Review Article

# Percutaneous Left Atrial Appendage Occlusion

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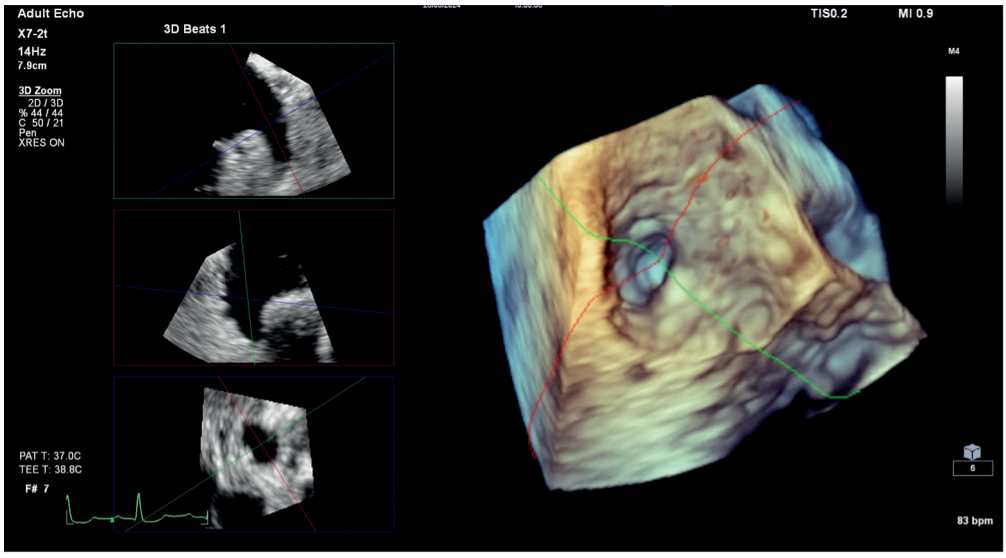
**Central Illustration: Percutaneous Left Atrial Appendage Occlusion**

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*Morphology of the LAA assessed by live multiplanar reconstruction from a 3D block obtained by focused zoom mode. Note, in the green frame, the reference of the circumflex artery, where the smallest diameter of the anchoring zone can be measured; in the red box, the largest diameter, with green and red intersecting lines displayed in the cross section (blue frame), and the 3D volume rendering image (large image on the right).*

## Abstract

Percutaneous occlusion of the left atrial appendage (LAA) is an alternative to oral anticoagulation for patients with atrial fibrillation (AF) or flutter who have high risk of cardioembolic events, but with a history or high risk of bleeding. In recent years, new generations of occluder devices have been developed, which, combined with greater experience of operators, have made it a safe procedure when properly indicated. Transesophageal echocardiography (TEE) plays a central role in assessing the morphology of the LAA, selecting device size, and image monitoring during the structural cardiovascular procedure.

## Keywords

Left Atrial Appendage Closure; Atrial Fibrillation; Coronary Occluaion

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## Introduction

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia. In 2010, the estimated worldwide number of men and women with AF was 20.9 million and 12.6 million, respectively.[1] More recent studies have estimated that the prevalence in the general population is between 0.4% and 3%; it is higher in males, with increasing age, and in developed countries.[2]

Systemic thromboembolism is the main complication of valvular and non-valvular AF. The left atrial appendage (LAA) is the main location of thrombi, and it is affected in 91% of thrombi formed in the left atrium in patients with non-rheumatic AF and 57% in those with rheumatic AF.[3]

The use of oral anticoagulation, with vitamin K antagonists (VKA) or new oral anticoagulants (NOAC), is currently the standard therapy for preventing thromboembolism, and it is superior to antiplatelet therapy.[4] When oral anticoagulation is chosen, NOAC (dabigatran, rivaroxaban, apixaban or edoxaban) should be preferred to VKA.[5]

However, the use of any anticoagulant increases risk of bleeding and may be contraindicated in some patients. The risk of major bleeding with the use of VKA or NOAC is estimated at 1.4% to > 3% per year.[6]

In this context, LAA occlusion has emerged as an important therapeutic alternative that can be performed through surgical or percutaneous techniques.

Surgical techniques include ligation, stapling, and amputation of the LAA. Their main limitation is the fact that they are indicated when combined with other cardiac procedures.[7]

There are two ways to approach the LAA through the percutaneous route. The first strategy uses devices that are inserted into the LAA to occlude it on its endocardial surface. The other uses a percutaneous epicardial ligation technique to externally exclude the LAA (for example, Lariat, which is unavailable in Brazil). Over the past few years, different LAA occlusion devices have been developed. This article will discuss the role of two-dimensional (2D) and three-dimensional (3D) transesophageal echocardiography (TEE) as a guide in LAA occlusion procedures, covering the main occluder devices used in Brazil (Watchman/Watchman FLX, Amulet and LAmbre).

