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Recurrence of Atrial Fibrillation Correlates With the Extent of Post-Procedural Late Gadolinium Enhancement

A Pilot Study

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OBJECTIVES We sought to evaluate radiofrequency (RF) ablation lesions in atrial fibrillation (AF) patients using cardiac magnetic resonance (CMR), and to correlate the ablation patterns with treatment success.

BACKGROUND RF ablation procedures for treatment of AF result in localized scar that is detected by late gadolinium enhancement (LGE) CMR. We hypothesized that the extent of scar in the left atrium and pulmonary veins (PV) would correlate with moderate-term procedural success.

METHODS Thirty-five patients with AF, undergoing their first RF ablation procedure, were studied. The RF ablation procedure was performed to achieve bidirectional conduction block around each PV ostium. AF recurrence was documented using a 7-day event monitor at multiple intervals during the first year. High spatial resolution 3-dimensional LGE CMR was performed 46 $\pm$ 28 days after RF ablation. The extent of scarring around the ostia of each PV was quantitatively (volume of scar) and qualitatively (1: minimal, 3: extensive and circumferential) assessed.

RESULTS Thirteen (37%) patients had recurrent AF during the 6.7 $\pm$ 3.6-month observation period. Paroxysmal AF was a strong predictor of nonrecurrent AF (15% with recurrence vs. 68% without, $p = 0.002$). Qualitatively, patients without recurrence had more completely circumferentially scarred veins (55% vs. 35% of veins, p = NS). Patients without recurrence more frequently had scar in the inferior portion of the right inferior pulmonary vein (RIPV) (82% vs. 31%, $p = 0.025$, Bonferroni corrected). The volume of scar in the RIPV was quantitatively greater in patients *without* AF recurrence ($p \leq 0.05$) and was a univariate predictor of recurrence using Cox regression ($p = 0.049$, Bonferroni corrected).

CONCLUSIONS Among patients undergoing PV isolation, AF recurrence during the first year is associated with a lesser degree of PV and left atrial scarring on 3-dimensional LGE CMR. This finding was significant for RIPV scar and may have implications for the procedural technique used in PV isolation. (J Am Coll Cardiol Img 2009;2:308–16) © 2009 by the American College of Cardiology Foundation

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Long-term success of catheter ablation for treatment of atrial fibrillation (AF) remains 60% to 80% (1–4). The goal of the most commonly used procedure electrically isolates the antrum of each pulmonary vein (PV) through an anatomically complete *circumferential* ablation. Recurrence of AF has been attributed to incomplete circumferential or transmural ablation of the PV ostia leading to reconduction (5) and to the existence of other triggers beyond the PVs (6). Imaging can contribute to the understanding of PV isolation therapy by visualizing the lesions that are created during catheter ablation (7–11). To exploit this capability, there are ongoing efforts to perform ablations under the guidance of cardiac magnetic resonance (CMR) or cardiac computed tomography (12,13).

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Not all PVs are equal as sources of AF or as targets for therapy. The upper PVs have the greatest proportion of AF triggers (14,15) and the greatest proportion of reconnected veins on follow-up (6). This reconnection may be caused by less well-ablated PVs during the procedure. There are fewer triggers in the left inferior pulmonary vein (LIPV) (14,15), but a lower rate of reconnection is found (6) during a repeat catheter ablation procedure. The right inferior pulmonary vein (RIPV) has the lowest proportion of initial AF triggers, but the highest proportion of new triggers on repeat study among patients with recurrent AF (6). The RIPV also stands out technically as the most difficult vein to ablate, due to poor catheter access (4,16,17).

High spatial resolution 3-dimensional (3D) late gadolinium enhancement (LGE) CMR (18,19) allows for noninvasive detection of left atrial (LA) ablation sites in patients with AF (7). The scar is observed as an accumulation of gadolinium contrast. We hypothesized that a greater volume of scar, and more circumferentially distributed scar, would lead to greater clinical success. Therefore, we studied the relationship of the volume and the distribution of LGE surrounding each vein to treatment success.

METHODS

Patients. Between April 2005 and May 2007, we scanned 59 consecutive patients after their first radiofrequency (RF) ablation for AF. From these, we excluded patients with suboptimal image quality (n = 24) (41%). The remaining 35 consecutive patients were enrolled in our imaging study (Table 1). The study was approved by the hospital committee on clinical investigations.

