

Anatomical analysis of recurrent conduction after circumferential ablation

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Abstract

Introduction There is general agreement on the importance of electrical isolation of antral (including pulmonary vein) myocardium for effective atrial fibrillation (AF) ablation. However, isolation is often impermanent, and return of conduction (RoC) is associated with recrudescence of AF. It is generally assumed that the mechanism of RoC is recovery of ablated myocardium, but this is based almost solely on experience after ablation at the venoatrial junctions. Our objective was to perform an anatomical analysis as a means to gain further insight into RoC risk factors and mechanism (s) after wide-area circumferential ablation.

Methods Retrospective review of data from 512 consecutive patients who underwent wide-area circumferential antral ablation. After achieving left and right antral electrical isolation, each patient underwent a period of observation for RoC during this initial procedure. In addition, 76 of the 512 patients underwent a repeat procedure at an average of 10 months later, at which time they were again assayed for RoC.

Results Left or right antral RoC was observed in 39 (8%) or 21 (4%) patients, respectively, during the initial procedure, and 26 (34%) or 16 (21%) patients, respectively, during the repeat procedure. Left antral RoC was more commonly observed among patients manifesting a long segment separating the circumferential lesion and the venoatrial junctions, and usually occurred in this segment, often at sites distant from ablated sites. Right antral RoC commonly

occurred in the anterior and superior antral regions, also often at sites that were distant from ablated sites.

Conclusions In the left antrum, there was a correlation between electrophysiologic (RoC) and anatomic (long segment) properties. The observation in both antra that RoC often occurred in previously unablated areas suggested that, as an alternative to recovery of ablated myocardium, a second mechanism of RoC was plausible: conduction via unablated myocardium, which was not immediately manifest. These observations have compelled us to modify our circumferential lesion.

Keywords Atrial fibrillation · Atrial · Electrogram · Intracardiac echocardiography · Ablation · Catheter ablation

1 Introduction

In catheter ablation of atrial fibrillation (AF), there is general agreement on the importance of electrical isolation of antral (including pulmonary vein) myocardium. However, isolation is often impermanent, and return of conduction (RoC) is associated with recrudescence of AF. It is generally assumed that the mechanism of RoC is recovery of ablated myocardium [1, 2]. However, this is based almost solely on experience after ablation at the venoatrial junctions. Our objective was to perform an anatomical analysis as a means to gain further insight into RoC risk factors and mechanism (s) after wide-area circumferential ablation.

2 Methods

This analysis was approved by the Institutional Review Board of the University of Pittsburgh Medical Center.

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2.1 Patients

This report encompasses data from 512 consecutive patients who underwent catheter ablation intended to cure a syndrome of paroxysmal or persistent AF (Table 1). All patients had normal left ventricular ejection fraction. No patient had significant valve disease or previous ablation procedures involving the left atrium. Antiarrhythmic agents were discontinued at least five half-lives (>1 month for amiodarone) prior to the initial and repeat procedures, except for 56 and 17 patients, respectively.

2.2 Initial procedure

All patients underwent the same procedure, the details of which have been reported previously [3–5]. Important elements included cardiac computed tomography (CT), performed within 24 h of the procedure, from which multidimensional left atrial images were generated for each patient [6], as well as general anesthesia using jet ventilation, which maximized spatial precision during mapping and ablation [4]. Intracardiac navigation included intra-left atrial echocardiography (ICE; UltraICE™, Boston Scientific, Natick, MA, USA) and magnetic tracking (CARTO™; Biosense Webster, Diamond Bar, CA, USA) [3]. ICE provided direct, real-time visualization of the endocardial surfaces of both antra, contiguous atrial and extra-atrial anatomy, and the anatomic location of the mapping/ablation electrode [7]. CARTO provided record-keeping as to the spatial position of the electrode at each mapped/ablated site. Mapping and ablation were performed during sinus rhythm only, with cardioversion performed to achieve this prior to ablation, as necessary. The distal electrode was 7 French, 3–4 mm in length, \pm open irrigation (irrigation utilized in 215 [42%] patients, in whom the irrigant was ambient temperature normal saline at 17 cm³/min). Radiofrequency power (RF) titration during ablation lesion applications was guided by electrogram amplitude reduction to <10% of their pre-ablation baseline, which typically required stable electrode–endocardial contact for 30 s at a peak power of 25–30 watts. Electrode temperature was recorded passively. Bipolar electrograms (ablation

electrode-to-2-mm-length ring electrode with 2-mm inter-electrode spacing, 30–500-Hz filtering, and 1–2-cm/mV gain) were recorded using commercial systems (EP Medsystems or Prucka). Pacing to confirm exit block was performed at long pacing cycle lengths (10–20% less than sinus cycle length) in unipolar fashion via the ablation electrode.

