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

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Background—The Intracardiac Echocardiography Guided Cardioversion Helps Interventional Procedures study evaluated the concordance of intracardiac echocardiography (ICE) with transesophageal echocardiography (TEE) in patients with atrial fibrillation (AF).

Methods and Results—Patients with AF undergoing right heart catheterization underwent left atrium (LA) and interatrial septal (IAS) imaging by TEE and ICE. A blinded comparison of the 2 modalities was performed at a core laboratory. Ninety-five patients aged 58 ±12 years completed the study. The LA was profiled in all patients with both techniques, and concordance for image quality was 96%. LA appendage (LAA) imaging was achieved in 85% with ICE and 96% with TEE. There was no difference in the presence of spontaneous echo contrast between ICE and TEE during LA imaging, but there was a trend toward a greater incidence in the LAA with TEE (P=0.109). Intracardiac thrombus was uncommonly seen (TEE, 6.9%; ICE, 5.2%). The concordance for the presence or absence of thrombus was 97% in the LA and 92% in the LAA, but the latter was detected more frequently with TEE. IAS imaging was achieved in 91% with ICE and in 97% with TEE (P=0.177). Concordance for patent foramen ovale and atrial septal aneurysms was 100% and 96%, respectively. A negative ICE examination was associated with absence of dense echo contrast or thrombus on TEE in 86%.

Conclusions—This study provides validation for the use of ICE for LA and IAS imaging. ICE imaging was less sensitive compared to TEE for LAA thrombus identification.

Clinical Trial Registration—URL: http://www.clinicaltrials.gov. Unique identifier: NCT00281073.

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Key Words: ablation ■ echocardiography ■ imaging ■ arrhythmia ■ thrombus

Direct-current cardioversion of atrial fibrillation (AF) has been used to reestablish sinus rhythm in patients with AF. The presence of either intraatrial thrombi or their precursors with their propensity for systemic embolism is a major concern for patients with AF undergoing cardioversion. Inability to clinically identify these patients at risk has prompted short-term anticoagulation with warfarin before attempting cardioversion in all patients. Transesophageal echocardiography (TEE) has been demonstrated to be a sensitive tool to detect septal defects, left atrial (LA) thrombi, and spontaneous echo contrast (SEC).1-3 Recently, LA imaging with TEE has been used to identify patients at low risk for thromboembolism after cardioversion.4 TEE currently is
widely regarded as 1 method of imaging that can identify patients with AF who are candidates for immediate cardioversion.6,5 Immediate cardioversion after TEE in these low-risk patients has not been associated with a higher risk of embolic events than cardioversion after anticoagulation.6 The recognition of systemic thromboembolism as a significant potential complication of cardioversion or ablation during interventional electrophysiology procedures in patients with AF has stimulated interest in the clinical evaluation of catheter-based intracardiac echocardiography (ICE). Initial experience with intracardiac phased-array imaging has demonstrated the efficacy and feasibility of this technology for intracardiac application and its capability in high-resolution imaging of endocardial structures. Its effectiveness in visualizing LA thrombi during ablative procedures has been demonstrated in observational studies.7–12 ICE has been used to assist in diagnosing the frequency of dense SEC, which could identify an increased risk of LA thrombus.12

However, a comparative study of these the TEE and ICE imaging techniques is currently unavailable. We undertook a prospective, multicenter trial (the Intracardiac Echocardiography Guided Cardioversion Helps Interventional Procedures [ICE-CHIP] trial) that compared cardiac imaging of the LA, LA appendage (LAA), and interatrial septum (IAS) with these 2 techniques in patients with AF undergoing invasive cardiac procedures. The purpose of this study was to assess objectively ICE and TEE imaging of these structures in a multicenter trial.

Methods
The ICE-CHIP trial design and methods have been reported previously.13 This prospective, open-label, multicenter investigation compared 2 distinct imaging modalities (TEE and ICE). The study hypothesis was that ICE is comparable to TEE in visualization of LA pathology or atrial-septal defects. The overall design was a paired comparison of ICE with TEE in patients with AF undergoing cardiac catheterization or electrophysiological studies that could predispose patients to stroke. Figure 1 is a flow diagram that outlines the major domains imaged by the 2 imaging procedures and their elements. A blinded comparison of the 2 imaging modalities was performed by an independent core echocardiography laboratory. The study protocol was approved by the individual center institutional review committees for all participating centers.

