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Chapter

Left Atrial Appendage Closure for Stroke Prevention

Serkan Asil

Abstract

Atrial fibrillation is the most common chronic arrhythmia worldwide, and stroke is its most common complication. Approximately 20% of all ischemic strokes attributed to atrial fibrillation. Left atrial appendage thrombi are 90% responsible for embolic strokes in patients with non-valvular atrial fibrillation. In patients with atrial fibrillation, systemic anticoagulation is highly effective in lowering the risk of stroke. Bleeding problems and non-adherence hamper adequate anticoagulation therapy. As an alternative to stroke prevention with medical treatment, left atrial appendage closure is feasible and has proven to be an alternative to anticoagulation in non-valvular atrial fibrillation patients. Various left atrial appendage closure methods and devices have been defined and applied surgically and percutaneously. Exclusion of the left atrial appendage potentially minimizes the risk of embolic stroke and may eliminate chronic anticoagulation requirements. This chapter reviews left atrial appendage closure for stroke prevention in non-valvular atrial fibrillation.

Keywords: atrial fibrillation, left atrial appendage closure, stroke prevention

1. Introduction

Worldwide, atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in adults [1]. The present prevalence of AF in adults is between 2% and 4%, with a 2.3-fold increase expected due to increased lifespan in the general population [1]. Increasing age is a main AF risk factor [2]. Additionally, the rising prevalence of other comorbidities and modifiable risk factors, such as hypertension (HT), diabetes mellitus (DM), heart failure (HF), coronary artery disease (CAD), chronic kidney disease (CKD), obesity, and obstructive sleep apnea (OSA), are critical [2]. Thromboembolic stroke in patients with atrial fibrillation may be attributed to the production and embolization of atrial thrombi, which primarily originate from the left atrial appendage.

Regardless of the treatment strategy of rate and rhythm control, treatment efforts must also focus on preventing thromboembolic events. The most vital complication attributed to AF is embolic stroke, and a meta-analysis of 50 studies detected AF in 24% of patients with embolic stroke of undetermined source [3]. Patients with AF are at high risk for thromboembolism, especially ischemic stroke. The risk of stroke in patients with non-valvular AF is approximately 5% per year [4]. Furthermore,
compared to non-AF strokes, AF-related strokes are associated with increased mortality and morbidity, emphasizing the need of more effective stroke prevention in these patients.

The risk of stroke due to AF is specified by risk scores determined from population-based studies, and current guidelines recommend using the CHA\textsuperscript{2}DS\textsuperscript{2}VASc score for this purpose [2]. Based on the analysis of 1084 patients, Lip et al. validated this risk model and demonstrated incremental risk of embolic events with rising scores [5]. In patients with a risk score of 2 and above, oral anticoagulants (OAC) are recommended, considering the risk of bleeding. It can be recommended by evaluating the benefit-harm in patients with a score of 1 [2]. Many antithrombotic agents have been studied to prevent an ischemic stroke from AF. Studies that started with aspirin have shifted to

