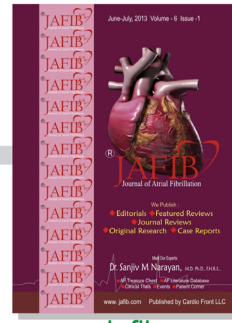
JAFIB
Featured Review
Journal of Atrial Fibrillation



www. jafib.com

Role of Cardiac Imaging for Catheter-based Left Atrial Appendage Closure

Sébastien Marchandise MD, Joëlle Kefer MD, PhD, Jean-Benoît le Polain de Waroux MD, PhD, Christophe Scavée MD Jean-Louis Vanoverschelde MD, PhD

Division of Cardiology, Cardiovascular Department, Cliniques Universitaires St-Luc, Université Catholique de Louvain, Brussels, Belgium

Abstract

Thromboembolic stroke is the most serious complication in patients suffering from Atrial Fibrillation. Atrial thrombi have a predilection to form in the left atrial appendage. Accordingly, oral anticoagulation is recommended for patients with high risk of stroke. However, it is widely underused and problems of compliance are associated with serious risk of bleeding or inefficacy. In these patients with non-valvular atrial fibrillation, percutaneous occlusion of the left atrial appendage might help to reduce the risk of thromboembolism.

Cardiac imaging plays a crucial role at all stages of this procedure and trans-esophageal echocardiography represents the current gold-standard for the assessment of the left atrial appendage. Cardiac imaging is mandatory to precisely determine the left atrial appendage anatomy and to select the appropriate size for the device. Finally, real time three-dimension echocardiography is a powerful additional tool that improves the safety profile of the procedure. 3D-transoesophageal echocardiography allows for the accurate assessment of left atrial appendage anatomy and helps determine if it's suitable for device implantation. Finally, it also allows for continuous visualization of all intracardiac devices and catheters during the procedure, and the clear delineation of device positioning in the left atrial appendage.

Introduction

Stroke is the most serious complication of Atrial Fibrillation (AF).[1] Irrespective of the rhythm management strategy, long-term Oral Anticoagulant (OAC) therapy is recommended according to the patient thromboembolic risk profile. In real life however, classic and new OAC are not totally reliable in preventing thromboembolic events.[2-5] Moreover, OAC are often poorly tolerated and have a narrow therapeutic window.[2,6] Percutaneous Left Atrial Appendage (LAA) occlusion was developed as an alternative therapeutic option to prevent stroke in high risk AF patients who are not candidates for a long term anticoagulant therapy.[6,7,8] In this article, we discuss the LAA anatomy and the role of cardiac imaging for catheter-based LAA closure. According to recent studies, obliteration or amputation of the LAA might help to reduce the risk of thromboembolism in non-valvular AF.[7,8,9] Surgical exclusion or excision of the LAA is safe and effective in patients with AF history undergoing an open heart surgery or a coronary artery bypass grafting surgery.[15,16] However, the long-term results of these procedures remain controversial.[17] Percutaneous LAA closure has been developed with promising results,[7,8,9] and is now a days indicated by the guidelines as a valuable alternative for patient with a high risk of stroke and contraindications for long-term oral anticoagulation.[6] Currently,[3] different devices are proposed for percutaneous LAA obliteration: the PLAATO system (Appriva Medical) is not available anymore, the WATCHMAN device (Boston Scientific, Natick, MA, USA) and the AMPLATZER® Cardiac Plug prosthesis (St. Jude Medical Inc., Saint Paul, USA). (Figure 1) Preliminary results with those devices demonstrated the feasibility of percutaneous LAA obliteration.[8,9,18]

Disclosures:
None.

Corresponding Author:
Sébastien Marchandise, MD,
Division of Cardiology,
Cliniques Universitaires St-Luc, Avenue
Hippocrate, 10-2888,
B-1200 Brussels, Belgium

Role of Cardiac Imaging for Catheter-Based Left Atrial Appendage Closure.

Cardiac imaging plays a key role at different stages of the procedure.

