Accuracy of Intracardiac Echocardiography for Assessing the Esophageal Course Along the Posterior Left Atrium: A Comparison to Magnetic Resonance Imaging

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Echocardiography for Esophageal Location. ***Background:*** **Atrioesophageal fistula is a potentially fatal complication of ablation in the left atrium (LA) to treat atrial fibrillation.**

Objective: **The objective of our study was to systematically evaluate the diagnostic potential of intracardiac echocardiography (ICE) for accurately assessing the esophageal course along the posterior LA.**

Methods: **Thirty-five patients underwent magnetic resonance imaging (MRI) before and ICE during pulmonary vein (PV) isolation to visualize the esophagus. The location of the esophagus was determined in relation to the PVs and anatomic regions of the LA by both ICE and MRI. Using the MRI images as a reference, the accuracy of ICE localization was assessed.**

Results: **The most common location for the esophagus to appear was the mid-posterior wall (80% of patients by ICE, 71% of patients by MRI), followed by the left posterior wall (71% of patients by ICE, 63% of patients by MRI) and the right posterior wall (60% of patients by ICE, 51% of patients by MRI). The esophagus was seen to course near the left PV antrums (left superior PV antrum 34% of patients by ICE and MRI; left inferior PV antrum 34% of patients by ICE, 37% of patients by MRI), left superior PV (17% of patients by ICE, 20% of patients by MRI), left inferior PV (17% of patients by ICE and MRI), right inferior PV antrum (29% of patients by ICE, 37% of patients by MRI) and the right inferior PV (3% of patients by ICE, 17% of patients by MRI). The sensitivity for esophageal location by ICE compared to that by MRI ranged between 33% (right inferior PV) and 92% (left superior PV antrum, left inferior PV antrum, and mid-posterior wall). The specificity for esophageal location by ICE compared to that by MRI ranged between 60% (mid-posterior wall) and 100% (right inferior PV). The positive predictive value ranged between 80% (left inferior PV) and 100% (right inferior PV). The negative predictive value ranged between 84% (right inferior PV antrum) and 96% (left superior PV antrum).**

Conclusion: **Phased array ICE provides rapid, real-time localization of the esophagus during LA ablation that is comparable to MRI.** *(J Cardiovasc Electrophysiol, Vol. 18, pp. 169-173, February 2007)*

atrial fibrillation, pulmonary vein isolation, intracardiac echocardiography, esophagus

Introduction

Atrioesophageal fistula is a potentially fatal complication of left atrial (LA) ablation procedures for atrial fibrillation.[1-5] It is estimated that more than 60 patients have suffered this complication, which carries with it a mortality rate of greater than 75%.[6] Real-time knowledge of the esophageal position may reduce the incidence of this complication. An efficient means of imaging the esophagus and assessing its anatomic location relative to key LA landmarks is desirable.

Intracardiac echocardiography (ICE) is a useful tool during pulmonary vein isolation (PVI) to facilitate transseptal access, visualize pulmonary venous anatomy, and to titrate radiofrequency energy delivery.[7,8] ICE can also visualize the esophagus in relation to posterior LA structures.[9] The diagnostic accuracy of ICE compared to sequential axial imaging modalities such as computed tomography (CT) or magnetic resonance imaging (MRI) for assessing the course of the esophagus along the posterior LA and the esophageal proximity to key LA structures has not been reported. The purpose of this study was to compare the anatomic location of the esophagus by ICE to the esophageal location by MRI in patients undergoing pulmonary vein (PV) isolation.

Methods

The study population consisted of 35 patients with symptomatic paroxysmal atrial fibrillation resistant to medical therapy referred for PV isolation between February and May 2005. Patient demographics are displayed in Table 1.

Within 2 weeks prior to ablation, all patients underwent MRI imaging to demonstrate pre-procedure PV anatomy on a 1.5 Tesla magnet (Magnetom Avanto, Seimens Medical Solutions, Erlangen, Germany) with high-performance gradients. Images were acquired using fast-imaging steady precession (True FISP) and double IR half-Fournier single-shot turbo spin echo (HASTE DB) protocols. Data acquisition was performed at a slice width of 1.1 millimeters. Imaging was initiated at the transaxial level of the aortic arch and carried caudally to cover the cardiac chambers. The MRI images

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TABLE 1
Patient Demographics

Age	55 ± 10 years
Men	61%
Hypertension	13%
Coronary artery disease	7%
Congestive heart failure	8%
Antiarrhythmic drugs	78%

were interpreted by an investigator (JG) prior to the ablation procedure. The location of the esophagus in relation to the posterior LA and the pulmonary veins on each axial MRI image obtained was recorded.