<table>
<thead>
<tr>
<th>Anticoagulation strategy</th>
<th>Comparison group</th>
<th>Study name</th>
<th>Cerebral events risk</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspirin</td>
<td>Placebo</td>
<td>Hart et al. (meta-analyses of six trials) [6].</td>
<td>Relative risk reduction 22% (CI 2–38)</td>
<td>Superiority of aspirin over placebo</td>
</tr>
<tr>
<td>Warfarin</td>
<td>Placebo</td>
<td>Hart et al. (meta-analyses of six trials) [6].</td>
<td>Relative risk reduction 62% (CI 48–72)</td>
<td>Superiority of warfarin over placebo</td>
</tr>
<tr>
<td>Aspirin</td>
<td>Placebo</td>
<td>Hart et al. (meta-analyses of five trials) [6].</td>
<td>Relative risk reduction 36% (CI 14–52)</td>
<td>Superiority of warfarin over aspirin</td>
</tr>
<tr>
<td>Dual Antiplatelet (Aspirin and clopidogrel)</td>
<td>Warfarin</td>
<td>Connolly et al. ACTIVE W [7].</td>
<td>Relative risk 1.44 (95% CI 1.18–1.76)</td>
<td>Trial stopped early due to benefit with warfarin</td>
</tr>
<tr>
<td>Aspirin</td>
<td>Warfarin</td>
<td>Connolly et al. ACTIVE A [8].</td>
<td>Relative risk 0.72 (95% CI 0.62–0.83)</td>
<td>Bleeding risk 1.57 (95% CI 1.29–1.92)</td>
</tr>
<tr>
<td>Dabigatran 110 mg twice daily</td>
<td>Warfarin</td>
<td>Connolly et al. RELY [9].</td>
<td>Relative risk 0.91 (95% CI 0.74–1.11)</td>
<td>Bleeding risk is lower with dabigatran</td>
</tr>
<tr>
<td>Dabigatran 150 mg twice daily</td>
<td>Warfarin</td>
<td>Connolly et al. RELY [9].</td>
<td>Relative risk 0.66 (95% CI 0.53–0.82)</td>
<td>Bleeding risk is similar between groups</td>
</tr>
<tr>
<td>Rivaroxaban 20 mg daily</td>
<td>Warfarin</td>
<td>Patel et al. ROCKET AF [10].</td>
<td>Relative risk 0.79 (95% CI 0.66–0.96)</td>
<td>Similar overall bleeding, less intracranial/fatal</td>
</tr>
<tr>
<td>Apixaban 5 mg twice daily</td>
<td>Warfarin</td>
<td>Granger et al. ARISTOTLE [11].</td>
<td>Relative risk 0.79 (95% CI 0.66–0.95)</td>
<td>Less overall bleeding and all-cause mortality</td>
</tr>
<tr>
<td>Edoxaban 30 mg daily</td>
<td>Warfarin</td>
<td>Guigliano et al. ENGAGE-AF [12].</td>
<td>Relative risk 1.07 (95% CI 0.87–1.31)</td>
<td>Less bleeding and cardiovascular death</td>
</tr>
<tr>
<td>Edoxaban 60 mg daily</td>
<td>Warfarin</td>
<td>Guigliano et al. ENGAGE-AF [12].</td>
<td>Relative risk 0.79 (95% CI 0.63–0.99)</td>
<td>Less bleeding and cardiovascular death</td>
</tr>
</tbody>
</table>

Table 1. Summary of antithrombotic therapy studies for stroke prevention in atrial fibrillation.
OAC agents with the clear benefit of warfarin in this area. Although long-term anticoagulation with warfarin is adequate, many drawbacks exist. The narrow therapeutic window complicates its use and compels a delicate balance between lack of efficacy and significantly elevated bleeding risk, and regular control blood tests are required. In addition, the presence of many drug and food interactions makes it more challenging to use in patients with advanced age and multisystem disease. In recent years, direct-acting anticoagulants (DOAC) (dabigatran, rivaroxaban, apixaban, edoxaban) that do not require routine monitoring have made a breakthrough in the treatment and have been used routinely. Antithrombotic therapy studies are briefly summarized in Table 1.

2. Left atrial appendage closure

In non-valvular atrial fibrillation, the thrombus originates in the left atrial appendage (LAA) in 90% of the patients [13]. The primary rationale for LAA closure is that the remaining small risk no longer warrants OAC after excluding the LAA as an embolic source. Exclusion of the LAA either by surgical or catheter-based means has been implemented in recent years.

LAA is the tubular blind-ended embryonic remnant of the left atrium, and its shape, number of lobes, depth, and orifice diameter varies and the risk of thrombus may vary according to these variables [14, 15]. Although it is known that LAA is an embryonic remnant, it also has some functions. For example, modulation of sympathetic and parasympathetic tone, decompression of the left atrium when atrial pressure rises, production of natriuretic peptide (primarily atrial natriuretic peptide), and contribution to the diastolic filling of the left ventricle [16].

