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Intracardiac Echocardiography From the Left Atrium for Procedural Guidance of Transcatheter Left Atrial Appendage Occlusion

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CME/MOC Objective for This Article: At the end of the activity the reader should be able to: 1) compare the safety and efficacy of peri-procedural guidance with transesophageal or intracardiac echocardiography for transcatheter left atrial appendage occlusion; 2) recognize the tasks performed for optimal imaging acquisition using intracardiac echocardiography during transcatheter left atrial appendage occlusion; and 3) appraise the significance of cardiac computed tomography in ruling out thrombotic material in the left atrial appendage.

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ABSTRACT

OBJECTIVES The aim of this study was to compare the efficacy and safety of intracardiac echocardiography (ICE) from the left atrium (LA) with transesophageal echocardiography (TEE) for procedural guidance of transcatheter left atrial appendage occlusion (LAAO).

BACKGROUND TEE with general anesthesia is the current gold standard to guide LAAO. By the use of ICE from the LA, LAAO can be performed in local anesthesia and may potentially have advantages over TEE.

METHODS A single-center, cohort study of patients undergoing LAAO with the Amplatzer Cardiac Plug or Amulet (St. Jude Medical, St. Paul, Minnesota). Procedures were guided by ICE from the LA with local anesthesia (n = 109) or TEE using general anesthesia (n = 107). All patients had pre-procedural cardiac computed tomography. Efficacy outcomes were technical success, procedural success, and peridevice leakage at TEE 8 weeks after LAAO. Safety outcome was a composite of periprocedural complications.

RESULTS Technical success was achieved in 99% of both the TEE and ICE group. Procedural success was similar between groups: 94.4% success rate in the TEE-guided group, and 94.5% in the ICE-guided group. Major periprocedural complications occurred in 4.7% of the TEE group and 1.8% of the ICE group. Rate and degree of peridevice leak did not differ between groups at follow-up. Turnover time in the catheter laboratory, and contrast use were reduced with ICE.

CONCLUSIONS LA ICE to guide LAAO as compared with TEE appears to be effective and safe, without increased procedure-related complications. The rate of peridevice leak is low and similar to TEE-guided procedures. Time spent in the catheterization room may decrease substantially. (J Am Coll Cardiol Intv 2017;10:2198–206)

Oral anticoagulation (OAC) has been the standard therapy to prevent stroke in atrial fibrillation (1), but left atrial (LA) appendage occlusion (LAAO) has emerged as an alternative. LAAO is increasingly used in patients with a high bleeding risk or intolerance to OAC (1–3). The efficacy and safety has been demonstrated in randomized clinical trials (4) and several observational "real-world" studies (2,3,5,6).

Periprocedural visualization of the left atrial appendage (LAA) is the key to a successful implantation (7). Tasks typically performed are exclusion of LAA thrombus, device sizing, guiding of the transseptal puncture, and device deployment with confirmation of device position and adequate LAA closure. This is typically performed with transesophageal echocardiography (TEE) under general anesthesia. However, alternative options have been pursued to facilitate logistics and avoid general anesthesia. Thus, TEE guidance with conscious sedation, and LAAO under fluoroscopic guidance alone have been described (2,7–9).

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Intracardiac echocardiography (ICE) can be used to guide LAAO in local anesthesia. ICE from a right atrial (RA) position has been described as feasible, reproducible, and safe (10–13). Though it could perform the tasks typically provided by TEE (10,11,13), the visualization of the LAA has been inconsistent and suboptimal (10,11,14,15). Especially far-field resolution, delineation of the LAA, and peridevice leak

ABBREVIATIONS AND ACRONYMS

ACP = Amplatzer Cardiac Plug

ASD = atrial septal defect

CT = computed tomography

ICE = intracardiac echocardiography

IQR = interquartile range

LA = left atrial/atrium

LAA = left atrial appendage

LAAO = left atrial appendage occlusion

OAC = oral anticoagulation

RA = right atrial/atrium

TEE = transesophageal echocardiography

evaluation have been impaired. One case report and 2 small observational studies have recently shown the feasibility of ICE performed directly from the LA (16–18). Frangieh et al. (18) found similar procedural efficacy and safety of ICE- and TEE-guided procedures. However, this was a small study with limited follow-up, and TEE was still used preprocedurally for device sizing and exclusion of LAA thrombus. To fully implement ICE-guided LAAO, eliminating the need of preprocedural TEE, would be ideal (19). This may be achieved with cardiac computed tomography (CT). Its 3-dimensional technique with high spatial resolution is ideal for imaging of complex anatomic structures such as the LAA. LAA dimensions measured by cardiac CT are generally larger than with TEE and angiography (20–22), but the correlation remains good, and cardiac CT may even be associated with favorable outcomes (20,21). The sensitivity for detection of LAA thrombus is high, with a negative predictive value of 96% to 100% (23,24).

