98.2°F, heart rate of 126 beats per minute, a respiratory rate of 18 per minute, blood pressure of 162/79 mmHg, and oxygen saturation of 100% on air. Physical examination revealed a thin man with a smooth, symmetrically enlarged thyroid gland and an elevated jugular venous pressure. He had fine inspiratory crackles at the bases of both lung fields and bilateral lower extremity pitting edema. Cardiovascular examination revealed an irregularly irregular rhythm and a grade 2/6 systolic murmur in the pulmonic area.

Laboratory data confirmed that the patient was hyperthyroid. Other abnormalities included a normocytic anemia and an elevated B-natriuretic peptide. Electrocardiogram showed atrial fibrillation with a rapid

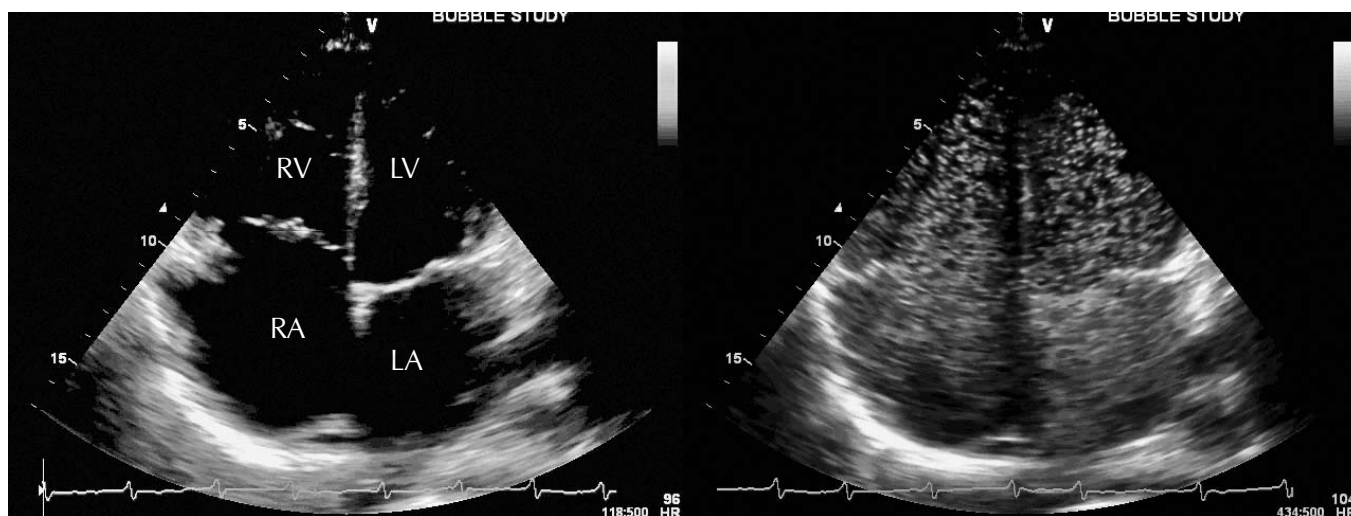


Figure 1. Apical four-chamber echocardiographic frames before (left) and seconds after (right) systemic venous injection of agitated saline (bubble study) demonstrating early nearly simultaneous opacification of both sides of the heart consistent with a right-to-left intracardiac shunt. LA=left atrium; LV=left ventricle; RA=right atrium; RV=right ventricle.

ventricular response without ischemic changes. Chest radiograph was consistent with mild pulmonary edema. Transthoracic echocardiogram revealed biatrial and right ventricular enlargement with paradoxical motion of the ventricular septum. An agitated saline “bubble” study revealed early, nearly simultaneous filling of both atria suggesting a right-to-left intracardiac shunt (Figure 1). A transesophageal echocardiogram demonstrated a sinus venosus atrial septal defect measuring approximately 20 mm in diameter (Figure 2). There was no anomalous pulmonary venous return. Right heart catheterization demonstrated a step up in mean oxygen saturation from 64% in the vena cavae to 80% in the right atrium, pulmonary arterial (PA) hypertension (PA pressure of 51/18 mm Hg), and no significant elevation of pulmonary vascular resistance. The pulmonary-to-systemic flow ratio (Qp:Qs) was calculated at 2.3:1. Thus, the volume of the left-to-right shunt across the defect far exceeded that of the right-to-left shunt. The patient was referred for surgical repair of his sinus venosus atrial septal defect.

