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Special Report

Cardiovascular Imaging of the Left Atrium in Patients With Structural Heart Disease: What Does the Interventionalist Need to Know?

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Introduction

Real-time concurrent cardiovascular imaging is necessary for 2 categories of cardiovascular structural intervention in the left atrium: closure of interatrial septal defects and left atrial appendage (LAA) exclusion. Intracardiac echocardiography and transesophageal echocardiography (TEE) are the imaging techniques used to direct and optimize transeptal puncture as well as catheter and device placement; they are also used to monitor for cardiac emergencies, such as tamponade and device embolization. Each technique minimizes the use of contrast dye. The key to successful LAA exclusion is careful preprocedural planning, which includes performing both echocardiography and computed tomography angiography of the chest with contrast.

Closure of Interatrial Septal Defects

Percutaneous closure of interatrial septal defects is restricted to secundum atrial septal defects (ASDs) and patent foramen ovale (PFO) defects, which together account for more than 90% of interatrial septal defects. Septum primum and sinus venosus ASDs are not amenable to percutaneous closure. Preprocedural imaging with intracardiac echocardiography or TEE can be used to assess the anatomy, location, and size of an interatrial septal defect. Figure 1 shows a secundum ASD visualized with TEE. Two-dimensional and 3-dimensional imaging are used to define the anatomic landmarks surrounding the ASD and to measure the size of the ASD. Doppler echocardiography is used to identify the direction of the shunt flow, determine the gradient between the left and right atria, and estimate the right ventricular systemic pressure. Although ASDs can be characterized and assessed using cardiac computed tomography and magnetic resonance imaging, real-time imaging in the cardiac catheterization laboratory is available only with TEE or intracardiac echocardiography. Figure 2 shows examples of ASDs with unique shapes.[1]

In asymptomatic children, an ASD should be closed if evidence of right heart dilatation is present or if the ASD measures more than 5 mm and does not spontaneously close as the child grows. In older patients, a hemodynamically significant ASD is defined by a ratio of pulmonary blood flow to systemic cardiac stroke volume greater than 1.5. These larger defects should be closed if pulmonary artery pressure is elevated, pulmonary vasoreactivity is increased because of changes in the vascular bed after pharmacologic challenge, or a lung biopsy shows reversible changes. Cryptogenic stroke is an indication for closure of a hemodynamically insignificant ASD or PFO. In the Randomized Evaluation of Recurrent Stroke Comparing PFO Closure to Established Current Standard of Care

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Treatment (RESPECT) trial (ClinicalTrials.gov identifier NCT00465270),[2] 980 patients (18-60 years of age) who had a PFO and cryptogenic stroke were randomly assigned to undergo percutaneous PFO closure with the Amplatzer PFO Occluder (St Jude Medical) or medical management. These patients were then monitored for recurrent stroke for nearly 6 years. The rates of serious adverse events were low. Procedural adverse risk was also low, at 2.4%. Ultimately, a 45% reduction in the risk of recurrent ischemic stroke was observed in patients who underwent PFO device closure. Furthermore, a 62% reduction was seen in relative risk in favor of PFO closure for reducing the risk of recurrent cryptogenic stroke. The technical success rate was 99%, and the procedural success rate was 96%. As a result, the Amplatzer device was approved by the US Food and Drug Administration for PFO closure in patients with cryptogenic stroke. The Amplatzer device consists of 2 disks that straddle the interatrial septal defect and can be easily deployed through venous access (Fig. 3). During the interventional procedure, intracardiac echocardiography or TEE is useful for guidance because of the superior real-time image quality. Three-dimensional TEE can be used to define anatomy, confirm ASD size, and measure the rims on the perimeter of the ASD to confirm that there is enough tissue to safely deploy the device. Imaging can also be used to confirm device positioning and assess for residual shunting at the end of the procedure.