This study was initiated to compare the efficacy and safety of LAAO procedures guided by either ICE from the LA or TEE in a consecutive cohort with cardiac CT used as pre-procedural imaging modality.

METHODS

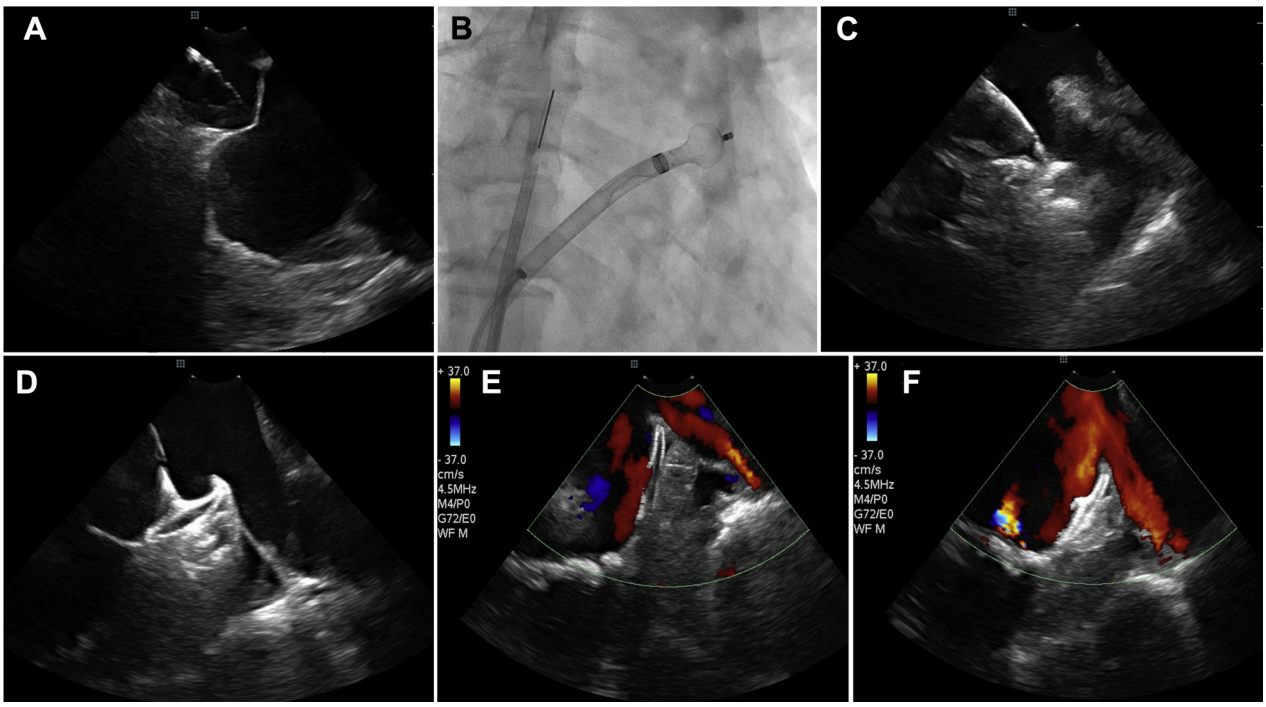
STUDY DESIGN. This was a retrospective, observational cohort study based on a single-center prospective LAAO registry at Aarhus University Hospital, Denmark. A comparative study of TEE versus ICE from the LA for guiding LAAO was performed on 216 patients consecutively undergoing LAAO between March 2010 and November 2016. All patients had an Amplatzer Cardiac Plug or Amulet device (St. Jude Medical, St. Paul, Minnesota) implanted. As of January 2015, all procedures by default were performed under local anesthesia using ICE guidance from the LA. However, during a transition period, 11 patients had LAAO performed with ICE in general anesthesia with a TEE probe inserted as a back-up imaging modality. These patients were pre-defined to be included in the ICE group. A subgroup analysis of the latest 50 cases of LAAO within each imaging group was pre-specified.

