# Left Atrial Appendage Occlusion/Exclusion: Procedural Image Guidance with Transesophageal Echocardiography

Alan F. Vainrib, MD, Serge C. Harb, MD, Wael Jaber, MD, Ricardo J. Benenstein, MD, Anthony Aizer, MD, Larry A. Chinitz, MD, and Muhamed Saric, MD, PhD, *New York, New York; and Cleveland, Ohio*

Atrial fibrillation is the most common arrhythmia worldwide and is a major risk factor for embolic stroke. In this article, the authors describe the crucial role of two- and three-dimensional transesophageal echocardiography in the pre- and postprocedural assessment and intraprocedural guidance of percutaneous left atrial appendage (LAA) occlusion procedures. Although recent advances have been made in the field of systemic anticoagulation with the novel oral anticoagulants, these medications come with a significant risk for bleeding and are contraindicated in many patients. Because thromboembolism in atrial fibrillation typically arises from thrombi originating in the LAA, surgical and percutaneous LAA exclusion/occlusion techniques have been devised as alternatives to systemic anticoagulation. Currently, surgical LAA exclusion is typically performed as an adjunct to other cardiac surgical procedures, which limits the number of eligible patients. Recently, several percutaneously delivered devices for LAA exclusion from the systemic circulation have been developed, some of which have been shown in clinical trials to reduce the risk for thromboembolism. These devices use an either purely endocardial LAA occlusion approach, such as the Watchman and Amulet procedures, or both an endocardial and a pericardial (epicardial) approach, such as the Lariat procedure. In the Watchman and Amulet procedures, a transseptally delivered structure composed of nitinol is placed in the LAA orifice, thereby excluding the LAA from the systemic circulation. In the Lariat procedure, a magnet link is created between a transseptally delivered endocardial wire and epicardially delivered pericardial wire, followed by epicardial suture ligation of the LAA. (J Am Soc Echocardiogr 2017;■:■-■.)

*Keywords:* Transesophageal echocardiography, 3D, Left atrial appendage occlusion, Lariat device, Watchman device, Amulet device

Atrial fibrillation (AF) is the most common cardiac arrhythmia, affecting >3 million people in the United States alone. The prevalence of AF increases with age. The incidence of AF in the United States is projected to increase to 7.56 million by 2050 because of the aging population.[1]

Because of its significant morbidity and mortality, AF is associated with substantial personal, societal, and economic costs. AF is estimated to cost the United States approximately $6 billion each year.[2]

Systemic thromboembolism is the major complication of both valvular and nonvalvular AF. The left atrial appendage (LAA) is the most common site of thrombus formation, accounting for 91% of left heart thrombi in patients with nonrheumatic AF and 57% of thrombi in patients with rheumatic AF.[3]

Anticoagulation with orally, intravenously, or subcutaneously administered compounds is the most common method of preventing thromboembolism in patients with AF. Antiplatelet agents such as aspirin or clopidogrel can be used as an alternative to systemic anticoagulation but have been shown to have inferior efficacy compared with anticoagulation.

Satisfactory anticoagulation with oral warfarin with a target international normalized ratio of ≥2 to 3 has been demonstrated to reduce the risk for stroke and systemic embolism by 67% compared with placebo[4] and by 45% compared with aspirin.[5] Newer anticoagulants (such as dabigatran, apixaban, and rivaroxaban) have been shown to be at least noninferior to warfarin in nonvalvular AF.[6-8]

Unfortunately, all anticoagulants have significant bleeding risk and may be contraindicated in certain patients. The risk for major bleeding (typically defined as a reduction in hemoglobin level of ≥2 mg/dL, transfusion of 2 U of packed red cells, or symptomatic bleeding occurring at a critical site or resulting in death) with either warfarin or newer agents is estimated at 1.4% to >3% per year.[9]

Because most thrombi related to nonvalvular AF typically reside in the LAA, surgical or percutaneous techniques of LAA exclusion have been developed as alternatives to systemic anticoagulant and antiplatelet therapy. These exclusion procedures act locally at the level of the LAA to prevent thrombi from entering the systemic circulation.

Surgical techniques used for LAA exclusion have included ligation, clipping, stapling, and amputation.[10-12] A major limitation of these procedures is that they are typically performed as adjuncts to other cardiac procedures, and therefore only a small number of patients with AF are eligible for them.

Percutaneous LAA occlusion/exclusion devices (Figure 1) include the PLAATO (eV3, Plymouth, MN; no longer on the market),

From the Leon H. Charney Division of Cardiology New York University Langone Medical Center, New York, New York (A.F.V., R.J.B., A.A., L.A.C., M.S.); and the Cleveland Clinic, Cleveland, Ohio (S.C.H., W.J.).

Reprint requests: Muhamed Saric, MD, PhD, New York University, 560 First Avenue, New York, NY 10016 (E-mail: *muhamed.saric@nyumc.org*).