Circumferential ablation of each antrum was the product of a series of “abutting” lesions, defined by overlap of adjacent 2-mm-diameter spherical CARTO icons, each icon demarcating one RF application (Fig. 1) [3]. In the right antrum, the circumferential lesion was consistently greater than 1 cm distal (e.g., toward the center of the left atrial cavity) to any “venotrial junction,” each of which was defined using ICE by a plane perpendicular to the convergence (“carina”) of ipsilateral pulmonary veins (Fig. 1) [3, 5, 7, 8]. In the left antrum of some patients, the circumferential lesion was less than 1 cm distal to certain (anterior) portions of the venotrial junctions (Fig. 1). In these patients, the carina joined the anterior antrum wall within 1 cm of the “lateral ridge,” the convergence of pulmonary vein and appendage antra, and defined in the present study using ICE [3, 5, 7, 9]. Hereinafter, such patients are said to have manifested “short common segment” (SCS) anatomy, because there was a short segment of anterior wall proximal to the circumferential lesion but distal to the venotrial junctions (Fig. 1). The remaining patients, in whom the carina joined the anterior antrum one or more centimeters proximal to the lateral ridge, are hereinafter said to have manifested “long common segment” (LCS) anatomy (Fig. 1). The entire myocardial territory, including antral myocardium and pulmonary vein investitures, proximal to a circumferential lesion is hereinafter termed an “enclosed region.”

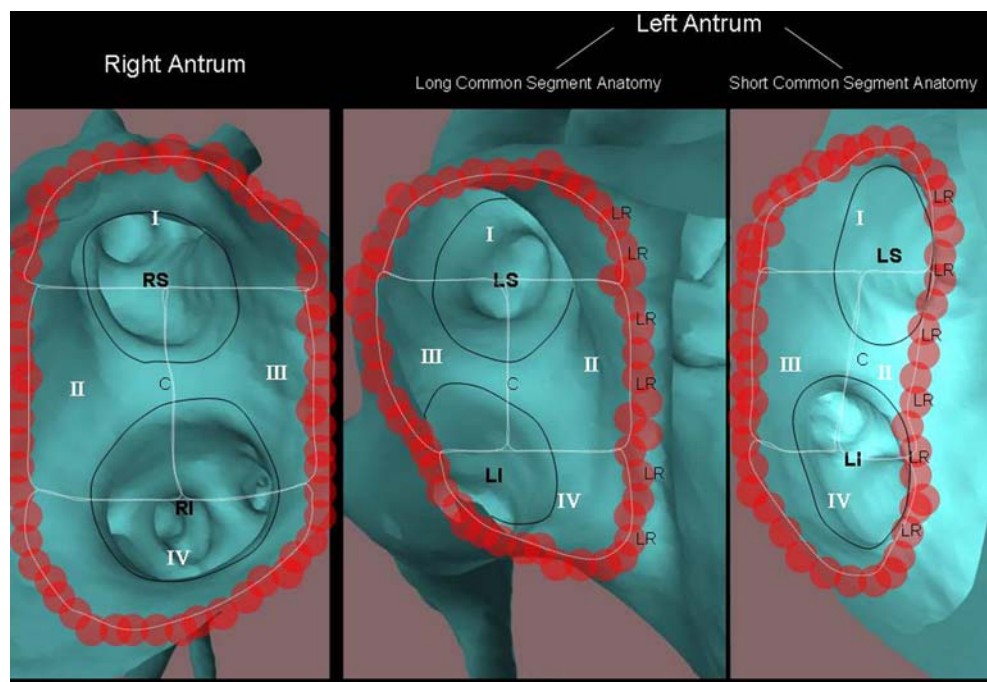
After deployment of a circumferential lesion, mapping of the enclosed region was performed, with anatomical demarcation of each mapped site based on the point of endocardial contact of the distal electrode as visualized using ICE. If electrical isolation was not observed, the location of residual sites of sinus impulse entry, defined by earliest activation time of enclosed myocardium, were pinpointed [5]. At these sites, additional individual (“sec-

Table 1 Data on cases of catheter ablation to cure a syndrome of paroxysmal or persistent AF

	Initial procedure (all pts)	Initial procedure (RoC pts)	Repeat procedure (all pts)	Repeat procedure (RoC pts)
Number of patients	512	58	76	36
Age (years)	58 \pm 7	61 \pm 5	51 \pm 6	53 \pm 4
Male (%)	84	88	79	75
Paroxysmal AF (%)	71	81	91	86
LA volume (cm ³) ⁶	94 \pm 14	101 \pm 11	89 \pm 9	94 \pm 5

pts patients

Fig. 1 CT-derived endocardial vantage of right and left antra, depicting typical circumferential lesions comprised of overlapping focal lesions (red spheres). Each enclosed region, which included pulmonary vein investitures, was subdivided into roughly equi-area quadrants, demarcated by dotted lines: *I* (superior); *II* (anterior); *III* (posterior); *IV* (inferior). Venoatrial junctions are depicted by the black lines. In the patient manifesting SCS anatomy, overlap of the anterior portions of the circumferential lesion and those of both venoatrial junctions was typical. LR=lateral ridge; C=carina; LS=left superior, LI=left inferior, RS=right superior, RM=right middle, and RI=right inferior pulmonary veins, respectively



ondary”) ablation lesions were delivered, using the same power titration strategy as for the circumferential lesion, until isolation of the enclosed region was achieved [3, 5].

