Ablation outcomes for atypical atrial flutter versus recurrent atrial fibrillation following index pulmonary vein isolation

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Abstract
Background: Data related to electrophysiologic characteristics of atypical atrial flutter (AFL) following atrial fibrillation (AF) ablation and its prognostic value on repeat ablation success are limited. Methods: We studied consecutive patients who underwent a repeat left atrial (LA) ablation procedure for either recurrent AF or atypical AFL, at least 3 months after index AF ablation, between January 2012 and July 2019. The demographics, clinical history, procedural data, complications, and 1-year arrhythmia-free survival rates were recorded for each subject after the first repeat ablation. Results: A total of 336 patients were included in our study. Among these 336 patients, 102 underwent a repeat ablation procedure for atypical AFL and 234 underwent a repeat ablation procedure for recurrent AF. The mean age was 63.7 ± 10.7 years, and 72.6% of patients were men. The atypical AFL cohort had significantly higher LA diameters (4.6 vs. 4.4 cm, p = .04) and LA volume indices (LAVi; 85.1 vs. 75.4 ml/m², p = .03) compared to AF patients at repeat ablation. Atypical AFL patients were more likely to have had index radiofrequency (RF) ablation (as opposed to cryoballoon) than recurrent AF patients (98% vs. 81%, p = .01). Atypical AFLs were roof-dependent in 35.6% and peri-mitral in 23.8% of cases. Major complications at repeat ablation occurred in 0.9% of the total cohort. Arrhythmia-free survival at one year was significantly higher in the recurrent atypical AFL compared to the recurrent AF cohort (75.5 vs. 65.0%, p = .04). Conclusion: In our series, roof-dependent flutter is the most common form of atypical atrial flutter post AF ablation. Patients developing atypical AFL after index AF ablation have greater LA dimensions than patients with recurrent AF. The

Abbreviations and Acronyms: AF, atrial fibrillation; AFL, atrial flutter; CB, cryoballoon; LA, left atrium; LAVi, left atrial volume index; PAF, paroxysmal atrial fibrillation; PsAF, persistent atrial fibrillation; PVI, pulmonary vein isolation; RF, radiofrequency; TEE, trans esophageal echocardiogram; TTE, trans thoracic echocardiogram.
success rate of first repeat ablation is significantly higher among patients with recurrent atypical AFL as compared to recurrent AF after index AF ablation.

KEYWORDS
atrial fibrillation, atypical atrial flutter, left atrial volume index, perimital atrial flutter, radiofrequency ablation, roof dependent atrial flutter

1 | INTRODUCTION

Catheter ablation (CA) of atrial fibrillation (AF) is a well-established procedure for the treatment of drug-refractory AF. Single-procedure AF ablation is successful in 60%–80% of optimal candidates, but many patients require repeat ablation.1 Atypical atrial flutter (AFL) has been reported in approximately 8% of patients following AF ablation using RF energy.2 Patients with AFL can be very symptomatic and refractory to medical therapy, often requiring repeat ablation procedures. While it is a common belief that the outcomes for repeat ablation procedures in patients who present with atypical AFL are superior to those observed in patients who present with recurrent AF, there are limited data available to support this assumption. This study aimed to describe the electrophysiological findings and the prognostic utility of recurrent atypical AFL versus recurrent AF after index AF ablation in a large contemporary cohort of patients at our center.

2 | METHODS

2.1 | Study cohort

We conducted a single-center, retrospective cohort study comprising patients, derived from an IRB-approved, prospectively populated clinical database of AF ablation patients. All patients underwent first repeat AF or atypical AFL ablation between January 2012 to July 2019 at the Johns Hopkins Hospital. A total number of 235 patients included in the present study underwent index AF ablation during the study period at either Johns Hopkins or an outside hospital. Of the 336 patients who participated in this analysis, 289 had an index PVI with RF energy, while 46 had index cryoballoon ablation. The total patient cohort was divided into two groups (recurrent AF and atypical AFL) based on the recurrent arrhythmia identified during clinical follow-up and prompting repeat ablation. Patients presenting with episodes of both AF and atypical AFL were included in the AF cohort.