Abbreviations and Acronyms

ASD, atrial septal defects
LAA, left atrial appendage
PFO, patent foramen ovale
TEE, transesophageal echocardiography

Left Atrial Appendage Exclusion

Left atrial appendage exclusion can be performed via a purely percutaneous approach with the Watchman device (Boston Scientific) or a via a hybrid percutaneous

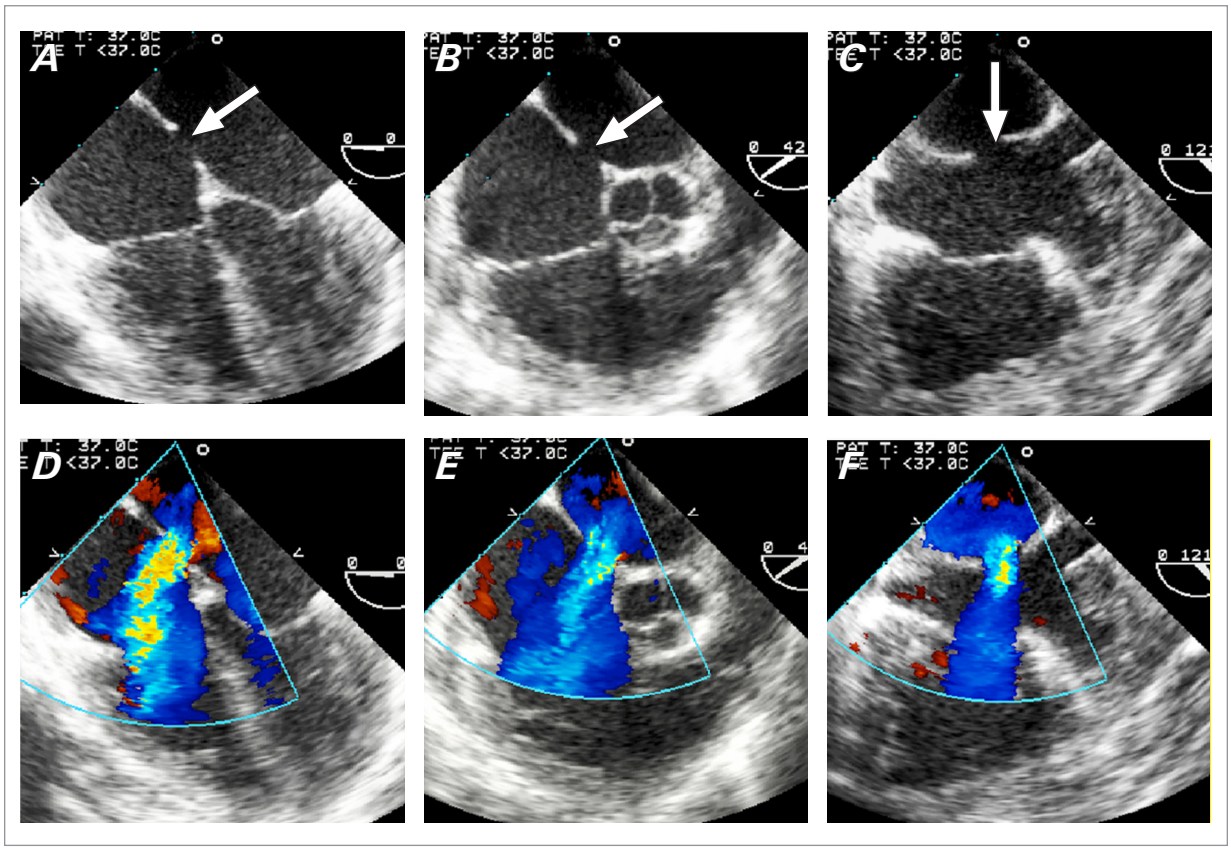

Fig. 1 A secundum atrial septal defect visualized on transesophageal echocardiography. Top row: Transesophageal echocardiograms show the 2-dimensional dropout of the secundum interatrial septum at **(A)** 0° view, **(B)** 42° view, and **(C)** 121° view. Arrows point to the atrial septal defect. Bottom row: Transesophageal echocardiograms show color Doppler shunt flow across the secundum atrial septal defect in **(D)** 0° view, **(E)** 42° view, and **(F)** 121° view.

