The Impact of CT Image Integration into an Electroanatomic Mapping System on Clinical Outcomes of Catheter Ablation of Atrial Fibrillation

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CT Image Integration for AF Ablation. Background: A detailed appreciation of left atrial/pulmonary vein (LA/PV) anatomy may be important in improving the safety and success of catheter ablation (CA) for atrial fibrillation (AF).

Objectives: The aim of this nonrandomized study was to determine the impact of computerized tomography (CT) image integration into a 3-dimensional (3D) mapping system on the clinical outcome of patients undergoing CA for AF.

Methods: Ninety-four patients (age: 56 ± 10 years) with AF (paroxysmal 46, persistent 48) underwent wide encirclement of ipsilateral PV pairs using irrigated radiofrequency ablation with the endpoint of electrical isolation. Ablation was guided by 3D mapping alone (electroanatomic 24, noncontact 23) in 47 (3DM group) patients and by CT image integration (Cartomerge®) in 47 (CT group). In persistent AF, a combination of linear ablation and targeted ablation of complex fractionated electrograms was also performed.

Results: Successful PV electrical isolation did not differ between the two groups. A significant reduction in fluoroscopy times was demonstrated in the CT group (49 ± 27 minutes vs 3DM group 62 ± 26 minutes, P = 0.03). Arrhythmia recurrence was reduced in the CT group (32% vs 51% in the 3DM group, P < 0.01). In 30 symptomatic patients (12 CT and 18 3DM), repeat procedures for AF (13 in 3DM and 5 CT, P ≤ 0.10) and AT (5 in 3DM and 7 CT, P = NS) were performed. Overall success on 7-day monitor off antiarrhythmic drugs was achieved in 60% in the 3DM group when compared with 83% in the CT group (P < 0.05) at a follow-up of 25 ± 5 weeks.

Conclusion: CA for AF guided by CT integration was associated with reduced fluoroscopy times, arrhythmia recurrence, and increased restoration of sinus rhythm. Improved visualization of complex LA geometries might improve the safety and success of CA for AF. (J Cardiovasc Electrophysiol, Vol. 17, pp. 1093-1101, October 2006)

Introduction

Catheter ablation (CA) of atrial fibrillation (AF) is successful in restoring sinus rhythm in up to 95% of patients.1-3 Segmental electrical isolation of the pulmonary veins (PVs)4 or wide encirclement of PV (WEPV) pairs with1,2 or without6,7 confirming electrical isolation form the cornerstone of ablation strategies for AF. Substrate modification by linear ablation or targeting complex fractionated activity may also be performed.7,8 WEPV has the potential advantage of including proximal arrhythmia foci and parasympathetic ganglia which might be missed when ablating closer to the veno-atrial junction.9 A perceived disadvantage of WEPV is that achieving true electrical isolation is difficult although whether isolation is required for procedural success is controversial.5,9 Achieving electrical isolation with WEPV may be challenging, because creating uninterrupted lines of conduction block with focal radiofrequency (RF) lesions placed over a long distance in complex 3-dimensional (3D) geometries can be difficult. Geometries reconstructed on 3D mapping systems have a resolution limited by the number of points acquired, which can make accurate definition of the left veno-atrial junctions difficult. In addition, variations in PV anatomy are frequent.10,11 For these reasons, PV stenosis as a result of inadvertent energy delivery within the PV is a potentially serious complication of CA of AF.12 While the use of additional imaging modalities like ultrasound can improve the efficacy and safety of the procedure they are restricted to imaging in 2 dimensions, and its use and interpretation require some experience.13
A more detailed representation of the atrial and PV anatomy can be provided by computerized tomography (CT) or magnetic resonance imaging (MRI). Recently, the ability to maneuver catheters guided by radiological images integrated into 3D mapping system has been capitalized on in the context of clinical usage. Although prior studies have provided validation for the use of image integration in animals and humans, the impact on the ablation procedure and clinical outcomes have not been evaluated. We performed a nonrandomized study to examine the clinical effect of CA guided by CT integration, compared to CA guided by 3D mapping without CT integration.