Its complex shape with low-flow zones makes it prone to stasis, which can be seen in transesophageal echocardiography (TEE) as spontaneous echo contrast or reduced pulsed-wave velocity [17]. This change in the anatomy and hemodynamics of the LAA is of significant importance before the closure procedure. While direct visual evaluation may be acceptable in surgical closures, especially if percutaneous closure is planned, LAA diameter, depth, type, presence of thrombus, and interatrial septal anatomy should be evaluated in detail before the procedure with TEE, computed tomography (CT), and cardiac magnetic resonance imaging (MRI).

2.1 Surgical left atrial appendage closure

Surgical LAA exclusions were first performed in the 1940s but found limited application because they prolong the surgical procedure and require special techniques [18]. However, surgical techniques and devices have been developed in recent years, and LAA closure has been applied in patients who undergo cardiac surgery for other reasons if AF is accompanied. The only randomized controlled study on this subject, the Left Atrial Appendage Occlusion Study (LAAOS), was published in 2005 [19]. Seventy-seven patients with AF undergoing coronary artery bypass surgery were randomized 2:1 as LAA closure and LAA no closure. As a result of the study, it was specified that the procedure is safe, but the high rate of incomplete closure was not suitable for event evaluation [19]. In a retrospective study of 205 patients who underwent mitral valve replacement, a lower incidence of stroke was found in the group that underwent LAA closure (58 patients-52 had successful ligations) [20]. In light of this study data, the American College of Cardiology recommended considering LAA closure in AF patients who will undergo mitral valve surgery [21]. In a retrospective
cohort study of 10,524 Medicare recipients with atrial fibrillation undergoing cardiac surgery, LAA closure resulted in a significant reduction in hospital admissions due to thromboembolism compared to non-closure (unadjusted, 4.2% vs. 6.2%; adjusted hazard ratio, 0.67) [22]. In a meta-analysis of five studies following had been analyzed – beneficial in one study, harmful in one study, and neutral in three studies, it was stated that there was not enough evidence for routine recommending closure [23]. In this meta-analysis, incomplete closure rates were between 55 and 65%, and residual LAA flow or incomplete LAA closure may be associated with an increased risk of stroke [23, 24].

Surgical LAA closure or exclusion during cardiac surgery remains controversial for routine practice. The LAA structure is variable, and the risk of procedure complications increases due to its location close to the epicardial circumflex artery, the great cardiac vein, the endocardial mitral annulus, and the left upper pulmonary vein. European Society of Cardiology Atrial fibrillation guideline recommends that surgical occlusion or exclusion of the LAA be considered with class IIB recommendation level for stroke prevention in patients with AF undergoing cardiac surgery [2].

2.2 Catheter-based left atrial appendage closure

The primary downside to surgical LAA closure is that which holds little interest as a stand-alone procedure. The trials researching its utility included only patients undergoing cardiac surgery for another indication. Therefore, the appeal of a percutaneous procedure for closure of the LAA in patients at high risk for stroke and suboptimal candidates for anticoagulation because of hemorrhage is obvious and led to the development of the percutaneous catheter-based device systems. Percutaneous LAA closure has been applied since 2002 in Europe and since 2003 in the USA in patients with high thromboembolism risk and contraindications to OAC treatment.

There are two basic methods of LAA closure, endocardial and epicardial. LAA closure is performed by endovascular delivery of a nitinol-based device via a dedicated sheath inside the LAA. After the implant, antithrombotic treatment is required to prevent device-related thrombosis until endothelialization occurs. In percutaneous epicardial LAA exclusion, LAA closure is secondary to the epicardial ligation of the LAA. No foreign body is in touch with the bloodstream, and post-procedural antithrombotic treatment is usually undue unless a residual leak is present. Many devices have been developed for this purpose, the first of which is the Percutaneous LAA occluder (PLAATO, eV3, Inc., Plymouth, MA, USA) (Figure 1). The device was covered with a self-expanding nitinol cage and a non-thrombogenic PTFE membrane. Ostermayer et al. reported that PLAATO system implantation was performed on 111 non-valvular AF patients in a non-randomized, multi-center study [25]. The procedure was successfully terminated in 108 patients (97.3%). In a 6-month follow-up, a thrombus was detected on the device in one patient. In the successful long-term follow-up of 91 patients, stroke developed in two (2.2%) patients. In the 5-year results of the North American cohort of this study, the annual stroke rate of 64 patients was 3.8% in this population [26].