PRE-PROCEDURAL CARDIAC CT AND INTRA-PROCEDURAL ANGIOGRAPHY. All patients, regardless of TEE or ICE guidance, had cardiac CT performed before LAAO for anatomic analysis, device sizing, and exclusion of LAA thrombus. Cardiac CT was performed on Siemens SOMATOM Definition Flash or SOMATOM Force scanners (Siemens, Forchheim, Germany) using electrocardiographic triggering targeting a diastolic phase for heart rates $<$70 beats/min and a systolic phase for heart rates $\geq$70 beats/min. Datasets were obtained using high-pitch spiral acquisition with kilovolts between 70 and 140 depending on body weight. Contrast volumes (Iomeron [iomeprol], Bracco Imaging, Milan, Italy, or Optiray [ioversol] 350 mg/ml, Mallinckrodt Pharmaceuticals, Staines-upon-Thames, United Kingdom) of 40 to 70 ml were used depending on renal function and body weight. If LAA thrombus could not be clearly ruled out a preprocedural TEE was performed.

A periprocedural LAA angiogram with contrast (Omnipaque [iohexal] 350 mg/ml, GE Healthcare, Chicago, Illinois) served as additional anatomic guidance. The optimal angiographic projections were chosen from the cardiac CT dataset. Most often, only a single LAA angiogram was performed in a right anterior oblique angulation of about 30° with either about 10° cranial or caudal tilting.

ICE FROM THE LEFT ATRIUM. The 9-F ViewFlex Xtra ICE catheter (St. Jude Medical) was used to obtain the ICE images with the Zonare ViewMate Ultrasound Console (St. Jude Medical). The LAAO operator maneuvered the ICE catheter, while a catheter laboratory nurse operated the echocardiography console. A double right femoral vein access was used, with a medial 9-F 20-cm Terumo sheath (Terumo Europe, Leuven, Belgium) for introducing the ICE catheter, and a lateral insertion for the transseptal sheath and later the delivery sheath. The ICE catheter was initially positioned in the mid-RA, with a slight posterior flex and a clockwise rotation to obtain the septal view for guiding the transseptal puncture in an inferoposterior part of the fossa ovalis. The transseptal sheath was introduced into the LA followed by removal of the dilator. A GW002 guidewire was inserted through the transseptal sheath into the left upper pulmonary vein. The TorqVue 45/45 delivery sheath (St. Jude Medical) was advanced over the GW002 wire into the LA and retracted into the inferior vena cava to dilate the transseptal hole. Thereafter, the ICE probe was aligned with the GW002 wire and advanced along the wire into the LA through the same atrial septal puncture hole. A probe position at the entrance of the left upper pulmonary vein was primarily used for device deployment (**Figure 1**). After placing the ICE probe in the LA, the device delivery sheath was advanced again over the GW002 wire into the LA. The procedure was finalized by closing the femoral access sites with a figure-8 suture.

FIGURE 1 ICE and Angiographic Views for Guiding LAAO



(A) Septal view with the transseptal needle tenting in the inferior part. **(B)** Angiographic view of the ICE catheter at the entrance of the left upper pulmonary vein, and the Amulet device unsheathed into a ball configuration inside the LAA. **(C)** The corresponding ICE view with the Amulet in ball position. **(D)** Evaluation of device position before release. **(E and F)** Color Doppler evaluation of the device in multiple planes to exclude peridevice leakage. ICE = intracardiac echocardiography; LAA = left atrial appendage; LAAO = left atrial appendage occlusion.

In general, ICE was used to facilitate the transseptal puncture, confirm the position and stability of the device before and after release, and to rule out significant peridevice leakage. Likewise, ICE served to monitor for complications throughout the procedure. Device sizing relied predominantly on measurements obtained by the pre-procedural cardiac CT.

TEE-GUIDED LAAO. TEE guidance was performed under general anesthesia using the X7-2t probe with the Philips iE33 console (Philips Healthcare, Eindhoven, the Netherlands). The probe was introduced once the patient was anesthetized and intubated, and hereafter, a single venous puncture was performed. The LAAO procedure followed the principles previously described (7). Hemostasis was secured by manual compression at the end of the procedure.

