INTRODUCTION

Patent foramen ovale (PFO) and atrial-septal aneurysm (ASA) are congenital cardiac abnormalities that are highly prevalent in the general population. Observational studies have found an association between these anomalies and several neurologic diseases, including stroke, decompression sickness from SCUBA diving, migraine, and others. In this chapter, we will discuss the diagnosis of PFO and ASA, review the data that implicate them as causes of neurologic disorders—particularly cryptogenic stroke in the young—and assess the available treatment options.

BACKGROUND

The foramen ovale, first described in 1564 by Italian surgeon Leonardi Botali, is an opening in the fossa ovalis created by the overlap of the atrial septum primum and secundum. During fetal development, resistance in the pulmonary circulation leads to higher pressure in the right atrium relative to the left, allowing oxygenated blood arriving from the
umbilical vein to cross through the foramen ovale into the systemic circulation. Following birth, increased blood flow through the pulmonary circulation leads to a relative increase in left atrial pressure pushing the septum primum against the septum secundum and functionally closing the foramen ovale. In most cases, fibrous adhesions result in a permanent anatomical closure of the flap. However, in a significant proportion of the population, adhesions fail to seal the septum, allowing the persistence of the communication between the right and left atria of the heart.

Patent foramen ovale is a common finding in the general population: three autopsy series have reported an overall prevalence of 17%, 27%, and 29%, respectively (1–3). One of the studies observed that the prevalence of PFO declines as the age of the population sampled increases, implying that anatomical closure can occur in adulthood as well (1). Most echocardiographic studies have demonstrated lower prevalences for PFO (3.2–18%), reflecting the difficulty of detecting a shunt that is potentially but not continuously open (4–7). However, the SPARC (Stroke Prevention: Assessment of Risk in a Community) study, a population-based prospective study of stroke risk factors, evaluated 581 patients by transesophageal echocardiography and agitated saline contrast and found a PFO prevalence of 25.6%, comparable to the autopsy studies (8).

An ASA is present when redundant tissue in the region of the fossa ovalis results in excessive septal wall motion during respiration. ASA is not commonly found in isolation; 71–83% also have a PFO present (9–11). The prevalence of ASA has been estimated to be 1–8% in unselected populations (12,13). The SPARC study reported a prevalence of 2.2% (8).

**DIAGNOSIS OF PFO AND ASA**

Atrial-septal abnormalities are most often diagnosed by transthoracic echocardiogram (TTE) or transesophageal echocardiogram (TEE) with agitated saline contrast injected into an antecubital vein. TEE is considered the standard for PFO diagnosis, as it permits optimal visualization of the interatrial septum and maximal sensitivity for detection of saline contrast in the left atrium if a shunt is present (14,15). A study of 100 patients undergoing endovascular closure found that two-dimensional TEE measurements were strongly correlated with direct invasive balloon sizing ($r^2 = 0.8; p < 0.0001$) (16). Although the antecubital vein is preferable for injection of saline contrast because of its ease of access, femoral injection might be a more reliable method. The degree of right to left shunting after injecting agitated saline into the femoral vein has been highly correlated with balloon sizing ($r^2 = 0.7; p < 0.0001$), whereas there was no correlation when the injection was given through an antecubital vein (16). Provocative maneuvers have also been shown to increase the sensitivity of these studies. The Valsalva maneuver was the most reliable way to produce a significant right-to-left pressure gradient compared to inspiration, expiration, or cough (17).

Diagnosis of ASA is made by measuring the total excursion of the septal wall into the left and right atrium throughout the respiratory cycle. There is no clear consensus on the degree of motion that is considered excessive, although most studies have chosen a cut-off of 10–15 mm. As noted, visualization of the interatrial septum is best accomplished with TEE.

There is significant variability in the identification of atrial abnormalities on echocardiogram. Two blinded sonographers reviewed 581 TEEs that were performed for the French PFO/ASA study, a large prospective analysis of cryptogenic stroke patients. They