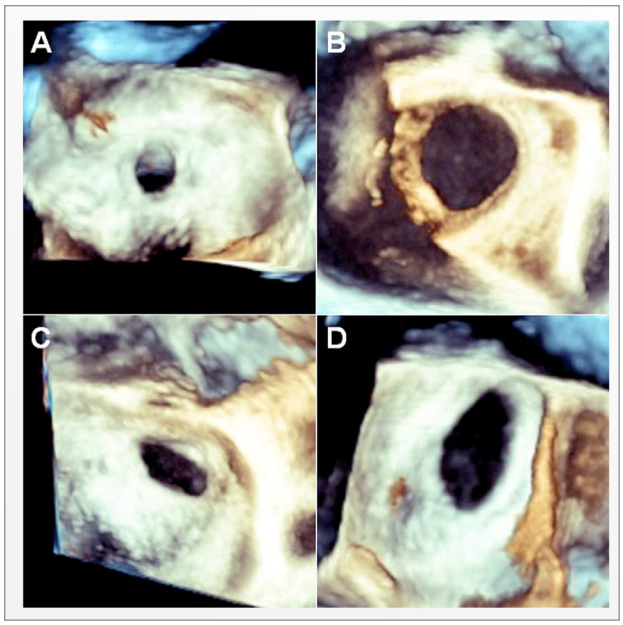

Fig. 2 Three-dimensional transesophageal echocardiograms show examples of atrial septal defects with unique shapes and sizes: (**A**) small and round, (**B**) large and round, (**C**) small and oval, and (**D**) large and oval. Defect size and shape can be used to help predict optimal implanted device size.[1]

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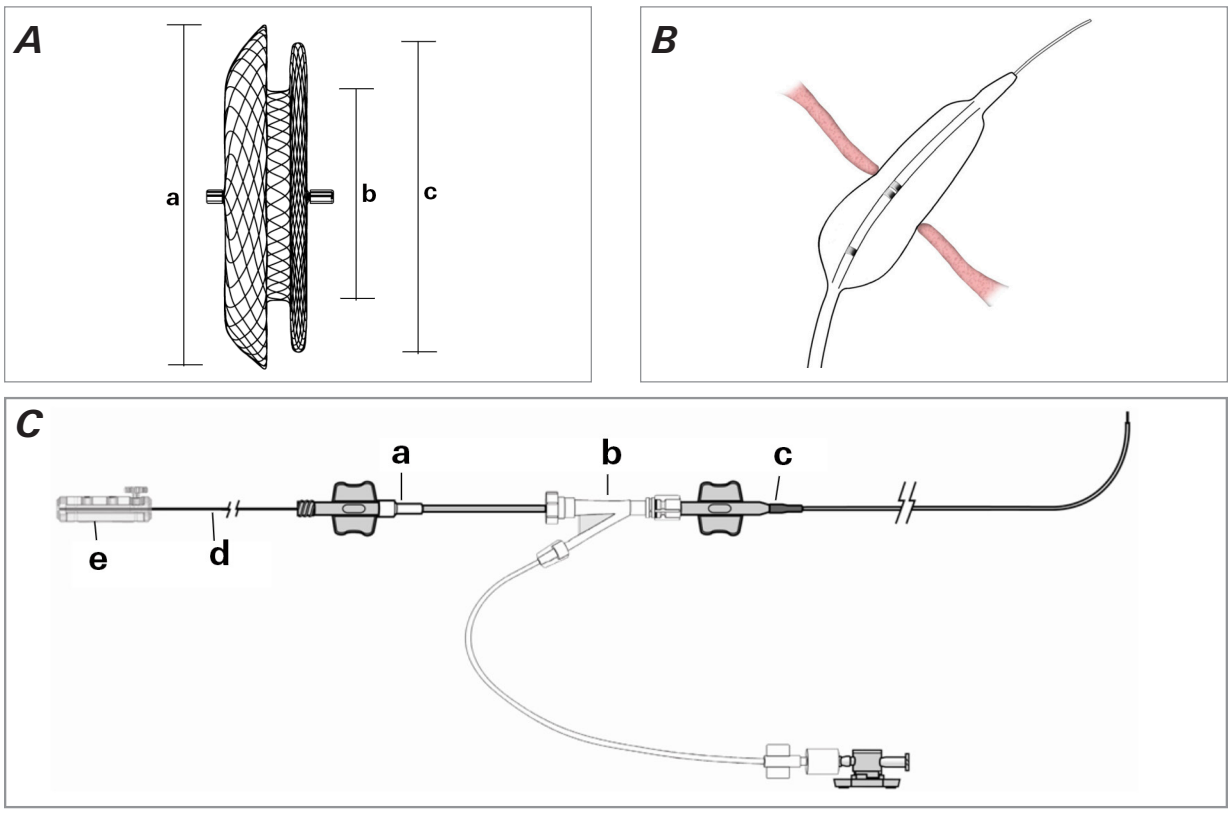