Patient Selection
Patients with spontaneous AF with or without underlying heart disease undergoing an invasive catheterization procedure involving right heart catheterization were screened. Men or women aged ≥18 years who gave informed consent for participation in the study were enrolled. They had undergone a transthoracic echocardiogram within the prior 14 days, showing absence of intracardiac thrombi. Each patient was imaged by TEE immediately before or within 48 hours of the ICE procedure. Study exclusion criteria have been reported previously and included patients in whom placement of an ICE catheter in the right atrium for adequate atrial visualization was technically not feasible.

Imaging Technology and Study Procedures
The TEE examination was performed according to standard practice guidelines.14 All approved TEE systems were permitted in the study, including biplane and multplane TEE systems. The TEE procedure was performed with a 0° to 80° field of view at different levels. Images were stored on coded media without patient or institutional identifiers and were submitted in random order for review to the core laboratory. The ICE technology used in the current study was the View Mate System (EP MED Systems; West Berlin, NJ). This system uses a 64-element parallel-drive phased-array transducer, with the transducer being located at the tip of the probe and the base connected to an isolation box. It is introduced into the body mounted on a deflectable ViewFlex catheter, which is a 9-F deflectable-tip intravascular catheter. The 2D imaging frequencies range from 4.5 to 8.5 MHz with 0.5-MHz increments, and pulse wave frequencies vary from 5 to 7.5 MHz. It has an auto-optimized zoom function and is capable of providing high-resolution detailed 2D ultrasound images with tissue penetration of 11 cm, with the shallowest image depth available being 1 cm from the lens. The images are visualized on the ViewMate platform.

Imaging by ICE was done during the diagnostic or therapeutic invasive catheterization procedure. The phased-array ultrasound imaging catheter was introduced through an 11-F hemostatic sheath and positioned under fluoroscopic guidance in the right atrium. After catheter coupling to the ViewMate imaging platform, imaging frequency was optimized by the operator using adjunctive gain, depth, and focal length controls to define anatomic structures and minimize noise. Imaging was performed at different levels in the right atrium, if needed. Imaging targets included the coronary sinus orifice, fossa ovalis, IAS, tricuspid valve, LA, LAA, orifice of all pulmonary veins, mitral valve, papillary muscles, aortic and pulmonary valve leaflets, and adjoining left ventricular (LV) and right ventricular (RV) myocardium. Intracardiac physiology in the region of appendage, mitral valve, and IAS was examined with color flow and spectral Doppler echocardiography.

In the study, TEE and ICE were used to assess the presence of any SEC or thrombus in the LA and LAA as well as the presence of a patent foramen ovale (PFO) or interatrial septal defect (ASD). SEC was defined as slow-moving, continuous echoes, indicating a low flow state, whereas a clot was a well-defined mass, which could be immobile or show varying degrees of mobility. The diagnosis of clot would be more definitive if it is associated with poor wall motion in the region of the clot and SEC. TEE and ICE also were used to evaluate the presence of mobile or fixed atherosclerotic plaques throughout the length of the aorta, especially the ascending aorta and the aortic arch.

Study End Points, Definitions, and Analysis
The study end points included (1) assessment of the presence of thrombus or SEC in the LA or LAA and (2) assessment of the IAS for the presence of a PFO, ASD, and septal aneurysm. The primary end points for imaging concordance were to compare rates of detection of thrombus, dense SEC, ASD, and PFO in patients in whom the IAS and LA (including appendages) could be fully imaged. Secondary outcome measures were analyzed to characterize the ICE imaging modality but were not used in the efficacy evaluation of ICE.

Complete imaging was defined as visualization of the entire structure with clear definition and adequate image quality. Incomplete imaging was defined as failure to visualize the entire structure and absence of clear definition or adequate image quality.