PV isolation procedure and documentation of recurrence. The circumferential PV isolation procedure has been described elsewhere (20). Briefly, an 8-mm (n = 29) standard tip or a 3.5-mm (n = 6) externally irrigated tip ablation catheter was used for ablation, advanced through a Mullins sheath into the LA. A circumferential catheter, advanced through a second Mullins sheath, was placed at each PV ostium to guide ablation and to confirm PV entrance and exit block (21). The RF ablations were placed 5 to 10 mm outside of each PV ostium until electrical PV isolation was achieved. For the 8-mm catheter, the maximum temperature setting was 52°, and maximum power output was 50 W; for the 3.5-mm catheter, power was limited to 30 W. Ablation was performed for 30 to 120 s at each site, based on changes in local electrograms. All PVs were routinely isolated in all patients, without routine addition of empiric ablation lines in the LA. As part of our standard method of stepwise ablation, in 8 patients with inducible atrial tachyarrhythmias, 1 or more additional ablation lines were made. In 6 patients ablation was performed from the LIPV inferiorly and anteriorly to the mitral annulus (the "mitral isthmus") for LA flutter; in 2 patients, ablation was created along the LA "roof," from the left superior pulmonary vein (LSPV) to the right superior pulmonary vein (RSPV). In 3 patients, ablation was created at the superior vena cava-right atrium junction for persistently inducible AF after LA ablation had been completed. Catheter manipulation was guided by fluoroscopy, intracardiac ultrasound, and 3D electroanatomic mapping systems (CARTO [Biosense Webster, Diamond Bar, California] and/or NAVx [Endocardial Solutions, St. Paul, Minnesota]). A single highly experienced operator (M.E.J.) performed 33 of 35 (94%) of the RF ablation procedures. Post-procedure, patients were monitored for recurrence of AF using an event monitor for 2 weeks post-procedure; and they were scheduled to undergo mobile outpatient cardiac telemetry monitoring for 7 days at 1, 6, and 12 months post-procedure.

Recurrent AF was defined as any symptomatic or asymptomatic episode lasting longer than 10 s, occurring more than 30 days after the ablation procedure. The dates of recurrence or dates of most

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

CMR = cardiac magnetic resonance

PV = pulmonary vein

LA = left atrium/atrial

LGE = late gadolinium enhancement

LIPV = left inferior pulmonary vein

LSPV = left superior pulmonary vein

RIPV = right inferior pulmonary vein

RF = radiofrequency

RSPV = right superior pulmonary vein

ROI = region of interest

3D = 3-dimensional

Table 1. Subject Characteristics

	All Subjects (n = 35)	AF Recurrence (n = 13)	No AF Recurrence (n = 22)
Age (yrs)	56 ± 13	55 ± 13	57 ± 13
Male gender (%)	31 (88)	12 (92)	19 (86)
Paroxysmal AF* (%)	17 (49)	2 (15)	15 (68)
Persistent AF (%)	10 (28)	6 (46)	4 (18)
Permanent AF (%)	8 (23)	5 (38)	3 (14)
Heart rate (beats/min)/% in SR	62/89%	69/69%	57/100%
LA volume (ml/m^2)	63 ± 17	65 ± 22	61 ± 12
Valvular heart disease (%)	2 (6)	1 (8)	1 (5)
Any mitral regurgitation (%)	19 (54)	7 (54)	12 (54)
Hypertension† (%)	15 (43)	9 (69)	6 (27)
LV ejection fraction	0.57 ± 0.08	0.56 ± 0.08	0.58 ± 0.09
Total RF ablation time (s)	3,600 ± 1,000	3,500 ± 1,000	3,600 ± 1,000
RF ablation number by CARTO‡	145 ± 47	166 ± 45	129 ± 42

*p = 0.002; †p = 0.015; ‡p = 0.04, all others p = NS.
AF = atrial fibrillation; LA = left atrial; LV = left ventricular; RF = radiofrequency; SR = sinus rhythm.

recent follow-up were used to construct survival curves.