Fig. 3 Devices used to treat patent foramen ovale (PFO). **A**) Diagram of the Amplatzer Septal Occluder. The device consists of 2 disks that straddle the interatrial septal defect and can be easily deployed through venous access: (**a**) Left atrial disc, (**b**) device waist, and (**c**) right atrial disc. **B**) Diagram of an expanded sizing balloon for accurate measurement of minimum PFO diameter. **C**) Schematic of the Amplatzer TorqVue LP Delivery System: (**a**) loader, which introduces the device into the delivery catheter; (**b**) hemostasis valve with extension tube and stopcock, which allows flushing of the delivery system and controls back-bleeding; (**c**) delivery catheter, which provides a pathway through which a device is delivered; (**d**) delivery wire (optional), which attaches to the device to control its movement through the delivery catheter; and (**e**) plastic vise (optional), which attaches to the delivery wire, serving as a "handle" for detaching (unscrewing) the delivery wire from the device. Amplatzer, Amplatzer TorqVue, and TorqVue are trademarks of Abbott or its related companies. Reproduced with permission of Abbott, ©2024. All Rights Reserved.

and pericardial approach with the Lariat device (SentreHEART, Inc). Both techniques are used to decrease the risk of stroke in patients with atrial fibrillation, particularly patients at high risk of bleeding because of oral anticoagulants. Preprocedural imaging of the LAA with TEE is used to exclude left atrial or appendage thrombus and to define the size and shape of the LAA. Detailed TEE measurements of the LAA at 0°, 45°, 95°, and 135° help assess the optimal size and suitability of the device. During transseptal puncture, the interventionalist uses TEE with biplane or 3-dimensional imaging of the interatrial septum as a guide.

The Lariat Device

The Lariat device, which was developed at The Texas Heart Institute, can be carefully deployed by the interventional cardiologist but requires both percutaneous intracardiac access of the LAA and extracardiac pericardial access. With this technique, TEE is used to guide the magnetized intracardiac lead across the interatrial septum and into the LAA, where it will "find" the magnetized intrapericardial snare placed percutaneously into the pericardial space. Once the 2 leads are magnetically joined, the Lariat device is advanced around the LAA from the pericardium to exclude the LAA from the outside of the heart. The result is the long-term, permanent transmural exclusion of the LAA, which may be the reason Lariat device recipients have a sustained long-term reduction in atrial fibrillation burden. Real-time imaging is used during device placement to assess device position. After deployment, assessing device placement and scanning for residual complications, including pericardial effusion, are imperative.

The Watchman Device

For LAA exclusion with the Watchman device, the device is advanced across the interatrial septum into the ostium of the LAA. It is maneuvered percutaneously to exclude the inlet of the LAA; thus, flow into the LAA is occluded if the Watchman device is successfully deployed. Confirmation of residual flow is assessed using TEE, and the device is repositioned to ensure maximum LAA exclusion. Figure 4 shows a transesophageal echocardiogram before Watchman device deployment. The LAA is measured at the waist where the device will sit. Biplane imaging allows simultaneous viewing of orthogonal views, shortening the imaging time. Biplane imaging of the interatrial septum also allows the interventionalist to visualize the puncture of the septum both inferiorly and posteriorly, which creates space within the atrium to maneuver the device into the LAA. Figure 5 shows a Watchman device,[3] which looks like a little parachute, lodged in the LAA, where it sits flush with the LAA inlet. Over time, blood will clot on the backside of the device. The transesophageal echocardiogram in Figure 6 demonstrates the confirmatory tugging of the device with the catheter still attached to the center of the Watchman device. Real-time imaging confirmed no residual flow on either side of the device, which appears to be well placed. Residual interatrial septal defect after catheter removal is common and should spontaneously close over time.