OUTCOME VARIABLES. Outcome variables followed the latest Munich consensus paper on definitions and endpoints (25). In short, the primary efficacy outcome was technical success, defined as a device implanted in the correct position, without device-related complications and no peridevice leaks >5 mm on color Doppler. Secondary efficacy outcomes were procedural success (technical success without procedure-related complications), and the rate and degree of residual peridevice leaks and atrial septal defects (ASDs) at TEE performed 8 weeks after LAAO. Residual leaks were categorized according to the width of the TEE color Doppler jet as: no leak, 1 to 3 mm, 3 to 5 mm or >5 mm peridevice leak (25). The safety outcome was a composite of major periprocedural complications including stroke (hemorrhagic and ischemic), pericardial effusion requiring drainage, device embolization, major bleeding, and transient ischemic attack. Access-related complications served as an additional safety outcome.

STATISTICAL ANALYSIS. Continuous variables were expressed as mean ± SD, or median (interquartile range [IQR]), and were compared using the Student *t* test or Mann-Whitney *U* test as appropriate.

TABLE 1 Baseline Characteristics

	TEE (n = 107)	ICE (n = 109)	p Value
Age, yrs	73.0 ± 9.7	73.0 ± 7.8	0.99
Female	28 (26)	41 (38)	0.07
Classification of atrial fibrillation			
Paroxysmal	45 (42)	52 (48)	0.67
Persistent	8 (8)	7 (6)	
Permanent	54 (50)	50 (46)	
Comorbidities			
Hypertension	86 (80)	91 (83)	0.55
Congestive heart failure	21 (20)	16 (15)	0.34
Ischemic heart disease	31 (29)	23 (21)	0.18
Diabetes mellitus	23 (22)	23 (21)	0.94
Ischemic stroke or TIA	59 (55)	50 (46)	0.18
Prior intracranial hemorrhage	44 (41)	51 (47)	0.41
Prior bleeding	86 (80)	94 (86)	0.28
Left ventricular ejection fraction, %	60 (55-60)	60 (50-60)	0.08
Glomerular filtration rate, ml/min/1.73 m^2	66 (50-81)	67 (53-85)	0.47
Primary indication for LAAO			
Previous bleeding event during OAC	83 (78)	88 (81)	0.93
Cerebral amyloid angiopathy	5 (5)	5 (5)	
High risk of bleeding	11 (10)	9 (8)	
Stroke despite OAC	8 (7)	7 (6)	
Mean CHA_2DS_2-VASc score	4.4 ± 1.6	4.1 ± 1.6	0.13
Mean HAS-BLED score	4.1 ± 1.1	4.1 ± 0.9	0.83

Values are mean ± SD, n (%), or median (IQR).

ICE = intracardiac echocardiography; IQR = interquartile range; LAAO = left atrial appendage occlusion; OAC = oral anticoagulation; TEE = transesophageal echocardiography; TIA = transient ischemic attack.

Categorical variables were reported as absolute numbers and proportions, and compared using the chi-square or Fisher exact test. A 2-tailed p value <0.05 was considered statistically significant. Statistical analysis was performed using STATA (STATA IC, version 14.2, StataCorp, College Station, Texas). The study conformed to the Declaration of Helsinki. According to Danish law, ethical committee approval was not required for the current study. The Danish Health and Medicines Authorities and the Danish Data Protection Agency approved the study protocol (1-16-02-419-16).

TABLE 2 Procedural and Periprocedural Characteristics

	TEE (n = 107)	ICE (n = 109)	p Value
Technical success,	106 (99.1)	108 (99.1)	0.99
Procedural success	101 (94.4)	103 (94.5)	0.99
Device implanted			
Amplatzer Cardiac Plug	75 (70)	0	
Amplatzer Amulet	32 (30)	108 (100)	
Mean number of devices used	1.2	1.1	0.054
Contrast usage, ml	70 (55-82)	60 (47-71)	<0.001
Fluoroscopy time, min	14 (10-22)	15 (11-19)	0.63
Total time in the cath lab, min	116 (94-143)	87 (77-106)	<0.001
Time venous puncture until vascular closure, min	55 (37-75)	44 (36-52)	<0.001
Time from arrival at cath lab until venous puncture, min	38 (30-45)	29 (23-34)	<0.001
Time from vascular closure until exit cath lab, min	22 (17-29)	14 (12-22)	<0.001
Time at post-anesthesia care unit, min	91 (72-135)	–	–
Days of admission	2 (2-2)	2 (2-2)	0.94

Values are n (%) or median (interquartile range).