Methods

Study Population

The study population consisted of 94 patients who underwent CA of AF at a single institution. All patients had symptomatic documented AF and had failed at least two antiarrhythmic drugs. CA was guided by CT image integration into an electroanatomic mapping (EAM) system (Cartomerge™, Biosense Webster, Inc., Diamond Bar, CA, USA) in 47 consecutive patients (CT group) and comparisons were made with the immediately preceding 47 patients who had undergone a similar ablation strategy guided by a 3D mapping system, either electroanatomic (CARTO, Biosense Webster, Inc.) or EnSite NavX (St. Jude Medical, St. Paul, MN, USA) mapping (3DM group). Patients were not included if they had undergone prior ablation for AF.

Electrophysiologic Study and RF Ablation

Electrophysiologic study was performed in the postabsorptive state under conscious sedation. Oral anticoagulation was administered for at least 4 weeks prior to the procedure and transesophageal echocardiography was performed within 24 hours of the procedure to exclude left atrial thrombus. All patients gave written informed consent.

Computed tomography

A multislice helical CT (GE Lightspeed Ultra 8-slice scanner, GE Healthcare Technologies, WI, USA) was performed prior to the procedure in the CT group. The imaging technique has been described previously. In brief, following a test bolus, 80 mL of nonionic contrast (Omnipaque 300, Amersham Health, Oslo, Norway) was injected at 5 mL/second via an antecubital vein. Scanning was performed in a single breath hold in the cranio-caudal direction at the level of the atrium using simultaneous acquisition of eight sections (each 1.25 mm), beam collimation of 10 mm, table speed 16.75 mm/0.5 second (0.5 second tube rotation time, 120 kV, 310 mA). Contiguous 1.25 mm axial CT slices were reconstructed from the CT data using a soft tissue algorithm and the resulting DICOM data recorded onto CD-ROM.

3D mapping

The 3D geometry of the left atrium (LA) was created by collection of at least 50 widely spaced points. The PVs and their origins were identified and tagged using PV angiography, and the presence of PV electrograms on the circular mapping catheter noted.

3D mapping with CT integration

The segmentation and registration of the CT image into the EAM system using custom-designed software (Cartomerge™) has been previously described in detail. Using proprietary software tools, segmentation of the cardiac image was performed to separate the LA and the PVs from the surrounding cardiac structures (Fig. 1). The LA and the PVs were then exported into the real-time mapping system for registration. Registration of the CT image was performed using landmark and surface mapping (Fig. 2). Points

Figure 1. Segmentation process: The final stage in antero-posterior (AP) and postero-anterior (PA) views demonstrating the removal of surrounding cardiac and mediastinal structures to isolate the left atrium and pulmonary veins (right panel), which are now ready for registration. Ao = aorta; E = esophagus; LA = left atrium; PA = pulmonary artery; RA = right atrium; RV = right ventricle.
Points easily identifiable on fluoroscopy and the CT image at the proximal or first order venous branches of at least three different PVs were used for landmark registration (left panel). Additional selective PV angiography was performed to accurately define the position of the mapping catheter during the registration process, to ensure the branch point identified during EAM matched that on CT. Next, surface registration was performed to further refine the match between the CT and the true left atrial geometry (right panel). LM = landmark point.

easily identifiable on fluoroscopy and the CT image at the proximal or first order venous branches of at least three different PVs were used for landmark registration. The ablation catheter was maneuvered under fluoroscopic guidance to the selected location and a point acquired on the EAM system. Additional selective PV angiography was performed to accurately define the position of the mapping catheter during the registration process, to ensure that the branch point identified during EAM matched that on CT (Fig. 2). Next, surface registration was performed to further refine the match between the CT and the true left atrial geometry, by creating an electroanatomical shell with at least 30 widely spaced points predominantly from the lateral, septal, roof, inferior and posterior LA walls. Catheter contact was ensured by fluoroscopic visualization of catheter mobility in relation to cardiac motion and a discrete atrial electrogram. Next, the overall closeness of fit was assessed using customized software which provides a point-by-point review of registration accuracy. If required, additional landmark and surface registration points were taken to achieve an overall accuracy of <3 mm. In addition, each PV was entered with the ablation catheter and the ostium was identified by dragging the catheter back under fluoroscopic guidance to assess the correct representation of the veno-atrial junction on the registered CT image.