After achieving isolation, a brief (approximately 30 min, but not prospectively stipulated nor recorded) period of observation ensued, during which the enclosed region was monitored for evidence that sinus impulse entry had recurred (RoC). If RoC was observed, activation mapping of the enclosed region was repeated to locate and ablate the mediating site(s).

The procedure endpoint, which was the same for all patients regardless of presenting AF syndrome, was isolation of left and right enclosed regions. This endpoint was met in 510 of 512 patients (see below).

2.3 Repeat procedure

In some patients with recrudescing AF, a second (“repeat”) procedure was performed using the same techniques as in the initial procedure. At the start of this procedure, electrogram amplitude mapping was used to reconstruct the circumferential and any secondary lesions from the initial procedure on the CARTO image. Previously ablated sites were defined by an amplitude $\leq 25\%$ of that recorded at corresponding sites during the initial procedure (prior to ablation); sites meeting this criterion were tagged with a CARTO icon.

Next, each enclosed region was assessed for evidence that sinus impulse entry had recurred (RoC). If RoC was observed, focal ablation lesions were delivered along the previous circumferential lesion path at any sites where amplitude suggested possible myocardial viability in the opinion of the operator (criteria were neither specified nor

recorded). If lesions along the previous circumferential path were either not indicated or RoC persisted after their delivery, activation mapping of the enclosed region was performed to locate and ablate the mediating site(s).

The procedure endpoints, which were the same for all patients regardless of presenting AF syndrome, were (1) isolation of left and right enclosed regions and (2) identify and ablate “important” (frequent and repetitive) sources of atrial ectopy outside of the enclosed regions.

2.4 Analytical methods

To facilitate data collation, in each patient, each enclosed region was divided into roughly equal surface area quadrants (Fig. 1). Reported linear distances, based on separation between endocardial points representing either anatomical structures or icons, were measured using CARTO software.

Comparison of continuous variables utilized the Mann–Whitney rank sum test. Comparisons of categorical variables utilized the Chi-squared analysis of contingency tables. Assay for correlation utilized the Pearson product moment method. For each analysis, a *p* value of <0.05 was considered significant. Data are reported as mean \pm SD, unless otherwise noted.

3 Results

3.1 Initial procedure

In two patients, the procedure was aborted due to anesthesia intolerance; in one of these patients, left atrial isolation was

achieved prior to procedure termination. The data thus summarize an experience with left antrum ablation in 511 patients and right antrum ablation in 510 patients (Table 1).

In the left antrum, 367 patients (72%) manifested LCS anatomy, with the separation between carina and lateral ridge measuring 1.9 ± 0.6 cm (range 1.0–3.2 cm). The remaining 144 patients (28%) manifested SCS anatomy, with the separation measuring 0.3 ± 0.5 cm (range 0–0.9 cm). Supernumerary veins [6] were present on the left in two (0.4%) and on the right in 210 (41%) patients. Observations are presented separately for each antrum:

(a) Left antrum

After completion of the circumferential lesion (61 ± 18 RF applications: no significant difference in this number between patients manifesting SCS versus LCS anatomies), isolation of the enclosed region was apparent in 117 patients (23%), more commonly among patients with SCS (69 of 144, 48%) than LCS (48 of 367, 13%; $p < 0.001$) anatomy (Fig. 2). Secondary lesions were most commonly required in quadrant II ($p < 0.001$ versus quadrants I, III, or IV; Fig. 3). The number of secondary lesions required was greater in patients with LCS (6 ± 2 , range 1–18) than SCS (2 ± 1 , range 1–6; $p = 0.006$) anatomy. RoC was observed in 39 patients (8%), more frequently among patients with LCS (35 of 367, 10%) than SCS (four of 144, 3%; $p = 0.02$) anatomy (Fig. 2). Among patients with LCS anatomy, RoC

was more common if secondary lesions had not been required (11 of 48 patients, 23%) than if they had (24 of 319 patients, 8%; $p = 0.002$). The vigor of the recurrent connection was tested in 28 patients by pacing in the enclosed region, during which 1:1 activation of non-enclosed myocardium at cycle lengths between 250 and 500 ms was observed in each patient. AF was not induced during pacing, and spontaneous AF events were not observed. In each of the 39 patients, RoC was mapped to a single area of the enclosed region, which was located more commonly in quadrant II than in quadrants I, III, or IV (all $p < 0.001$; Fig. 3), with concentration in the territory between carina and lateral ridge (Fig. 4). The distance between the RoC area and the nearest ablation lesion (circumferential or secondary) was 1.3 ± 0.9 (range 0.1–3.1) centimeters; in 26 patients (67%), RoC was located more than 1 cm from the nearest ablation lesion. It was eliminated with a median of two (range 1–7) RF applications, which, in 31 of the 39 patients, did not abut the circumferential lesion (Fig. 4).