The ablation procedure consisted of PV antral isolation during conscious sedation. A description of this ablation technique has been previously described.[10] All patients underwent ICE using a 10 Fr phased array catheter (Acuson AcuNav Diagnostic Ultrasound Catheter, Siemens Medical Systems; Aspen Console, Acuson, Siemens Medical Systems) imaging system introduced through an 11 Fr left femoral venous sheath. The ICE catheter was fluoroscopically guided to the right atrium and oriented to visualize the posterior LA. Real-time ICE images were obtained to identify the LA, PVs, and the esophagus. The location of the esophagus in relation to posterior LA structures was determined and recorded by an investigator (BL) blinded to the interpretation of the MRI. When the ablation catheter tip was seen in proximity to the esophagus on ICE, radiofrequency energy was not delivered in this location or the power was reduced to 15–20 watts.

In patients in whom the esophagus could not be readily visualized, a carbonated beverage was used as echogenic contrast (Fig. 1). After ensuring a level of consciousness such that the patient was able to follow simple commands, 10 mL of carbonated beverage were drawn into a syringe and injected slowly into the patient's mouth. The patient was then asked to swallow. At this point, ICE imaging of the posterior left atrium was performed again and visualization of the esophagus was accomplished. If necessary, this was repeated.

For both MRI and ICE, images of the posterior LA were divided into 11 anatomic regions spanning the posterior LA wall from the left pulmonary veins (LPV) to the right pulmonary veins (RPV) (Fig. 2). The location of the esophagus was counted in each of the segments in which it was seen by both imaging modalities (i.e., can be seen in multiple segments in all patients). The segments in which the esophagus was counted on ICE were compared to the segments where the esophagus was counted on MRI (Figs. 3 and 4).

Statistics

SPSS Version 10.0 (SPSS, Chicago, IL, USA) computer software was used for statistical analysis. Sensitivity, specificity, and positive and negative predictive values were calculated using MRI as the gold standard test to determine esophageal position. The sensitivity was defined as the patients with the esophagus at location "X" on MRI and the same location on ICE divided by all of the patients with the esophagus at location "X" on MRI. The specificity was defined as the patients with esophagus not at location "X" on MRI and not at the same location on ICE divided by all of the patients with esophagus not at location "X" on MRI. The