CMR imaging of RF ablation sites. CMR was performed 30 to 60 days after the PV isolation procedure using a Philips 1.5-T CMR scanner (Achieva, Philips Healthcare, Best, the Netherlands), 20 to 25 min after administration of 0.2 mmol/kg Gd-DTPA (Magnevist, Berlex Laboratories, Wayne, New Jersey), using a 3D LGE CMR sequence as previously described (7,22,23). Technical scan parameters included 3D inversion recovery gradient echo sequence, 1 RR interval between inversions, repetition time (TR)/echo time (TE)/flip angle (θ) = 5.3 ms/2.1 ms/25°, 32 × 32 × 12.5 cm field-of-view, 250 Hz/pixel receiver bandwidth, matrix 224 × 224 × 23 to 32 Nz, average inversion time (TI) = 280 ms, 1.4 × 1.4 × 4 to 5 mm spatial resolution reconstructed to 0.6 × 0.6 × 2 to 2.5 mm spatial resolution. Electrocardiogram triggering (~150 ms end-diastolic window), navigator gating, and fat suppression were employed during the 4- to 8-min scan time.

Data analysis. Analyses of the extent of scarring of the PVs and LA were performed using 2 metrics: a *quantitative* measure of scar volume in each PV region and a *qualitative* visual measure of scar circumferentiality. These measurements were compared with the clinical outcome of AF recurrence on follow-up.

QUANTITATIVE SCAR VOLUME MEASUREMENT. Image processing was performed in Matlab 7.1 (Mathworks, Natick, Massachusetts) by a blinded observer (D.C.P.). To regionally quantify scar for each slice in the 3D volume (Fig. 1), the pixels containing hyperenhanced regions were identified using thresholding. A patient-specific threshold was chosen by visually comparing the results of multiple thresholding values to the scarred region in the original image. The minimum threshold that eliminated most LA blood pool pixels was chosen. After thresholding, isolated high signal intensity voxels were removed. Within the LA, each pixel was classified as belonging to 1 (or more) of 5 areas: LIPV, LSPV, RIPV, RSPV, and LA posterior wall. The classification of scarred voxels was made by drawing regions of interest (ROIs) in each slice encompassing each area of the LA (Fig. 1). The total volume of scar in each region and in each slice was measured by summation over all slices. Because the inferior/superior PVs often share a common branch point, the ROIs for ipsilateral inferior/superior PV ostia often overlapped (Fig. 2B, LIPV and LSPV, arrow). The ROIs for the posterior wall and inferior PVs also overlap. The drawing of ROIs and choice of thresholds add an element of subjectivity to the scar volume measurement. Nevertheless, at our center, the inter- and intraobserver variability for total scar volume measurement, including choice of threshold and ROIs, have been measured. For intraobserver variability, the coefficient of linear regression was R = 0.89 with a mean bias ± standard deviation of 0.33 ± 1.69 ml; for interobserver variability, R = 0.88 with a bias of −0.96 ± 1.87 ml (11).

VISUAL DISPLAY. For visual display of the scar, the 3D LGE (Figs. 1 and 2) were registered to contrast-enhanced magnetic resonance angiographic images (24) of the same patient, using

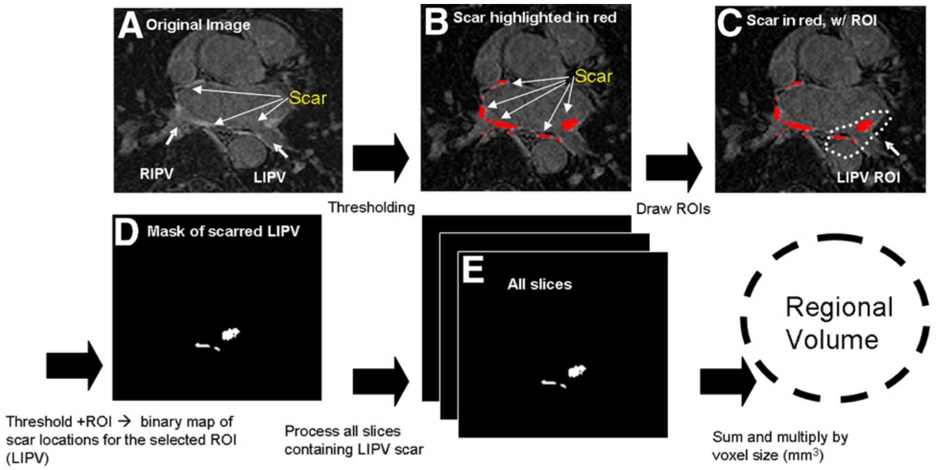

Figure 1. Methodology for Measuring Scar Volumes

(A) Original late gadolinium enhancement images of scar with hyperenhanced scar. **(B)** Scar is highlighted **(in red)** using signal thresholding, separating scar from normal tissues. **(C)** Regions of interest (ROIs) are used to identify scar on each slice as belonging to the left inferior pulmonary vein (LIPV), right inferior pulmonary vein (RIPV), left superior pulmonary vein, right superior pulmonary vein, and posterior wall. **(D)** Each slice is analyzed using thresholding ands ROIs to identify scarred pixels in each region. **(E)** Total scar is summed over all slices.