(b) Right antrum

After completion of the circumferential lesion (83 ± 18 RF applications), isolation of the enclosed region was apparent in 352 patients (69%; Fig. 5). Secondary lesions were more commonly required in quadrants I and II combined than quadrants III and IV combined ($p < 0.001$; Fig. 3). RoC was

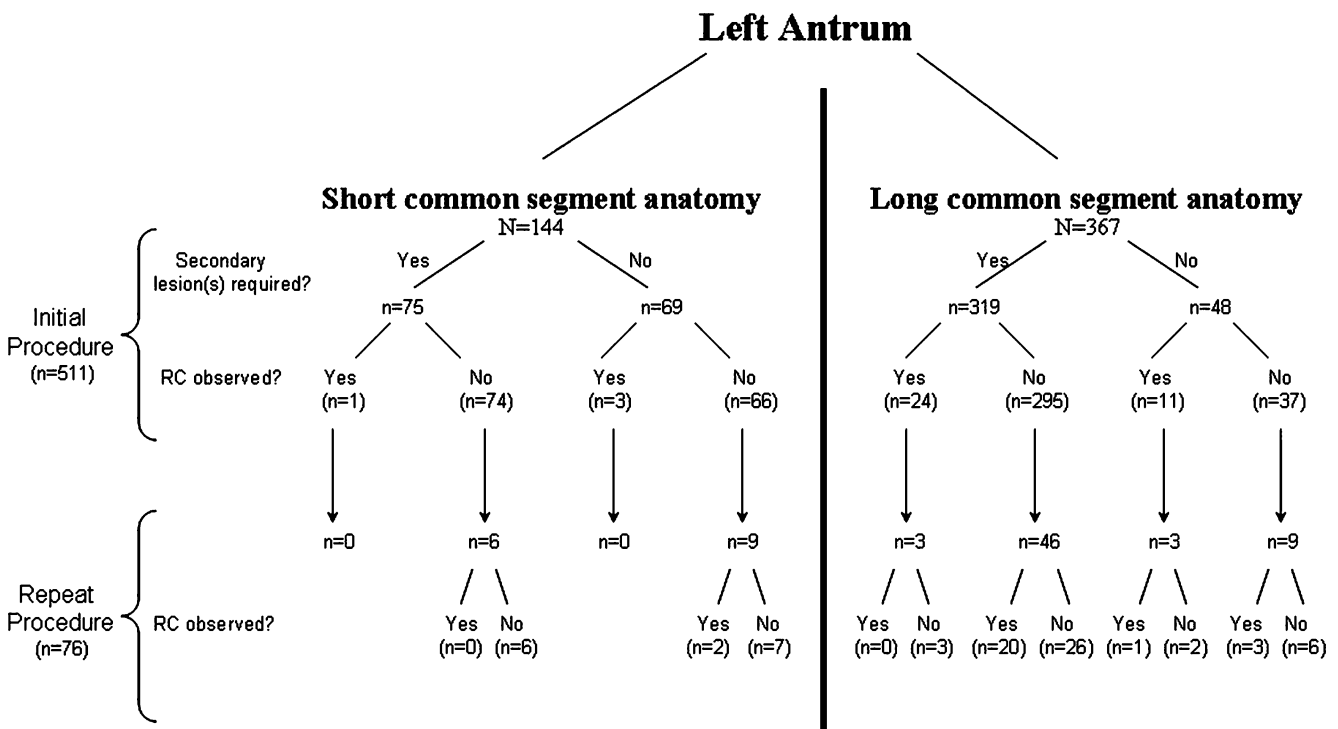
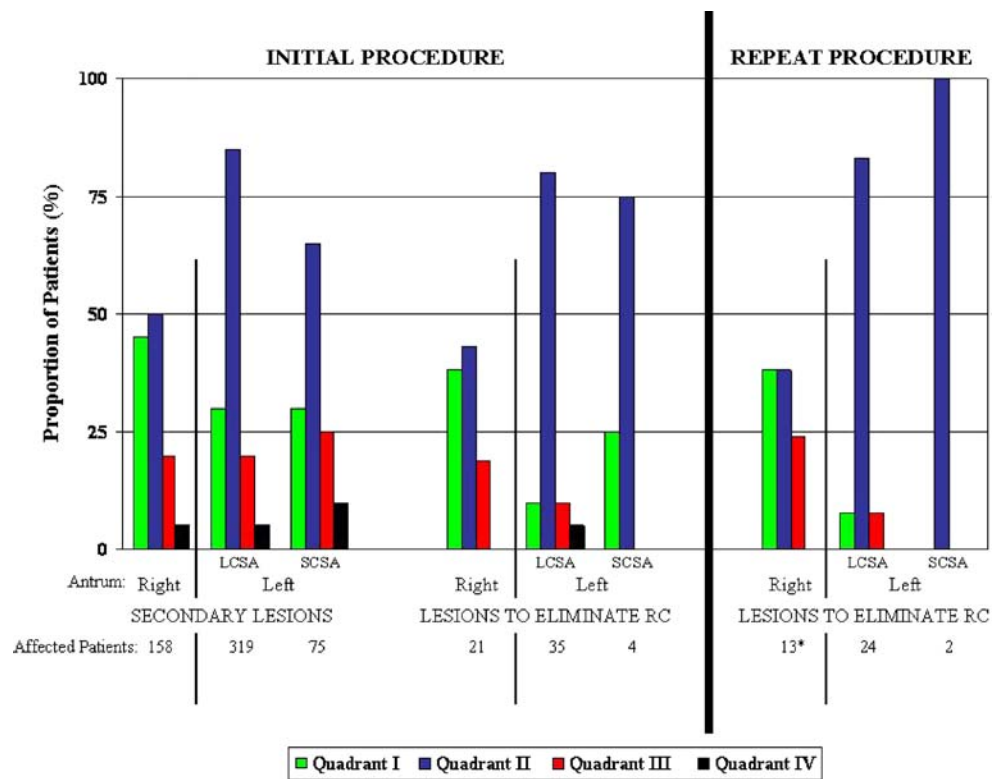