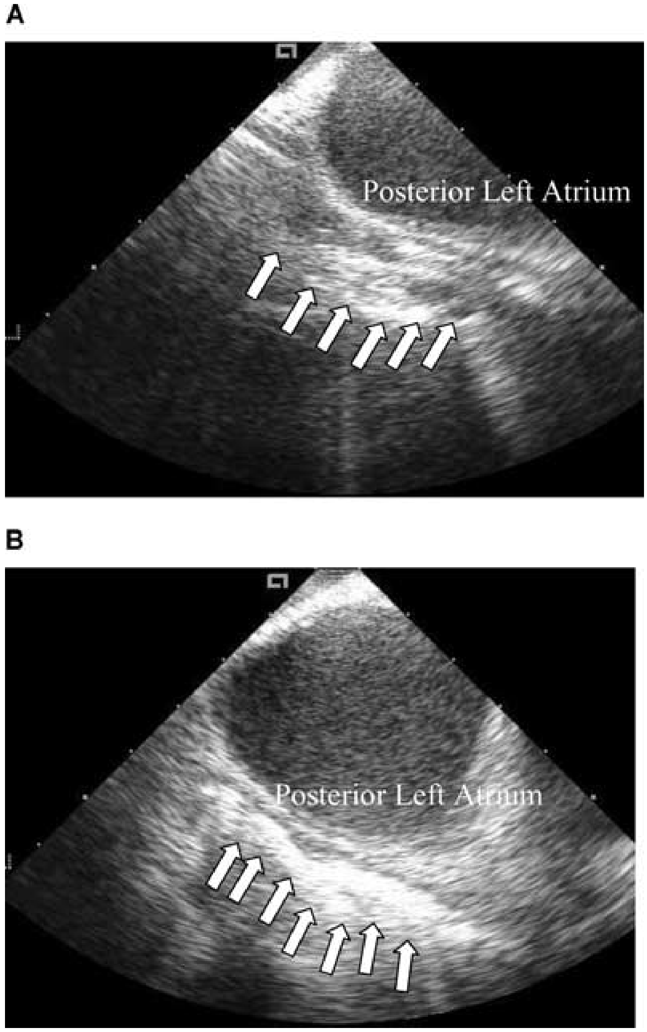
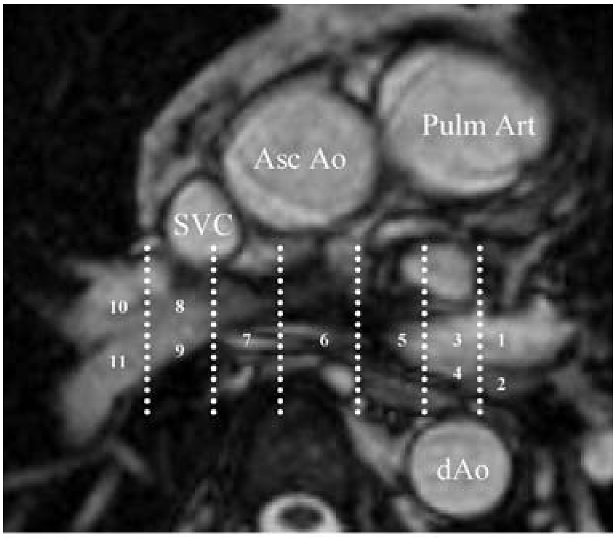


Figure 1. *ICE image of the esophagus (arrows) in the same patient before (A) and after (B) the administration of carbonated beverage as contrast.*

positive predictive value was defined as the patients with the esophagus at location "X" on MRI and the same location on ICE divided by all of the patients with the esophagus at location "X" on ICE. The negative predictive value was defined as the number of patients without the esophagus at location "X" on MRI and not at the same location on ICE divided by all of the patients with the esophagus not at location "X" on ICE. The prevalence of the esophagus at each of the 11 segments as assessed by ICE and MRI were compared with a chi-square test; a P value less than or equal to 0.05 was considered to be statistically significant.

Results

The esophagus was seen in all patients on MRI and ICE. A carbonated beverage was used as contrast to visualize the esophagus by ICE in eight (23%) patients. In these patients requiring a carbonated beverage, there were no unusual anatomic features of the esophagus noted. Additionally, there was no observed change in the esophageal location during the swallowing of the carbonated beverage. Furthermore, there was no occurrence of aspiration as a result of this small amount of fluid being administered orally to the patient.



Segment Number	Corresponding Anatomic Location
1	LSPV
2	LIPV
3	LSPV antrum
4	LIPV antrum
5	Left posterior atrial wall
6	Mid posterior atrial wall
7	Right posterior atrial wall
8	RSPV antrum
9	RIPV antrum
10	RSPV
11	RIPV

Figure 2. *Location of reference points on MRI of study patient. The vertical lines represent the demarcation of the boundary between segments. SVC = superior vena cava, Asc Ao = ascending aorta, PA = pulmonary artery, dAo = descending aorta.*

