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Editorial

Left Atrial Appendage Occlusion Device Placement and the Integration of Echocardiography–Fluoroscopy Fusion Imaging

INTEGRATION OF innovative technology and new procedures have often moved forward in a parallel fashion. One example is the advent of fluoroscopy leading to successes in transcatheter procedures and subsequent improvements in both. The addition of transesophageal echocardiography (TEE) during transcatheter procedures with simultaneous fluoroscopy has been synergistic, giving the proceduralist data from both modalities. It is not surprising that finding technological means to combine these modalities is a natural step, such as is seen in Echocardiography-Fluoroscopic Fusion Imaging (EFFI) systems. The combination of the two imaging modalities into one image may provide the interventionalist with improved understanding of structural anatomy and device positioning for a successful procedure.

Transcatheter procedures are performed with two separate modalities directed by two physicians, and while effective, may still provide challenges in workflow and communication. Meucci et al. provide a stepwise approach to the application of EFFI, focusing on the utilization of a specific system in the occlusion of the left atrial appendage (LAA).[1] Meucci et al. focus on their experience placing the Watchman device to perform left atrial appendage occlusion (LAAO) and the role that the EFFI system EchoNavigator (Boston Scientific, Phillips, Best, Netherlands) plays during the procedure. EchoNavigator, like other EFFI products, is an imaging software system that integrates real-time transesophageal echocardiography images with fluoroscopic projections obtained in real time. This process by which EFFI, controlled by the echocardiographer, displays real-time TEE images that are projected in correct spatial orientation as an overlay onto fluoroscopic projections. The potential applications of EFFI are numerous across structural heart interventional procedures, however, descriptions of its use are still lacking. Meucci et al. make attempts to simplify the application of EFFI by proposing a stepwise approach to its application in the context of LAAO for atrial fibrillation (AF).[1] This associated editorial aims to expand on the topic of LAAO and to further describe and discuss the application of EFFI to the LAAO procedure.

Transcatheter occlusion of the LAA approach has been approved for use in the United States for patients with AF and concurrent contraindications to anticoagulation. AF is the most common arrhythmia experienced in clinical practice, with a prevalence of 0.4% to 1% in the general population, and the frequency increases with age.[2] AF is associated with significant morbidity and mortality from ischemic stroke, with one in six patients who experience stroke, as the result of atrial fibrillation.[2] Oral anticoagulants, notably warfarin, have been the traditional therapy in the prevention of stroke in these patients and patients with significant risk factors for stroke are selected for these therapies.[3] However, a narrow therapeutic window, frequent testing requirements, suboptimal patient compliance, and increased bleeding risk are barriers to lifelong oral anticoagulant therapy.[4] Although many of these barriers can be eliminated with the alternative novel oral anticoagulants, the risk for bleeding persists. Patients are stratified based upon their bleeding risk, and those at too high of risk for bleeding are not prescribed these therapies.[5] This of course does not eliminate the risk of stroke and thus a substantial number of patients remain on suboptimal therapy.

The LAA has been identified as the primary source for embolic stroke in AF. Mechanical occlusion or exclusion has been used as an alternative therapy in patients with AF unable to tolerate the demand or bleeding risk of oral anticoagulants.[6,7] Minimally invasive devices such as the WATCHMAN LAAO device (Boston Scientific, St. Paul, MN) have been developed for this purpose and have an advantage over more invasive surgical approaches to LAA exclusion. Although there are numerous LAAO devices in use, the Watchman is the only one that holds FDA approval. Watchman was first described in 2007 as a mechanical device–based solution to stroke prevention through LAAO.[8] It is a self-expanding nickel-titanium alloy implant deployed via a transseptal access sheath and once deployed, circumferential fixation barbs fix the device in the appendage to prevent embolization. Prospective randomized trials have sought to compare warfarin therapy to mechanical LAAO via Watchman and have found

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Watchman to be noninferior to systemic therapy when evaluating for the risk of embolic events.[6,7] Evidence for Watchman efficacy has been described with long-term outcomes demonstrating reduction in thromboembolic and bleeding risk and found Watchman superior to systemic therapy for cardiovascular and all-cause mortality risk.[6,9]