## LAA anatomy

Knowledge of LAA anatomy is fundamental to guide the occlusion procedure. The LAA is a complex "finger-shaped" projection from the anterolateral portion of the left atrium. Internally, it begins with a typically ovoid orifice, with a major and minor diameter. The orifice continues to the neck region, then the body, ending at its apex.

The definition of the anatomic LAA orifice differs from the definition of the landing zone for occluder devices. This will be discussed in detail for each occlusion device addressed below.

The LAA orifice is separated from the left pulmonary veins by the left lateral ridge (ligament of Marshall or Coumadin ridge). The LAA may contain one or more lobes, which are projections from its body.

Anatomic variants of the LAA have been described,[8] including the classic forms known as "chicken wing," "windsock," "cauliflower or broccoli," and "cactus." Other morphologies can be found, for example, "seahorse," "whale tail," and "swan." Currently, new technologies in 3D echocardiography assist in defining the number of lobes with greater accuracy, for example, photorealistic rendering or TrueVue®. They also assist in defining morphology, especially when transparency is added to this technology (TrueVue® with Glass®). Of these variants, the "chicken wing" morphology is the most common. However, it is related to greater difficulty in LAA occlusion, due to its broad width and shallow depth.

## Review of percutaneous LAA occlusion procedures

It is important to develop a common language between interventionalists, who are more familiar with fluoroscopy, and the echocardiographers who guide the procedure by means of TEE.

The right anterior oblique caudal view corresponds to approximately 135º on TEE and generally reveals the major axis of the LAA orifice. The right anterior oblique cranial view corresponds to approximately 45º on TEE and generally reveals the minor axis of the LAA orifice.

There are common steps to all LAA occlusion procedures, regardless of the type of occlusion device used.[9] Each procedure begins will peripheral venous puncture, generally through the right femoral vein. The second step is atrial septal puncture with the objective of gaining access to the left atrium. Subsequently, specific steps are taken according to the type of occluder device used.

Atrial septal puncture should be performed in the posterior-inferior position of the fossa ovalis to facilitate the catheter's path to the LAA, located in the anterolateral position. It is important to underscore that, in case of other procedures, such as percutaneous edge-to-edge mitral repair (MitraClip and Pascal), the puncture of the atrial septum should be in the posterior-superior position of the fossa ovalis to ensure adequate height above the mitral valve plane to facilitate the procedure.

The use of TEE is fundamental to guide puncture in the posterior-inferior portion of the fossa ovalis, in addition to evaluating the thickness and mobility of the septum or the presence of an atrial septal defect. Some situations may represent anatomical challenges to successful transseptal puncture. In lipomatous hypertrophy, puncture should be preferred in the thinnest portion of the fossa ovalis rather than in the hypertrophied edges. In the presence of a large atrial septal aneurysm, the interventionist should be alerted that excessive advancement of the transeptal puncture catheter may lead to perforation of the left atrial free wall.

The catheter is positioned against the atrial septum, forming a tent which, once in the correct position, must be continued with the puncture. The short-axis planes of the aortic valve and bicaval valve are used to guide the anterior, posterior, superior, and inferior positions in the atrial septum (Figure 1), preferably using multiplanar imaging, with xPlane (Philips) or MultiD (GE) (inferior and superior in one plane; anterior and posterior in the other) or, more recently, puncture guided by live multiplanar reconstruction with MultiVue (Philips) or FlexSlice (GE).

3D TEE, using 3D zoom of the atrial septum, can help confirm that transseptal puncture has occurred in a favorable location. A step-by-step approach for high-quality 3D imaging of the atrial septum has been described using the TUPLE maneuver (image obtained by the 3D zoom-focused mode, of the interatrial septum at 0° by TEE).[10]

## Watchman/Watchman FLX device

Watchman/Watchman FLX device is implanted in the LAA after puncture of the atrial septum. It has a polyester membrane that covers a self-expandable nitinol frame with barbs at its distal