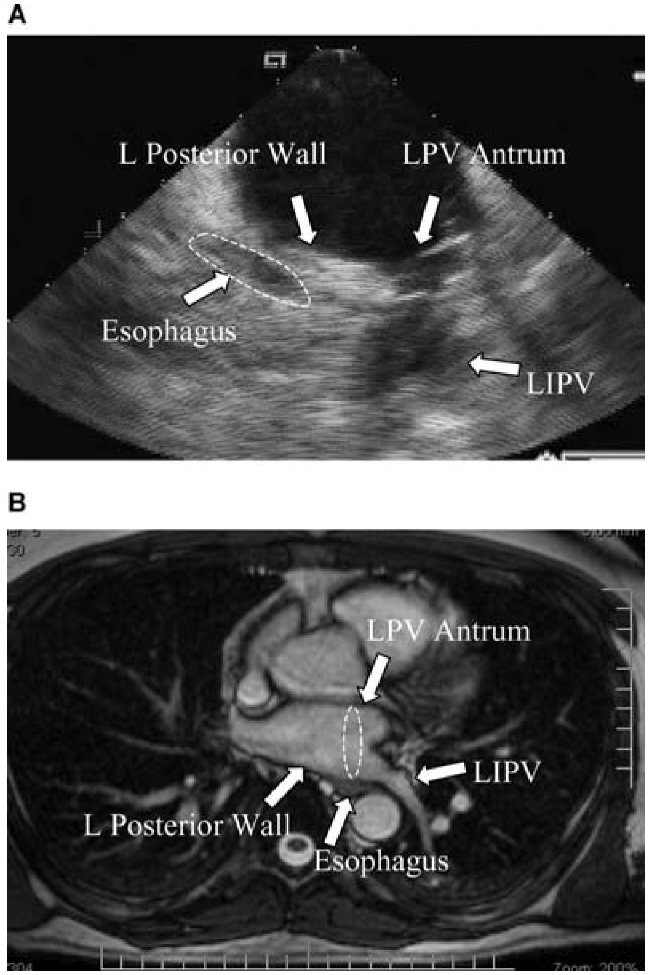


Figure 3. *Esophagus at left pulmonary veins in the same patient by ICE and MRI. A: ICE image of the LA with a lasso catheter positioned at the antrum of the left pulmonary venous system. In this view, the esophagus is visible as well in proximity to the left inferior PV (LIPV), the LPV antrum, and the left posterior LA wall. B: Standard axial MR angiographic imaging.*

The esophagus was seen in 122 total segments on MRI and 121 segments on ICE. The prevalence of the anatomic locations of the esophagus is shown in Table 2. The esophagus was seen in all 11 segments, except near the right superior PV and the right superior PV antrum, by both MRI and ICE. The differences in prevalence of esophageal location as assessed by ICE compared to MRI were not statistically significant in 10 of 11 segments. In the right inferior PV segment, the difference in prevalence was significant ($P \leq 0.05$).

The most common locations for the esophagus to appear were in the mid-posterior wall (80% of patients by ICE, 71% of patients by MRI), followed by the left posterior wall (71% of patients by ICE, 63% of patients by MRI) and the right posterior wall (60% of patients by ICE, 51% of patients by MRI). The esophagus was seen to course near the left superior PV antrum in 34% of patients by ICE and MRI; near the left inferior PV antrum in 34% of patients by ICE and 37% by MRI; near the left superior PV in 17% of patients by ICE and 20% by MRI; near the left or inferior PV in 17% of patients by ICE and MRI; near the right inferior PV antrum in 29% of patients by ICE and 37% by MRI and near the right inferior PV in 3% of patients by ICE and 17% by MRI.

The sensitivity for esophageal location by ICE compared to that by MRI (Table 2) ranged between 33% (right inferior PV) and 92% (left superior PV antrum, left inferior PV antrum and mid-posterior wall). The specificity for esophageal location by ICE compared to that by MRI ranged between 60% (mid-posterior wall) and 100% (right inferior PV). The positive predictive value ranged between 80% (left inferior PV) and 100% (right inferior PV). The negative predictive value ranged between 84% (right inferior PV antrum) and 96% (left superior PV antrum).

Discussion

Our findings suggest that the location of the esophagus on ICE during PV isolation is similar to that seen on the preprocedural MRI. In fact, in 10 of the 11 segments, the prevalence of the esophageal location on ICE compared with MRI was not significantly different. The right inferior PV was the only segment in which a significant difference in prevalence of the location of the esophagus between the two imaging modalities was seen ($P \leq 0.05$). This may be attributed to the relatively low prevalence of the esophageal course tracking near this PV.