scaling of voxel sizes and translation in the x, y, and z directions. The rigid registration was performed using landmarks and recorded image coordinates. The registered scar images, after thresholding and masking to include only scarred pixels, were combined with the magnetic resonance angiogram, and the resulting images were surface rendered to visualize the scar in 3D.

QUALITATIVE ASSESSMENT. An experienced reader with >1.5 years clinical CMR/LGE experience, blinded to outcome, graded the *circumferentiality* of scar around each PV using a pre-established grading system, on a scale of 1 (no LGE or only 1 quadrant of a PV ostium with LGE) to 3 (extensive scarring and ≥3 quadrants with LGE) using the source 3D data sets and a public domain image viewer (ImageJ 1.37v, National Institutes of Health, Bethesda, Maryland). A second experienced reader independently analyzed the data to provide a measure of interobserver variability. Due to the known technical difficulty in ablating the RIPV, the inferior portion of the RIPV ostia was analyzed as to the presence or absence of scar. Finally, the visibility of additional ablation lines on the LGE images was also assessed in an unblinded fashion. Pre-ablation LA volumes were measured at end-systole, by planimetering magnetic resonance functional images of the LA in the 2- and 4-chamber views (11,25), with indexing to body surface area.

Statistics. Continuous measurements are presented as mean ± standard deviation and were compared using the Wilcoxon rank sum test. Categorical variables are expressed as numbers and percentages and were compared using Fisher exact test. Where appropriate, Bonferroni correction was used to correct for multiple testing. Estimated AF-free survival was calculated using the product-limit method (Kaplan-Meier analysis) with comparison of strata using the log-rank test. The relationship of RIPV scar with the recurrence of AF was further assessed using proportional hazards regression. The natural log transformation of RIPV scar was used in this analysis because the data were not normal. A 2-sided value of $p < 0.05$ was considered significant. Statistical analyses were performed using SAS for Windows (version 9.1, SAS Institute Inc., Cary, North Carolina) or Stata IC 10 (StataCorp, College Station, Texas).

RESULTS

Subjects were followed for 6.7 ± 3.6 months after RF ablation. Clinical recurrence of AF was noted in 13 patients (37%), with an average time to recurrence of 109 ± 75 days. Eight of the 13 patients (62%) with AF recurrence had symptomatic improvement, defined as >90% reduction in symptoms. Twelve of the 35 patients (34%) were treated with antiarrhythmic medications, after the RF ablation. Patients with and without recurrence were similar in age, gender, LA volume, left ventricular ejection fraction, and total RF ablation times (Table 1). Hypertension ($p = 0.015$), nonparoxysmal versus paroxysmal AF ($p = 0.002$),