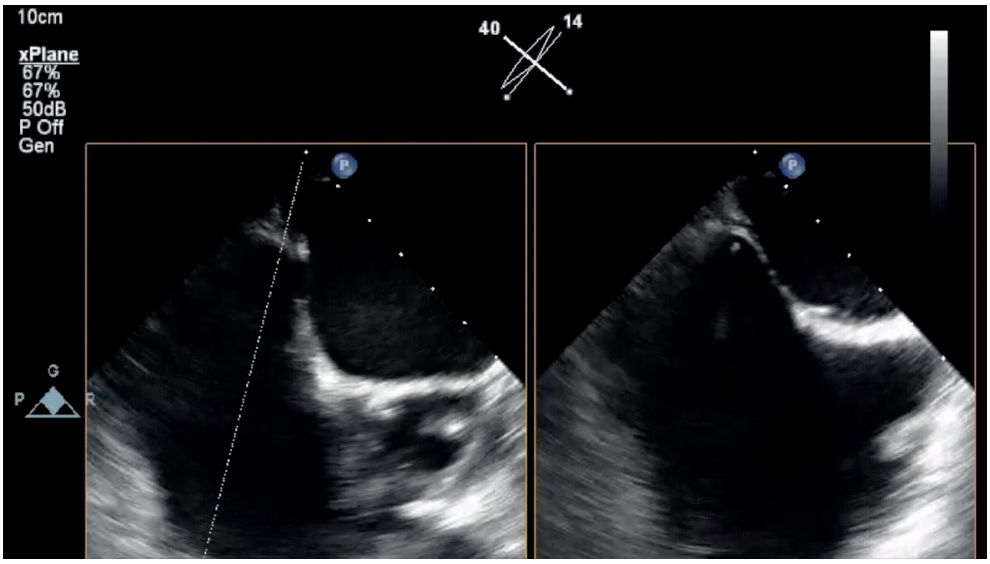


**Figure 1 –** *Transseptal puncture site using multiplanar mode (xPlane) to guide the procedure. In the image on the left (short axis of the aorta), it is possible to observe the formation of a "tent" in a posterior position of the septum. In the image on the right (caval axis, manually adapted in the orthogonal view), the needle is positioned inferiorly in the septum, close to the inferior cava. Subsequently, "posterior-inferior" puncture was performed.*

end to anchor the device adequately in the LAA. Its insertion is guided by means of fluoroscopy and TEE. It is available in 5 different diameter sizes (Table 1 and Figure 2), with 3-mm increments (diameter at the end of the atrial side of the device).

Watchman is currently the device with the largest number of studies. A meta-analysis[11] of long-term outcomes (5 years) of the two main randomized clinical trials (PROTECT AF[12] and PREVAIL[13]) comparing the use of anticoagulation with warfarin against LAA occlusion with a Watchman device in patients with non-valvular AF showed similar protection against stroke for both therapies, but the LAA occlusion group showed lower rates of disability or death, mainly due to a reduction in major bleeding, particularly hemorrhagic stroke.

## Preprocedural assessment

Assessment should focus on the presence or absence of intracardiac thrombus, presence and quantification of pericardial effusion, characteristics of the atrial septum (aneurysm, lipomatous hypertrophy), presence or absence of valvular abnormalities, complex aortic atheroma (> 4 mm), intracardiac shunts, and assessment of orifice size and LAA depth.

The LAA should be measured in the 0º, 45º, 90º, and 135º planes (Figure 3), with the objective of establishing the largest diameter for orifice fixation of the occluder device ("landing zone") and the depth of the LAA, because these are the measurements used to select device size. The landing zone is defined as the measurement of the circumflex artery (0º plane) or the upper edge of the mitral annulus (45º, 90º, and 135º planes) up to 2 cm below the left lateral ridge. Depth is measured by tracing a line from the "landing zone" plane to the apex of the LAA (Figure 4). The chosen diameter of the device must be greater than 8% to 20% (15% to 30% in some references) of the measured diameter of the LAA for adequate compression of the device inside the LAA (Table 1). Despite the above guidelines and due to the limitations of 2D imaging, the largest landing zone diameter is not always obtained in standard planes and is underestimated. Therefore, the use of 3D TEE (Central Illustration) to measure landing zone diameter through multiplanar reconstruction, maintaining adequate temporal resolution (> 18 frames per second), helps to reduce these limitations and obtain landing zone diameter more accurately and reproducibly.[15] This makes it possible to use automated software (3D Auto LAA, Philips) that quickly and accurately provides measurements such as area, perimeter, and major and minor diameter.

Another factor that must be considered in LAA measurements is the patient's volume status, mainly due to the fasting period for the exam. A prior study has shown that LAA measurements (orifice diameter and depth) varied according to patients' volume status (on average 2 mm) and that this variation could significantly impact the choice of device size.[16]

## Assessment during the procedure

After peripheral venous puncture, followed by inferior-posterior puncture of the fossa ovalis of the atrial septum, as previously described, the catheter must be guided to the LAA orifice. 3D TEE has the advantage of allowing visualization of the entire length of the catheter (from where it traverses the atrial septum to the LAA orifice). After introduction into the LAA orifice, contrast injection is performed for fluoroscopic visualization of the LAA and radiopaque marks of the device that must be aligned with the LAA orifice. Once the ideal position has been confirmed, the Watchman device is slowly removed from the sheath, while remaining attached to the delivery cable.