SEC was defined as slow-moving, continuous echoes, indicating a low flow state, swirling slowly within the structure cavity. When present, the gain was systematically decreased to exclude noise artifacts caused by excessive gain. In dense SEC, continuous contrast...
fills the entire cavity of the structure and does not clear with the cardiac cycle. In mild SEC, intermittent contrast is seen, often in only part of the structure.

Thrombus was defined as a dense, well-circumscribed mass, which could be immobile or show varying degrees of mobility, acoustically distinct from the underlying endocardium or trabeculations. A definite thrombus was visualized in ≥2 views of the structure. A probable thrombus was visualized in 1 view of the structure.

Septal imaging assessed the whole extent of the atrial septum for any ASD or a PFO. Color Doppler echocardiography as well as saline contrast studies with maneuvers, such as the Valsalva maneuver, were used to transiently raise the right atrial pressure.

Analysis
ICE and TEE images were evaluated at a core laboratory by 2 independent observers (S.S., N.N., or T.L.). Interobserver differences were resolved by a third observer. The images were displayed in random order without clinical information on the patient and analyzed by means of the evaluation software provided by the manufacturer, and analysts were blinded to site and individual patient to minimize interpretation bias. Imaging quality control was done by an external echocardiographer-consultant.

Statistical analysis was conducted by an independent statistical group (M.L.C.) with SAS version 9.1. Concordance between the techniques was calculated as the number of subjects with identical findings on ICE and TEE divided by the number of subjects with readings on both ICE and TEE. Thus, although unpaired data were available, concordance analyses required both imaging techniques with adequate quality images. Proportions were compared using Fisher exact test. CIs for sensitivity, specificity, positive predictive value, and negative predictive value were calculated using the exact binomial test.

Results
Patient Population
Ninety-five patients (male sex, 80; mean age, 58±12 years) were enrolled in the study. AF was >6 months duration in 91% of patients, 3 to 6 months in 3%, and <3 months in 1%. The indication for cardiac catheterization included a diagnostic electrophysiological study in 31% of patients, right atrial ablation procedure in 7%, and an LA ablation procedure in 85%.

Technical Image Quality Assessment
Images of sufficient quality, as judged by the core laboratory, for each of the 3 anatomic structures were included in the final analysis. Table 1 shows the study imaging procedure completion for LA and LAA imaging between the 2 techniques for the entire study population. The LA was profiled in all patients with both techniques. The study imaging for the LA with ICE was rated as complete in 94% of patients and...

Table 1. Study Image Quality and Concordance Between ICE and TEE

<table>
<thead>
<tr>
<th></th>
<th>LA ICE</th>
<th>LA TEE</th>
<th>LA Both</th>
<th>LAA ICE</th>
<th>LAA TEE</th>
<th>LAA Both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete, %</td>
<td>94</td>
<td>100</td>
<td>96</td>
<td>85</td>
<td>96</td>
<td>82</td>
</tr>
<tr>
<td>Incomplete, %</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Not profiled, %</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Percent concordance</td>
<td>96</td>
<td>82</td>
<td></td>
<td></td>
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</tbody>
</table>

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Figure 2. A, SEC as visualized in the LA by ICE and TEE imaging techniques in the same patient. B, SEC as visualized in the LAA by both ICE and TEE imaging techniques.
with TEE in 100% of patients. The percentage concordance for complete imaging of the LA was 96% (Table 1). The LAA could not be profiled with ICE in 3% of patients. For the LAA, complete imaging was achieved with ICE in 85% of patients and with TEE in 96%. The percentage concordance for complete imaging for the LAA was 83% between the 2 techniques (Table 1). Figure 2 shows an example of visualization of both LA and LAA by ICE and TEE in the same patient. Note the ability of both techniques in complete studies to visualize these structures. The omitted study elements included peak flow velocity by TEE in the LAA in 74% and by ICE in 95%. Color flow Doppler imaging at the IAS was absent with TEE in 29% of patients and with ICE in 53%.

Procedural Complications
In this trial, there were no adverse events or complications reported for ICE or TEE. Such complications would have included local or retroperitoneal bleeding, vascular damage, and hematoma formation as well as damage to cardiac structures, perforation, or embolization.