For most locations, there is a high sensitivity and specificity for visualizing the esophagus by ICE compared with MRI. The relationship was least accurate for the right inferior PV and right inferior PV antrum because of the infrequency of the esophagus appearing near the right veins; this finding was also reported by other investigators.[12–14]

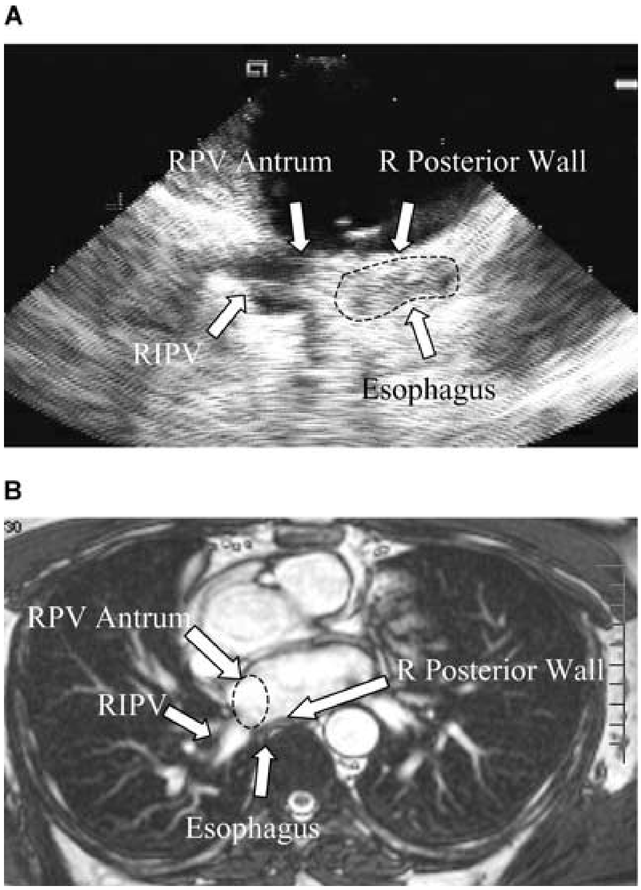


Figure 4. *Esophagus at right pulmonary vein in the same patient by ICE and MRI. A: ICE image of the LA with a lasso catheter positioned at the antrum of the right pulmonary venous system. In this view, the esophagus is visible near the right inferior PV (RIPV), RPV antrum, and right posterior LA wall. B: Standard axial MR angiographic imaging.*

The fact that the MRI was performed on average 2 weeks prior to ICE, and the prevalence of esophageal location was similar for the two modalities, suggests that the esophagus does not move very much or spends little time in other locations with movement. Other investigators have reported significant (≥2 cm) esophageal movement during the procedure performed under conscious sedation.[11] However, our data did not confirm this finding despite the use of conscious sedation in our series.

A commonly used alternative approach to visualize the esophageal lumen during PV isolation is barium swallow. However, we believe real-time ICE to be a viable alternative to barium swallow because it is a useful tool to facilitate transseptal access, visualize pulmonary venous anatomy, and to titrate radiofrequency energy delivery. Also, it does not consistently pose the risk of aspiration seen in patients receiving barium paste under conscious sedation. This may be more problematic in situations where barium requires repeat applications during a lengthy procedure.

Prior investigators have looked at esophageal location in relation to the LA with other real-time modalities. Kottkamp et al. reported their experience using an electromagnetic mapping system (CARTO, Biosense-Webster, Waterloo, Belgium) to reconstruct the LA and to anatomically tag the esophagus in 30 patients undergoing catheter ablation for atrial fibrillation.[12] The tagging of the esophagus was performed by placing a CARTO catheter through a gastric tube into the esophagus. They found the esophageal course to be highly variable and in close proximity to the LPV, RPV, and posterior LA. Similar to our findings of 80% on ICE and 71% on MRI, they found that in 63% of the patients, the esophagus descended in the mid-posterior LA. Also in line with our findings, the rest were mostly divided between the left posterior LA, the right posterior LA, and at the level of the LPVs. In their report, only one patient had an esophageal course near the RPVs. Despite the relatively low frequency in which the esophagus was seen near the right veins in comparison to the left in our series, we saw 29% on ICE and 37% on MRI near the right inferior PV antrum. They adjusted the encircling lines in 17 patients, 14 on the left, and three on the right due to the close proximity of the PVs to the esophagus. Furthermore, they found that all patients had contact between the esophagus in the mid- to inferior areas of the posterior LA. In almost all patients, this resulted in the abandonment of ablative lines in this region in favor of superior lines. The major drawback to this technique is that it requires additional instrumentation of the esophagus, potentially adding to the cost and risks of the procedure.