**Table 1 – Watchman and Watchman FLX**

| | | | | | |
|---|---|---|---|---|---|
| **FDA indications** | | | | | |
| ➢ Non-valvular FA and increased risk of stroke and systemic embolism based on CHADS2 or CHA2DS2-VASc | | | | | |
| ➢ Eligible for anticoagulation with warfarin | | | | | |
| ➢ Appropriate justification for the use of non-pharmacological therapy | | | | | |
| **Device sizes** | | | | | |
| **Watchman** | | | | | |
| Device diameter (mm) | 21 | 24 | 27 | 30 | 33 |
| LAA orifice variation (mm) | 17-19 | 20-22 | 23-25 | 26-28 | 29-31 |
| Compression diameter (mm) | 16.8-19.3 | 19.2-22.1 | 21.6-24.8 | 24-27.6 | 26.4-30.4 |
| **Watchman FLX** | | | | | |
| Device diameter (mm) | 20 | 24 | 27 | 31 | 35 |
| LAA orifice variation (mm) | 14-18 | 16.8-21.6 | 18.9-24.3 | 21.7-27.9 | 24.5-31.5 |
| **Compression diameter: + 10% to 30% (observation: values obtained by TEE)** | | | | | |
| **Exclusion criteria** | | | | | |
| ➢ LAA orifice diameter greater than 30.4 mm or less than 16.8 mm | | | | | |
| ➢ LAA depth less than the width of the LAA orifice | | | | | |
| ➢ Proximity of a secondary LAA lobe to the plane of the LAA orifice (< 1 cm) | | | | | |
| ➢ Presence of intracardiac thrombus | | | | | |

*AF: atrial fibrillation; LAA: left atrial appendage; TEE: transesophageal echocardiography.*

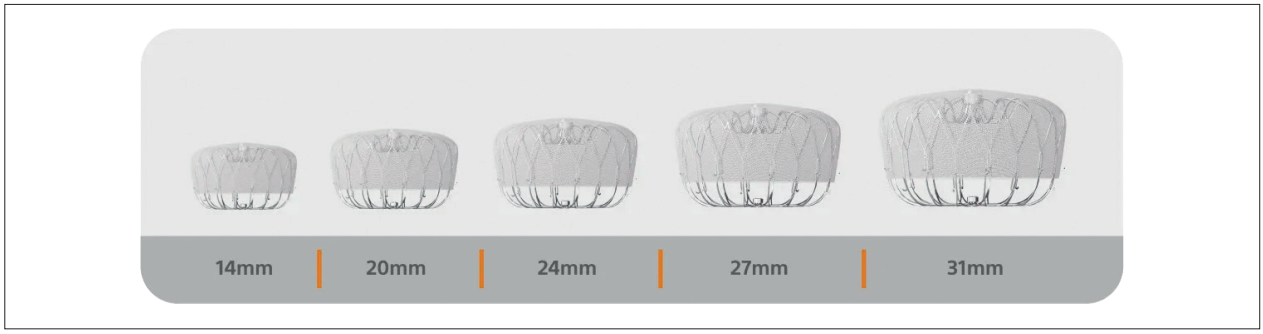


**Figure 2 –** *Watchman FLX device with sizes that treat ostia from 14 mm to 31 mm.*[14]

Before the device is released, the 4-step mnemonic checklist known as PASS (position, anchor, size, and seal) should be met:

- **Position:** Ideally, the device "shoulder" (curved part of the device at the level of the LAA orifice) should not protrude excessively from the LAA. If there is device shoulder protrusion, it should be less than 40% to 50% (approximately 4 to 7 mm) of the device depth.
- **Anchoring:** A "tug test" should be performed. The device should be retracted and observed to verify that it returns to the original position, monitoring with TEE or fluoroscopy
- **Size:** The device diameter should be measured after compression in the LAA, and it should be 80% to 92% of the original device diameter. Device measurement should be from "shoulder to shoulder," in the 0º, 45º, 90º, and 135º planes, observing the "threaded insert" in the center of the device, to ensure that maximum width has been measured.
- **Seal:** Assessment for para-device leak (PDL)[17] should be carried out by measuring the vena contracta of the PDL (diameter of the narrowest cross-section of the plane between the device and the LAA wall) using 2D TEE with color Doppler in the 0º, 45º, 90º, and 135º planes. A PDL vena contracta of < 5 mm is acceptable. A Nyquist limit of 35 to 45 cm/s should be applied, and 3D TEE with color Doppler can be used to assess circumferential extent. PDL can be classified as mild (< 3 mm), moderate (3 to 5 mm), or severe (≥ 5 mm).