The challenge of a minimally invasive approach to LAAO is the complex and variable anatomy of the LAA in addition to passage of the delivery system across the interatrial septum at a specific plane that will allow easiest access to the LAA. These variables create many challenges to Watchman placement. The LAA itself is a complex structure, typically presenting as a finger-like projection from the left atrium that can be highly variable in size, shape, orientation, and spatial relationship to surrounding structures.[10,11] The LAA has been classified into the following four main morphologies: chicken wing, cactus, windsock, and cauliflower, with the chicken wing variant being the most prevalent but also one of the most difficult for LAAO given its typically shallow depth before an acute bend in the appendage.[12] These challenges have placed a heavy burden on accurate and detailed imaging both during the preprocedural planning phase but also, and most importantly, during real time procedural guidance. LAA ostial diameter, landing zone diameter, and LAA length are key details that determine sizing of the device. Preprocedural computed tomography can be helpful but two- and three-dimensional (3D) TEE guidance are reliable for making accurate measurements as well as providing real-time guidance. The constant movement from the beating heart and translational movements from normal respiration, as well as small, unrealized movements of the delivery catheter by the interventionalist will create fluctuations in alignment. This challenge may be overcome with real-time EFFI guidance as described herein.

A combination of fluoroscopy and TEE commonly is used for LAAO imaging guidance. The joining of echocardiographic and fluoroscopic images has always required a coordinated effort between the echocardiographer and the interventionalist. Each modality has its benefits to aid in optimizing understanding for the interventionalist; however, the 2 modalities use different rotational planes, which can be challenging to simultaneously conceptualize catheter and device positioning on both TEE and fluoroscopic images. The EFFI systems bridge this gap by overlaying the TEE image in the proper orientation on the fluoroscopic image.[13] This is achieved by registering and tracking the face of the TEE probe on fluoroscopy, allowing the system to then recognize the depth, rotation, and omniplane relative to the gantry.[14] Additionally, multiple image panes can be presented in addition to the EFFI, such that TEE or fluoroscopy images may be viewed independently for further clarity. The EFFI technology preserves all the functions of TEE including 3D, color Doppler, and X-plane, as well as adding the ability to place markers in 3D space as reference points on fluoroscopy. This combination promotes the synergistic relationship of using both imaging modalities to facilitate numerous steps to LAAO.[1,15]

Meucci et al. demonstrates the application of EFFI within the various steps of the LAAO procedure. Here additional information and comments regarding these steps are further discussed. The preparation for LAAO begins with induction of general anesthesia, followed by placement of the TEE probe. Before proceeding, LAA thrombus must be ruled out as it is a direct contraindication to LAAO owing to instrumentation of the appendage and embolic stroke risk. This is achieved through multiple two-dimensional TEE imaging planes (0°, 45°, 90°, and 135°). During this process, the LAA morphology and dimensions also are appreciated, taking care to measure the ostial size, number of lobes, and length to ensure the appendage can accommodate one of the many sizes of the Watchman device.[16] One should also consider 3D echo, as it has been shown to be most accurate for true ostial diameter measurement.[17]

Once the preparatory imaging has been complete, femoral venous access is achieved and a transseptal puncture (TSP) device is passed into the right atrium. TSP should be performed through the inferior and posterior aspect of the fossa ovalis to facilitate approach for the device toward the anteriorly and superiorly positioned LAA.[12,18,19] It is important that the fossa ovalis is crossed and not the surrounding muscular rim, as this is in fact an infolding of the atrial walls, and TSP in this area can result in atrial perforation and pericardial effusion.[20] EFFI as well as 3D TEE can be helpful in identifying the fossa ovalis using EFFI to aid TSP by using a bicaval TEE view with x-plane demonstrating the inferior-superior and anterior-posterior planes.[15,19] The placement of 3D markers within the fluoro-space on EFFI using TEE as the imaging modality improves the identification of the correct location for the TSP, specifically by allowing the interventionalist a marker in which to orient the tip of the crossing catheter and then further manipulation of catheter orientation can be done with TEE imaging. Visualizing tenting before TSP, especially using biplane imaging, can aid in orientation and may avoid injury to the left atrial wall. Once the septum is crossed, TEE is used to verify placement of a stiff guidewire in the left upper pulmonary vein. This location, either of the pulmonary vein or the ostium of the LAA, can be marked in the 3D fluoro-space as well using EFFI. These 3D markers remain on the fluoroimaging screen and can provide additional reference points during the procedure to avoid withdrawing or incorrectly placing these catheters.