Follow-Up Imaging

Surveillance imaging is performed after deployment of either the Watchman device or the Lariat device at

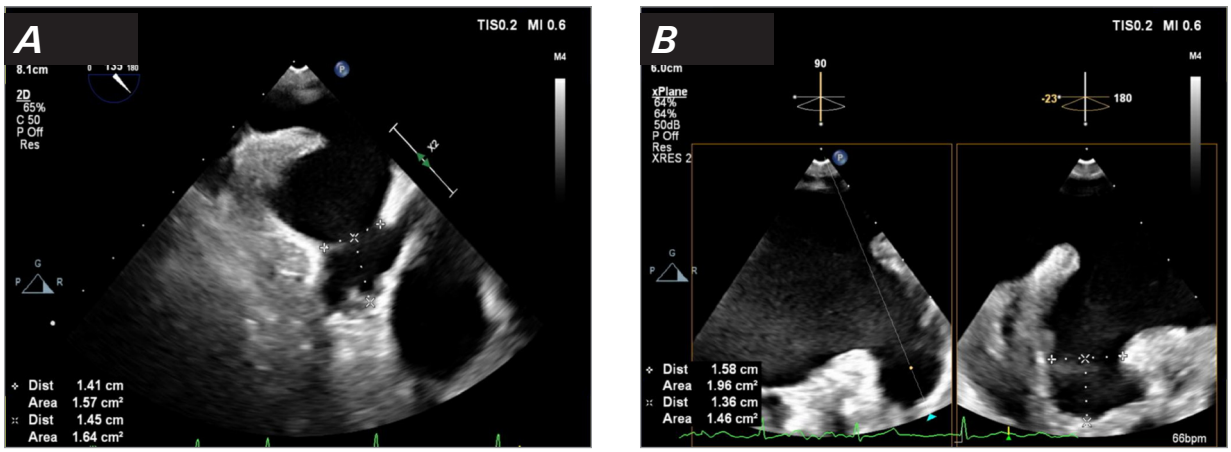

Fig. 4 Transthoracic echocardiogram shows left atrial appendage (LAA) sizing before Watchman device deployment and LAA exclusion. **A**) Measurement of LAA diameter and depth; (**B**) X-plane LAA view at 45° and 135°.