Patient Selection

According to their medical history, their thromboembolic profile (CHA_2DS_2-VASc) and bleeding risk (HAS-BLED), patients with non-valvular AF who are not candidates for a long term OAC can be eligible for a percutaneous LAA occlusion.[6] Two-dimensional and Three-dimensional transthoracic echocardiography (2D- and 3D-TTE) allows for determining the left ventricular systolic function

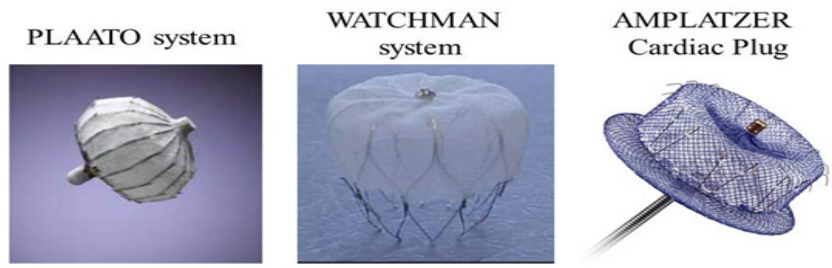


Figure 1: Left side: The PLAATO LAA occlusion device is composed of a nitinol frame with expanded polytetrafluoroethylene membrane. Anchors on the frame provide stability for the device, Center: The WATCHMAN device (Atritech, Inc., Minneapolis, MN, USA) is a nitinol frame with barbs for anchoring. The membrane is initially permeable until it becomes endothelialized.Right side: The AMPLATZER® Cardiac Plug prosthesis (St. Jude Medical Inc., Saint Paul, USA)

and for identifying potential procedural contraindications such as significant valvular disease or severe left atrium dilatation (>60mm).[9,18] However, TTE is not sensitive enough to detect the presence of atrial thrombi or to assess the anatomy and the dimensions of the LAA.[13] Therefore, the use of 2D- and 3D-transeosophageal echocardiography (2D- and 3D-TEE), multi-detector computed tomography (MDCT) or Cardiac Magnetic Resonance Imaging (cMRI) is mandatory when planning the procedure.

As it plays a crucial role to guide the landing of the prosthesis in real time during the LAA occlusion, TEE has become the gold-standard technique for the assessment of the LAA.[19-22] LAA anatomy is very complex, and careful evaluation by multiplane TEE is the first important step. The exact size of the LAA orifice, which is often irregular, should be measured in several planes. MDCT appear to be a safe alternative to 2D-TEE. Its sensitivity for the detection of LAA thrombi is at least comparable with TEE [23] and when associated with contrast injection, it yields to high quality 3-D images of the LAA anatomy. A few authors also proposed to use Cardiac MRI to assess the LAA anatomy and to detect LAA thrombi, however its role for percutaneous closure of the LAA needs to be better defined.[24]

Procedure Planning and Assessment of LAA Anatomy

LAA is a tubular and muscular structure derived from the left wall of the primary atrium, which forms during the third week of gestation. LAA resembles a cone and communicates with the LA through an orifice located between the left superior pulmonary vein