The WATCHMAN (Boston Scientific, Marlborough, MA, USA) is the other closure system most studied and has the only randomized controlled trial between LAA closure and warfarin (Figure 1). The WATCHMAN consists of a self-expanding Nitinol frame covered by a 160 μm polyester membrane on its left atrial side. The device has a fixation barb around the mid-perimeter to secure the occlude to the left atrial
appendage wall. Measuring the width and length of the LAA before the procedure is essential to select the device diameter. There are five devices with diameters between 21 and 33 mm available to fit in different LAA ostium. The device’s size should be 10–20% larger than the LAA ostium diameter.

The WATCHMAN LAA closure system was tested in a pilot study of 75 patients in terms of safety and efficacy, and the successful placement rate was found to be 88% [27]. Five of the first 16 patients developed device-related complications (two device embolization, one air embolism, one surgical device removal due to incorrect position, and one delivery system fracture requiring surgery) [27]. These complications led to design changes to the fixation barb and a second-generation device was used. No device embolization was found in other remaining 53 patients who have implemented a WATCHMAN device [27].

A prospective, randomized, multicenter PROTECT-AF study (percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation: a randomized non-inferiority trial) comparing LAA closure and long-term OAC therapy with the WATCHMAN LAA system with non-valvular AF (CHADS2 score ≥ 1), a total of 707 patients using OAC were
randomized to the device and control groups in a 2:1 ratio [28]. This study had a non-inferiority design with a composite primary efficacy endpoint of cerebral events, cardiovascular death, and embolic event. In a mean follow-up of more than 1 year, the primary endpoint incidence was 3% in the device group, 4.9% in the OAC group, and the annual stroke rate was 2.3% in the device group and 3.2% in the OAC group [28]. Continued efficacy of the WATCHMAN device was demonstrated at a 4-year follow-up [29]. Procedural severe complications were observed in 12% of patients in the PROTECT-AF study. The most common severe complications are pericardial effusion (5%) requiring surgical or percutaneous intervention and acute stroke due to embolism (1.1%) [28].

Because of lingering safety concerns from the PROTECT AF trial, a second confirmatory trial, PREVAIL, randomized 407 patients 2:1 to device versus warfarin [30]. PREVAIL did not achieve non-inferiority for its primary efficacy outcome due to a low stroke rate in the control arm. At 18-months, the primary endpoint rate was 0.064 in the device group versus 0.063 in the control group (RR 1.07, 0.95% CI 0.57–1.89) [30]. However, procedural complications decreased from 8.7% in PROTECT-AF to 4.2% in PREVAIL, especially rates of pericardial effusion requiring surgical repair decreased in this trial to 0.4% (compared to 1.6% in PROTECT AF) [30]. These findings led to the general conclusion that LAA closure is both safe and effective. A meta-analysis evaluating bleeding outcomes for the 1.114 patients enrolled in PROTECT-AF and PREVAIL over the median of 3.1 years of follow-up showed similar overall bleeding rates between groups (3.5 vs. 3.6 events per 100 patient-years, RR 0.95, 95% CI 0.66–1.40 p = 0.84) [31]. However, there were significantly fewer ischemic events in LAA closure (1.8 vs. 3.6 events per 100 patient-years RR 0.49, 95%CI 0.32–0.75 p = 0.001) [31]. Furthermore, the combined 5-year PROTECT-AF and PREVAIL results demonstrated a numerically higher ischemic stroke, but this difference did not reach statistical significance (HR: 1.71; p = 0.080), also reductions in major bleeding, hemorrhagic stroke, and mortality in the device arm [32].

The EWOLUTION, a prospective, multicenter, single-arm registry, included 1020 patients undergoing WATCHMAN implantation that was designed to assess the real-world impact of LAA closure [33]. Thromboembolic and bleeding risk scores were higher in patients than in randomized controlled trials. After a median of 2 years of follow-up, the ischemic stroke rate was 83% lower than expected by the CHA2DS2-VASc score. According to documented data, the major bleeding rate was reduced by 46% compared to normal rates when warfarin was used. The implant success was high (98.5%), and procedure and device-related adverse severe events ≤7 days were seen in 2.8% of patients (including death 0.4%; major bleeding 0.9%; tamponade 0.3%; device embolization 0.2%) [33].