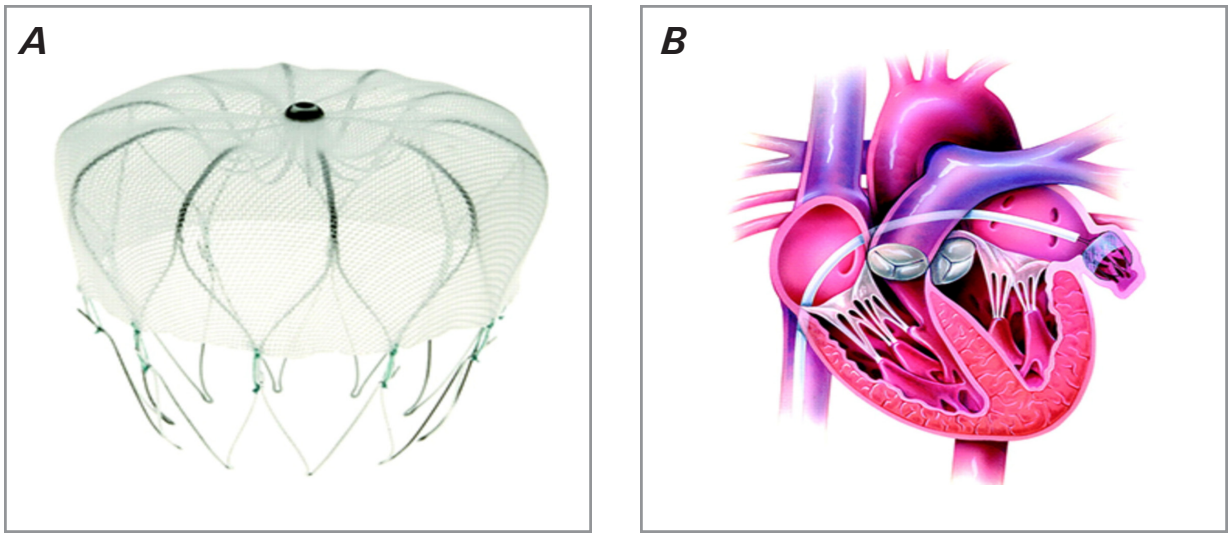

Fig. 5 Watchman device. **A**) Photograph shows the Watchman left atrial appendage (LAA) closure device. **B**) Schematic shows the Watchman LAA closure device in anatomical position.[3] Reproduced from Cueff et al. *Heart*. 97(9), 721-726. Reprinted with permission from *Heart* (©2011). BMJ Publishing. All Rights Reserved.

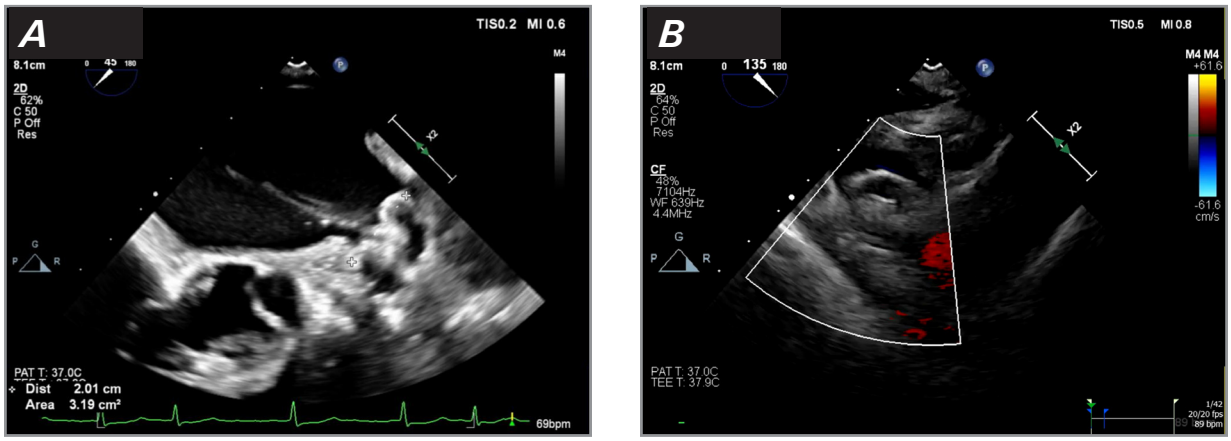

Fig. 6 Transesophageal echocardiograms were obtained during placement of the Watchman device. **A**) Intraprocedural positioning of the Watchman device. Imaging shows the confirmatory tugging of the device with the catheter still attached to the center of the device. **B**) Real-time imaging of residual flow on either side of the Watchman confirms accurate placement.

carefully timed intervals during follow-up. According to the most up-to-date information, thrombus formation on the Watchman device occurs in 3.7% of cases at follow-up.[4] As shown in Figure 7 on page 6, imaging from a patient at 1-month follow-up after Watchman device insertion showed evidence of a thrombus with a long, sinewy tail (Fig. 7A). After continued anticoagulation, follow-up imaging showed that the thrombus had resolved (Fig. 7B). This patient was maintained over the long term on a novel oral anticoagulant.