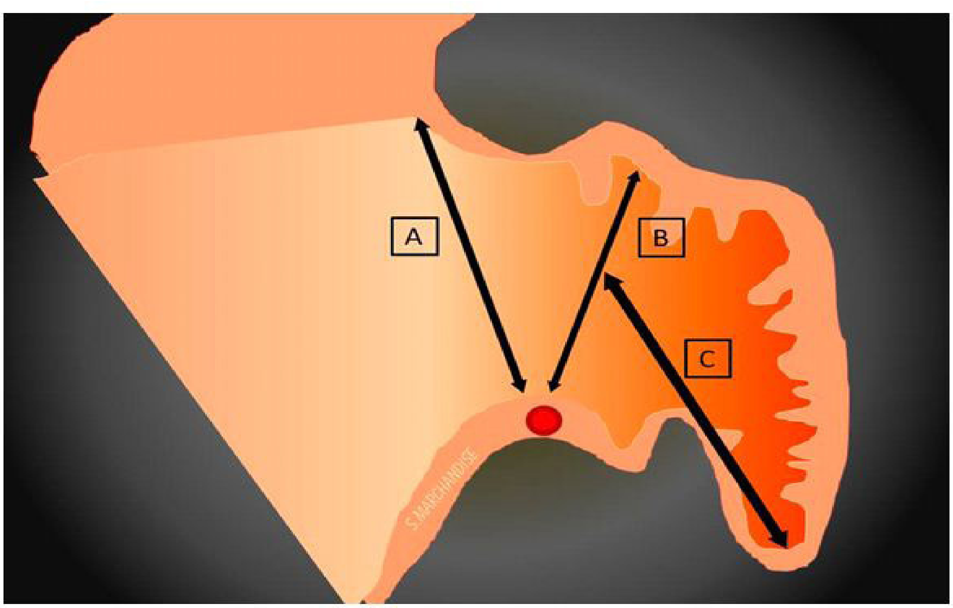


Figure 2: Illustration of the 3 most important measurements to acquire to select the appropriate prosthesis size: measurement of the LAA ostium (A), landing zone diameters (B), depth of the LAA (C)

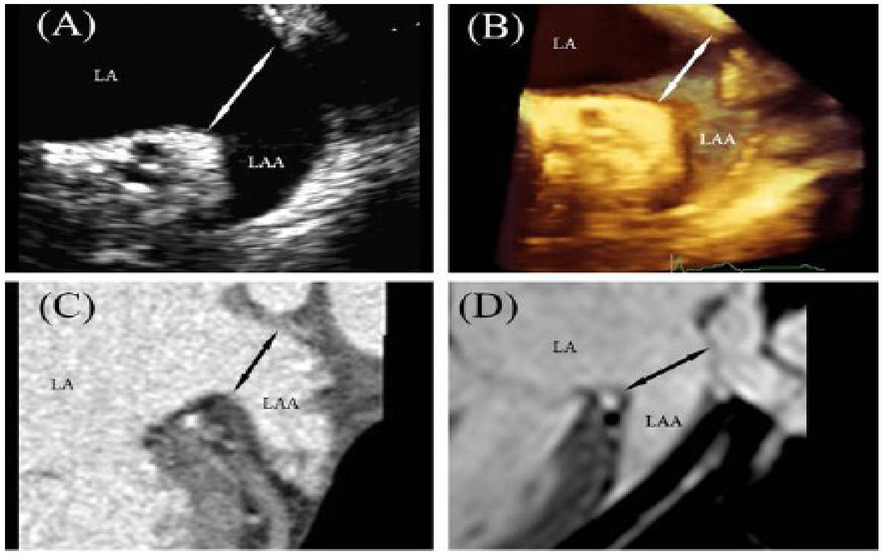


Figure 3: Characterization of LAA size and anatomy. Measurement of the LAA landing zone diameter at 60° by 2D-TEE (A), 3D-TEE (B) with corresponding measurements obtained by MDCT (C) and cMRI (D) . LA = Left Atrium; LAA = Left Atrial Appendage.

and left ventricle. There is an important inter-individual variability in the anatomy and size of LAA. In approximately 54% of cases, LAA had 2 or more lobes (range 1-4).[14] In AF patients, the volume of the LAA increases.[12] In those patients, atrial thrombi have a predilection to form in the LAA .[11] The exact pathogenesis of clot formation in the LAA has not been fully elucidated; however, relative stasis which occurs in the appendage owing to its shape and the trabeculations within it is thought to play a major role.[10-14]

When planning an LAA occlusion procedure, non-invasive imaging is needed to precisely determine the LAA anatomy (thrombus, accessory lobes, orifice diameter and depth) (Figures 2,3). The accurate measurement of the LAA orifice diameters and landing zone is of paramount importance to avoid either prosthesis oversizing, which carry a risk of perforation and cardiac tamponade, or prosthesis undersizing, which is associated with a risk of device embolization or residual leak. Therefore, it is recommended to measure the LAA orifice diameter by using several imaging techniques. In our experience, gross anatomical information is commonly provided by 2D-TEE. However, 2D-TEE does not adequately allow a complete visualization of the LAA. Moreover, it tends to underestimate the LAA ostium diameter.[21] Three-dimensional imaging modalities (3D-TEE, MDCT or cMRI) are more reliable and accurate than 2D-TEE for the assessment of LAA orifice size.[25] Real time 3D-TEE currently represents our first-line approach as it can be used during the procedure itself and provides a full view of the LAA without any radiation exposure or contrast administration (Figure 4).