The WATCHMAN FLX is a next-generation LAA closure device in the WATCHMAN family. In its US-approval trial (PINNACLE FLX), Watchman FLX has demonstrated equally favorable efficacy and safety profile [34].

LAA closure has also been performed using the Amplatzer devices. The Amplatzer Cardiac Plug (ACP) is a device developed specifically for LAA closure. In the first European experience with the ACP device, LAA closure was successfully performed in 132/137 patients (96%). Serious complications were seen in 10 (7%) patients in the first 24 hours [35]. In a multicenter retrospective study that investigated the safety, feasibility, and efficacy of the ACP device, 1047 patients were evaluated [36]. The success rate of the procedure was 97.3%. There were 52 (4.97%) periprocedural significant adverse events. In 1001/1019 (98.2%) of successfully implanted patients, follow-up was completed (average 13 months, total 1349 patient-years). All-cause
mortality was 4.2% after one year. At the follow-up, no deaths were attributed to the device. During the follow-up period, there were nine strokes (0.9%) and nine transient ischemic attacks (0.9%) [36].

The Amplatzer AMULET (Figure 1) is an iterative design advance on the original ACP device. The configuration maintains the concept and the basic structure of the original version but was intended to improve device performance and increase the device’s safety (including sealing and stability). The Amulet is a self-expanding nitinol device with two pre-mounted components (a lobe and a disc) on a single cable. The external disc provides more appropriate coverage of the LAA ostium. The distal lobe comprises of six to 10 pairs of stabilizing hooks across its diameter to anchor to the LAA and provide stability, which is enhanced by its gentle radial force and proximal disc traction. The most extensive study with the AMULET, LAA closure device, was an observational registry study [37]. In the study that included 1088 patients, AMULET was successfully implanted in 99% of cases. In TEE performed 1 to 3 months after the procedure, residual flow in the LAA was not observed in 98.4% of patients. The observed ischaemic stroke rate was 2.9% per year. Device-related thrombus was reported in 1.7% of patients [37].

AMULET IDE trial was designed to evaluate the safety and effectiveness of the Amulet LAA closure compared with the Watchman device [38]. The trial was designed for 1:1 randomized and multicenter, and 1878 patients enrolled in study. The AMULET device was non-inferior to the Watchman device for the primary safety endpoint (14.5% versus 14.7%; difference = −0.14 [95% CI, −3.42 to 3.13]; P < 0.001 for noninferiority). Major bleeding and all-cause death were similar among groups (10.6% versus 10.0% and 3.9% versus 5.1%, respectively). Procedure-related

<table>
<thead>
<tr>
<th>Device</th>
<th>Design</th>
<th>Size</th>
<th>Proper LAA characteristics</th>
<th>Delivery System</th>
<th>Approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watchman</td>
<td>Single lobe</td>
<td>20–24–27–31–35</td>
<td>15 to 32 mm, width 1/2 device size, depth</td>
<td>14-Fr sheath; single-curve or double-curve</td>
<td>CE Mark (2005); FDA (2015)</td>
</tr>
<tr>
<td>(Endocardial)</td>
<td>(Boston Scientific)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amulet</td>
<td>Distal lobe and proximal disc</td>
<td>16, 18, 20, 22, 25, 28, 31, and 34</td>
<td>11 to 31 mm, width &gt; 12 to 15 mm, depth</td>
<td>12-Fr or 14-Fr sheath; double curve</td>
<td>CE Mark (2013)</td>
</tr>
<tr>
<td>(Endocardial)</td>
<td>(Abbott)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAmbré (Lifetech</td>
<td>Double (umbrella and cover)</td>
<td>16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36</td>
<td>The size of the implant would be 4 to 8 mm larger than the measured LAA orifice.</td>
<td>8–10- Fr sheath</td>
<td>CE Mark (2016);</td>
</tr>
<tr>
<td>Scientific Co., Ltd.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasel (Cardia Inc.)</td>
<td>Double (bulb and sail)</td>
<td>16, 18, 20, 22, 24, 26, 28, 30, 32</td>
<td>Maximum measured landing zone, with ≥25% oversizing.</td>
<td>10–12-Fr sheath</td>
<td>CE Mark (2016)</td>
</tr>
<tr>
<td>Lariat</td>
<td>Non-absorbable suture</td>
<td>40 and 45 (suture loop)</td>
<td>Up to 40 mm width Up to 70 mm length.</td>
<td>13.5-Fr epicardial sheath; 8.5-Fr endocardial sheath; magnet-tip wires; endocardial balloon</td>
<td>CE Mark (2015); FDA 510(k) (2006), surgical use only</td>
</tr>
</tbody>
</table>