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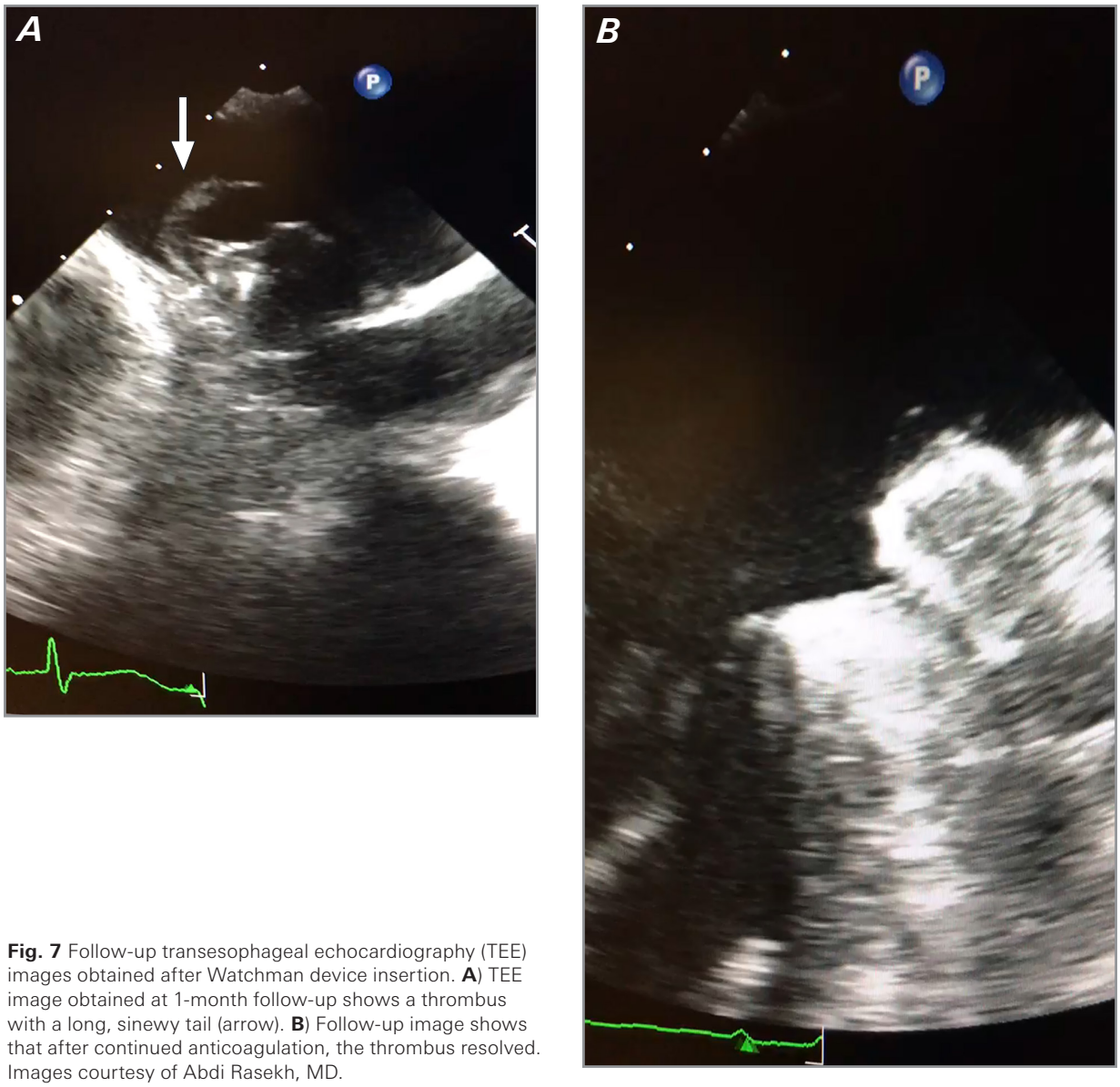

Fig. 7 Follow-up transesophageal echocardiography (TEE) images obtained after Watchman device insertion. **A**) TEE image obtained at 1-month follow-up shows a thrombus with a long, sinewy tail (arrow). **B**) Follow-up image shows that after continued anticoagulation, the thrombus resolved. Images courtesy of Abdi Rasekh, MD.

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