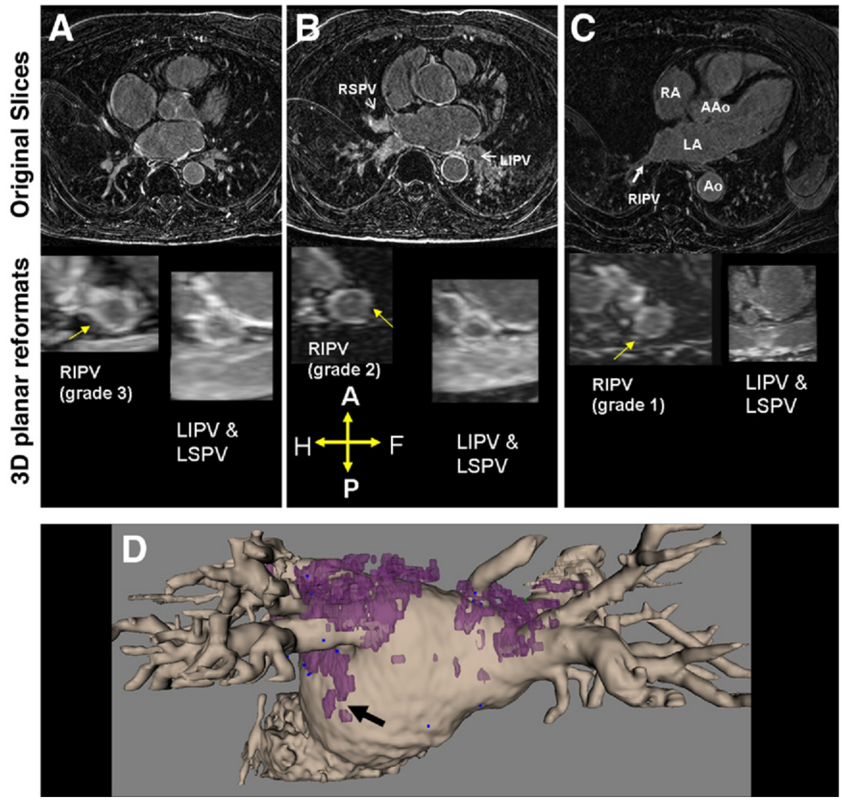

Figure 2. **3-Dimensional LGE Images in 3 Patients, With a Volume-Rendered View**

Three patients, 2 without recurrence of atrial fibrillation **(A and B)** and 1 with recurrence of atrial fibrillation **(C)**. **Top panels** show a late gadolinium enhancement (LGE) slice from the 3-dimensional (3D) volume. **Bottom panels** show planar reformats across pulmonary vein ostia. The orientation is shown in **bottom panel B**. The reformats provide examples of qualitative gradings for the RIPV of **(A)** 3: complete; **(B)** 2: partial; and **(C)** 1: no scar. **(D)** A 3D volume-rendering of the scar for Patient B. A mitral isthmus line is observed **(arrow)** (Online Video 1). A = anterior; AAo = ascending aorta; Ao = aorta; F = foot; H = head; LA = left atrium; LSPV = left superior pulmonary vein; p = posterior; RA = right atrium; RSPV = right superior pulmonary vein; other abbreviations as in Figure 1.

and a greater number of ablations as recorded by the CARTO system ($p = 0.04$) were all associated with recurrent AF (26,27).

Study of post-ablation LGE. Figure 2 shows images from 3 patients, including a source image and a planar reformat. The reformats show examples of complete (Fig. 2A), partial (Fig. 2B), and minimal (Fig. 2C) ablations of the RIPV. Figure 2D presents a 3D volume rendering of the magnetic resonance angiogram, overlaid with segmented scar, for 1 patient. This 3D method of visual display is useful for appreciating the scar circumferentiality. A 3D movie of scar fused with the MR angiogram is provided as a supplement (Online Video 1).

Table 2 compares the *quantitative* results for scar volume. In all regions, except the LIPV, there was *less* scar among the group of patients with AF recurrence, with a significant difference found for the RIPV. AF-free survival was significantly associated with RIPV scar ($p = 0.03$) (Fig. 3).

The *qualitative* results are shown in Table 3. RIPV scar was lower in the recurrent versus nonrecurrent patient groups. The LIPV was more fully scarred in nonrecurrent patients, and this trended toward significance. The interobserver qualitative agreement was 66%, with a kappa value of 0.46, showing moderately good agreement.

All 6 (100%) mitral isthmus ablation lines were visualized. Both (100%) of ablation lines across the LA roof were visualized. Two of 3 (66%) lines extending around the superior vena cava were observed in the images. Figure 2D shows a mitral isthmus line in 1 patient (arrow).

Using a qualitative score of 3 to indicate a fully circumferential ablation, we found that 2.2 (55% assuming 4 PVs) veins in patients without AF recurrence and 1.4 (35%) veins in patients with AF recurrence were fully ablated (Table 4). Ablation in the inferior portion of the RIPV ostia was a significant predictor of recurrence ($p = 0.025$). The

Table 2. LA Scar Volumes as Predictors of AF Recurrence

LGE Volume (ml)	All Subjects (n = 35)	Recurrent (n = 13)	Nonrecurrent (n = 22)	p Value (Recurrence vs. No Recurrence)	p Value (Bonferroni Corrected)
Region					
Total*	7.4 ± 4.4	6.8 ± 4.1	7.8 ± 2.6	0.247	NS
LIPV	2.3 ± 1.4	2.4 ± 1.3	2.2 ± 0.8	0.746	NS
LSPV	1.1 ± 0.8	1.0 ± 0.7	1.1 ± 0.7	0.746	NS
RIPV	2.1 ± 1.2	1.6 ± 1.0	2.4 ± 0.8	0.008	<0.05
RSPV	1.6 ± 1.2	1.5 ± 1.4	1.7 ± 0.9	0.195	NS
PW	2.2 ± 1.7	2.1 ± 2.3	2.2 ± 1.3	0.282	NS