Fig. 2 Left antrum data summarized for initial and repeat procedures, separated by brackets. Secondary lesions were additional lesions deployed within the enclosed regions to achieve its isolation, if

isolation was not observed after completion of the circumferential lesion. RC=recurrent conduction. N=number of patients

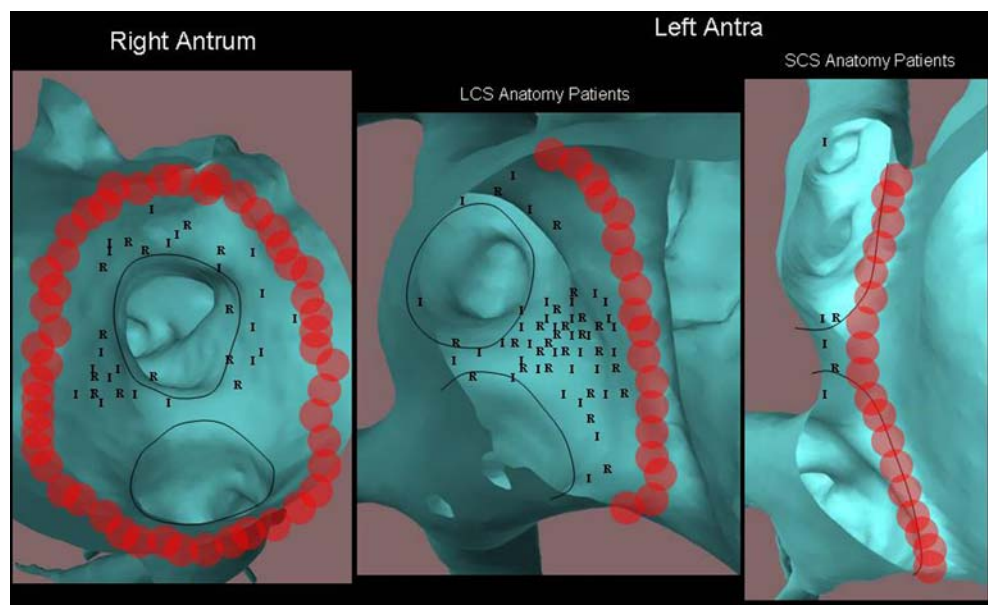
Fig. 3 Summary of locations for secondary and RoC lesions, regionalized by quadrant (Fig. 1). Data represent proportion of patients in whom one or more lesions were required in a given quadrant. *LCSA*, *SCSA*= patients manifesting long or SCS left antral anatomy, respectively. *Although 16 patients were observed to have RC in this group, excluded are the three patients in whom it was eliminated by ablation along the original circumferential lesion path



observed in 21 patients (4%), unrelated to whether (three of 158 patients, 2%) or not (18 of 352 patients, 5%) secondary lesions had been required. Of these 21 patients, two also had RoC observed in the left antrum. The vigor of the recurrent connection was tested in 13 patients, in each of whom 1:1 activation of non-enclosed myocardium at cycle lengths between 250 and 600 ms was demonstrated. In each of the 21 patients, RoC was mapped to a single area of the

enclosed region, which was located more commonly in quadrants I or II than III or IV ($p < 0.001$; Fig. 3). The distance between the RoC area and the nearest ablation lesion was 1.1 ± 0.7 (range 0.1–2.6) centimeters; in 12 patients (57%), RoC was located more than 1 cm from the nearest ablation lesion. It was eliminated with a median of one (range 1–5) RF applications, which, in 15 of the 21 patients, did not ablate the circumferential lesion (Fig. 4).

Fig. 4 Approximate locations to where myocardium mediating RoC was mapped in each affected individual, during initial (I) or repeat (R) procedures



3.2 Repeat procedure

This procedure was performed on 76 patients at 10 ± 6 months (range 6–16 months) after the initial procedure. These was a subset of the 124 patients who suffered recrudescence AF after the initial procedure; the other 48 patients declined repeat procedure, opting instead for pharmacotherapy, surgical ablation, or AV node ablation. Although no data are presented, there were no obvious differences in clinical characteristics, cardiac structure/function details, or initial ablation procedure experience between the 76-patient group and the 48-patient group.