Once TSP is complete, the echocardiographer can further use EFFI to place 3D reference points as guidance for the Watchman delivery system into the LAA, with a point on the left circumflex artery and another on the ligament of Marshall. Meucci et al. describe their process in which these points identify the anatomic borders of the LAA os, although alternative options would include placing a single point within the middle of the plane of LAA os as it joins the left atrium. The Watchman delivery sheath is then advanced into the left atrium and redirected into the LAA using guidance points. Once in the LAA, the sheath is passed into the most distal segment of the LAA and markers on the sheath, along with previous LAA measurements, help to determine device selection and size.

The Watchman implant is then passed into the LAA, and its position confirmed with EFFI before deployment. After deployment, EFFI is used again to ensure the "PASS" criteria (Position, Anchor, Size, Seal) are met before complete release of the implant.[16,18] First position is confirmed with the point of maximal diameter of the device being at or just deep to the LAA ostium with no gaps present at any angle. Anchoring of the device is challenged with a tug test, where the system is gently retracted and released one to two cm observing that the device and LAA move together. Adequate sizing is determined by measuring the maximal diameter of the implant on TEE and observing at least 8% to 20% compression. Finally, seal of the device is assured with color Doppler interrogation while sweeping with the omniplane from 0˚ to 135˚.

Discussion

Continued advancement in interventional cardiac therapies have necessitated the need for improved imaging and guidance techniques to both facilitate a successful procedure and reduce time and overall risk to the patient. Specifically, for LAAO procedures, a thorough understanding of the complex anatomy and orientation of the interatrial septum and LAA is required. Both TEE and fluoroscopy have their benefits and drawbacks. TEE is adept at differentiating the soft tissue structures of the heart, however, this modality can struggle to track precise catheter placement owing to shadowing and artifact. Fluoroscopy provides a better tracking of device movement across a broad range of views but exposes the patient to large doses of radiation and contrast when heavily relied upon. As indicated by Meucci et al., EFFI acts as a bridge in communication between the echocardiographer and the interventionalist, translating the dual image acquisition into one easy to understand picture, and thereby capturing the benefits of each imaging modality. EFFI increases the spatial awareness in 3D space for the interventionalist and can increase confidence of their skills. Especially for those less experienced, it may flatten the learning curve for a new procedure.

Enhanced imaging techniques like EFFI may help reduce overall risk to the patient through improved efficiency. There is evidence to suggest that EFFI may contribute to reduce risk significantly to the patient by reducing overall operative time and thus reduce anesthetic exposure, as well as reduced radiation dose and lower contrast agent required.[21-24] Comparing EFFI with TEE and fluoroscopy imaging without fusion technology demonstrates reduced radiation exposure, suggesting that the symbiotic relationship produced with fusion imaging is beneficial.[21] EFFI is a safe and easy improvement that uses existing hardware platforms. Synchronization takes less than 5 minutes to perform, and if there are any complications with the software or the providers are not satisfied with the image product, no commitment has been made, and the providers may revert to TEE and fluoroscopy being individually operated. EFFI may help optimize imaging to each patient, as standard imaging planes are typically used (30˚ right anterior oblique for example), but each patient will have anatomic variability that may not align with these standards. With real-time overlay, images can be tweaked for optimization in each patient as the case demands.

Table 1
The Key Aspects of the Placement of a Left Atrial Appendage Occlusion Device and the Utility of Various Imaging Modalities for that Portion of the Procedure

Aspect of LAA Occlusion Procedure	2D Echo	3D Echo	Fluoro	EFF
LAA thrombus	++	++	-	-
Transseptal puncture	++	++	+	+++
LAA dimensional measurements	++	+++	+	+++
Spatial relationship of LAA to surrounding structures	+	++	-	+++
LAAO Device positioning	++	++	+	+++
LAAO Device leak	++	+	++	+

NOTE. Utility is denoted as such: + some utility, ++ good utility, +++ excellent utility, - no utility.
Abbreviations: EFF, echocardiography-fluoroscopic fusion, LAA, left atrial appendage; LAAO, left atrial appendage occlusion, 2D, two-dimensional; 3D, three dimensional.