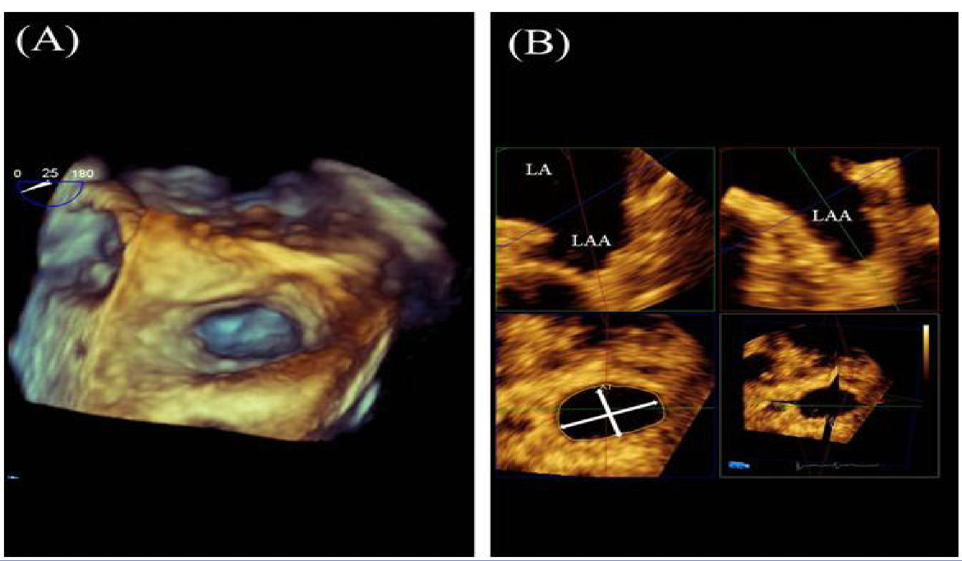


Figure 4: "En face" view of the left atrial appendage (LAA), obtained by using real-time 3D-TEE (A); the LAA long axes were aligned using the multiplanar reconstruction mode of QLab-3DQ software (Philips Medical Systems, Andover, MA) allowing visualization of the LAA orifice in the short axis (B). The area and the maximum and minimum diameters of LAA orifice, were measured from the short-axis view (the LAA orifice is rarely a perfect circle but often oval). LA = Left Atrium; LAA = Left Atrial Appendage