In each of the 76 patients, there were no significant differences in antral dimensions (CT) noted prior to initial versus prior to repeat procedure. Observations during the repeat procedure are presented separately for each antrum:

(a) Left antrum

At the beginning of this procedure, RoC was apparent in 26 of 76 patients (34%), more frequently among patients with LCS (24 of 61 patients, 39%) than SCS (two of 15 patients, 13%) anatomy ($p=0.1$; Figs. 2 and 5), and was not associated with the need for secondary lesions or the occurrence of RoC during the initial procedure. In the one patient who had RoC during both initial and repeat procedures, the areas mediating the conduction were clearly spatially separate. The vigor of the recurrent connection was tested in 24 of the 26 patients, in each of whom 1:1 activation of non-enclosed myocardium at cycle lengths between 250 and 450 ms was demonstrated. In addition, in six of the nine patients in whom it was attempted, burst

pace (5 s at 100-ms cycle length) resulted in AF, which either terminated spontaneously or required cardioversion. In 14 of 26 patients, RF applications (median four, range 0–18) along the original circumferential lesion path were deemed necessary, but in each patient, RoC persisted after these. In each of the 26 patients, RoC was mapped to a single area of the enclosed region, which was located more commonly in quadrant II than in quadrants I, III, or IV (all $p<0.001$; Fig. 3), with an anatomical propensity similar to that noted in patients with RoC during the initial procedure (Fig. 4). The distance between the area mediating the conduction and the nearest ablation lesion was 1.2 ± 0.9 (range 0.1–2.8) centimeters; in 17 patients (65%), this area was located more than 1 cm from the nearest ablation lesion. Conduction was eliminated with a median of two (range 1–6) RF applications, which in 23 patients did not abut the circumferential lesion. After this, no further RoC was observed in any patient.

(b) Right antrum

At the beginning of this procedure, RoC was apparent in 16 of 76 patients (21%), and was not associated with the need for secondary lesions or the occurrence of RoC during the initial procedure (Figs. 5 and 6). Of these 16 patients, six also had RoC in the left antrum. The vigor of the recurrent connection was tested in ten of the 16 patients, in each of whom 1:1 activation of non-enclosed myocardium at cycle lengths between 250 and 500 ms was demonstrated. In addition, in four of the six patients in whom it was attempted, burst pacing (5 s at 100-ms cycle length) resulted in AF.

Fig. 5 CARTO images from two patients, each demonstrating recurrent conduction discovered during a repeat procedure. Each antrum is viewed so as to demonstrate its anterior wall. The gray icons demarcate locations of low electrogram amplitude, and thus were classified as “previously ablated sites”; taken together, they recapitulated the circumferential lesion deployed during the initial procedure in each antrum (the antrum orifice is shown in white). Sinus rhythm activation maps of myocardium enclosed by the circumferential lesion site are demonstrated, coded by color spectrum with red earliest and violet latest

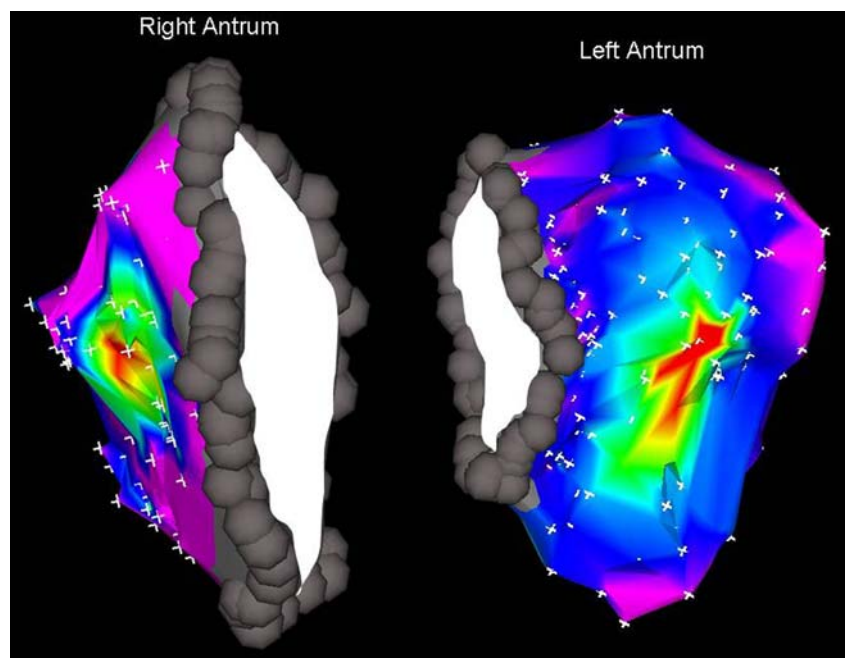
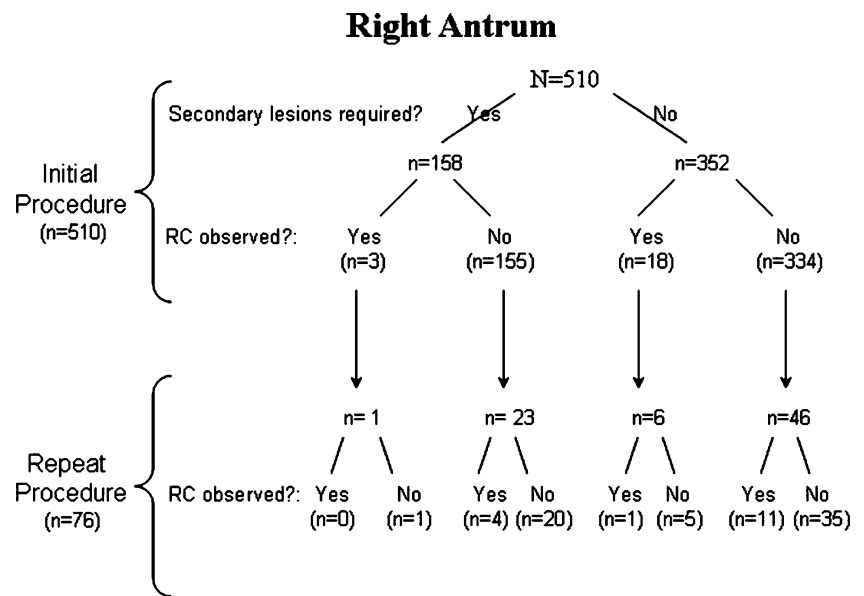