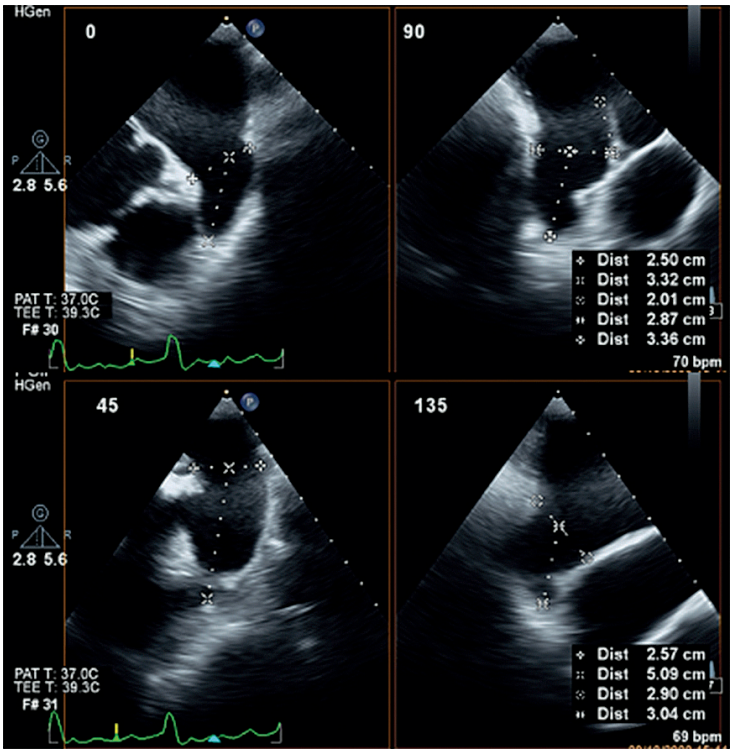


**Figure 3 –** *TEE: display of planes and measurements at 0º, 45º, 90º, and 135º of the LAA using the multiplanar cutting tool (xPlane) for the Watchman device.*

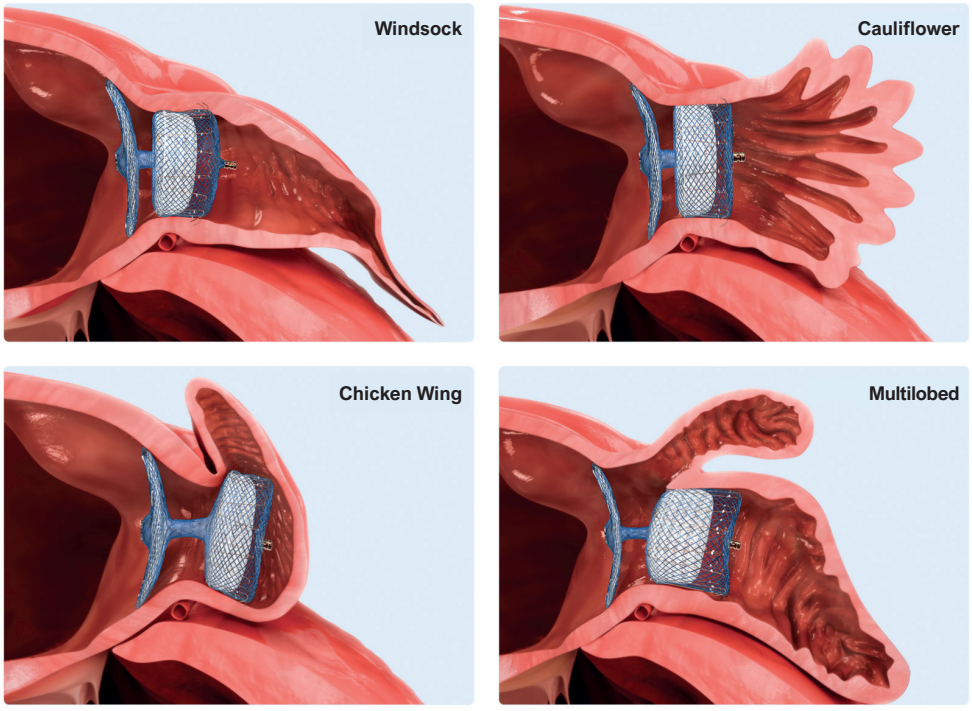


**Figure 4 –** *Illustration of the Amulet device, composed of a lobe and a disc connected by a central articulating waist, in the treatment of different LAA morphologies.*[21]

When the PDL is ≥ 5 mm or when any criteria of the PASS checklist are not met, the Watchman device should be repositioned or exchanged for one with a larger diameter.

After the Watchman device has been implanted and the catheter withdrawn, it is necessary to assess the size of the atrial septal defect (ASD) related to the procedural transseptal puncture. An ASD less than 10 mm is acceptable. When the ASD is > 10 mm, it may require percutaneous closure.

Pericardial effusion is the most important immediate complication to be assessed by TEE in LAA occlusion procedures. Generally, it reflects intraprocedural perforation of one of the cardiac cavities, such as the right atrium, left atrium, and LAA.

TEE monitoring of pericardial effusion in multiple planes is essential, mainly using transgastric planes and the 4-chamber plane of the middle esophagus, focusing on the right atrioventricular junction. Comparison with preprocedural images and differential diagnosis with epicardial fat are important.