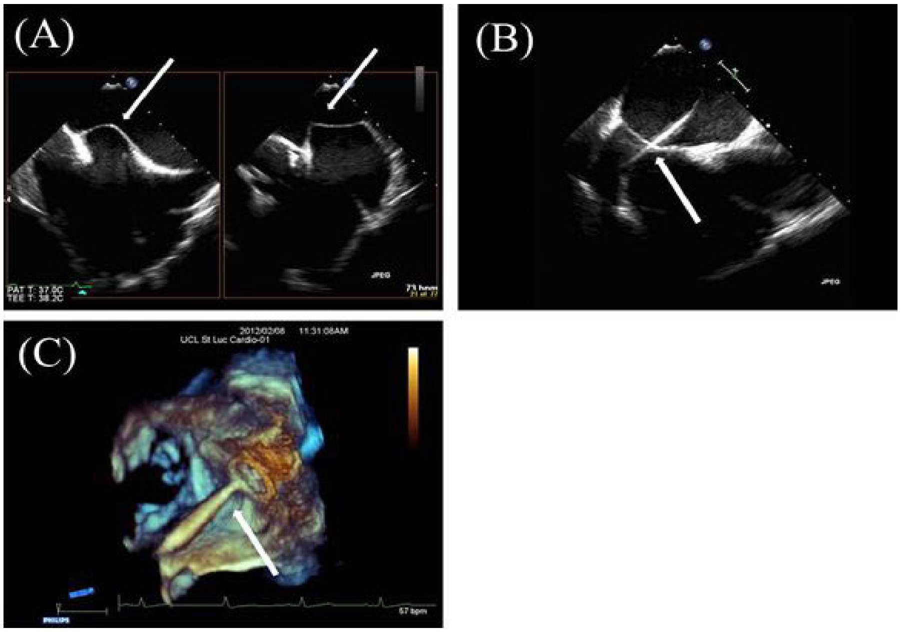


Figure 5: Two dimensional-TEE demonstrating the tenting of the fossa ovalis (arrow) toward the left atrium (LA) before transseptal catheterization. (A) The echo of the guidewire (arrow) is seen in the right atrium and the left atrium (B) Three-dimensional TEE. Imaging of the intra cardiac area of interest including the delivery sheath and the AMPLATZER® Cardiac Plug into LAA (C)

Procedure Guidance

During the procedure itself, both TEE and contrast angiography plays a major role to guide the procedure. TEE or Intracardiac Echocardiography (ICE) can be used to guide the transseptal puncture.[27] TEE, ICE and LAA contrast angiography in several projections (usually 4 for TEE and 2 for contrast angiography) confirm the LAA orifice dimensions. Based on these measurements and according to the different manufacturers charts and recommendations, the size of the device is chosen. The positioning of the device in the LAA cavity is monitored by TEE and fluoroscopy (Figure 5). At all stages of the procedure, full visualization of the intracardiac catheters and devices is important in order to avoid complications. Catheters can be seen on the 2D images. However, their exact location is difficult to determine as it is impossible to align all of them in only one imaging plane. Using real time 3D-TEE allows for imaging the entire intracardiac region with all the catheters in live. Real time 3D-TEE contributes largely to increase the safety of the procedure and the confidence of the cardiologist who manipulates the catheters. In particular, it allows for the direct visualization of the anatomical relationships between the mitral valve, the pulmonary veins and LAA. Once the device is positioned in the LAA, its position is re-assessed prior to final deployment. The real time 3D zoom mode with a "en face" visualization of the device evaluates the anatomical fit of the prosthesis (Figure 6B and 6C). If the placement appears suboptimal, the device can be re-positioned until satisfactory result has been achieved.

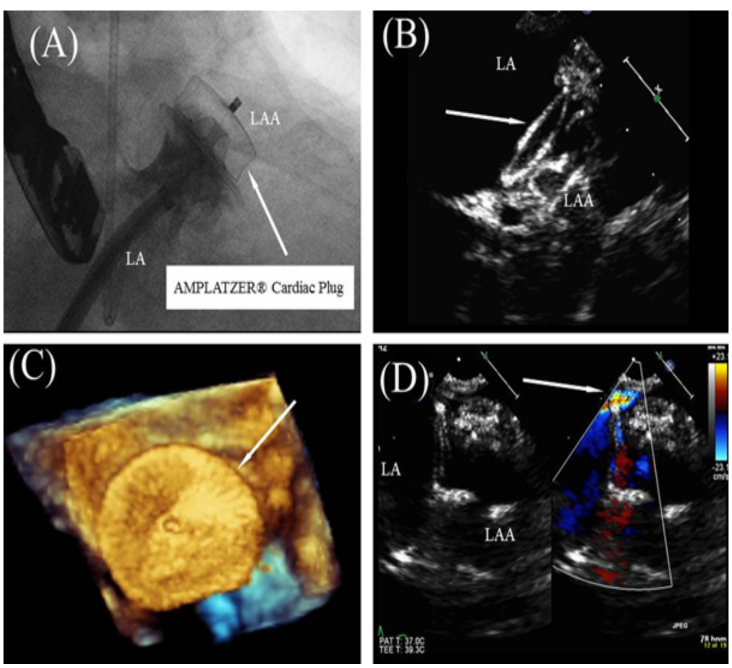


Figure 6: Two dimensional-TEE demonstrating the tenting of the fossa ovalis (arrow) toward the left atrium (LA) before transseptal catheterization. (A) The echo of the guidewire (arrow) is seen in the right atrium and the left atrium (B) Three-dimensional TEE. Imaging of the intra cardiac area of interest including the delivery sheath and the AMPLATZER® Cardiac Plug into LAA (C)