Fig. 6 Right antrum data summary for both initial and repeat procedures



In 12 of 16 patients, RF applications (median seven, range 0–22) along the original circumferential lesion path were deemed necessary; in three of these patients, RoC was no longer apparent after these lesions. In the remaining 13 patients (the nine in whom RoC persisted after additional RF applications along the original circumferential lesion path, plus the four in whom no additional applications along the path were deemed necessary), RoC was mapped to a single area of the enclosed region, which was located more commonly in quadrants I and II than III and IV ($p < 0.001$; Fig. 3). The distance between the area mediating the conduction and the nearest ablation lesion was 1.2 ± 0.4 (range 0.2–2.3) centimeters; in eight patients (62% of 13), RoC was located more than 1 cm from the nearest ablation lesion. It was eliminated with a median of two (range 1–8) RF applications, which, in ten patients, did not ablate the circumferential lesion (Fig. 4). After this, no further RoC was observed again in any patient.

3.3 Additional findings

A number of factors were assessed for a relationship with the occurrence of RoC. We could find no significant association with pre-ablation AF syndrome (paroxysmal versus persistent), cardioversion at the start of the procedure (presence versus absence), CT-derived left atrial volume (greater versus less than 100 cm³), type I/III antiarrhythmic drug therapy within five half-lives of the procedure (presence versus absence), or ablation electrode (irrigated versus non-irrigated).

No patient underwent ablation outside the antra during the repeat procedure. The 36 patients with RoC eliminated during the repeat procedure have been followed for 11 ± 9 (range 7–67) months. Given a 3-month post-procedure

interval during which AF recurrences were not considered, 24 patients have been AF-free in the absence of antiarrhythmic drug.

4 Discussion

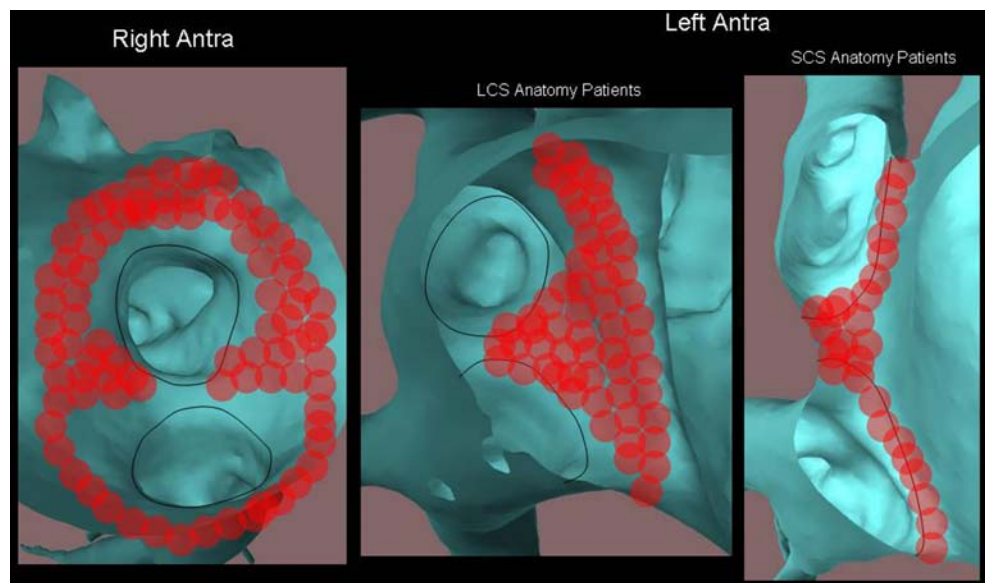
Our data are consistent with multiple previous reports linking RoC to recrudescence AF [10–16]. It is generally held that the mechanism of RoC is recovery of ablated myocardium (“mechanism A”) [1, 2]. The observations made in the present study do not contradict the existence of this mechanism. However, they do suggest that an alternative mechanism may also exist: based on our observation that conduction commonly occurred in areas at a distance from prior ablation lesions, we hypothesize that RoC can be mediated by previously unablated myocardium bridging non-enclosed and enclosed regions (“mechanism B”)—this myocardium does not support conduction immediately after other routes are eliminated, a dormancy phenomenon which could be due to its innate properties (for example, “impedance mismatch” between the myocardium bridging non-enclosed and enclosed regions and the myocardium investing the enclosed region, which can be transient [17]), or to an indirect effect of distant ablation lesions (as an example, edema, which has been shown to extend beyond the ablated tissue, can conceivably interfere with intermyocyte electrical communication, and is transient [18]). Although the data do not provide details as to the temporal spectrum of the dormancy, as in previous reports, our data demonstrate that it could resolve in less than 30 min [19]. However, temporal overlap should not necessarily imply mechanistic overlap, and we believe that mechanisms A and B are