The demographics, clinical history, procedural data, complications, and outcomes were recorded for each case. Patients found to have typical AFL only at repeat ablation were excluded from this analysis. Arrhythmia recurrence and peri-procedural complications were ascertained based on monitoring strategies put forth in the 2017 Heart Rhythm Society1 (HRS) consensus document. Arrhythmia recurrence was defined as any AF or atrial tachyarrhythmia (AT) sustained for >30 s recorded by a surface electrocardiogram or rhythm monitoring device after a 90-day blanking period. Procedure-related complications, such as major bleeding, minor bleeding, phrenic nerve palsy, cerebral embolism, pericardial effusion/tamponade, atrioesophageal fistula, or extended hospitalization, were assessed.

2.2 | Left atrial size assessment

LA diameter was assessed with a preprocedural transthoracic echocardiography (TTE; n = 256), when available. LA diameter >4 cm on TTE was defined as enlarged based on the American Society of Echocardiography guidelines.1 LA volume was measured using preprocedural contrast-enhanced cardiac computed tomographic (CT) imaging (n = 236), when available. CT images were obtained using a 320-detector scanner (Aquilion ONE, Canon Medical Systems) and prospective scan acquisition targeted at 40% of the R-R cycle (end-systole) without padding. Images were reconstructed with a slice thickness of 1 mm and a soft reconstruction kernel (FC03) and then transferred to a commercially available image workstation (Vitrea, Vital Images, Minneapolis, MN, USA) for analysis. The software includes a cardiac chamber volume analysis algorithm, which allows automated tracing of the contrast-enhanced left atrial cross-sectional border contours and computes volume by interpolating the vertical increments of 1 mm for the structure’s craniocaudal extension. The algorithm truncates borders in the proximal portion of the pulmonary veins and includes the left atrial appendage for volumetric assessment. Indexed volumes were calculated by dividing the volumes by body surface area and recorded as LA volume index (LAVI).

2.3 | Repeat mapping and ablation strategy

All repeat ablations for patients in this study were performed using RF energy. Femoral site access was obtained, and intravenous heparin was administered to maintain activated clotting times >350 s. After performing a double transseptal puncture, a Lasso or PentaRay mapping catheter ( Biosense Webster) was positioned in the left atrium. An electroanatomic map of the left atrium was obtained using the CARTO system (Biosense Webster) and superimposed on a pre-acquired cardiac CT image.

AFL cohort: In all AFL patients, simultaneous voltage and activation mapping were performed in patients presenting in AFL. Patients presenting in sinus rhythm underwent a flutter induction protocol consisting of both atrial burst pacing and atrial programmed stimulation until flutter was successfully initiated. Activation mapping of AFL was supplemented with entrainment mapping from
Based on the location of critical isthmus identification, flutters were classified as (1) peri-mitral, (2) roof-dependent, and (3) other (including multi-loop circuits, idiosyncratic flutters involving ablation lesion sets, and transitioning flutters with more than one stable circuit). All flutter forms occurring spontaneously or resulting from radiofrequency (RF) delivery during the first repeat ablation were documented. Following the conclusion of targeted AFL ablation, PV isolation was assessed and addressed as needed (below).

AFL ablation was performed targeting the critical isthmus with a transecting lesion anchored to either pre-existing anatomical structures (i.e., mitral valve annulus) or with iatrogenic scars (e.g., left PV Ostia after pulmonary vein isolation [PVI]), generating linear ablation lines. Conduction block across the ablation line was verified by 3D electroanatomical mapping with a multipolar mapping catheter in normal sinus rhythm (NSR). RF ablation was performed until (1) the tachycardia terminated or (2) converted into a second form, identified by a significant change in CS activation or in combination with alteration of surface electrocardiogram (ECG) morphology. Termination of the tachycardia was considered as ablation success if it occurred directly during RF delivery with or without prior prolongation of tachycardia cycle length (TCL) and in the absence of a premature atrial beat (≤90% TCL). Re-induction protocols were performed at the discretion of the operator.

AF Cohort: PVs were assessed for reconnection in all patients, and re-isolation was performed for those showing the electrical reconnection. A 4-mm, open-irrigated, contact force-sensing RF catheter (ThermoCool SmartTouch, Biosense Webster) was used, and re-isolation of the PVs was performed using a real-time automated display of RF application points (Visitag, Biosense Webster) with predefined catheter stability settings. Starting energy delivery parameters were 25 to 35 watts on the posterior LA wall and 35 to 45 watts at other sites. The target contact force was between 5 and 20 g at all sites. Esophageal temperature was monitored, and the RF delivery paused if the esophageal temperature increased by 0.5°C. In patients with recurrent AF, but with durable isolation was assessed and addressed as needed (below).