Catheter ablation

A 6-F quadripolar catheter was positioned in the coronary sinus (CS). A double transeptal puncture was performed and intravenous heparin was administered to maintain an activated clotting time of between 300 and 400 seconds. A circumferential steerable 14-pole catheter was positioned as close as possible to the PV ostium (Orbiter PV, Bard EP, Lowell, MA, USA).

Left atrial circumferential ablation (LACA) was performed to encircle the left- and right-sided PVs in pairs 1–2 cm from their ostia, as defined by PV angiography and the 3D map. At the anterior aspect of the left PVs, ablation was performed along the ridge between the LAA and the PV ostia (Fig. 3). In all patients, energy was delivered through a 3.5-mm irrigated tip catheter with flow limited to 2 mL/minute and power limited to 30 W and temperature to 50°C for left atrial ablation. Energy was delivered until the amplitude of the local bipolar atrial electrogram had been reduced by >80% or was <0.1 mV. The PVs were continuously assessed for electrical disconnection using the circular mapping catheter (Fig. 4). If veno-atrial electrical connections persisted, further ablation was performed at the LACA line guided by the activation sequence on 14-pole circular catheter until electrical isolation was achieved. If this was not successful, then further applications (power 20 W and temperature 50°C) were made at the veno-atrial junction. This process was then repeated for the contralateral PVs. If AF continued following PV electrical isolation, a combination of the following was performed: (i) roof line—an ablation line joining the superior aspects of each LACA ring, (ii) mitral isthmus line—a linear lesion created from the inferior aspect of the left WE ablation line to the mitral annulus, and (iii) complex fractionated electrograms—left and right atria were mapped systematically for fractionated potentials which were then targeted for ablation. If at any stage AF organized to AT, activation and entrainment mapping were performed. Bidirectional conduction block was not routinely demonstrated at the mitral isthmus or LA roof. If AF continued following the linear ablation and targeting of fractionated electrograms, internal cardioversion (CV) was performed. The procedure was completed with a cavotricuspid isthmus (CTI) ablation (power 50 W, temperature 60°C using irrigation rates of 30 mL/minute) in all patients requiring CV and where typical atrial flutter had been previously documented. Unidirectional conduction block was confirmed by activation mapping at the tricuspid annulus during pacing from the proximal CS and by the demonstration of widely spaced double potentials along the CTI.
Post ablation management

All patients were treated with subcutaneous Enoxaparin 1 mg/kg twice daily until an international normalized ratio (INR) of between 2.0 and 2.5 had been achieved on coumadin. Patients were discharged on the day following the procedure without antiarrhythmic medication and reviewed at 6 weeks and 6 months. At discharge and each follow-up, a 7-day Holter monitor was used to assess arrhythmia burden. Arrhythmia recurrence was defined as any atrial tachycardia or fibrillation episode lasting greater than 30 seconds on the Holter-monitoring, 12-lead ECG or telemetry. If patients developed symptomatic, sustained atrial arrhythmia that persisted after 6 weeks, a repeat procedure was advised. For repeat procedures, a double transeptal puncture and assessment for PV electrical isolation was performed. If PV electrical reconnection was demonstrated, mapping was performed along the prior ablation lines of WE and the gaps targeted. If necessary, ablation was performed between the superior and inferior PVs. If AF persisted, repeat mapping of both atria for complex fractionated electrograms was performed. If AF continued, internal CV was performed and all four PVs were reassessed for electrical isolation; and the presence of block at the LA roof, mitral isthmus, and CTI
was assessed. If at any time AF organized to AT, activation mapping was performed. AT was defined as an organized atrial rhythm with a stable cycle length, morphology, and activation sequence. An AT was considered macro-reentrant if the entire cycle length could be accounted for by mapping of one chamber. Focal AT was characterized by centrifugal activation from a localized source on activation mapping.