ANATOMY OF ATRIAL SEPTAL DEFECT

The population of adults with congenital heart diseases in United States is estimated to be increasing at a rate of five percent every year. Atrial septal defect (ASD) constitutes the biggest proportion of this rapidly growing cohort accounting for approximately one-third of adult congenital cases. Anatomically, atrial septal defects are classified into three main categories: ostium secundum, ostium primum, and sinus venosus defects. Of these, ostium secundum defects, located in the region of fossa ovalis, are the most commonly diagnosed, noted in as many as 75% of patients. Ostium primum defect, located in the lower part of atrial septum, is noted in approximately 15% of patients, while the sinus venosus defect constitutes only about five to 10%.¹ In addition, two other rare types have been described, the inferior vena cava form of the sinus venosus defect and the coronary sinus septal defect, also referred to as the ‘unroofed coronary sinus’.²

Sinus venosus ASD (SVASD), originally described in 1858, is an interatrial communication usually located at the junction of the right atrium and superior vena cava (SVC).³ It is bounded by the right atrial free wall posteriorly but lacks a clear margin on the superior aspect because of an overriding SVC. This defect is usually associated with partial anomalous pulmonary venous return, wherein some pulmonary veins, usually from the right upper and middle lobes, drain either into the SVC or the right atrium.² This coexistence with anomalous venous connection is present in approximately 85% cases of SVASD.⁴

PATHOPHYSIOLOGY

The clinical manifestations of SVASD, as is true for any form of ASD, are determined by the physiological

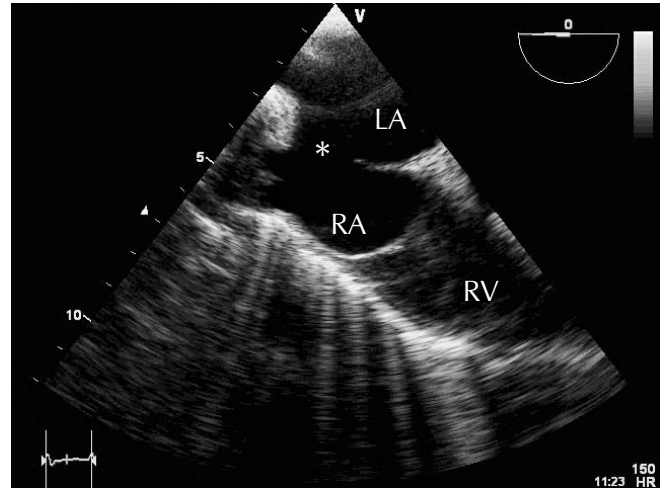


Figure 2. Transesophageal echocardiogram demonstrating an atrial septal defect (*) at the junction of the atrial septum and superior right atrial wall, consistent with a sinus venosus atrial septal defect. LA=left atrium; RA=right atrium; RV=right ventricle.

consequences of shunting from one atrium to another. The magnitude and direction of the shunt are determined by the size of the defect and the relative compliance of the ventricles. As seen in this patient, in SVASD there may be a small amount of right-to-left shunting because of the overriding SVC, even when there is a large left-to-right shunt. An ASD must be at least 10 mm in diameter to permit a significant shunt across the defect. In addition, the presence of valvular stenosis (right- or left-sided) as well as the presence of pulmonary hypertension can affect the direction and magnitude of flow across the atrial defect. One of the most important objective measures in the assessment and management of an ASD is the degree of left-to-right shunting as measured by the ratio of flow in the pulmonary (Qp) and systemic circulations (Qs). A left-to-right atrial shunt is considered significant when the Qp:Qs ratio is greater than 1.5:1. This level of shunting is usually associated with right heart dilation and adverse long-term outcomes.^{2,5}

CLINICAL PRESENTATION

Because of the absence of symptoms in a large number of patients and the lack of striking findings on physical examination, ASD of any anatomical form can go undetected for years.⁶ Although most patients become symptomatic at some point in their lives, the age of symptom onset varies greatly. Exercise intolerance secondary to dyspnea or fatigue is the most common presenting symptom. Alternatively, the development of sequelae such as supraventricular arrhythmias, right heart failure, paradoxical embolism, or recurrent pulmonary infections may bring the patient to medical attention. Atrial arrhythmias such as atrial flutter and fibrillation are age-related manifestations of atrial

remodeling secondary to long standing right-sided volume overload and rarely occur before 40 years of age.^{2,7,8} A fixed split of second heart sound is the auscultatory hallmark of ASD. The splitting of the second heart sound is fixed as the phasic changes in systemic venous return to the right atrium during respiration are accompanied by reciprocal changes in the volume of shunted blood from the left atrium to the right atrium. This minimizes the respiratory changes in the right and left ventricular stroke volumes that are normally responsible for physiological splitting.^{1,9} In addition, because of the large right ventricular stroke volume, patients usually have a systolic ejection murmur best heard in the second left intercostal space. If pulmonary hypertension develops, a loud P2 (pulmonic valve closure sound) is heard. Cyanosis, resulting from Eisenmenger's physiology, may be present in patients with severe pulmonary hypertension and reversal of shunt.²