### 2.4 | Clinical follow-up

All patients were observed in the hospital for a minimum of one night postablation. Routine follow-up (history, exam, and electrocardiography or Holter) was performed to detect clinically relevant recurrence of arrhythmia, in a manner consistent with the AF Expert Consensus Statement. All patients were seen at the outpatient clinic or by a local cardiologist at 3, 6, and 12 months, and additionally, if prompted by symptoms. Event monitors were arranged for patients in whom symptoms suggestive of recurrence developed in the postbanking phase of follow-up. If present at the time of ablation, antiarrhythmic drug therapy was discontinued at the 3-month follow-up visit. One-year outcomes were assessed in all patients via clinical follow-up, electronic health record review, or phone interview.

### 2.5 | Statistical analysis

Continuous variables were described with measures of central tendency and dispersion (mean and standard deviation). Categorical variables were described as frequencies or modes when appropriate. Continuous variables were evaluated by t test, and categorical variables compared with $\chi^2$ or Fisher’s exact test. The cumulative probability of survival free from atrial arrhythmia was displayed according to the Kaplan–Meier method, with comparisons of cumulative event rates by the log-rank test. Follow-up for all patients was censored at one year after repeat ablation. A $p$ value of < 0.05 was considered statistically significant. All analyses were performed using SPSS Statistics Software for Windows version 23.0 (IBM Corporation).

### 3 | RESULTS

#### 3.1 | Baseline clinical characteristics

A total of 336 patients underwent first repeat ablation for recurrent AF or atypical AFL at our center from January 2012 to July 2019. Of these, 234 (69.6%) patients underwent repeat ablation for AF, and 102 (30.3%) underwent repeat ablation for atypical AFL. The mean age was 63.7 ± 10.7 years in the total cohort, and the majority were white and men (Table 1). The mean body mass index (BMI) was 29.9 ± 5.5 kg/m², and the mean CHA2DS2-VASc score was 2 ± 1.4, respectively, with no significant difference between cohorts. Patients with atypical AFL were older than those with recurrent AF (65.6 vs. 62.9 years, $p = .01$) and had a greater proportion of diabetics (22.1% vs. 11.0%, $p = .01$). A greater proportion of the patients in the recurrent atypical AFL cohort had a history of prior cardioversion (58.8% vs. 43.2%, $p = .01$) and cardioversions in the preceding 1 year (47.1% vs. 28.2%, $p < .01$) respectively. Similarly, a greater proportion of the patients in the recurrent atypical AFL cohort were not prescribed antiarrhythmic drugs (AAD) before the repeat ablation (43.1% vs. 29.0%, $p < .01$) as compared to the recurrent AF cohort. Other comorbidities remained comparable between the two cohorts.

#### 3.2 | Imaging characteristics

The mean LA diameter for the total cohort was 4.4 ± 0.7 cm (Table 2). The mean LAVI was 77.5 ± 26.2 ml/m². The mean left ventricular...
### TABLE 1  Baseline characteristics, for all patients and by recurrent atrial fibrillation versus recurrent atypical atrial flutter at presentation for repeat ablation