Evaluation of Procedural Efficacy

Once the position of the device appears anatomically satisfactory, the device is released. TEE and contrast angiography are used to evaluate immediate procedural efficacy. Colour Doppler 2D-TEE is used to assess potential residual communication between the LAA and the left atrium[8] (Figure 6).

Detection of Procedural Complications and Evaluation of Long Term Results

At the end of the procedure, echocardiography is used to assess the absence of any possible early complications, which might include pericardial effusion and cardiac tamponade, device dislodgement or embolization and abnormal mitral valve movement.

During follow-up, TEE, MDCT or cMRI are performed at predetermined intervals to assess the long-term results and to exclude any late complications. The final device position is appreciated by using the 2D-TEE and 3D-TEE zoom mode with "en face" visualization of the LAA orifice (especially for the AMPLATZER® Cardiac Plug prosthesis). Colour Doppler is used to exclude any residual communication between the LAA and the left atrium. Both 2D- and 3D- imaging techniques are used to exclude the presence of any intra-car diac clots or thrombus covering the device. Some reports showed that MDCT has a superior image resolution and might be helpful to non-invasively evaluate the device position and assess the LAA after obliteration.[28,29] Cardiac MRI also seems to be an interesting non-invasive alternative to confirm the correct positioning of the occluder and to detect residual LAA leaks.[30]

Conclusions:

Percutaneous LAA occlusion procedure is a safe and effective alternative for patients with non-valvular AF at high risk for thromboembolism who are not candidates for long term anticoagulant therapy. Cardiac imaging play a crucial role at all stages of the procedure. Conventional 2D-TEE is the current gold-standard for the assessment of the LAA. However, real time 3D TEE imaging is a powerful additional tool that helps to improve the safety of the procedure. Real time 3D TEE allows for the evaluation of the LAA anatomy and for determining its suitability for device implantation. It also allows for continuous visualization of all intracardiac devices and catheters during the procedure and the clear delineation of device position in the LAA.

References:

1. Lloyd-Jones DM, Wang TJ, Leip EP, Larson MG, Levy D, Vasan RS, D'Agostino RB, Massaro JM, Beiser A, Wolf PA, Benjamin EJ. Lifetime risk for development of atrial fibrillation: the Framingham Heart Study. Circulation. 2004;110:1042–1046.
2. Nieuwlaat R, Olsson SB, Lip GY, Camm AJ, Breithardt G, Capucci A, Meeder JG, Prins MH, Lévy S, Crijns HJ; Euro Heart Survey Investigators. Guideline-adherent antithrombotic treatment is associated with improved outcomes compared with undertreatment in high-risk patients with atrial fibrillation. The Euro Heart Survey on Atrial Fibrillation. Am Heart J. 2007 Jun;153(6):1006-12.
3. Connolly SJ, Ezekowitz MD, Yusuf S, Eikelboom J, Oldgren J, Parekh A, Pogue J, Reilly PA, Themeles E, Varrone J, Wang S, Alings M, Xavier D, Zhu J, Diaz R, Lewis BS, Darius H, Diener HC, Joyner CD, Wallentin L; RE-LY Steering Committee and Investigators. Dabigatran versus warfarin in patients with atrial fibrillation, N Engl J Med 2009; 361:1139-1151
4. Patel MR, Mahaffey KW, Garg J, Pan G, Singer DE, Hacke W, Breithardt G, Halperin JL, Hankey GJ, Piccini JP, Becker RC, Nessel CC, Paolini JF, Berkowitz SD, Fox KA, Califf RM; ROCKET AF Investigators. Rivaroxaban versus warfarin in nonvalvular atrial fibrillation, N Engl J Med 2011
5. Granger CB, Alexander JH, McMurray JJ, Lopes RD, Hylek EM, Hanna M, Al-Khalidi HR, Ansell J, Atar D, Avezum A, Bahit MC, Diaz R, Easton JD, Ezekowitz JA, Flaker G, Garcia D, Geraldes M, Gersh BJ, Golitsyn S, Goto S, Hermosillo AG, Hohnloser SH, Horowitz J, Mohan P, Jansky P, Lewis BS, Lopez-Sendon JL, Pais P, Parkhomenko A, Verheugt FW, Zhu J, Wallentin L; ARISTOTLE Committees and Investigators, Apixaban versus warfarin in patients with atrial fibrillation. N Engl J Med 2011;365(10):883-91
6. Camm AJ, Lip GHY, De Caterina R, Savelieva I, Atar D, Hohnloser SH, Hindricks G, Kirchhof P, 2012 focused update of the ESC Guidelines for the management of atrial fibrillation An update of the 2010 ESC Guidelines for the management of atrial fibrillation Developed with the special contribution of the European Heart Rhythm Association, Eur Heart J. 2012 Nov;33(21):2719-47
7. Bayard YL, Omran H, Neuzil P, Thuesen L, Pichler M, Rowland E, Ramondo A, Ruzyllo W, Budts W, Montalescot G, Brugada P, Serruys PW, Vahanian A, Piéchaud JF, Bartorelli A, Marco J, Probst P, Kuck KH, Ostermayer SH, Büscheck F, Fischer E, Leetz M, Sievert H. PLAATO (Percutaneous Left Atrial Appendage Transcatheter Occlusion) for prevention of cardioembolic stroke in non-anticoagulation eligible atrial fibrillation patients: results from the European PLAATO study. EuroIntervention. 2010 Jun;6(2):220-6
8. Block P, Burstein S, Casale P, Kramer P, Teirstein P, Williams D, Reisman M. Percutaneous left atrial appendage occlusion for patients in atrial fibrillation suboptimal for warfarin therapy. 5 years results of the PLAATO. J Am Coll Cardiol Card Interv 2009;2:594-600.
9. Holmes D, Reddy V, Turi Z, Doshi S, Sieverts , Buchbinder M, Mullin C, Sick P. Percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation : a randomised non-inferiority trial. Lancet 2009;374:534-42.
10. Al-Saady NM, Obel OA, Camm AJ. Left atrial appendage: structure, function, and role in thromboembolism. Heart 1999;82:547-554.
11. Hart RG, Halperin JL. Atrial fibrillation and stroke : concepts and controversies. Stroke 2001;32;803-808
12. Stöllberger C, Ernst G, Finsterer J. Images in cardiology: seven enigmatic dwarfs, Heart 2000;84:584
13. Agmon Y, Khandheria BK, Gentile F, Seward JB. Echocardiographic assessment of the left atrial appendage. JACC, 1999;34;1867-1877
14. Veinot JP, Harrity PJ, Gentile F, Khandheria BK, Bailey KR, Eickholt JT, Seward JB, Tajik AJ, Edwards WD. Anatomy of the normal left atrial appendage: a quantitative study of age-related changes in 500 autopsy hearts: implications for echocardiographic examination. Circulation, 1997; 96:3112–3115
15. Johnson WD, Ganjoo AK, Stone CD, Srivyas RC, Howard M. The left atrial appendage: our most lethal human attachment! Surgical implications.Eur J Cardiothorac Surg. 2000;17:718 –722.
16. Healey JS, Crystal E, Lamy A, Teoh K, Semelhago L, Hohnloser SH, Cybulsky I, Abouzahr L, Sawchuck C, Carroll S, Morillo C, Kleine P, Chu V, Lonn E, Connolly SJ. Left atrial appendage occlusion study (LAAOS): results of a randomized controlled pilot study of left atrial appendage occlusion during coronary bypass surgery in patients at risk for stroke. Am Heart J. 2005;150:288 –293.
17. Kanderian AS, Gillinov AM, Pettersson GB, Blackstone E, Klein AL. Success of surgical left atrial appendage closure: assessment by transesophageal echocardiography. J Am Coll Cardiol 2008;52:924-929
18. Park JW, Bethencourt A, Sievert H, Santoro G, Meier B, Walsh K, Lopez-Minquez JR, Meerkin D, Valdés M, Ormerod O, Leithäuser B. Left atrial appendage closure with Amplatzer cardiac plug in atrial fibrillation: initial European experience.. Catheter Cardiovasc Interv. 2011 Apr 1;77(5):700-6
19. Khan GN, Dairywala IT, Liu Z, Li P, Carroll J, Vannan MA. Three-dimensional echocardiography of left atrial appendage thrombus, Echocardiography. 2001 Feb;18(2):163-6
20. Chan SK, Kannam JP, Douglas PS, Manning WJ. Multiplane transesophageal echocardiographic assessment of left atrial appendage anatomy and function. Am J Cardiol. 1995 Sep 1;76(7):528-30.
21. Shah SJ, Bardo DM, Sugeng L, Weinert L, Lodato JA, Knight BP, Lopez JJ, Lang RM. Real-time three-dimensional transesophageal echocardiography of the left atrial appendage: initial experience in the clinical setting, J Am Soc Echocardiogr.