Abbreviations as in Table 1.

RESULTS

A total of 216 consecutive patients undergoing LAAO were included in the study, with 107 and 109 patients in the TEE group and ICE group, respectively. Mean age was 73 years, and the majority in both groups was male. The primary indication for LAAO was prior major bleeding events in 78% and 81% of the TEE and ICE groups, respectively. Baseline characteristics were comparable between groups (Table 1).

Pre-procedural cardiac CT was unable to clearly rule out LAA thrombus in 8 (7%) patients in the ICE group. Subsequent TEE excluded thrombus in 7 of 8, whereas the latter had his procedure postponed until TEE confirmed thrombus resolution.

PROCEDURAL IN-HOSPITAL EFFICACY. Technically successful device implantation was achieved in 99.1% of both the TEE and ICE groups. In the TEE group, 1 case did not meet the criteria for technical success due to device embolization during the first day. The device was successfully snared from the descending aorta, and a subsequent successful procedure was performed 1 month later. A shallow LAA neck (LAA depth <12 mm) caused a failed device implantation in the ICE group. This was known from the pre-procedural CT, but an implantation attempt carried on, after informing the patient of the risk of an unsuccessful procedure. The procedural success was 94.4% in the TEE group, and 94.5% in the ICE group. In 82% of TEE-guided procedures, and 90% of ICE-guided procedures, the first device selected was implanted (p = 0.12).

Overall time spent in the catheter laboratory was significantly reduced with ICE guidance. Although contrast use decreased with ICE, the fluoroscopy time was similar between groups (Table 2). Patients in the TEE group spent a median of 91 min (IQR: 72 to 135 min) at the post-anesthesia care unit before returning to the ward, whereas the ICE group returned directly to the ward. Length of hospital stay was similar in both groups.

Analysis of the latest 50 procedures within each imaging group, revealed no significant difference in

technical and procedural success. The turnover time remained significantly shorter in the ICE group, whereas procedure time was similar between TEE and ICE (Online Table 1).

EFFICACY AT FOLLOW-UP. Follow-up was performed after a median of 55 days (IQR: 48 to 66 days). It was complete in 96% and 95% of the TEE and ICE groups, respectively. Reasons for incomplete follow-up were patient unwillingness (n = 6), death before scheduled visit (n = 2, both due to heart failure), and patient cancellation due to other noncardiac surgery (n = 1).

No or <3-mm residual leaks were found in 91% and 95% of the TEE and ICE groups, respectively (**Table 3**). No statistical difference in rate and degree of residual leaks was found between the groups. Similarly, residual peridevice leaks were equally distributed between the Amplatzer Cardiac Plug (ACP) and Amulet device (Online Table 2). The puncture hole in the atrial septum was completely closed in 65% of the ICE group and in 74% of the TEE group. The small residual ASDs at 8 weeks follow-up were all <8 mm in both groups.

ADVERSE EVENTS. The procedure-related major adverse event rate was 3.2% in the total cohort. None of these were fatal. Procedure-related major adverse events occurred in 4.7% of TEE-guided procedures, and 1.8% of ICE-guided procedures (p = 0.28). Complications are listed in **Table 4**. Two patients in the ICE cohort experienced pericardial effusion with cardiac tamponade, occurring 6 and 8 h after the procedure. Both patients were successfully treated by pericardiocentesis. Access-site-related complications were not significantly different between the TEE and ICE groups.

Device-related thrombosis occurred in 3 (1.4%) patients during follow-up: 2 in the TEE group and 1 in the ICE group (2 ACP and 1 Amulet device). One device thrombus was associated with lower limb ischemia in a patient with previous double femoral bypass surgery (TEE group). In the ICE group, major bleeding events occurred in 3 (2.8%) patients. All were gastrointestinal. An ischemic stroke occurred in 1 (0.9%) patient in the ICE group. The patient had previously suffered ischemic stroke despite well-regulated anticoagulation. TEE was performed without signs of peridevice leaks, device-related thrombosis, or cardioembolism. No strokes or major bleeding events occurred in the TEE group.