Study End Points
SEC is shown in Table 2 and Figure 3. Table 2 shows the presence of any SEC in the LA or LAA with the 2 techniques. There was no significant difference in the presence of any SEC between ICE and TEE during LA imaging (Figure 3). The incidence of any SEC in the LAA detected with TEE compared to ICE was not significantly different (P=0.109) (Figure 3). Percentage concordance for the presence of SEC was 65% for the 2 techniques in the LA and 60% in the LAA.

Table 2. Incidence and Concordance of SEC Seen With ICE and TEE

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Incidence of Any SEC, % (no./n)</th>
<th>Dense SEC, % (no./n)</th>
<th>Percent Concordance</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICE</td>
<td>50 (40/80)</td>
<td>13 (10/80)</td>
<td>65</td>
</tr>
<tr>
<td>TEE</td>
<td>56 (41/73)</td>
<td>18 (13/73)</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>35 (24/69)</td>
<td>6 (4/69)</td>
<td></td>
</tr>
<tr>
<td>LAA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICE</td>
<td>24 (18/76)</td>
<td>5 (4/76)</td>
<td>60</td>
</tr>
<tr>
<td>TEE</td>
<td>36 (26/72)</td>
<td>17 (12/72)</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>8 (5/64)</td>
<td>0 (0/64)</td>
<td></td>
</tr>
</tbody>
</table>

Dense SEC was seen in the LA in 12.5% of ICE studies and 17.8% of TEE studies, but limited paired data were recorded.

Figure 2 shows SEC detected with both techniques in the same patient. Note that substantial and dense SEC is observed with both techniques in the LA (Figure 2A). In the LAA, dense SEC was less common with ICE (ICE, 5.3%; TEE, 16.7%) (Figure 2B). Note that the LAA is visualized with both techniques, and the presence of SEC in both the LA and the LAA is clearly seen. Also note the similarity in density and extent of the finding.

Intracardiac Thrombus
As seen in Table 3, intracardiac thrombus was uncommonly seen with both techniques (TEE, 6.9%; ICE, 5.2%). Figure 4 shows the incidence of intracardiac thrombus with ICE and TEE in the LA and LAA. The percentage concordance for the presence or absence of thrombus was 97% in the LA and 92% in the LAA. Note that probable thrombus in the LA was detected more frequently by ICE than by TEE; however, thrombus of the LAA was more frequently detected or reported with TEE versus ICE. All patients with LA or LAA thrombus on TEE demonstrated moderate or dense SEC in the LA or LAA on ICE imaging. Figure 5 shows the presence of a medial LA thrombus identified with ICE that was not seen on TEE.

Table 3. Summary of Thrombi Seen on ICE and TEE in LA and LAA

<table>
<thead>
<tr>
<th>LA</th>
<th>TEE</th>
<th>LA</th>
<th>TEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definite clot</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Probable clot</td>
<td>3</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

IAS Imaging
In unpaired analyses, an atrial septal aneurysm was detected by TEE in 4 (9%) of 45 patients and by ICE in 5 (15%) of 34 patients. A PFO was detected in 2 of 42 patients with TEE, but neither had a complete ICE study for PFO detection. In paired analyses, there was no ASD identified by either technique. The percentage concordance in paired analysis for the presence of a PFO was 100%. The percentage concordance in paired analysis for the presence of atrial septal aneurysm was 96%.

Figure 3. Incidence and concordance of SEC in LA and LAA using ICE and TEE.

Figure 4. Incidence of intracardiac thrombi in the LA and LAA by ICE and TEE imaging techniques.
Concordance of ICE for TEE Findings in the LA or LAA

Both techniques showed a fully negative examination in 32% and a positive examination in 12% (Table 4). A negative ICE examination (defined as absence of any SEC or thrombus on ICE) was associated with absence of dense SEC or thrombus on TEE in 86%; however, the association of a positive ICE study (defined as presence of any SEC or thrombus on ICE) with dense SEC or thrombus on TEE was only 42%.

Discussion

This report details the findings of a prospective, multicenter comparative study with ICE and TEE using blinded observers to compare the findings of these 2 techniques. Furthermore, detailed comparative evaluation of these 2 methods in different intracardiac structures has been reported. To our knowledge, this comparative ICE and TEE imaging trial is the first reported to use a core laboratory.