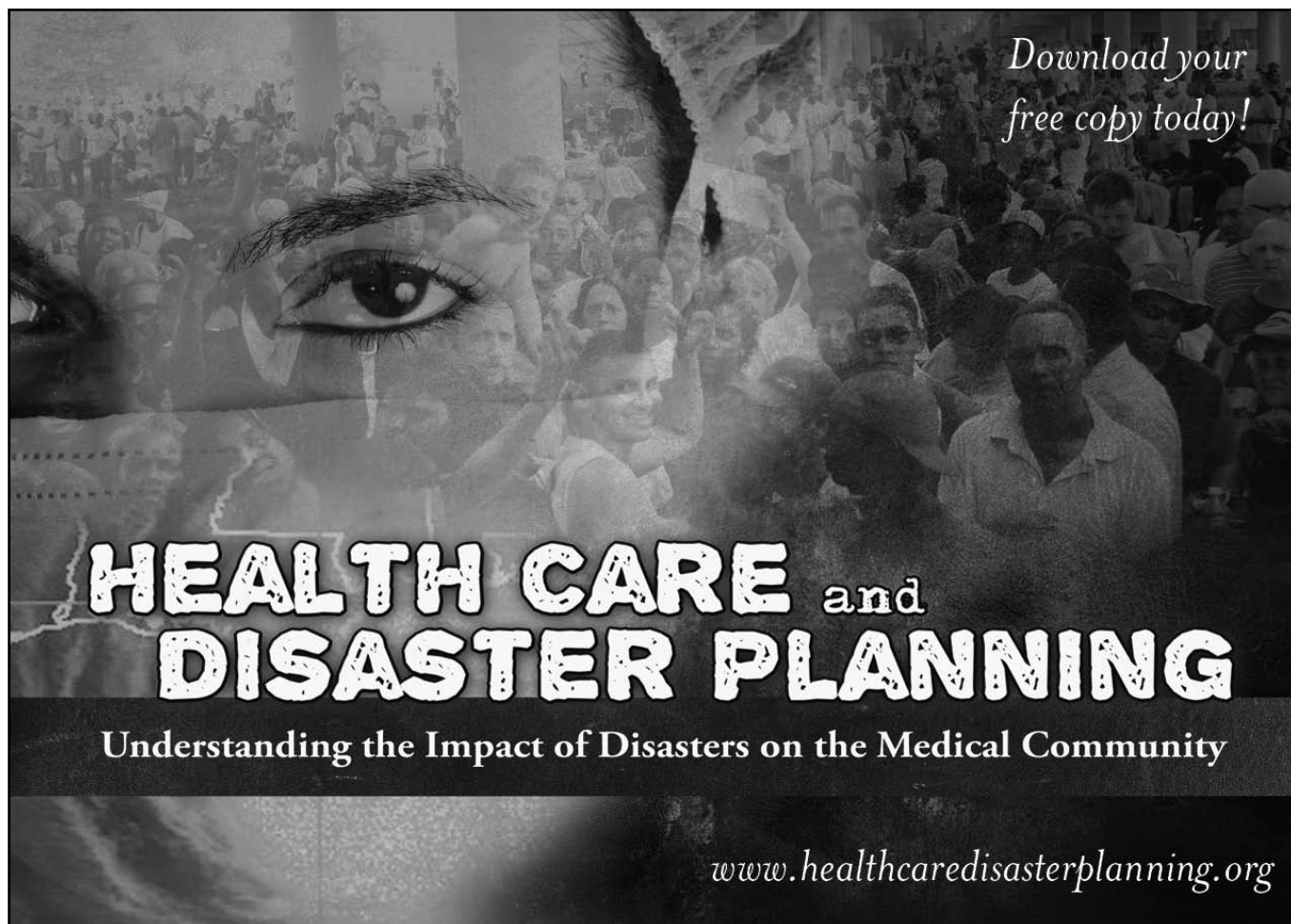
WORKUP AND MANAGEMENT

The hemodynamic and anatomic changes of a long standing defect are manifested on a chest radiograph by prominence of the pulmonary arteries, right sided chamber

dilation, and a pattern of shunt vascularity, in which the small pulmonary arteries are especially well visualized at the periphery of both lungs.^{1,7}