To ensure equal follow-up periods for the cases and controls, follow-up was censored at 6 months for patients in both groups. The clinical outcome was assessed on 7 day Holter monitor at 6 months, with ablation failure defined as any atrial tachycardia or fibrillation episode lasting greater than 30 seconds.

**Statistical Analysis**

All variables are expressed as mean ± SD. Comparisons between groups were performed with either an unpaired Student’s t-test or where a normal distribution could not be assumed the Mann-Whitney U-test. Categorical variables expressed as numbers and percentages were compared with a chi-square test. A P value <0.05 was considered statistically significant.

**Results**

**Patient Characteristics**

The study population consisted of 94 consecutive patients (75 males, 19 females, mean age: 56 ± 10 years) who underwent their first CA for AF between December 2003 and September 2005. Patient characteristics for the 3DM and CT groups are presented in Table 1.

**Procedure Characteristics**

The characteristics of the index procedure are described in Table 2. A significant reduction in fluoroscopy time was demonstrated in the CT group (49 ± 27 minutes) as compared to the 3DM group (62 ± 26 minutes, P = 0.03). A trend to a shorter procedure duration was demonstrated in the CT group (268 ± 61 minutes, compared to the 3DM group (302 ± 100 minutes, P = 0.12). Otherwise, there was no significant difference in the procedures performed or the initial outcomes between the CT and the 3DM groups. Operator experience was similar within each group.

**Image Registration for CT Group**

The cardiac rhythm at the time of CT was sinus in 21 patients and AF in 26. One patient who had been in sinus rhythm during the CT was in AF during the ablation procedure. At least three PVs were used for landmark registration in all patients. Registration error is the distance in mm between the point acquired on the LA electroanatomic geometry and the closest CT surface. A significant difference in landmark registration error was demonstrated between the right-sided and the left-sided PVs. The registration error for the right superior PV (RSPV) was 5.1 ± 2.9 mm versus 6.7 ± 3.4 mm for the left superior PV (LSPV) (P = 0.04) and 6.4 ± 3.8 mm for the left inferior PV (P = 0.14). The registration error for the right inferior PV (4.6 ± 1.7 mm) was significantly smaller than that for the LSPV (P = 0.01) and the left inferior PV (P < 0.01). The mean number of map points collected for surface registration was 36.5 ± 14. The mean surface registration error was 2.4 ± 0.4 mm, with a standard deviation of 1.9 ± 0.4 mm. During the CA, repeat registration was required in 2 of 47 patients when it became apparent that the CT image did not correlate with the true anatomy.

**Recurrence**

The long-term outcome is presented in Table 3. Recurrent atrial tachyarrhythmias were significantly reduced in the CT group (15 patients, 32%) when compared with the 3DM group (26 patients, 55%, P < 0.01). Within the 3DM group, there was no significant difference in recurrence between ablation guided by CARTO (14 patients) versus NavX (12 patients, P = NS). Repeat procedures were performed in 30 patients (18 in the 3DM group and 12 in the CT group, P = 0.20) and not in 11 (controlled on medication in 7, asymptomatic in 3, and death during follow-up in 1).

In the 3DM group (18 patients), AT was focal in 1 patient (2 foci: crista terminalis 1 and CS ostium 1) and macro-reentrant in 4 (perimetal in 3 and CTI dependent in 1). AF organized to macro-reentrant AT in a further six patients, with successful restoration of sinus rhythm during linear ablation.
Table 3