Table 2. Most common left atrial appendage closure devices and main characteristics.
<table>
<thead>
<tr>
<th>Device</th>
<th>Trial</th>
<th>Study design</th>
<th>Number</th>
<th>Implant success</th>
<th>Procedure-related complications</th>
<th>Systemic thromboembolism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watchman (Endocardial)</td>
<td>PROTECT AF 2009</td>
<td>Randomized control trial</td>
<td>707 patients</td>
<td>91%</td>
<td>12%</td>
<td>3 events per 100 patient years</td>
</tr>
<tr>
<td>(Boston Scientific)</td>
<td>[28]</td>
<td>2:1 randomization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREVAIL 2014 [30]</td>
<td>Randomized control trial</td>
<td>407 patients</td>
<td>95%</td>
<td>5%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>EWOLUTION 2017 [33]</td>
<td>Prospective observational</td>
<td>1020</td>
<td>99%</td>
<td>3%</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Reddy et al. 2017 [32]</td>
<td>Prospective observational</td>
<td>3822</td>
<td>96%</td>
<td>2%</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Amulet (Endocardial)</td>
<td>Landmesser et al.</td>
<td>Prospective observational</td>
<td>1088</td>
<td>99%</td>
<td>6%</td>
<td>3% per year</td>
</tr>
<tr>
<td>(Abbott)</td>
<td>2017 [37]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L'Ambre (Lifetech Scientific Co., Ltd.)</td>
<td>Huang et al. 2017 [39]</td>
<td>Prospective observational</td>
<td>153</td>
<td>99%</td>
<td>6%</td>
<td>1%</td>
</tr>
<tr>
<td>Lariat (Epicardial)</td>
<td>Lakkireddy et al.</td>
<td>Retrospective observational</td>
<td>712</td>
<td>94%</td>
<td>10%</td>
<td>—</td>
</tr>
<tr>
<td>(SentreHeart)</td>
<td>2016 [40]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Main studies of percutaneous left atrial appendage closure devices.
complications were higher for the AMULET device (4.5% versus 2.5%), primarily related to more frequent pericardial effusion and device embolization [38].

Other less common endocardial LAA closure devices are WAVECREST (Biosense Webster, Diamond Bar, CA, USA), LAMBRE (Lifetech Scientific, Shenzhen, China), ULTRASEAL (Cardia Inc. – Eagan, MN, USA), OCCLUTECH (Occlutech International. Tables 2 and 3 summarize left atrial appendix closure device features and main study results.

LARIAT (SentreHeart, Redwood City, CA, USA) is a suture-based LAA exclusion device that allows epicardial LAA ligation with no device left in the endocardial area. Therefore, LAA occlusion is secondary to the epicardial ligation of the LAA. In the multicenter observational registry study concerning 712 patients, LARIAT was successfully performed in 682 patients (95.5%) [40]. The complete exclusion was achieved in 669 patients (98%), while 13 patients (1.8%) had a trace leak (<2 mm). There was one death related to the procedure. Ten patients (1.44%) had cardiac perforation necessitating open surgery, while another 14 (2.01%) did not require surgery. Delayed complications (pericarditis, pericardial and pleural effusion) occurred in 34 (4.78%) [40].