The rate of pericardial effusion related to the Watchman procedure is 2.2% to 5%.[18] This rate has reduced over time and may be attributed to the better experience of interventionists, monitoring of the procedure with TEE, use of a curved guide wire, and use of a pigtail catheter to avoid injury to the LAA.[19]

Other possible procedure-related complications include stroke (rate of 0.9%), device embolization (rate of 0.6%), air embolism, and thrombus formation during the procedure.[18,19]

## Post-procedure assessment

After Watchman device implantation, endothelialization occurs in approximately 45 days. Therefore, during this period, patients must use warfarin and aspirin. After 45 days, TEE must be performed. If there are no complications (discussed in further detail below), warfarin should be suspended, and therapy with clopidogrel associated with aspirin should be continued for 6 months from the date of device implantation. After this period, clopidogrel should be suspended, continuing the use of aspirin. The main objectives of follow-up with TEE are as follows:

- Reassess device position and stability to ensure that no part of the device has embolized or shifted.
- Reassess presence of PDL. When < 5 mm (approximately 32% of patients), it is not associated with an increased risk of thromboembolism; therefore, warfarin can be discontinued.[20]
- Assessment for device-related thrombus (thrombus on the left atrial side, seeing that thrombus on the LAA side is expected). They are more common in the threaded insert area of the device (slower endothelialization) and in any LAA trabeculations uncovered by the device.
- Assessment of interatrial shunt related to transseptal puncture during the procedure. Scarring of the atrial septum is common after transseptal puncture, but when there is ASD > 10 mm, percutaneous closure should be considered.
- Assessment of other cardiac structures, focusing mainly on pericardial effusion.

## Amulet device

Amulet is the second-generation Amplatzer LAA occlusion device. It consists of a self-expanding nitinol frame, covered by sewn polyester mesh, composed of a lobe and a disc connected by a central articulating waist (Figure 4). The lobe is implanted approximately 10 to 12 mm distal to the anatomic LAA orifice, and it functions as the main mechanism for anchoring the device in the LAA, by means of circumferentially located stabilizing wires. The proximal end of the central hinged waist, unlike the threaded insert of the Watchman device, is located internal to the device, which would theoretically have the benefit of reducing device-related thrombus formation.

The Amulet device is available in 8 different sizes, which correspond to the lobe diameter of the device (Table 2). The disc diameter corresponds to the size of the lobe diameter plus 6 mm (for devices size 16 to 22 mm) or plus 7 mm (for devices size 25 to 34 mm).

While the Watchman device is compatible with LAA diameters ranging from 16.8 to 30.4 mm, the Amulet device can be compatible with a greater variation in LAA diameter sizes (11 to 32 mm).

The exclusion criteria are the same as the Watchman device, differing in the following anatomical criteria:

**Table 2 – Amulet device sizes**

| Nº do dispositivo ou diâmetro do lobo (mm) | 16 | 18 | 20 | 22 | 25 | 28 | 31 | 34 |
|---|---|---|---|---|---|---|---|---|
| Largura máxima da landing zone (mm) | 11-13 | 13-15 | 15-17 | 17-19 | 19-22 | 22-25 | 25-28 | 28-31 |
| Profundidade mínima do AAE (mm) | ≥10 | ≥10 | ≥10 | ≥10 | ≥12 | ≥12 | ≥12 | ≥12 |
| Altura do lobo (mm) | 7.5 | 7.5 | 7.5 | 7.5 | 10 | 10 | 10 | 10 |
| Altura da cintura articulada (mm) | 5.5 | 5.5 | 5.5 | 5.5 | 8 | 8 | 8 | 8 |
| Diâmetro do disco (mm) | 22 | 24 | 26 | 28 | 32 | 35 | 38 | 41 |
| Diâmetro da bainha (Fr) | 12 | 12 | 12 | 12 | 12 | 12 | 14 | 14 |
| Fios estabilizadores (pares) | 6 | 6 | 8 | 8 | 8 | 10 | 10 | 10 |

*LAA: left atrial appendage.*

- The landing zone diameter of the Amulet device cannot be larger than 32 mm or smaller than 11 mm.
- Minimum depth is 10 mm for devices from 16 to 22 mm.
- Minimum depth is 12 mm for devices from 25 to 34 mm.

There is a prospective, multicenter, observational study that mainly evaluated safety outcomes after Amulet LAA occlusion device implantation in 1073 patients.[22] Data from this study showed a high success rate in device implantation (98.8%) and low rates of periprocedural and postprocedural complications (for example, 0.3% for stroke, 0.1% for device embolization, and 0.5% for pericardial effusion).