<table>
<thead>
<tr>
<th>Repeat Procedures</th>
<th>3D Mapping (n = 47)</th>
<th>CT Integration (n = 47)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurrent AT/AF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>55% (26)</td>
<td>32% (15)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Paroxysmal AF</td>
<td>52% (12)</td>
<td>26% (6)</td>
<td>&lt;0.10</td>
</tr>
<tr>
<td>Persistent/Permanent AF</td>
<td>58% (14)</td>
<td>38% (9)</td>
<td>&lt;0.20</td>
</tr>
<tr>
<td>Time to recurrence (weeks)</td>
<td>1.7 ± 1.5</td>
<td>3.3 ± 2.2</td>
<td>NS</td>
</tr>
<tr>
<td>Repeat procedure</td>
<td>38% (18)</td>
<td>26% (12)</td>
<td>0.20</td>
</tr>
<tr>
<td>Rhythm at start of procedure</td>
<td>AF 13 AT 5</td>
<td>AF 5 AT 7</td>
<td>0.10</td>
</tr>
<tr>
<td>PV reconnection</td>
<td>100%</td>
<td>100%</td>
<td>NS</td>
</tr>
<tr>
<td>1 PV</td>
<td>6%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>2 PVs</td>
<td>11%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>3 PVs</td>
<td>28%</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>4 PVs</td>
<td>55%</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>Successful repeat PV isolation</td>
<td>18 (100%)</td>
<td>12 (100%)</td>
<td>NS</td>
</tr>
<tr>
<td>Rhythm following PV isolation</td>
<td>AF 7 AT 10 SR 1</td>
<td>AF 4 AT 7 SR 1</td>
<td>NS</td>
</tr>
<tr>
<td>Number of Focal AT</td>
<td>2</td>
<td>4</td>
<td>NS</td>
</tr>
<tr>
<td>Number of macro-reentrant AT</td>
<td>10</td>
<td>7</td>
<td>NS</td>
</tr>
<tr>
<td>Cardioversion to SR</td>
<td>6</td>
<td>4</td>
<td>NS</td>
</tr>
<tr>
<td>Freedom from AT/AF off antiarrhythmic medication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paroxysmal AF</td>
<td>71%</td>
<td>94%</td>
<td>0.17</td>
</tr>
<tr>
<td>Persistent/Permanent AF</td>
<td>50%</td>
<td>73%</td>
<td>0.20</td>
</tr>
<tr>
<td>Overall</td>
<td>60%</td>
<td>83%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Follow-up (weeks)</td>
<td>25 ± 4</td>
<td>24 ± 6</td>
<td>NS</td>
</tr>
</tbody>
</table>

at the mitral isthmus in three, CTI in two, and LA roof in one. AF terminated to sinus rhythm in one patient at the time of electrical isolation of the RSPV. The remaining six patients underwent successful CV to sinus rhythm.

Of the 12 patients in the CT group, AT was focal in 3 patients (4 foci: PV ostium in 2, perinodal in 1, and CS ostium in 1) and macro-reentrant in 4 (7 circuits utilizing the LA roof in 4, mitral isthmus in 3, and CTI in 1). AF became organized and terminated to sinus rhythm during PV electrical isolation in one. The remaining four patients underwent successful CV to sinus rhythm.

Complications

In the 3DM group, there were two pericardial effusions, one requiring pericardiocentesis and one LSPV stenosis. In the CT group, there was one intraoperative transient ischemic attack (TIA).

Clinical Outcome

Maintenance of sinus rhythm was significantly higher in the CT group (Fig. 5). At a mean follow-up of 25 ± 5 weeks, sinus rhythm was present without antiarrhythmic medication.

Clinical outcomes

![Clinical outcomes](chart.png)

* p < 0.05

Figure 5. Clinical outcomes were significantly improved in the CT group when compared with the 3D mapping group. A subanalysis was performed to compare patients in the first and the last half of each group over the study period, to determine the potential effect of a “learning curve” on the observed results. No such difference was demonstrated.
in 39 patients (83%) in the CT group when compared with 28 patients (60%) in the 3DM group (P < 0.05). Within the 3DM group, there was no significant difference in success between ablation guided by CARTO (13 patients) versus NavX (15 patients, P = NS). There was no difference in the outcomes for patients in the first half of each group when compared with the second half (P = NS, Fig. 5). In the CT group, four patients were in persistent AF or AT on antiarrhythmic medication and four were in paroxysmal AF (two on antiarrrhythmic medication). In the 3DM group, 9 patients were in persistent AF or AT on antiarrhythmic medication and 10 were in paroxysmal AF (8 on antiarrhythmic medication). There was one unrelated death 2 months post AF ablation in the 3DM group and one acute coronary syndrome in the CT group.