Electrocardiographically, a relationship between ASD and incomplete right bundle branch block has been noted for more than 50 years.¹⁰ A junctional or low atrial rhythm may be present in SVASD. Atrial flutter or atrial fibrillation are commonly seen when patients present beyond the first four decades of life.^{1,7}

Transthoracic echocardiography is a well-established tool for the assessment of atrial septal defects. It allows the operator to visualize the type and size of the defect, and the direction of the shunt. Furthermore, an estimation of the physiological significance of the shunt may be obtained by the size of the cardiac chambers, the presence/absence of paradoxical septal motion (indicating right ventricular volume or pressure overload), as well as an estimation of shunt ratio based on flow in the pulmonary and aortic circuits.² However, because of the location of SVASD, transthoracic echocardiography has inherent limitations in visualizing the defect as well as the presence of anomalous pulmonary venous connections.¹¹ An agitated saline "bubble" study, where saline with microbubbles of air is



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injected into a peripheral vein and the movement of the bubbles across the defect visualized, may enhance the sensitivity of echocardiography. Transesophageal and Doppler color-flow echocardiography are particularly useful in detecting SVASD and anomalous pulmonary venous drainage.¹ With recent technological advances, real time three-dimensional echocardiography allows greater spatial resolution and more accurate characterization of true ASD geometry and morphology.¹²

Even though echocardiography remains the first-line imaging modality, cardiac magnetic resonance imaging (MRI) and computed tomography (CT) can provide complementary information, especially for the detection of associated anomalies and for assessing changes in pulmonary vasculature.¹³ Cardiac MRI may have an important role in the detection of SVASD and PAPVC in adult patients for whom other investigations have not provided a complete explanation for enlarged right-sided chambers.¹⁴

With rapid progress in interventional cardiology over the last two decades, the role of cardiac catheterization in adults with ASD has evolved from being a purely diagnostic modality to having an increasingly important role in delivering therapy, especially to patients with secundum ASD.¹⁵ In patients with SVASD, cardiac catheterization provides information about pulmonary arterial pressures and hemodynamics, assessment of flow and oxygen saturations in pulmonary and aortic circuits, evaluation of

left heart function, as well as an assessment of the coronary arteries for the older patient.²

The decision to repair any kind of ASD is based on clinical and compiled information from imaging modalities, including size and location of ASD, hemodynamic impact of the left-to-right shunt and associated right-sided cardiac volume overload, and the presence and degree of pulmonary hypertension.¹⁶ Indications for ASD closure in adults are right atrial and right ventricular dilation by echocardiography, MRI, or CT (in the presence of an ASD and in the absence of advanced pulmonary arterial hypertension) associated with one or both of the following: (1) ASD minimum diameter > 10 mm on echocardiography; and/or (2) Qp:Qs greater than 1.5:1 by echocardiographic or cardiac MRI flow assessment, or from oxygen saturation runs when cardiac catheterization is performed.²

Advanced pulmonary hypertension or severe left heart failure contraindicate ASD closure. In both of these settings, the ASD may be physiologically needed by the patient as a "pop-off" valve, and its closure could have adverse hemodynamic consequences such as acute right ventricular failure.⁷

Percutaneous device closure is increasingly being employed for repair of secundum ASDs. However, the unique anatomy of the defect and its association with anomalous pulmonary venous connection makes surgical closure the only feasible option for SVASD repair. Possibly

because of the associated anomalous pulmonary venous return, repair of SVASD has been associated with greater operative and late morbidity compared with secundum ASD.¹⁷

Based on retrospective studies, there is compelling evidence suggesting that early repair of ASD can favorably modify long-term outlook with regards to survival and freedom from adverse cardiac events.^{18,19} Studies of patients with SVASD have also noted that repair at an older age is an independent predictor of late mortality, adverse cardiac events, and worse functional outcome.^{16,17} The natural history of unrepaired ASDs suggests that in patients with clinically overt disease, 75% are dead by the age of 50 years and 90% by 60 years.⁶ It is therefore suggested that all types of ASDs that meet criteria for repair should be considered for timely closure irrespective of age.²

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