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EDITORIAL COMMENT

Intracardiac Echocardiography for Endovascular Left Atrial Appendage Closure

Is it Ready for Primetime?*

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Endovascular left atrial appendage (LAA) closure (LAAC) is increasingly performed as an alternative to oral anticoagulation for stroke prevention with nonvalvular atrial fibrillation. Good procedural imaging during LAAC is essential for the acute and long-term procedural success. The major tasks for procedural imaging include provision of high-quality images of the LAA and surrounding structures to: 1) exclude pre-existing LAA thrombus; 2) provide LAA measurements for device sizing; 3) guide placement of access sheaths; 4) optimize positioning of device; 5) visualize peridevice leak or uncovered proximal LAA lobes; 6) assess device stability to minimize embolization; and 7) evaluate for procedural complications such as pericardial effusion, impingement of surrounding structures, and thrombus on device apparatus.

Transesophageal echocardiography (TEE) remains the conventional gold standard and unsurpassed modality to assess the aforementioned features, and the preferred procedural imaging for most laboratories performing LAAC. Despite superior imaging prowess to guide device implantation, TEE is invasive, typically requiring both endotracheal (general anesthesia) and esophageal intubation. Although there are centers adept at performing TEE with light sedation (without general anesthesia), the relatively long duration of these procedures are uncomfortable for most patients, compounded by increased risk of complications from gagging/coughing reflex and risk of aspiration. Therefore, a less intrusive alternative with intracardiac echocardiography (ICE) that requires only local anesthesia for venous access is highly appealing, both for procedural logistics obviating the need for anesthesiologists and echocardiographers, and for improved patient comfort and recovery time.

Since the introduction of ICE in 1960, it has been increasingly used to guide structural and electrophysiological interventions. Several ICE probe positions have been described that can influence LAA image quality. The simplest approach is placing the probe in the right atrium (RA), which is also the standard position to image the fossa ovalis for transseptal puncture. However, the distance from the RA probe to the LAA is often beyond the depth of field, and the image plane perpendicular to LAA axis, resulting in poor image quality. The probe can be advanced into the coronary sinus, and even the great cardiac and anterior interventricular veins, to improve visualization of the long-axis and oblique views of the LAA (1). However, coronary sinus size may be restrictive, and the Thebesian and Vieussens valves may hinder cannulation with ICE; moreover, there is risk of perforation with a stiff probe in the thin-walled cardiac venous system. The right ventricular outflow tract, and the main and left

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TABLE 1 Observational series of ICE-guided LAA closure

First Author (Ref. #)	Year	N	ICE Position	LAA Device	Technical Success	Procedural Success	Study Comments
Mraz et al. (2)	2007	30	RA	PLAATO Watchman	100%	NA	Procedural TEE in all patients. ICE only to guide transseptal puncture and positioning of the guide catheter
Berti et al. (3)	2014	121	RA, CS	ACP Amulet	96.7%	93.4%	Pre-procedural TEE. Procedural ICE & fluoroscopy. No follow-up TEE reported.
Masson et al. (4)	2015	37	LA (double transseptal)	ACP	97.3%	89.2%	Pre-procedural TEE. Procedural ICE & fluoroscopy. TEE at 3 months, only 3.3% leak.
Matsuo et al. (5)	2016	27	RA (or LA or LUPV)	Watchman	100%	96.3%	Pre-procedural TEE. Procedural ICE & fluoroscopy. TEE at 45 days, no flow 51.9%, <5-mm flow 48.1%.
Frangieh et al. (6)	2016	32	LA (single transseptal)	Watchman	100%	100.0%	Pre-procedural TEE. Procedural ICE & fluoroscopy. When compared to 44 TEE-guided cases, longer time to transseptal puncture and closure with ICE.
Korsholm et al. (7)	2017	109	LA (single transseptal)	ACP Amulet	99.1%	94.5%	Pre-procedural CTA. Procedural ICE & fluoroscopy. No difference in success and complication rates compared to TEE.

The PLAATO (Percutaneous Left Atrial Appendage Transcatheter Occlusion) device is manufactured by ev3 Endovascular (North Plymouth, Minnesota), the ACP and Amulet are manufactured by Abbott Vascular (Minneapolis, Minnesota), and the WATCHMAN device is by Boston Scientific (Natick, Massachusetts).

ICE = intracardiac echocardiography; CS = coronary sinus; CTA = computed tomography angiography; LA = left atrium; LAA = left atrial appendage; LUPV = left upper pulmonary vein; NA = not available; RA = right atrium; TEE = transesophageal echocardiography.

pulmonary arteries are additional positions closer to the LAA for improved imaging, and can provide long-axis and en face LAA views, but more complex probe manipulations are required (1). The best images are from the left atrium (LA) due to the close proximity of the probe to the LAA. However, this approach requires traversing the interatrial septum with the probe through the same or another transseptal puncture. The probe can also be advanced into the left upper pulmonary vein to visualize the LAA long axis. Overall, these probe positions can provide complementary images of LAA ostium and body to guide closure, with potentially comparable image quality to TEE and the capability of interrogating all procedural features outlined in the preceding text. However, complex probe manipulations are required with a considerable learning curve, and multiple imaging positions are needed to provide circumferential LAA/device assessments. This may be technically cumbersome and not feasible in all patients, and coupled with lack of 3-dimensional capability, often results in incomplete visualization especially when assessing circumferential device compression and sealing.