The main findings of this trial are the following:

1. Both techniques can be performed with a high degree of safety in virtually all patients with AF.
2. LAA and septal imaging is achieved with both methods in the majority of patients.
3. SEC detection in the LA and LAA is accomplished with substantial concordance by both techniques.
4. ICE and TEE did not show concordance for LA and LAA thrombus detection.
5. ICE and TEE are highly concordant for IAS visualization.
6. A completely negative ICE study is associated with TEE findings showing absence of dense SEC or thrombus.
7. An abnormal ICE study does not frequently reflect similar TEE findings, and absence of LAA thrombus on this study does not reflect absence of thrombus on TEE.

The findings of this trial validate the safety of the ICE technique as applied in electrophysiological and catheterization procedures. Importantly, imaging ability and quality for LA imaging were high with both methods, but LAA imaging was more limited with ICE as used in this study. For the IAS imaging, both methods were useful. However, absence of color flow Doppler imaging of the septum and peak LAA flow velocity in a proportion of patients limited some paired analyses of the 2 techniques. Detailed Doppler imaging was less frequently used than expected by the operators in this study, which could be related to the potential for further prolongation of extended duration interventional electrophysiological procedures.

SEC and Thrombus Detection

The incidence of SEC and thrombus identification probably is related to the refractory and recurrent AF in this population undergoing electrophysiological evaluation for therapy. This trial shows that any SEC detection by both techniques in the AF population was quite high, whereas dense SEC was less common and seen equally often in the LA by both methods but less often by ICE in the LAA. These findings compare with prior reports using TEE, which have shown a 20% incidence of dense SEC in the Stroke Prevention in Atrial Fibrillation II analysis.

Furthermore, although LAA thrombus detection was uncommon by both techniques, it was clearly more frequent with TEE. Three of these 5 patients, however, had SEC on the ICE image, which was dense in 2 and moderate in 1. Two patients did not have this finding and would not have been suspected to be at risk by ICE. These data also would imply that additional views to detect LAA thrombi beyond a single right atrial image are warranted. Alternative locations such as different right atrial

Table 4. Concordance of ICE for TEE Findings in the LA or LAA

<table>
<thead>
<tr>
<th></th>
<th>Mean % (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity of ICE for TEE</td>
<td>69 (41.3–89.0)</td>
</tr>
<tr>
<td>Specificity of ICE for TEE</td>
<td>67 (51.1–80.0)</td>
</tr>
<tr>
<td>Predictive value of negative*</td>
<td>86 (69.7–95.2)</td>
</tr>
<tr>
<td>ICE examination for TEE</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Predictive value of positive*</td>
<td>42 (23.4–63.1)</td>
</tr>
<tr>
<td>ICE examination for TEE</td>
<td></td>
</tr>
</tbody>
</table>

*Defined as absence (negative) or presence (positive) of any echocardiographic contrast and thrombus in ICE.
views, the coronary sinus, and right ventricular outflow tract or pulmonary artery are being evaluated. However, 1 LA thrombus believed to be present on ICE imaging by all 3 observers was not detected on all views by TEE.

There is currently no gold standard for imaging the LA and LAA. CT, MRI, intraoperative measurements, and autopsy studies have all been used for comparative evaluation.1-3 TEE imaging of thrombi has been validated in 1 study with intraoperative findings at mitral valve replacement in patients with valvular heart disease with a positive predictive accuracy of 86%.1 Similar data in patients with AF are not available. In the Assessment of Cardioversion Using Transesophageal Echocardiography study, 14% of patients undergoing TEE demonstrated LA or LAA thrombus.5,6 Comparison of planar and segmented CT and TEE imaging shows definite variability in LAA imaging between methods.15 The increased incidence of probable thrombus in the LA with ICE merits critical comment as well. These patients should have significant SEC as well. Three-dimensional echocardiography or TEE and CT may provide more information in the future about whether this is accurate. In addition, differentiation from trabeculation or ridges in the appendage often is difficult with TEE in some patients, and ICE offers an important opportunity for confirmation as an imaging alternative during an electrophysiological or a catheterization procedure.