2008 Dec;21(12):1362-8.

22. Perk G, Biner S, Kronzon I, Saric M, Chinitz L, Thompson K, Shiota T, Hussani A, Lang R, Siegel R, Kar S. Catheter-based left atrial appendage occlusion procedure: role of echocardiography. Eur Heart J Cardiovasc Imaging. 2012 Feb;13(2):132-8. Epub 2011 Sep 8.
23. Mario J. Garcia. Tomography: A Word of Caution Detection of Left Atrial Appendage Thrombus by Cardiac Computed. J. Am. Coll. Cardiol. Img. 2009;2;77-79
24. Mohrs et al. Thrombus Detection in the Left Atrial Appendage Using Contrast-Enhanced MRI: A Pilot Study. AJR 2006; 186:198–205
25. Nucifora G, Faletra FF, Regoli F, Pasotti E, Pedrazzini G, Moccetti T , Auricchio A. Evaluation of the Left Atrial Appendage With Real-Time 3-Dimensional Transesophageal Echocardiography: Implications for Catheter-Based Left Atrial Appendage Closure. Circ Cardiovasc Imaging 2011;4;514-523.
26. Wang Y, Di Biase L, Horton RP, Nguyen T, Morhanty P, Natale A. Left atrial appendage studied by computed tomography to help planning for appendage closure device placement. J Cardiovasc Electrophysiol. 2010 Sep;21(9):973-82.
27. MacDonald ST, Newton JD, Ormerod OJ. Intracardiac echocardiography off piste? Closure of the left atrial appendage using ICE and local anesthesia. Catheter Cardiovasc Interv. 2011 Jan 1;77(1):124-7.
28. Poulter RS, Tang J, Jue J, Ibrahim R, Nicolaou S, Mayo J, Saw J. Cardiac computed tomography follow-up of left atrial appendage exclusion using the Amplatzer Cardiac Plug device. Can J Cardiol. 2012 Jan-Feb;28(1):119.
29. Marchandise S, Scavée C, Goesaert C, Vanoverschelde J-L, Kefer J. Interest of Non Invasive Imaging in Left Atrial Appendage Transcatheter Occlusion Using the AMPLATZER® Cardiac Plug combined With a Pulmonary Vein Isolation for Atrial Fibrillation. Acta Cardiol. 2011 Oct;66(5):653-6.
30. Mohrs OK, Wunderlich N, Petersen SE, Pottmeyer A, Kauczor HU. Contrast-enhanced CMR in patients after percutaneous closure of the left atrial appendage: a pilot study. J Cardiovasc Magn Reson. 2011 Jul 4;13:33.