distinct, although they may coexist in a given patient. Almost all prior characterizations of RoC relate to segmental or circumferential ablation at the venoatrial junction; we are aware of only one which addressed RoC after wide-area circumferential ablation as we do here. In the report of Satomi et al., each of 25 patients who underwent circumferential ablation with isolation and had recrudescence of AF was demonstrated to have RoC during a repeat study [20]. In this report, the CARTO images of encircling lesions deployed during the initial procedure show clear gaps, despite using an RF titration methodology similar to ours. Elimination of RoC was achieved, guided by fluoroscopy and lasso catheters, by ablation at sites which the authors imply were along the initial circumferential lesion path. No information as to location or laterality of these sites is provided.

To our knowledge, this is the first report to correlate the likelihood of achieving isolation with circumferential ablation alone (that is, prior to secondary lesions), an electrophysiologic property, with antral morphology (LCS versus SCS), an anatomic property. The data are consistent with previous characterizations of the left antral region, which support the presence of a functionally variable myocardial tract investing the antrum's anterior wall, extending between carina and lateral ridge [9, 21]. This region also interfaces with myocardial and neural tissues comprising the ligament of Marshall, which could have been involved [22]. We were unable to detect a correlation such as this in the right antrum, but our findings are consistent with previous characterizations of the antrum, which demonstrate fascicles of the broad proximal interatrial bundle interdigitating with those of deeper myocardial layers, with tracts projecting onto contiguous septal and posterior atrial walls [5, 23–26].

Several limitations to these data warrant discussion. First, this was a retrospective analysis. Although the procedure was mature and performed reproducibly during the period of this study, there were some variations in methodology (e.g., introduction of irrigation, operator discretion as to the need for ablation along the circumferential lesion path during the repeat procedure) and looseness of data collection (e.g., variation in duration of the observation period for RoC during the initial procedure). Second, the relative brevity of the RoC observation period, coupled with the lack of use of a provocative agent such as adenosine [27], ensure that our data were an underestimate of the actual rate of RoC. However, given the similarity of RoC observations during the initial and repeat procedures, there is no reason to suspect that additional RoC events that might have been observed with a longer observation period during the initial procedure would have invalidated our key conclusion, the existence of mechanism B. Third, the repeat study was performed on only a small subset of the cohort, all of whom had recrudescence of AF. Although this may bias our findings, the risks associated with revisiting the left atrium preclude a more systematic evaluation. Fourth, the incidence, mechanism, and locations of RoC are likely specific to our ablation technique. For example, as noted above, Satomi et al. intimated that the mechanism of RoC in their patients was recovery of regions along the circumferential lesion path [20]. As noted above, the images portraying their lesions suggested that areas of the circumferential lesion may have been more prone to recovery than in our technique, which emphasized lesion overlap. Fifth, the conceptualized dimensions of the circumferential lesions (uniformly 2 mm in breadth and transmural) are clearly hypothetical. Non-transmurality along the circumferential lesion could invalidate our findings. However, myocardial thickness along the lesion path was consistently

Fig. 7 Depiction of the modified circumferential lesions, demonstrating a broadening to include regions in which secondary lesions were commonly necessary and which commonly mediated RoC



less than 5 mm, which is well within the lesion depth expected to result using our power titration paradigm [28, 29]. Two additional functional observations support our assumption of uniform transmural: (1) isolation after circumferential ablation during the initial procedure, particularly of the right antrum, was common and (2) most areas in which RoC occurred did not abut the circumferential lesion, which would be expected if RoC was due to non-transmural [3, 5, 7]. Rather than the mistaken assumption of transmural, a more likely error was our conceptualization of lesion breadth, the underestimation of which would have supported mechanism B at the expense of mechanism A. Finally, the accuracy of our technique for reconstructing, during the repeat procedure, the circumferential lesion from the initial procedure using electrogram amplitude may be challenged. However, we feel that the similarities in the anatomical characterizations of RoC made during the initial (when precise information as to circumferential lesion location was available) and repeat procedures serves in support of the repeat procedure findings.

The apparent commonness of mechanism B among patients with recrudescence AF compelled us to modify our circumferential lesions (Fig. 7). This has significantly increased the number of RF applications comprising the lesions in both left (86 ± 14 applications) and right (111 ± 21 applications) antra, and decreased the requirement for left (13%) and right (4%) secondary lesions. We await a sufficient experience with this modification to determine whether it is associated with a reduction in recrudescence AF after the initial procedure.

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Dr. Chandhok: none

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