Preprocedural assessment should follow the same precautions described for the Watchman device. However, there is an important difference regarding the definition of the landing zone and depth measurements for both devices. For the Amulet device, the landing zone is defined as the diameter measured 10 to 12 mm distal to the diameter of the LAA anatomic orifice and perpendicular to the axis of the LAA neck. For the Amulet device, depth is defined as the perpendicular distance traced from the middle of the plane of the LAA anatomical orifice to the LAA wall, unlike the depth for the Watchman device, which was defined as the distance, not necessarily perpendicular, from the plane of the landing zone to the LAA apex (Figure 5).

The implantation of the Amulet device is similar to that of the Watchman, with the same steps for venous and atrial septal puncture, with differences in the assessment of LAA dimensions (described above) and device release.

The Amulet device is released in two steps. Initially, the lobe is partially unsheathed, remaining in a "ball" shape during monitoring with TEE, with the aim of confirming the correct positioning for release, and then completely unsheathed. In the second step, the disc is unsheathed, completing LAA occlusion. The device should be released after a 5-step checklist, described below:

- The device lobe should be shaped like a "tire" to ensure adequate device compression and fixation of the stabilizing wires.
- There should be a degree of separation between the lobe and the disc to ensure a good seal.
- The side of the disc, in relation to the left atrium, should be concave to ensure a good seal.
- The lobe axis should be perpendicular to the neck of the LAA to ensure adequate stability.
- At least two thirds of the lobe should be positioned in a plane adjacent to the circumflex artery to ensure stability. To confirm stability, a gentle "pull" on the disc can be performed.

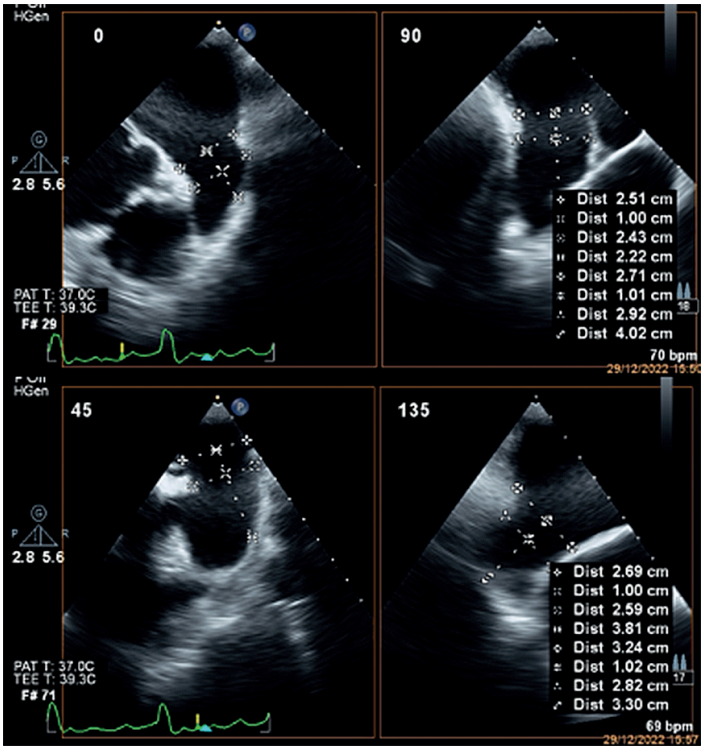


**Figure 5 –** *Transthoracic echocardiogram: display of planes and measurements at 0º, 45º, 90º, and 135º of the LAA using the multiplanar cutting tool (xPlane) for the Amulet device.*

- Following release of the Amulet device, an assessment of possible immediate and late complications should be carried out, similar to the assessment previously described for the Watchman device.

### LAmbre device

The LAmbre device (LifeTech Technology Ltd., Shenzhen, China) has the characteristics of being made of nickel-titanium alloy and constructed in two parts (Figure 6) that are released at different moments, an occlusion "umbrella" (auricular side) and a sealing disc (atrial side). During the procedure, the occluder is first positioned and released and, after testing its stability, the sealing disc is released. For this device, periprosthetic leak is considered significant when it is greater than 3 mm. In this device, the presence of a thrombus in the LAA would not be an absolute contraindication to the procedure due to its implantation method. There are two types of commercially available devices, a standard one and a second special type, developed for multilobed appendages with wide trabeculations and shallow spaces.[23]

When selecting the device to be implanted, it has been observed that tomography and 3D TEE had a good correlation and, considering the deformation of the orifice after occluder insertion, especially in atrial appendages that presented ostia with special morphology (for example, teardrop-shaped or triangular), choosing not based on diameter, but rather by ostial perimeter, assisted in optimal device selection, increasing implant success on the first attempt.[24]

The appearance of the device on 3D echocardiography is very characteristic, resembling the number 8 in the "en face" view after release (Figure 7). On fluoroscopy it is possible to see the umbrella and the sealing disc after release, very similarly to what is seen on TEE (Figure 8).