Discussion

This study reports the clinical outcome of patients with AF who underwent CA guided by CT integration into an EAM system. We compared procedural details and clinical outcomes with a control population who underwent a similar ablation strategy guided by a 3D mapping system but without CT integration. The main findings in the present study were that AF ablation guided by CT integration into an EAM system was associated with:

1. Significant reductions in fluoroscopy time.
2. Significant reductions in recurrent atrial arrhythmias.
3. Improved clinical success at a mean follow-up of 25 ± 5 weeks.

Image Integration into 3D Mapping Systems

Prior studies have determined the feasibility and validated the use of image integration into anatomically based electrophysiologic mapping systems to guide catheter manipulation. However, there are limited data on the clinical impact of a more detailed “real time” representation of the LA geometry.

Animal studies

Several studies have determined the accuracy of image integration for CT and MRI in contact and noncontact mapping systems. Accuracy had been determined by using the integrated image to guide CA to markers positioned on the cardiac surface and performing postmortem studies to measure the distance between the RF lesion and the predefined marker. In a porcine study, using MRI integration into a 3D mapping system, Dickfeld et al. reported an accuracy of 3.9 ± 0.5 mm for RF lesions in the right atrium. Using CT integration into a noncontact mapping system to guide CA in the LA, Sra et al. demonstrated an accuracy of 2.0 ± 3.6 mm between the RF lesion and buried electrode. As in the present study, using CT integration into an EAM system (Cartomerge), Dong et al. reported an accuracy of 1.8 ± 1.0 mm for lesion placement in the LA. Although calculated by online software, a registration error of 2.4 ± 0.4 mm presented in the current study compares favorably with the accuracy reported by postmortem animal studies. However, whether image integration translates into an improved procedural outcome for CA of complex atrial arrhythmias had not hitherto been determined.

Human studies

To date, clinical studies have been limited to the acute feasibility of image integration into an EAM system, the only system currently approved for clinical use in humans. Using multislice CT, Tops et al. reported an overall registration error of 2.1 ± 0.2 mm in 16 patients undergoing CA for AF. We reported the successful use of this new technology in 30 patients undergoing CA for AF with a registration error of 2.4 ± 0.3 mm. However, clinical outcomes were not available. In the present study, we report an improvement in the clinical outcome of CA for AF with successful restoration of sinus rhythm in 83% when compared with 60% for 3D mapping alone.

Clinical Implications

The number of CAs for AF is increasing exponentially, with this trend expected to continue as the efficacy and safety of the procedure improves. While AF ablation can be performed with success rates of 95% without image integration, the incorporation of a CT of the LA to guide catheter manipulation may enable lower volume electrophysiology centers to achieve similar results. An appreciation of the complex interplay between cardiac anatomy and electrophysiology is important in the success of ablation strategies for AF. The primary targets for ablation are the PVs and the surrounding atria or antrum. The efficacy of current catheter-based strategies has been partly limited by the compromised nature of PV and LA anatomy and the inadequate reconstruction of this anatomy by currently available mapping systems. In the present study, we report an improvement in clinical outcomes of CA for AF utilizing an integrated CT of the LA into a contact mapping system. The incidence of recurrent atrial tachyarrrhythmias and the long-term achievement of sinus rhythm was improved when compared with a similar patient cohort in whom CA was guided by 3D mapping alone. Possible reasons for this clinical effect are that:

1. Improved visualization of the mapping catheter within the atria may ensure better close apposition or “contact” with the atrial wall. CT integration offers the added benefit of displaying the atrial configuration and thus allowing completion of a ring of ablation lesions which follows the patient’s own anatomy rather than an empiric encirclement. This offers the benefit of displaying “skips” where symmetrical WE may not follow alterations in atrial architecture.