| Characteristics                                      | Total (n = 336) | Recurrent Atrial Fibrillation (n = 234) | Recurrent Atypical Atrial Flutter (n = 102) | p value |
|------------------------------------------------------|----------------|----------------------------------------|--------------------------------------------|---------|
| Age, years, mean ± SD                                | 63.7 ± 10.7    | 62.9 ± 11.3                            | 65.6 ± 8.8                                 | .04     |
| White, n (%)                                         | 295 (87.8)     | 206 (88)                               | 89 (87.3)                                 | .84     |
| Male, n (%)                                          | 244 (72.6)     | 167 (71.4)                             | 77 (75.5)                                 | .43     |
| Body mass index, kg/m², mean ± SD                    | 29.9 ± 5.5     | 29.7 ± 5.5                             | 30.5 ± 5.5                                | .20     |
| Duration of AF, years, mean ± SD                     | 7.4 ± 7.0      | 7.3 ± 6.9                               | 7.3 ± 7.3                                 | .96     |
| Congestive heart failure, n (%)                       | 50 (15)        | 31 (13.2)                              | 19 (18.6)                                 | .19     |
| Hypertension, n (%)                                   | 208 (61.9)     | 140 (59.8)                             | 68 (66.7)                                 | .23     |
| Diabetes mellitus, n (%)                              | 48 (14.3)      | 26 (11.0)                              | 23 (22.1)                                 | .01     |
| Stroke/TIA, n (%)                                     | 26 (7.7)       | 17 (7.2)                               | 9 (8.6)                                   | .80     |
| Vascular disease, n (%)                               | 42 (12.5)      | 28 (12)                                | 14 (13.7)                                 | .65     |
| CHA₂DS₂‐VASc score, mean ± SD                        | 2.0 ± 1.4      | 1.9 ± 1.4                              | 2.1 ± 1.4                                 | .20     |
| Obstructive sleep apnea, n (%)                        | 75 (22.3)      | 51 (21.8)                              | 24 (23.5)                                 | .83     |
| Home CPAP, n (%)                                      | 46 (61.0)      | 29 (12.4)                              | 17 (16.7)                                 | .39     |
| Chronic kidney disease, n (%)                         | 9 (2.7)        | 5 (2.1)                                | 4 (3.9)                                   | .58     |
| Valve disease, n (%)                                  | 21 (6.3)       | 15 (6.4)                               | 6 (5.9)                                   | 1.00    |
| Smoking history, n (%)                                | 84 (25)        | 59 (25.2)                              | 25 (24.5)                                 | 1.00    |
| Implantable cardiac device, n (%)                    | 28 (8.3)       | 17 (7.3)                               | 11 (10.8)                                 | .39     |
| H/o Prior cardioversion, n (%)                        | 161 (47.9)     | 101 (43.2)                             | 60 (58.8)                                 | .01     |
| H/o Cardioversion within one year, n (%)              | 114 (33.9)     | 66 (28.2)                              | 48 (47.1)                                 | .00     |
| ACE inhibitor, n (%)                                  | 61 (18.2)      | 38 (16.2)                              | 23 (22.5)                                 | .22     |
| Angiotensin II receptor blocker, n (%)                | 69 (20.5)      | 48 (20.5)                              | 21 (20.6)                                 | 1.00    |
| Beta blocker, n (%)                                   | 208 (61.9)     | 134 (57.3)                             | 74 (72.5)                                 | .01     |
| Statin, n (%)                                         | 115 (34.2)     | 70 (29.9)                              | 45 (44.1)                                 | .01     |
| Calcium channel blocker, n (%)                        | 131 (39)       | 89 (38)                                | 42 (41.2)                                 | .67     |
| Anticoagulation                                       |                |                                        |                                           | .41     |
| None, n (%)                                           | 8 (2.4)        | 6 (2.6)                                | 2 (2)                                     |         |
| Coumadin, n (%)                                       | 80 (23.8)      | 51 (21.8)                              | 29 (28.4)                                 |         |
| Direct oral anticoagulant, n (%)                      | 248 (73.8)     | 177 (75.6)                             | 71 (69.6)                                 |         |
| Antiarrhythmic                                        |                |                                        |                                           |         |
| Amiodarone, n (%)                                     | 110 (32.7)     | 75 (32.1)                              | 35 (34.3)                                 | .78     |
| Flecainide, n (%)                                     | 46 (13.7)      | 37 (15.8)                              | 9 (8.8)                                   | .12     |
| Sotalol, n (%)                                        | 18 (5.4)       | 14 (6)                                 | 4 (3.9)                                   | .61     |
| Dofetilide, n (%)                                     | 15 (4.5)       | 14 (6)                                 | 1 (1)                                     | .04     |
| Other antiarrhythmic, n (%)                           | 37 (11)        | 29 (12.4)                              | 8 (7.8)                                   | .22     |
| No antiarrhythmic, n (%)                              | 110 (32.7)     | 68 (29)                                | 44 (43.1)                                 | .00     |

Abbreviations: ACE, angiotensin-converting enzyme; AF, atrial fibrillation; CPAP, continuous positive airway pressure therapy; LV, left ventricular; TIA, transient ischemic attack.
ejection fraction (LVEF) was 57.2 ± 9.1%. Patients presenting with atypical AFL had greater mean LA diameter (4.6 vs. 4.4 cm, \( p = .04 \)) and LAVi (85.1 vs. 75.4 ml/m², \( p = .03 \)) compared to the recurrent AF cohort. Patients in the recurrent atypical AFL cohort had decreased LVEF (55.1% vs. 58.2%, \( p = .01 \)) compared to the recurrent AF cohort.