TABLE 3 Residual Peridevice Leaks and Residual ASDs at Follow-Up

	TEE (n = 103)	ICE (n = 103)	p Value
No peridevice leak	82 (80)	79 (77)	0.34
<3-mm peridevice leak	12 (11)	19 (18)	
3–5-mm peridevice leak	8 (8)	5 (5)	
>5-mm peridevice leak	1 (1)	0	
Residual ASD*	24/93 (26)	34/98 (35)	0.21
ASD size in mm	3.5 (2–6)	3.5 (1–8)	0.58

Values are n (%), n/N(%), or median (interquartile range). *Data on residual ASD was missing in 10 of 103 patients in the TEE cohort, and 5 of 103 patients in the ICE cohort.
ASD = atrial septal defect; other abbreviations as in Table 1.

DISCUSSION

This comparative study was designed to report the immediate procedural and short-term follow-up efficacy and safety of LAAO with ICE guidance directly from the LA. We found comparable technical and procedural success rates, and no significant difference in procedure-related complications between TEE and ICE-guided LAAO. Residual peridevice leaks occurred with similar rate and degree between imaging groups.

EFFICACY OF ICE-GUIDED LAAO. The feasibility of ICE to guide LAAO has been established (10–13,17,18), but little is known about its impact on procedural safety and efficacy. Reported technical success rates range between 96.7% and 100.0%, irrespective of RA or LA ICE probe position (10–13,17,18). Procedural success rates range between 90% and 100% (10,11,17,18). Our results confirm a high technical and procedural success rate with ICE from the LA. In addition, no difference was found when compared with TEE-guided procedures.

Follow-up data after ICE-guided procedures are sparse. Reported low sensitivity to detect peridevice leaks with the RA probe position (11), lack of

TABLE 4 Periprocedural Complications

	TEE (n = 107)	ICE (n = 109)	p Value
Major complications	5 (4.7)	2 (1.8)	0.28
Device embolization	1 (0.9)	0	
Pericardial effusion with tamponade	0	2 (1.8)*	
Ischemic stroke	1 (0.9)	0	
Hemorrhagic stroke	1 (0.9)	0	
Major extracranial bleeding	2 (1.9)†	0	
Death	0	0	
Access-related complications	1 (0.9)	4 (3.7)	0.37
Access-site hematoma >6 cm	1 (0.9)	3 (2.8)*	
Pseudoaneurysm	0	1 (0.9)	

Values are n (%). *One patient experienced both pericardial effusion and access-site hematoma. †One access-site retroperitoneal bleeding with significant drop in hemoglobin and need of blood transfusion, only accounted for in major periprocedural complications.
Abbreviations as in Table 1.

multiple plane imaging, and inconsistent image quality have raised concerns about suboptimal device positioning and residual peridevice leaks (19). However, Matsuo et al. (10) reported no residual leaks in 14 of 27 and <5 mm leak in 13 of 27 after Watchman (Boston Scientific, Natick, Massachusetts) implantation with RA ICE. Masson et al. (17) reported no peridevice leaks in 29 of 30 after ACP or Amulet implantation under LA ICE guidance. Similarly, we found a low rate of residual leaks with ICE guidance, and no difference compared with TEE-guided procedures.

Device sizing and exclusion of LAA thrombus remain essential in LAAO. We relied on preprocedural CT. The reliability of LA ICE for device sizing is questionable (11), especially due to the lacking 3-dimensional capabilities and the high eccentricity of the LAA. The sensitivity to detect LAA thrombus is 100% with cardiac CT, with a consistently high negative predictive value between 96% and 100% (23,24). However, the specificity and positive predictive value vary greatly. In our ICE group, 8 patients required additional TEE, and only 1 patient had LAA thrombus confirmed by TEE. However, we did not consistently use CT delayed imaging, which has been shown to increase both specificity and positive predictive value, without compromising the sensitivity (23,24). However, the combination of preprocedural CT and intraprocedural ICE appears to be a potential alternative to TEE to guide LAAO.