*Note that, since regions overlap, total scar is less than sum of scar in each region.
LGE = late gadolinium enhancement; LIPV = left inferior pulmonary vein; LSPV = left superior pulmonary vein; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein; PW = posterior wall; other abbreviations as in Table 1.

multivariate analysis of significant univariate predictors of recurrence (paroxysmal AF and RIPV scar volume) by Cox regression is shown in Table 5.

DISCUSSION

In this study of 35 AF patients undergoing their first RF ablation, our data demonstrate that the extent of LA scar, especially RIPV scar, assessed qualitatively and quantitatively by LGE CMR, predicts AF recurrence after catheter ablation for AF. Overall, the LIPV displayed the most circumferential LGE, followed by the RIPV, the LSPV, and the RSPV. The results are consistent with other studies showing that AF recurrence is associated with electrical reconnection in 1 or more PV, since incomplete scarring may be the cause of electrical reconnection. Yamada et al. (28) studied patients undergoing a second ablation, where only 40% of PVs were still electrically isolated using mapping, including 36% of LSPVs, 36% of RSPVs, 50% of LIPVs, and 50% of RIPVs, in good agreement with our data on PV scar in patients with recurrent AF. Verma et al. (5) found, in patients having a repeat electrophysiological study, that the number of reconnected veins was 2.0 (on average) for patients with recurrence, and only 0.2 for patients without recurrence; the culprit veins were not identified. In comparison, our study found that the number of noncircumferentially ablated veins was 2.6 (on average) for patients with recurrence, but only 1.8 for patients without recurrence.

Early recurrence, while strongly predictive, is not always followed by later recurrence (29,30), suggesting that healing occurs after RF ablation. Furthermore, at the time of ablation, local tissue edema and incomplete myocyte damage may contribute to the appearance of acute conduction block in patients who may later develop recurrent conduction after myocardial healing (31,32). The 3D LGE method is unique and complementary to electrophysiology studies, because it can assess the circumferentiality of PV scar at any time point—early or late—and provide information noninvasively for patients with and *without* recurrence.

Most operators place more emphasis on primary isolation of the superior veins; however, upon recurrence, the superior PVs are most likely to be reconnected (28,33). In our study, overall, the superior PVs were less circumferentially ablated than the inferior PVs (Table 3) in qualitative grading and also were surrounded by a lower volume of scar (Table 2). However, the greater volume of scar in the lower PVs might reflect inclusion of some adjacent posterior wall scar

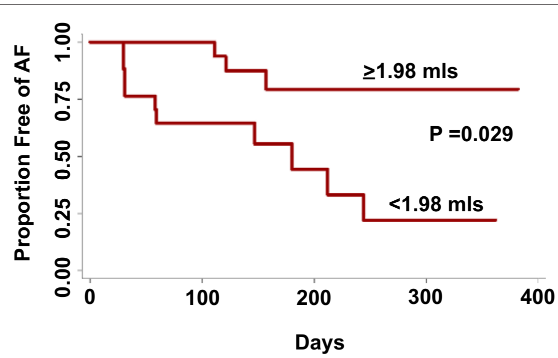

Figure 3. Kaplan-Meier AF Free Survival Curve Stratified by RIPV Scar

Kaplan-Meier survival curve showing atrial fibrillation (AF)-free survival time for patients using median scar volume cutoffs (1.98 ml), for patients with greater and lesser right inferior pulmonary vein (RIPV) scar volume measurement. More extensive scarring was associated with longer AF-free survival (p = 0.029).

Table 3. Qualitative Gradings* of the Extent of LA Scar, Separated by Region, as Predictors of AF Recurrence

Region	All Subjects (n = 35)	Recurrence (n = 13)	No Recurrence (n = 22)	p Value	p Value (Bonferroni Corrected)
LIPV	2.7	2.4	2.8	0.056	0.22
LSPV	2.1	1.9	2.2	0.389	NS
RIPV	2.3	1.9	2.5	0.032	0.13
RSPV	2.0	1.8	2.2	0.142	NS

*1 = minimal scar; 3 = circumferential scar.
Abbreviations as in Tables 1 and 2.

in the measurements or the challenges of imaging the upper PVs.