0894-7317/$36.00



https://doi.org/10.1016/j.echo.2017.09.014

| Abbreviations |
|---|
| **2D** = Two-dimensional |
| **3D** = Three-dimensional |
| **AF** = Atrial fibrillation |
| **ASD** = Atrial septal defect |
| **LAA** = Left atrial appendage |
| **PDL** = Para-device leak |
| **PEF** = Pericardial effusion |
| **TEE** = Transesophageal echocardiography |

Watchman (Boston Scientific, Maple Grove, MN), Amplatzer LAA occluders (Amplatzer Cardiac Plug and Amulet; St. Jude Medical, Minneapolis, MN),[13-15] and Lariat (Sentre-HEART, Palo Alto, CA).[16-18]

In the United States, currently the only device specifically approved by the US Food and Drug Administration for LAA occlusion is the Watchman device, which was cleared for general clinical use in March 2015.

The Lariat device has received class II clearance from the Food and Drug Administration via the 510(k) protocol. This device is not specifically approved for percutaneous LAA exclusion but rather for "facilitating suture placement and knot tying in surgical applications in which soft tissue is being approximated and/or ligated with a pre-tied polyester suture." Nevertheless, the Lariat has entered into clinical practice. There is increasing use of both devices in the United States.

The Amplatzer Cardiac Plug US pivotal trial began enrollment in 2013, but it was discontinued because of slower enrollment. The second-generation Amplatzer LAA occluder, referred to as the Amulet device, is currently being investigated in the United States in the Amulet trial.

The Watchman, Amplatzer Cardiac Plug, and Amulet device are delivered using peripheral venous access and transseptal puncture (a fully endovascular approach). In contrast, the Lariat procedure uses both an endocardial and a pericardial (epicardial) approach to create a magnet link between endocardial and pericardial wires, followed by epicardial suture ligation of the LAA. Another device that can ligate the LAA using an endocardial and a pericardial approach is the LASSO device (Aegis Medical Innovations, Vancouver, BC, Canada). This system uses electrical mapping rather than a magnetic link to locate and ligate the LAA and is currently being tested in the open-label LASSO AF trial.

All percutaneous LAA occlusion/exclusion procedures would not be possible without two-dimensional (2D) and three-dimensional 3D transesophageal echocardiography (TEE). In this review, we discuss the role of 2D and 3D TEE for periprocedural guidance of the percutaneous LAA occlusion/exclusion devices either currently commercially available or under clinical investigation in the United States, namely, the Watchman, Amulet, and Lariat.

## LAA ANATOMY

Detailed knowledge of LAA anatomy is essential for successful percutaneous LAA closure procedures. The LAA is a complex "fingerlike" projection from the anterolateral portion of the left atrium. Internally, it begins with an orifice that is typically ovoid and thus has a major and a minor orifice diameter. This orifice opens to its neck region, then its body, and ultimately ends in its apex (Figure 2).

The anatomic definition of LAA "orifice" is typically different from the "orifice" defined as the landing zone for various LAA occluder devices. This is addressed in detail with each individual occluder device description below.

The LAA orifice is separated from the left-sided pulmonary veins by the ligament of Marshall (also referred to as the left lateral or "Coumadin" ridge). The LAA may contain one or more lobes, defined as protrusions from its main body.[19]

Anatomic variants of the LAA are well described[20] and include the windsock, the broccoli (or cauliflower), the cactus, and the chicken wing (Figure 3). Of the known LAA variants, the chicken-wing morphology is the most common. However, it is also known to cause the greatest procedural difficulty with regard to LAA occlusion/exclusion. This is due to its broad width and shallow depth, which create a difficult situation regardless of the type of device used.

LAA anatomy is typically established during the screening process using gated cardiac computed tomographic angiography. It may also be confirmed using both intraprocedural TEE and fluoroscopy.

### Correspondence of Fluoroscopic and Transesophageal Echocardiographic Views of the LAA

It is important that a common language be developed between interventionalists, who are typically most familiar with fluoroscopy, and echocardiographers performing intraprocedural TEE.

The right anterior oblique caudal view is equivalent to approximately 135° on TEE and typically reveals the major axis of the LAA orifice (Figure 4).

The right anterior oblique cranial view is equivalent to approximately 45° on TEE and typically reveals the minor axis of the LAA orifice (Figure 5).

## OVERVIEW OF PERCUTANEOUS LAA OCCLUSION/EXCLUSION PROCEDURES

Irrespective of the LAA occlusion/exclusion device used, the basic steps are common to all percutaneous LAA occlusion/exclusion procedure. All percutaneous LAA occluder implantation procedures begin with peripheral venous access, which is typically obtained through the right femoral vein. Subsequently, a transseptal puncture is performed to gain access to the left atrium. Thereafter, specific steps for deployments of individual occluder devices are taken.

## TRANSSEPTAL PUNCTURE FOR PERCUTANEOUS LAA OCCLUDERS

### Overview

After peripheral venous access is obtained, typically through the femoral vein, a transseptal needle delivery catheter and dilator are passed through the inferior vena cava into the right atrium and temporarily placed in the superior vena cava. Thereafter, a transseptal needle is advanced through the delivery catheter.

Using transesophageal echocardiographic guidance, the whole system is then withdrawn from the superior vena cava into the right atrium and positioned against the inferior and posterior portion of the interatrial septum. The deliver catheter is then advanced against the interatrial septum to tent the interatrial septum at an appropriate location. Fluoroscopy and TEE are essential in guiding the proper location of tenting. The needle is then advanced, creating a transseptal puncture.