As we have discussed previously, EFFI can improve upon the current standard for image guidance for interventional structural heart procedures. Specifically, for LAAO we lay out what we believe to be the best imaging modalities for each step of LAAO (Table 1).

Alternatives to EFFI for LAAO have been described with intracardiac echocardiography (ICE) becoming more popular. We believe ICE to be gaining popularity for the same reason we believe EFFI to be beneficial, and that is because it helps eliminate the barrier between echocardiographer and interventionalist by putting all the imaging control in the hands of the interventionalist, improving understanding of the imaging data. ICE does have its limitations, including cost, fewer degrees of freedom when forming images, and is less sensitive to the detection of LAA thrombus than compared with TEE.[25] One way to overcome this is to pass the ICE probe into the LAA through another TSP, but this is also more invasive than TEE.[18] ICE does however eliminate the requirement for general anesthesia to facilitate the echocardiographic imaging. Fluoroscopy alone also has been described, but the sensitivity of LAA thrombus is lower than that of TEE, 3D capability of TEE would be lost, and it would likely increase contrast and radiation exposure to the patient when solely dependent on fluoroscopy for guidance. Visualizing the IAS is difficult on fluoroscopy and precise positioning of TSP is important, as we have discussed.[26]

We feel that EFFI technology is a useful tool that has two main benefits including improved display of 3D spatial relationships within the fluoro-space and improved communication/understanding of the location of the intracardiac devices. Regarding the first, the ability of the echocardiographer to identify points in 3D space and have those points be static such that movement and rotation of the gantry preserves this location can improve the interpretation of the two-dimensional fluoroscopic image into a 3D mental model. Improvements such as this can assist in nonstandard anatomy or viewing angles. The second and possibly more important benefit is the improved communication and understanding that can result from having both imaging modalities overlayed. In doing so, the two physicians can see what the other is seeing, no longer requiring one to describe what they *think* is happening. It has been our experience that these cases promote understanding and communication, leading to increased efficiency for certain aspects. TSP is one such example, as the proceduralist can efficiently move the crossing catheter to the correct septal position by using the marker on the screen. Once the catheter tip is at the marker, the efforts are then focused on correct orientation in the 30˚ to 40˚ view of the septum. Likewise, with a single point at the LAA os or multiple points describing the LAA os, the proceduralist no longer must ask where the wire or catheter is located; they have the identifying marks labeled in the fluoro-space and can quickly determine if the intracardiac device is appropriately positioned. The utility of EFFI is directly related to the capabilities of the specialists and their ability to use EFFI as a translation tool to bridge the gap between the two imaging modalities. The teamwork demonstrated in the step-by-step EFFI guidance of a Watchman device is commendable and certainly takes advantage of the many benefits of EFFI.[1] Improved efficiency of the user and finding additional opportunities for using EFFI will only further the multiple potential applications of this technology.