The clinical implications of our findings merit brief discussion. ICE imaging is most suitable for use when a comitant diagnostic or therapeutic catheterization procedure is planned. It is not a routine replacement for diagnostic TEE in the clinical setting. A negative ICE examination, defined as absence of both any SEC and thrombus in the LA or LAA, can predict absence of findings in a TEE examination that define patients at low risk for cardioversion with a level of negative predictive accuracy seen in the initial TEE validation studies mentioned previously. Furthermore, presence of dense SEC on an ICE image from the right atrium at electrophysiological study should give pause before LA catheterization or ablation procedures.

This study highlighted some other clinical issues as follows:

1. There is operator dependence in all echocardiographic imaging, and ICE imaging is no exception. The experienced operators in this study did not obtain multiple ICE views of the LAA from the right atrium in many patients, reflecting the need for standardization of technique and more operator experience and effort.

2. Detailed ICE imaging of the LAA from additional right atrial locations, the coronary sinus, right ventricular outflow tract, or pulmonary artery to visualize multiple lobes of the LAA or a TEE study should be considered before proceeding with an interventional procedure.16,17

3. ICE imaging may have future potential advantages in prolonged interventional catheterization or electrophysiological procedures with respect to patient tolerance and limiting the need for general anesthesia (eg, septal closure or AF ablation procedures) when imaging is needed over a longer period than in a diagnostic TEE study.

IAS Imaging
This study validates the high quality of ICE imaging of the IAS, which is comparable to TEE. Between the 2 techniques, concordance was high (90%), and detection of atrial septal aneurysm or PFO was consistent. However, the markedly lower use of color flow Doppler echocardiography with the ICE method reflected the limited operator use of this modality, which has been highly validated for PFO detection in autopsy specimen correlations.3 Atrial septal aneurysms also may have important implications for interventional procedures because transseptal puncture sites may be affected by septal aneurysms.

Economic Implications
This study was not designed to provide an economic comparison of the ICE and TEE techniques. However, ICE catheters are disposable items that cost $700 to $1,000, and although reuse has been performed, they are not labeled for this purpose. TEE probes cost approximately $35,000 but can be reused and may last several years. The mainframe platform for ICE costs $20,000 to $50,000, whereas it may cost $125,000 for TEE. Additional costs include the need for an echocardiographer during TEE procedures in the catheterization laboratory and an anesthesiologist if prolonged (>30 minutes) therapeutic interventions are planned with TEE. Diagnostic use of ICE to replace TEE clearly is unlikely because of the invasive nature of the ICE procedure and brief sedation needed for TEE.

Study Limitations
This study was performed with 1 proprietary phased-array system and may not be extrapolated to other types of ICE systems (eg, those using rotational transducers). There was no significant difference in study image quality between the 2 techniques when complete studies were obtained. However, the omission of study image elements was more likely to be more extensive with ICE when studies were not complete. The relatively lesser use of Doppler imaging for the LAA and IAS in these procedures and population emphasizes operator diligence to ensure a complete evaluation. There are potential risks of ICE based on the need for invasive procedures, which may not have been observed in the course of this study. These risks include the need for large vascular sheath placement, arteriovenous fistulae, perivascular bleeding, thrombosis, and embolism.

Conclusions
This prospective, comparative, multicenter study provides evidence-based validation of the use of ICE for imaging of the LA and IAS. LAA imaging with ICE solely from the right atrium in this study can be inadequate to identify thrombus. Improvement in this imaging modality requires more detailed views of the LAA with either more-intensive operator effort to obtain multiple views of the complete LAA or placement of the ICE probe at different locations (eg, pulmonary artery, right ventricular outflow tract, or coronary sinus) to obtain these images.16,17 Unless these approaches are used, TEE remains more sensitive and the preferred modality for this purpose.

Although therapeutic applications using the ICE technique for guidance are already in vogue for catheter ablation to perform transseptal puncture or monitor ablation, pulmonary vein physiology, or cardiac perforation as well as in septal
Sources of Funding

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Disclosures

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References


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