2. Accuracy of lesion placement to ensure continuity of linear ablation over complex anatomy is improved. We speculate that together, these factors may be important in producing transmural conduction block that is long standing.

Performing continuous linear lesions in complex anatomical structures remains a significant challenge to the electrophysiologist. Linear ablation has become the cornerstone for many catheter-based approaches to AF. The occurrence of “gaps” is responsible for the majority of recurrent atrial tachyarrhythmias following WEPV pairs. Identification and ablation of breaks in prior ablation lines frequently terminate the arrhythmia and provide long-term cure. Dong et al. demonstrated the potential to stretch or deform the atrial wall and leave gaps in ablation lines of 2 to 4 mm despite an apparently continuous
linear lesion displayed on contact mapping. \textsuperscript{15} A greater appreciation of the complex anatomy of the PV antrum, particularly in the region of the left PV/LAA ridge, may allow a more confluent lesion set. Although catheter motion and the local electrogram are integral in establishing catheter contact, accurate visualization of the atrial wall may be particularly useful in enlarged atria and in the presence of scarring. The identification of atrial scar has important prognostic implications\textsuperscript{26} and also precludes the need for ablation in a region which frequently involves the posterior LA. Avoiding unnecessary ablation in this region may reduce the risk of atrio-esophageal fistula. The role of anatomic structures, apart from the PVs in persistent and permanent AF, is becoming increasingly recognized. Haissaguerre et al. demonstrated the critical role of the PVs, CS and LAA, in successfully restoring sinus rhythm in patients with long-lasting persistent AF. Ablation involving a combination of PV electrical isolation, disconnection of other thoracic veins, complex atrial activity, and linear ablation produced sinus rhythm in 95\% of patients with 38\% requiring a second procedure.\textsuperscript{3,7} In addition, complex atrial activity does not occur randomly throughout the atria but at predefined anatomic locations.\textsuperscript{25}

Fluoroscopy provides limited soft tissue resolution and has prompted the development of 3D mapping systems to provide a more detailed anatomic reconstruction of the cardiac chamber. In the present study, ablation guided by CT integration demonstrated a significant reduction in fluoroscopy times. For segmental PV isolation, average fluoroscopy times may exceed 60 minutes.\textsuperscript{27} In patients with long-standing persistent/permanent AF, structural heart disease, or recurrent atrial tachyarrhythmias following a primary ablation, prolonged mapping and ablation may be required. Using fluoroscopy alone, Haissaguerre et al. reported a mean fluoroscopy time of 84 ± 30 minutes for complex ablation procedures in patients with long-standing persistent AF. A reduction in cumulative radiation exposure is an important component in improving the safety profile of the procedure for both patient and operator alike.

**Study Limitations**

CT was the radiologic imaging utilized in the current study although prior validation studies have included MRI. Though the present study is not a randomized control comparison, the findings are important as this technology is increasingly used in clinical practice despite a lack of clinical outcome data. The control group were consecutive patients from the time period immediately preceding the introduction of image integration with no change in the ablation strategy over the study period. Improved results may be considered a learning curve effect despite the findings from the subanalysis. Image integration may also act as a training tool to enhance the operator’s appreciation of atrial anatomy and lead to improved clinical outcomes. Only a prospective randomized trial can definitively compare the two techniques. Ideally, a longer follow-up period would allow a more complete assessment of the efficacy of image integration on ablation outcomes. Treatment failure was strictly defined as any atrial arrhythmia lasting more than 30 seconds; and therefore, arrhythmia burden would have been useful in patients classified as treatment failures.

**Conclusion**

CA for AF guided by CT integration into an EAM system was associated with reduced fluoroscopy times, arrhythmia recurrence, and increased restoration of sinus rhythm. Improved visualization of complex LA geometries might improve the safety and success of CA for AF.

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**References**