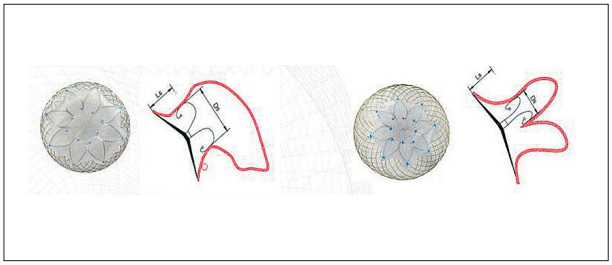

**Figure 6 –** *Photograph of the standard LAmbre device on the left with a schematic drawing of the positioning in the LAA; on the right: special device with a schematic drawing of the implant in a multilobed appendage. Note that, unlike the standard device, the special one has a smaller "umbrella" to adapt to one of the lobes of the LAA, with a proportionally larger sealing disc in relation to the first.*[25]

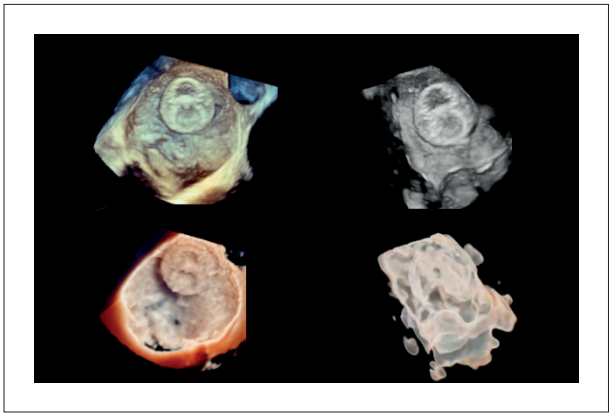

**Figure 7 –** *Volume rendering obtained by 3D transthoracic echocardiography demonstrating a characteristic "figure 8" appearance of the LAmbre device after release. A) standard volume rendering; B) color volume rendering; C) photorealistic rendering; D) transparency rendering*

## Conclusion

TEE is an essential tool in the preparation and execution of percutaneous LAA occlusion procedures. In preparation for the procedure, it is possible to estimate the size of the device to be implanted, as well as the morphology of the anatomical structure. It can also be used to guide implantation (transseptal puncture and positioning), assess the results (compression and presence of periprosthetic leak), and monitor possible complications (pericardial effusion, embolization).

## Author Contributions

Writing of the manuscript: Dutra LV, Gonçalves AC; critical revision of the manuscript for intellectual content: Dutra LV, Gonçalves AC, Assunção BMBL, Pinheiro Junior JA.

### Potential Conflict of Interest

Lucas Velloso Dutra: Philips Healthcare (speaker); Boston Scientific Corporation (speaker); Edwards Lifescience (speaker/proctor); Boynton (Lifetech): (proctor); Abbot Laboratórios do Brasil LTDA (proctor). Jairo Alves Pinheiro Junior: Boston Scientific Corporation (proctor) Abbot Laboratórios do Brasil LTDA (proctor) Micro Life Sciences Private Limited.

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### Study Association

This study is not associated with any thesis or dissertation work.

### Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

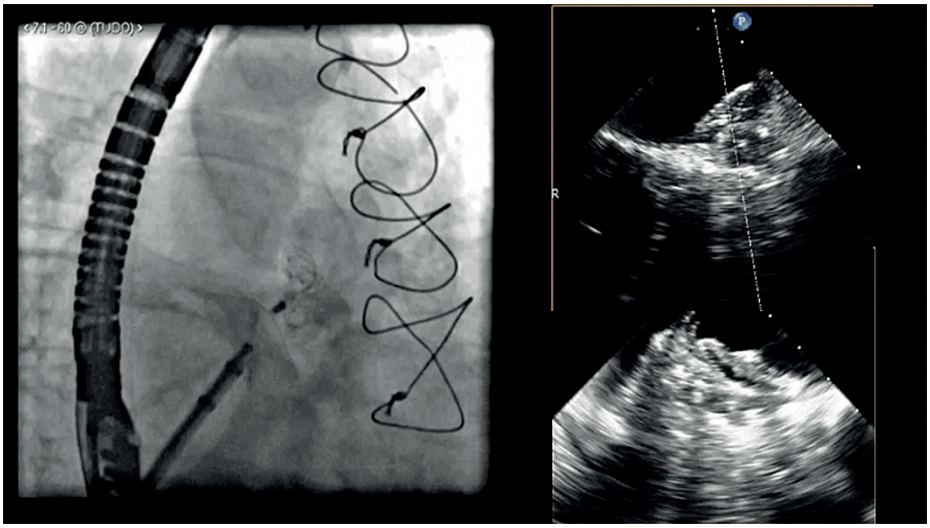

**Figure 8 –** *Comparison of the LAmbre device on fluoroscopy imaging (on the left) with multiplanar mode (xPlane) on 3D transthoracic echocardiography (on the right).*

## References

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