Several small observational series using ICE guidance for LAAC have been published in the past decade (**Table 1**). Mraz et al. (2) described the first attempts in 2007; however, they simultaneously used TEE. The ICE was positioned in the RA, and was only used to guide transseptal puncture and positioning the guide catheter into the LAA. Subsequent published studies used ICE throughout the procedure for imaging guidance without TEE (3-6). Procedural success rates in these small series were high, despite different ICE imaging positions used and different devices implanted. Of key importance, baseline pre-procedural TEE were performed in these ICE-guided cases, and were heavily relied upon for LAA measurements for device sizing. Indeed, discordant LAA measurements between ICE and TEE had been reported (5), especially if the LAA was not well visualized. Procedural fluoroscopy images were also strongly relied upon for assessing device position and peridevice leak. The combination of pre-procedural imaging and procedural fluoroscopy probably overcame most of the imaging limitations of ICE for LAA, especially if only right-sided positions were used. In the study by Frangieh et al. (6), 32 patients who underwent ICE-guided LAAC were compared with the same institution's earlier cohort of 44 patients with TEE guidance. There was no difference in technical success, fluoroscopy time, or hospitalization duration. However, the procedural time from femoral venous access to transseptal puncture and time to LAAC was longer with ICE. This is similar to our experience when we started using ICE guidance for LAAC. Nevertheless, this study was small and lacked follow-up clinical or imaging surveillance beyond the procedural phase.

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In this issue of *JACC: Cardiovascular Interventions*, Korsholm et al. (7) report the largest single-center retrospective experience of consecutive patients who underwent LAAC. From March 2010 to December 2014, 107 patients underwent TEE-guided LAAC under general anesthesia. All subsequent patients (n = 109) from January 2015 to November 2016 had ICE guidance with local anesthesia. Unlike earlier ICE studies, all patients in this study had baseline cardiac computed tomography angiography (CCTA) before LAAC to assess anatomy, size the device, and exclude thrombus. Procedural ICE was used to confirm the absence of LAA thrombus, facilitate transseptal puncture, confirm position and stability of the device, rule out significant peridevice leak, and monitor for complications. Of note, sizing was based upon CCTA measurements. Only the Amplatzer Cardiac Plug or Amulet devices (Abbott Vascular, Minneapolis, Minnesota) were implanted. Technical and procedural success rates were similar, with no significant difference in major periprocedural or access-related complications. The ICE group had shorter procedural time (venous puncture to vascular closure), arrival time to venous puncture, and vascular closure to laboratory exit time, each by ~9 to 11 min. Fluoroscopy time and days of admission were not different. In a subgroup analysis of the most recent 50 patients in each group, contrast use was lower (59 vs. 69 ml; $p = 0.03$), arrival time to venous puncture was shorter (27 vs. 38 min; $p < 0.001$), and LAAC to laboratory exit time was shorter (13 vs. 20 min; $p < 0.001$) with ICE. However, there was no difference in overall procedural or fluoroscopy time. Importantly, follow-up TEE at 6 weeks for the ICE group showed no or <3-mm peridevice leak in 96.1%, 3- to 5-mm leak in 3.9%, and device-associated thrombus in 1%; with no difference between groups.

The authors (7) should be commended for their excellent results with ICE guidance, which encompassed their earliest experience and successful integration of this imaging modality into their standard LAAC practice. It is encouraging that after overcoming the learning curve with this more technically demanding imaging modality, similar procedural duration and fluoroscopy time can be achieved. Notably, ICE guidance was safe and efficacious, and follow-up imaging showed no significant peridevice leak despite potential limitation of incomplete visualization of the LAA/device. There was no increased risk of complications, including access-related or iatrogenic atrial septal defects (present in 35% at follow-up, and <8 mm). These data are concordant with prior studies showing feasibility of ICE as an alternative to TEE for LAAC procedural-guidance. However, there are a few deficiencies with this study that require caution as to the broad applicability of these results. This a small, retrospective, nonrandomized study, subject to the biases of sampling error and prior experience in favor of ICE (operators were trained with TEE first before switching to ICE for LAAC). This is an experienced Danish center proficient with LAAC and use of CCTA for structural procedures, which is highly valuable for understanding anatomy and procedural pre-planning, thus facilitating and mitigating potential deficiencies of ICE guidance. These results may not be replicated by less experienced operators, or when the LAA anatomy is less well appreciated. Importantly, fluoroscopy during the procedure to assess device position and exclude significant peridevice leak is an essential adjunct to ICE guidance. Furthermore, ICE was performed from the LA in this study, and these outcomes may not be achieved by right-sided probe placement. Finally, only the Amplatzer device was used, and the results may not apply to other devices, especially regarding peridevice leak, which appears lower with this device due to its additional proximal disc, and thus may be less imperative to visualize and exclude procedural peridevice leak.

In summary, ICE-guided LAAC is feasible, with good procedural success and device outcomes compared with TEE guidance. As commercial experience grows with LAAC, novel techniques to better integrate this procedure into the standard day-to-day laboratory practice are important. ICE guidance simplifies the procedure by avoiding general anesthesia, reducing patient discomfort, and improving room turnover time. The additional cost of using ICE is an important consideration, but is at least partially offset by eliminating the need for anesthesiologists, echocardiographers, and nursing support for post-anesthetic recovery. Future cost-effectiveness analyses should be performed to understand the economic implications of this approach. In aggregate, results from multiple observational studies support the adoption of ICE guidance for LAAC; however, operators have to master the learning curve necessary to properly use this complex technique.

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