### 3.3 Characteristics of recurrent atypical AFL

Among the 102 patients who underwent repeat ablation for atypical AFL, 79 patients presented in AFL on the day of repeat ablation, and 23 presented in sinus rhythm (Figure 1). For those patients presenting in NSR, AFL was successfully induced with standard pacing protocols in 14/23 patients. Most patients had at least one documented atypical AFL, and the number of flutter circuits ranged from 0 to 5 (Table 3). Atypical AFL could not be documented in 9 (8.7%) of the patients during the ablation. A total of 36 (35.6%) of the patients had roof-dependent flutters. Peri mitral flutters were seen in 24 (23.8%) of the patients, and 33 (32.7%) patients had other flutter forms including idiosyncratic flutter circuits involving prior lesion sets in seven patients, multiple-loop flutter circuits in 16 patients, and transitioning flutters that were not durable enough for adequate mapping in 10 patients.

### 3.4 Initial ablation characteristics and interval between initial and repeat ablation

Among the 336 patients in this study, 213 underwent an initial AF ablation for paroxysmal AF (PAF), and 123 had an initial AF ablation for persistent AF (PsAF; Table 4). The proportion of patients with PAF and PsAF at the time of index ablation was comparable among the patients undergoing repeat ablation for AF and atypical AFL. A higher proportion of patients undergoing repeat ablation for atypical AFL underwent index RF ablation as compared to the patients undergoing repeat ablation for AF (99 (98%) of 102 patients versus 190 (81.2%) of 234 patients \( p < .01 \)). The remainder of the patients in both groups had an initial AF ablation with the cryoballoon system. For the total cohort, the mean duration between index and repeat ablation was 2.1 ± 2.9 years. There was no difference in the interval

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**TABLE 2** Imaging characteristics, for all patients and by recurrent atrial fibrillation versus recurrent atypical atrial flutter at presentation for repeat ablation

| Characteristics                  | Total (n = 336) | Recurrent Atrial Fibrillation (n = 234) | Recurrent Atypical Atrial Flutter (n = 102) | \( p \) value |
|----------------------------------|----------------|----------------------------------------|------------------------------------------|-------------|
| LA diameter by TTE, cm, mean ± SD | 4.4 ± 0.7      | 4.4 ± 0.7                              | 4.6 ± 0.9                                 | .04         |
| LA volume index by CT, ml/m², mean ± SD | 77.5 ± 26.2 | 75.4 ± 25.4                            | 85.1 ± 27.9                               | .03         |
| LV ejection fraction by TTE, mean ± SD | 57.2 ± 9.1   | 58.2 ± 8                               | 55.2 ± 11.0                               | .02         |

Abbreviations: CT, computed tomography; LA, left atrial; TTE, transthoracic echocardiogram.
between the index and repeat ablation in recurrent AF versus atypical AFL cohorts (2.2 vs. 1.9 years, \( p = .29 \)).

### 3.5 | Ablation procedure and acute outcomes

Among the 102 patients in the recurrent atypical AFL cohort, acute ablative success was achieved in 74 (73.3%; Table 3), of which 21 patients had perimital flutters, 28 patients had roof dependent flutter, and 25 patients had other flutter forms. Five (5%) patients had spontaneous termination of atypical AFL. A total of 9 (8.9%) patients required cardioversion to achieve NSR. Acute procedural success was achieved in 100% of patients in the recurrent AF cohort (Table 4). Of the 234 patients undergoing repeat ablation for recurrent AF, PV reconnection was seen in 196 (83.7%).

### 3.6 | Efficacy of ablation with follow-up

Freedom from atrial arrhythmia at one year of follow-up in the total cohort was 68.2%. Patients undergoing repeat ablation for atypical AFL had a significantly higher arrhythmia-free survival rate (75.5% vs. 65.0%, \( p = .04 \)) as compared to patients undergoing repeat ablation for AF (Figure 2) at 1 year of follow-up. Out of 111 patients with arrhythmia recurrence, 86 (77.4%) patients presented with AF, and 25 (22.5%) patients with atypical AFL. 13 (12.7%) patients presented with atrial fibrillation recurrence from the atypical AFL cohort. In a subgroup analysis of the atypical AFL cohort, there was no significant difference in the arrhythmia recurrence rates among patients with acute successful ablation as compared to those in whom the flutter circuit could not be identified/eradicated successfully (24.3% vs. 28.6%, \( p = .91 \)).

A total of 34 patients underwent repeat (3rd) ablation. PV reconnections were found to be present in 25 patients during the repeat ablation, and 14 patients had the presence of atypical AFL, of whom eight patients were classified to have perimital flutter, and in the remaining six patients flutter circuit either could not be not be mapped due to transitioning nature or included more than one stable circuits.