The same investigators compared the CARTO-tagged esophageal location with contrast-enhanced spiral CT scan with barium swallow performed a day prior to the

TABLE 2
Prevalence, Sensitivity, Specificity, Positive and Negative Predictive Values of Esophageal Location by ICE Compared to MRI

Esophageal Location	ICE Prevalence N (%)	MRI Prevalence N (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
LSPV	6 (17)	7 (20)	71	96	83	93
LIPV	6 (17)	6 (17)	67	96	80	93
LSPV antrum	12 (34)	12 (34)	92	96	92	96
LIPV antrum	12 (34)	13 (37)	92	95	92	91
Left posterior wall	25 (71)	22 (63)	91	69	84	90
Mid-posterior wall	28 (80)	25 (71)	92	60	86	86
Right posterior wall	21 (60)	18 (51)	89	76	81	93
RSPV antrum	0	0	-	-	-	-
RIPV antrum	10 (29)	13 (37)	90	95	90	84
RSPV	0	0	-	-	-	-
RIPV	1 (3)*	6 (17)	33	100	100	85

*P value <0.05 versus prevalence by MRI.

procedure.[13] The main finding of this study was that the electroanatomic reconstruction was accurate in determining the "true" anatomy of the LA, PVs, and esophagus in most regions of interest for atrial fibrillation ablation without relevant shifting of the esophagus. We find this study to be in agreement with our findings in that the anatomical relationships established by MRI performed, in our report, up to 2 weeks prior to the atrial fibrillation ablation, were consistent with those found at the time of the procedure as assessed by ICE. Furthermore, since the findings from these different imaging modalities performed at different times are comparable and ICE is already being utilized during the procedure, this may allow the option of dispensing with the CT scan or MRI, if not being performed for other purposes.

Redfearn and investigators measured esophageal temperature using a commercially available temperature probe in 16 patients undergoing atrial fibrillation ablation under general anesthesia.[14] They found the position of the esophagus to be midline in three patients, right-sided in two patients, oblique across the posterior LA close to the right inferior PV and left superior PV in one patient, and near the LPV ostia in the remaining 10 patients. This technique required general anesthesia in order to allow tolerability of the esophageal probe. The probe identified the general location of the esophagus in relation to the posterior LA and pulmonary vein based on a 3–4°C rise in temperature from baseline and assuming a linear degree of heating from the external esophagus relative to the lumen. This assumption did not take into account heating of the esophageal wall without recording a change in central luminal esophageal temperature. Furthermore, the safety zone of temperature rise from baseline has not been validated. Moreover, the insertion of this probe in and of itself could potentially result in perforation of the esophagus—a risk avoided by utilizing ICE to visualize the esophagus.

Ren and colleagues recently tested the hypothesis that ICE can provide real-time imaging of the esophagus and allow for the titration of radiofrequency energy by monitoring lesion development retrospectively in 79 patients and prospectively in 73 patients undergoing PV isolation to treat atrial fibrillation.[15] Their impetus to perform this study was a reference case of atrioesophageal fistula post LA ablation that resulted in patient death. They found that the longitudinal extent of the posterior LA and the esophageal wall could be identified in all 152 patients. Furthermore, they noted that monitoring posterior LA thickness and reduction of power and titration of duration of RF delivery limited the risk of esophageal involvement. This study did not compare two imaging modalities, as we did in this series; however, our findings are in agreement that the esophagus can be seen on ICE in all patients.

An additional limitation of ICE is that the esophageal lumen is often better visualized than the walls. However, this limitation is not unique to ICE. In fact, like ICE, barium swallow, electroanatomical 3D tagging, and the use of an indwelling temperature probe all delineate the lumen of the esophagus and not the outer wall. Therefore, if the ablation is performed along the posterior LA wall or the pulmonary veins near the esophagus, we suggest that a buffer zone be used to account for esophageal wall thickness.

Conclusion

Phased array ICE is a useful diagnostic tool for rapid, real-time localization of the esophageal location in relation to the posterior LA wall. Location of the esophagus by ICE correlates well with location determined by MRI. Knowledge of the esophageal location can help to ensure safe RF application and appropriate energy titration during ablation. This is of importance considering recent reports of esophageal fistulas and the resultant morbidity and mortality. Future work needs to be done to ascertain whether or not visualization of the esophagus improves outcomes with atrial fibrillation ablation, as this is beyond the scope of the present study.

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