In clinical practice, the most prevalent reason for LAA occlusion/exclusion is a perceived high bleeding risk or less frequently contraindications to OAC. On the other hand, LAA closure devices have not been tested in such groups at random. Most patients who would have been considered inappropriate for OAC treatment with warfarin a few years ago now seem to do well on DOAC, and LAA closure has not been compared to DOAC therapy or surgical LAA occlusion/exclusion in patients at risk for bleeding. In patients with anticoagulation contraindications, appropriately powered trials are needed to determine the optimum LAA closure indications compared to DOAC therapy [2]. The 2020 European Society of Cardiology Atrial Fibrillation guidelines recommends catheter-based LAA closure with class IIB level [2].

### 3. Procedure

Pre-procedural imaging is required to rule out LAA thrombus, examine LAA anatomy for appropriateness for percutaneous closure, and identify the optimal device sizing. Left atrial appendage thrombus is not an absolute contraindication for LAA closure. It has been reported that closure is performed by experienced operators, especially in the presence of a deeply located organized thrombus [41, 42]. The LAA is viewed in many planes with TEE, the most common being 0°, 45°, 90°, and 135° angles [43]. As a result, the maximum LAA dimensions for the LAA closure device are estimated (Figure 2). In addition, CT can be used. It offers a higher spatial resolution than TEE, allowing the 3D reconstruction of vital anatomical structures, and LAA thrombi can be ruled out safely with delayed acquisition imaging [44] (Figure 3). Each LAA closing device has different measurement areas and details to match its specifications. Since the AMULET device is used in our center, we used images of LAA sizing for AMULET in TEE, and procedural images of the device implantation.

The procedure should be performed under general anesthesia, and patients could be intubated for optimal TEE guidance. Fluoroscopy and three-dimensional (3D) TEE assistance should be used to accomplish transseptal puncture. If no anatomic changes hindered optimal alignment, the transseptal puncture should be performed at the inferoposterior site of the interatrial septum. Also, it is possible to utilize intracardiac echocardiography (ICE) during the implant procedure [45]. After a successful
transseptal puncture, the delivery catheter can be inserted in the left atrium. Once the delivery catheter is engaged in LAA, LAA angiography is performed to confirm its size, usually using an RAO caudal projection, which is roughly equivalent to a 135°
TEE view. For optimal sizing and safe sheath positioning, different views may be required. The deployment of LAA closure devices is done slowly and cautiously. After the device is positioned in the LAA, it is placed by unsheathing. LAA closure devices should be evaluated for proper alignment, compression, the absence of any peri-device leak, and stability before being released (the “tug test”) (Figure 4).

The patient must be treated with a combination of anti-thrombotic drugs (anti-platelet and/or anticoagulation) following the procedure, with the specific regimen being determined by the LAA closure device utilized and matched to the patient’s individual bleeding risk [46]. Complications related to LAAO are primarily acute; most of them can be detected by peri-procedural imaging. Cardiac perforation, pericardial effusion/tamponade, procedure-related stroke, and device embolization are common acute complications. In the late period of device implantation, device-related thrombosis and residual leakage-associated stroke can be seen. Surveillance imaging is needed to ensure proper LAA closure and the absence of device-related thrombosis at follow-up. TEE is the preferred imaging method because it gives real-time flow information without exposing the patient to radiation.

4. Conclusion

As a result, LAA closure is a proven treatment method with safety and effectiveness against warfarin. However, only the Watchman device has randomized controlled trials, other devices do not have randomized controlled trials yet, and current evidence was acquired from the registry and observational data. Furthermore, anticoagulants used in AF patients are mostly DOACs, and there is no randomized controlled study comparing DOACs. Despite these shortcomings, percutaneous LAA
closure may be a good alternative for patients who are not suitable for anticoagulation or experience life-threatening bleeding with anticoagulants.

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Conflict of interest

The authors declare no conflict of interest.
References


[13] Blackshear JL, Odell JA. Appendage obliteration to reduce stroke in cardiac
Atrial Fibrillation - Diagnosis and Management in the 21st Century


the AMPLATZER amulet device: One-year follow-up from the prospective global amulet observational registry. EuroIntervention. 2018;14:e590-e597