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References

1 Meucci F, Stolcova M, Mattesini A, et al. A simple step-by-step approach for proficient utilization of the EchoNavigator technology for left atrial appendage occlusion. Eur Heart J Cardiovasc Imaging 2020;22:725–7.
2 Fuster V, Ryden LE, Cannom DS, et al. 2011 ACCF/AHA/HRS focused updates incorporated into the ACC/AHA/ESC 2006 guidelines for the management of patients with atrial fibrillation: A report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. Circulation 2011;123:e269–367.
3 Lip GYH, Nieuwlaat R, Pisters R, et al. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial fibrillation using a novel risk factor-based approach: The euro heart survey on atrial fibrillation. Chest 2010;137:263–72.
4 January CT, Wann S, Calkins H, et al. 2019 AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: A report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol 2019;74:104–32.
5 Pisters R, Lane DA, Nieuwlaat R, et al. A novel user-friendly score (HAS-BLED) to assess 1-year risk of major bleeding in patients with atrial fibrillation: The Euro Heart Survey. Chest 2010;138:1093–100.
6 Reddy VY, Sievert H, Halperin J, et al. Percutaneous left atrial appendage closure vs warfarin for atrial fibrillation: A randomized clinical trial. JAMA 2014;312:1988–98.
7 Holmes DR, Kar S, Price MJ, et al. Prospective randomized evaluation of the Watchman Left Atrial Appendage Closure device in patients with atrial fibrillation versus long-term warfarin therapy: The PREVAIL trial. J Am Coll Cardiol 2014;64:1–12.
8 Sick PB, Schuler G, Hauptmann KE, et al. Initial worldwide experience with WATCHMAN left atrial appendage system for stroke prevention in atrial fibrillation. J Am Coll Cardiol 2007;49:1490–5.
9 Boersma LV, Ince H, Kische S, et al. Evaluating real-world clinical outcomes in atrial fibrillation patients receiving the WATCHMAN left atrial appendage closure technology: Final 2-year outcome data of the EWOLUTION trial focusing on history of stroke and hemorrhage. Circ Arrhythm Electrophysiol 2019;12:e006841.
10 Beigel R, Wunderlich NC, Ho SY, et al. The left atrial appendage: Anatomy, function, and noninvasive evaluation. JACC Cardiovasc Imaging 2014;7:1251–65.
11 Beutler DS, Gerkin R. The morphology of left atrial appendage lobes: A novel characteristic naming scheme derived through three-dimensional cardiac computed tomography. WJCS 2014;4:17–24.
12 Cabrera JA, Saremi F, Sanchez-Quintana D. Left atrial appendage: Anatomy and imaging landmarks pertinent to percutaneous transcatheter occlusion. Heart 2014;100:1636–50.
13 Gafoor S, Schulz P, Heuer L, et al. Use of EchoNavigator, a novel echocardiography-fluoroscopy overlay system, for transseptal puncture and left atrial appendage occlusion. J Interv Cardiol 2015;28:215–7.
14 Balzer J, Zeus T, Hellhammer K, et al. Initial clinical experience using the EchoNavigator system during structural heart disease interventions. World J Cardiol 2015;7:562–70.
15 Mitrev L, Trautman N, Vadlamudi R, et al. Anesthesia and transesophageal echocardiography for WATCHMAN device implantation. J Cardiothorac Vasc Anesth 2016;30:1685–92.
16 Mobius-Winkler S, Sandri M, Mangner N, et al. The WATCHMAN left atrial appendage closure device for atrial fibrillation. J Vis Exp 2012;60:3671.
17 Vivoli G, Gasparotti E, Rezzaghi M, et al. Simultaneous functional and morphological assessment of left atrial appendage by 3D virtual models. J Healthc Eng 2019;7:1–8.
18 Saw J, Lempereur M. Percutaneous left atrial appendage closure: Procedural techniques and outcomes. JACC Cardiovasc Interv 2014;7:1205–20.
19 Faletra FF, Nucifora G, Ho SY. Imaging the atrial septum using real-time three-dimensional transesophageal echocardiography: Technical tips, normal anatomy, and its role in transseptal puncture. J Am Soc Echocardiogr 2011;24:593–9.
20 Ho SY, McCarthy KP. Anatomy of the left atrium for interventional electrophysiologists. Pacing Clin Electrophysiol 2010;33:620–7.
21 Jungen C, Zeus T, Balzer J, et al. Left atrial appendage closure guided by integrated echocardiography and fluoroscopy imaging reduces radiation exposure. PLoS One 2015;10:e0140386.
22 Afzal S, Veulemans V, Balzer J, et al. Safety and efficacy of transseptal puncture guided by real-time fusion of echocardiography and fluoroscopy. Neth Heart J 2017;25:131–6.
23 Afzal S, Piayda K, Hellhammer K, et al. Real-time echocardiography-fluoroscopy fusion imaging for left atrial appendage closure: Prime time for fusion imaging? Acta Cardiol 2021;13:1–9.
24 Sundermann SH, Biaggi P, Grunenfelder J, et al. Safety and feasibility of novel technology fusing echocardiography and fluoroscopy images during MitraClip interventions. EuroIntervention 2014;9:1210–6.
25 Saksena S, Sra J, Jordaens L, et al. A prospective comparison of cardiac imaging using intracardiac echocardiography with transesophageal echocardiography in patients with atrial fibrillation: The intracardiac echocardiography guided cardioversion helps interventional procedures study. Circ Arrhythm Electrophysiol 2010;3:571–7.
26 Theriault-Lauzier P, Andalib A, Martucci G, et al. Fluoroscopic anatomy of left-sided heart structures for transcatheter interventions: Insight from multislice computed tomography. JACC Cardiovasc Interv 2014;7:947–57.