JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 7, NO. 11, 2014

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcin.2014.05.026

STATE-OF-THE-ART REVIEW

Percutaneous Left Atrial Appendage Closure

Procedural Techniques and Outcomes

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ABSTRACT

Percutaneous left atrial appendage closure technology for stroke prevention in patients with atrial fibrillation has significantly advanced in the past 2 decades. Several devices are under clinical investigation, and a few have already received Conformité Européene (CE)-mark approval and are available in many countries. The WATCHMAN device (Boston Scientific, Natick, Massachusetts) has the most supportive data and is under evaluation by the U.S. Food and Drug Administration for warfarin-eligible patients. The Amplatzer Cardiac Plug (St. Jude Medical, Plymouth, Minnesota) has a large real-world experience over the past 5 years, and a randomized trial comparing Amplatzer Cardiac Plug with the WATCHMAN device is anticipated in the near future. The Lariat procedure (SentreHEART Inc., Redwood City, California) has also gained interest lately, but early studies were concerning for high rates of serious pericardial effusion and major bleeding. The current real-world experience predominantly involves patients who are not long-term anticoagulation candidates or who are perceived to have high bleeding risks. This pattern of practice is expected to change when the U.S. Food and Drug Administration approves the WATCHMAN device for warfarin-eligible patients. This paper reviews in depth the procedural techniques, safety, and outcomes of the current leading devices. (J Am Coll Cardiol Intv 2014;7:1205–20) © 2014 by the American College of Cardiology Foundation.

Atrial fibrillation (AF) is estimated to affect 1.5% to 2% of the general population, and the prevalence is projected to increase to 12.1 million by 2030 in the United States (1). Unfortunately, AF is a major cause of stroke, increasing ischemic stroke risk by 5-fold, and is responsible for 15% of all strokes and 30% of strokes in patients age >80 years (2,3). Strokes associated with AF are also more severe, with victims having a 50% greater likelihood of becoming disabled or handicapped and >50% likelihood of death (4,5). Accordingly, stroke prevention with anticoagulation is among the main pillars of AF management, and anticoagulation guidelines have become more stringent. The Canadian Cardiovascular Society recommends anticoagulation for $CHADS_2$ (congestive heart failure history, hypertension history, age ≥75 years, diabetes mellitus history, stroke or transient ischemic attack symptoms previously) ≥1 and the European Society of Cardiology recommends it for CHA_2DS_2-VASc (congestive heart failure, hypertension, age ≥75 years, age 65 to 74 years, diabetes mellitus, stroke/transient ischemic attack/thromboembolism, vascular disease, sex female) ≥1 (6,7).

Several randomized placebo-controlled trials have demonstrated that oral anticoagulation (OAC) is highly effective in preventing thromboembolism with AF, with landmark meta-analysis showing 64% stroke reduction and 26% mortality reduction with warfarin (8,9). However, a significant proportion (30% to 50%) of eligible patients do not receive OAC due to absolute contraindications or perceived risks of bleeding (10). Long-term therapy with warfarin or novel oral anticoagulation (NOAC) is associated with lifetime major

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Manuscript received April 8, 2014; revised manuscript received May 1, 2014, accepted May 8, 2014.

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

ACP = Amplatzer Cardiac Plug

CCTA = cardiac computed tomography angiography

CE = Conformité Européene

FDA = Food and Drug Administration

ICE = intracardiac echocardiography

LAA = Left atrial appendage

NOAC = novel oral anticoagulation

OAC = oral anticoagulation

PET = polyethylene terephthalate

RAO = right anterior oblique

RR = risk ratio

TEE = transesophageal echocardiography

bleeding risks of 2.1% to 3.6% per year in recent clinical trials (11–13). Although intracranial hemorrhage is consistently lower with NOAC, the overall risk of major bleeding is not diminished with dabigatran or rivaroxaban compared with warfarin (12,13). Apixaban was the only agent that reduced major bleeding (11).