IMPROVED LOGISTICS. Overall procedural duration was reduced with ICE guidance. However, procedural duration was not different when comparing the latest 50 procedures in each group, indicating a time-dependent procedure-related learning curve. Improved stability of the Amulet device and the variations in device use might also affect procedure time. However, procedure time has been shown to be similar in a direct comparison of the ACP and Amulet device (26). Frangieh et al. (18) reported shorter procedure time with TEE (Watchman). However, the authors emphasized that increased experience may shorten procedure time with ICE guidance. Indeed, complexity is added to the procedure with ICE, and a learning curve should be expected. However, procedural duration may not necessarily be prolonged once the operator is familiarized with both the procedure and imaging modality. Interestingly, ICE guidance significantly reduced the turnover time in the catheter laboratory. Avoiding general anesthesia, endotracheal intubation and post-anesthesia care meaningfully improve turnover in the catheter laboratory. Thus, if changing to ICE-guided LAAO, one should not expect to reduce procedural duration; however, logistics and overall time used in the catheter laboratory may improve.

SAFETY OF ICE-GUIDED LAAO. ICE from the LA requires additional instrumentation, which theoretically might increase the procedural risk. However, in accordance with previous studies (17,18), we found a similar procedural safety of LAAO guided by ICE from the LA as procedures guided by TEE. Access-site complications were more frequent in the ICE group. However, stable access-site hematomas without clinical consequence were most common and were conservatively treated without further complications. In the TEE group, a patient with severe thrombocytopenia experienced retroperitoneal bleeding, with a significant drop in hemoglobin. A patient in the ICE cohort developed a pseudoaneurysm causing prolonged admission. In both cases, the cause was confirmed to be unintentional puncture of the femoral artery. Ultrasound-guided compression successfully treated both complications, without sequelae. Theoretically, the risk of arteriovenous fistula might increase with double venous puncture. A systematic post-procedural ultrasound examination of the access site was not used in this study.

Residual ASDs have been a concern about the additional transseptal crossing. Both single- and double-puncture techniques have been described (17,18), however the incidence of residual ASD at follow-up is poorly investigated. Data from the PROTECT-AF (WATCHMAN Left Atrial Appendage System for Embolic Protection in Patients With Atrial Fibrillation) study show an incidence of 34% at 45-day TEE, with a high spontaneous closure rate. In turn, no association with stroke or embolism has been identified (27). We found a small residual defect in 35% at 8 weeks follow-up. However, both incidence and size was not different from the TEE group. Thus, it appears safe to use ICE from the LA as guidance for LAAO, however further randomized trials are needed to confirm the results.

STUDY LIMITATIONS. The nonrandomized single-center design has limitations. Because the cohort consisted of 2 consecutively enrolled groups, it may impose a procedure-related learning curve favoring shorter procedure time in the ICE cohort. However, we tried to compensate by enrolling patients in the transition period into the ICE cohort, and by performing a subgroup analysis on the latest 50 procedures in each cohort. Similarly, the use of 2 different devices may impose a potential confounding effect. However, the confounding effect is

expected to be minimal because initial studies have been unable to show any clinical difference between the devices on procedure duration, efficacy, and safety (26,28).

CONCLUSIONS

ICE guidance from the LA in local anesthesia showed a high technical success rate of LAAO and a low adverse event rate not different from TEE guidance. Furthermore, the rate of significant residual peri-device leaks was minimal and similar to TEE-guided procedures. ICE from the LA is a promising imaging modality to guide LAAO in local anesthesia.

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PERSPECTIVES

WHAT IS KNOWN? LAAO is most widely performed with TEE under general anesthesia. ICE allows LAAO to be performed with local anesthesia, but little is known about the impact of ICE guidance on the efficacy and safety of LAAO.

WHAT IS NEW? LAAO guided by ICE from the left atrium reduced the overall time used in the catheter laboratory, as compared with TEE-guided procedures. This was without influencing procedural efficacy, procedure-related complications, or the rate and degree of peridevice leaks at follow-up.

WHAT IS NEXT? A multicenter randomized controlled trial and cost-effectiveness analyses of left atrial ICE versus TEE guided are needed.

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KEY WORDS intracardiac echocardiography, left atrial appendage occlusion, transesophageal echocardiography

APPENDIX For supplemental tables, please see the online version of this paper.

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