Importance of the RIPV. Both the quantitative and qualitative analyses identified the RIPV scar as the "lynch pin" (i.e., most highly correlated of all PV measurements to clinical success). This may be due to the unique technical difficulty of completely isolating the RIPV (4,16,17) resulting in greater variability of scar in that region. Notably, Gerstenfeld et al. (6) showed that upon recurrence the majority of new triggers arose from the RIPV. In a study of late recurrence (>12 months), Mainigi et al. (34) showed that the recurrences correlated with a reconnected or initially unisolated RIPV. In another study of patients with late recurrence, the RIPV was the most commonly reablated during a repeat ablation, followed closely by the left common vein (35). A recent case report by Reddy et al. (36), using 3D LGE to image LA scar after PV isolation, found scar discontinuity in the inferior RIPV ostia, which terminated AF when ablated in a follow-up procedure. Very recently, a study of patients during repeat procedures for recurrent AF showed that sites of chronic PV reconnection were located predominantly—and in roughly equal proportion—around the LSPV, RSPV, and RIPV, especially the inferior-posterior portion of the RIPV (33). This is remarkably similar to our findings that the LIPV is well ablated in all patients alike and that recurrence is highly correlated with lack of scarring in the inferior portion of the RIPV (31% vs. 82%). This may be due to the difficulty in accessing this portion of the RIPV. Previous findings, along with the results of our study, suggest that better RF ablation catheters and trans septal sheaths, improving access to right PVs and permitting more complete ablation of the RIPV, may reduce recurrence rates of AF. Newer assist devices such as steerable sheaths and remote magnetic navigation systems (37,38) may allow effective creation of LA ablations.

Study limitations. The sample size (n = 35) was small. A larger study will help to better define the RF ablation patterns that result in freedom from AF. This pilot study studied the relationship of many factors with recurrence, and the significance of each predictor was more difficult to establish after Bonferroni correction. The conclusions of this study are based on procedures performed from 2005 to 2007, during which time RF ablation techniques had been—and still are—evolving. While animal studies have shown excellent correlation of LGE CMR with areas of scar for myocardial infarction (9,18), such validation for detecting scar in the much thinner LA wall is lacking. There may be scar, which is below the threshold of detection by CMR, and detection of small scars may depend on overall image quality.

Table 4. Number of Veins With Fully Circumferential Ablation, Determined by a Qualitative Grading (Grade 3)

Region	All Subjects (n = 35)	Recurrent (n = 13)	Nonrecurrent (n = 22)	p Value (Recurrence vs. No Recurrence)	p Value (Bonferroni-Corrected)
LIPV	68% (21/31)	45% (5/11)	80% (16/20)	0.106	NS
LSPV	31% (9/29)	20% (2/10)	37% (7/19)	NS	NS
RIPV	52% (18/35)	31% (4/13)	64% (14/22)	0.086	NS
Inferior RIPV*	22/35 (63%)	4/13 (31%)	18/22 (82%)	0.004	0.025
RSPV	32% (11/34)	23% (3/13)	38% (8/21)	NS	NS
Patients with >2 fully ablated PVs	63% (22/35)	31% (4/13)	79% (15/22)	0.043	0.255
Number of fully ablated PVs†	1.9 (48%)	1.4 (35%)	2.2 (55%)	NS	NS

*Indicating the number of patients with an ablation on the inferior portion of the RIPV; †also expressed as percent assuming 4 pulmonary veins (PVs).
Abbreviations as in Table 2.

Table 5. Univariate and Multivariate Predictors of Time to AF Recurrence Using Cox Regression

Predictor	Univariate Hazard Ratio	p Value (Bonferroni-Corrected)	Multivariable Hazard Ratio	p Value (Bonferroni-Corrected)
(log) RIPV scar volume	0.29	0.049	0.39	0.220
Paroxysmal AF	0.19	0.017	0.21	0.045

Abbreviations as in Tables 1 and 2.

CONCLUSIONS

Among patients undergoing PV isolation, AF recurrence during the first year is associated with a lesser degree of PV and LA scarring on 3D LGE CMR. This finding was significant for RIPV scar and may have implications for the procedural technique used in PV isolation.

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Key Words: late gadolinium enhancement ■ catheter ablation ■ atrial fibrillation ■ CMR ■ left atrium.

APPENDIX

For an accompanying video and legend, please see the online version of this article.