Other concerns and contraindications with OAC include patients with renal and liver dysfunctions (for NOAC), high risk of falls, noncompliance, and those requiring dual antiplatelet therapy after stenting. For warfarin, there are additional issues with drug and diet interaction, the need for monitoring, and a narrow therapeutic window with time in therapeutic range of only 50% to 60% (14,15). Even with the relatively well-tolerated NOAC, the proportion of patients discontinuing NOAC during study follow-up was 15% to 25% (11–13). There is also residual stroke risk of 2% to 5% annually despite optimal anticoagulation (16). These challenges have led to device-based therapies for nonvalvular AF.

Transesophageal echocardiography (TEE), autopsy, and surgical reports confirmed that >90% of nonrheumatic AF-related left atrial thrombi were isolated to, or originated from, the left atrial appendage (LAA) (17). Thus, mechanical approaches to exclude the LAA from systemic circulation were explored, and early attempts by surgical removal or ligation of LAA developed over 60 years ago were limited by the invasiveness and by significant rates of incomplete exclusion that were associated with increased stroke risks (18,19). Minimally invasive approaches have been developed over the past 2 decades and can be broadly divided into endocardial and epicardial devices (**Table 1**). This paper reviews contemporary percutaneous LAA closure, with in-depth discussions of the procedural techniques and clinical outcomes of leading devices.

INDICATIONS FOR PERCUTANEOUS LAA CLOSURE

The current indications for percutaneous LAA closure vary geographically. Recently, the European Society of Cardiology implemented a class IIB recommendation for patients with high stroke risk and contraindications to long-term OAC (7). The majority of procedures performed in Europe adhere to this guideline as reported by Tzikas (20). Among ~1,000 LAA closures, 74% were for patients with major bleeding or at high bleeding risk. Other indications included coronary stenting (23%), drug interaction (18%), stroke on warfarin (16%), renal or hepatic disease (13%), labile international normalized ratio (7%), and risk of falls (7%). In Canada, LAA closure is generally restricted to patients with $CHADS_2 \geq 1$ and contraindications to long-term OAC, under the Health Canada special access program. In the United States, the Lariat procedure may be performed for patients at high risk for stroke with or without contraindications to OAC, but WATCHMAN may only be implanted under the CAP2 (Continued Access Protocol 2) registry for patients eligible for OAC (up until early 2014), pending U.S. Food and Drug Administration (FDA) approval.

DEVICES FOR PERCUTANEOUS LAA OCCLUSION

PLAATO. The PLAATO (Percutaneous Left Atrial Appendage Transcatheter Occlusion) device (Appriva Medical Inc., Sunnyvale, California) was the first percutaneous LAA device manufactured with the first human implant in 2001 (21). It consisted of a self-expanding nitinol cage (diameter 15 to 32 mm) with 3 anchors on each strut to stabilize the occluder. It was covered with nonthrombogenic polytetrafluoroethylene membrane to exclude blood flow into the remaining LAA. The PLAATO feasibility study involved 64 patients with AF and contraindications to OAC; the observed annual stroke risk was much lower than expected based on $CHADS_2$ score (3.8% vs. 6.6%) with 5-year follow-up (22). Despite this promising early result, the device was withdrawn from the market for commercial reasons.

WATCHMAN. The second dedicated LAA device to be manufactured was WATCHMAN, which was originally owned by Atritech Inc. (Plymouth, Minnesota) but acquired by Boston Scientific (Natick, Massachusetts) in 2011. The current second-generation WATCHMAN LAA Closure Technology consists of a self-expanding nitinol frame covered with permeable (160 μm) polyethylene terephthalate (PET) membrane (**Figure 1**). There are 10 active fixation anchors at the nitinol frame perimeter, designed to engage LAA tissue for device stability. The PET membrane covers ~50% of the proximal outer nitinol frame, which blocks thrombus embolization from the LAA and promotes healing and endothelialization. The device's spherical contour accommodates most LAA anatomy (case example, **Figure 2**). There are 5 sizes available (**Table 2**), delivered through dedicated 14-F sheaths with 12-F inner diameter and 75 cm working length. There are 3 dedicated access sheaths: double-curve, single-curve