### 4 | DISCUSSION

Whether patients returning after index PVI with new atypical AFL represent an attractive target for redo ablation has not been the subject of rigorous investigation. We sought to investigate the rates of arrhythmia-free 1-year survival in two cohorts of patients presenting with recurrent arrhythmia following PVI: those with atypical AFL only, and those with recurrent AF (with or without flutter). The main findings of our study are: (1) Patients undergoing repeat ablation for atypical AFL after index AF ablation have enlarged LA and higher LAVi; (2) use of RF energy in the index AF ablation is higher among patients developing recurrent atypical AFL; (3) Isolated roof dependent AFL and peri-mitral AFL account for roughly 60% for post-PVI flutters observed; (4) 1-year arrhythmia free survival rate is higher among patients in the recurrent AFL cohort.
higher among patients undergoing repeat ablation for atypical AFL as compared to recurrent AF.

We found that LA diameter and LA volume were significantly greater among patients developing atypical AFL as compared to recurrent AF after the index ablation. This finding is in line with previous studies which reported that greater LA diameter and LAVi independently predict de novo atypical AFL, highlighting the role of intrinsic structural alteration in mediating fixed reentry.

We also observed that the use of RF energy for index ablation was significantly higher among the patients developing recurrent atypical AFL as compared to recurrent AF. A number of previous studies have reported the factors predictive of atypical AFL recurrence after AF ablation, and few of the studies evaluated the predictive value of energy source (RF vs. cryo) during AF ablation. Julia et al; reported in their study that RF AF ablation is associated with a higher incidence of recurrent atypical AFL as compared to CB AF ablation. However, on adjusted analysis to determine the predictors of atypical AFL, the predictive value of RF ablation was attenuated. Although we did not have further data related to index AF ablation to perform an adjusted predictor analysis, our study with large sample size is important in suggesting that CB ablation of AF may be associated with a lower incidence of atypical AFL recurrence as compared to RF ablation. Similar to several other previously published studies, our study suggests that roof-dependent and perimital atypical atrial flutters are common in preablated patients. Our results derived from a large sample size extend the support to the hypothesis that previous AF ablation predisposes to the development of perimital and roof-dependent flutter forms.

**Table 4** Procedural characteristics, for all patients and by recurrent atrial fibrillation versus recurrent atrial flutter at presentation for repeat ablation

| Variables                                      | Total (n = 336) | Recurrent atrial fibrillation (n = 234) | Recurrent Atypical Atrial Flutter (n = 102) | p value |
|------------------------------------------------|----------------|----------------------------------------|---------------------------------------------|---------|
| AF type at index ablation                      |                |                                        |                                             | 0.53    |
| Paroxysmal, n (%)                              | 213 (63.4)     | 151 (64.5)                             | 62 (60.8)                                   |         |
| Persistent, n (%)                              | 123 (36.6)     | 83 (35.5)                              | 40 (39.2)                                   |         |
| Index ablation method                          |                |                                        |                                             | 0.00    |
| Radiofrequency, n (%)                          | 289 (86.3)     | 190 (81.2)                             | 99 (98)                                     |         |
| Cryoballoon, n (%)                             | 46 (13.7)      | 44 (18.8)                              | 2 (2)                                       |         |
| Time from index to first repeat ablation, years, mean ± SD | 2.1 ± 2.9 | 2.2 ± 3.0 | 1.9 ± 3.0 | 0.31 |
| Total reconnected PVs, mean ± SD              | 2.7 ± 1.3      | 2.8 ± 1.2                              | 2.3 ± 1.4                                   | 0.00    |
| Reconnected LSPV                               | 211 (70.3)     | 156 (75)                               | 55 (59.8)                                   |         |
| Reconnected LIPV                               | 201 (67)       | 145 (69.7)                             | 56 (60.9)                                   | 0.13    |
| Reconnected RSPV                               | 202 (66.9)     | 152 (73.4)                             | 48 (52.2)                                   |         |
| Reconnected RIPV                               | 195 (65.2)     | 144 (69.6)                             | 51 (55.4)                                   | 0.01    |
| PVI only, n (%)                                | 131 (39.1)     | 115 (49.1)                             | 16 (15.8)                                   | 0.00    |
| PVI plus additional ablation, n (%)            | 190 (56.5)     | 118 (50.4)                             | 72 (70.6)                                   | 0.00    |
| Additional ablation only, n (%)                | 14 (4.2)       | 1 (0.4)                                | 13 (12.7)                                   | 0.00    |
| Roof ablation, n (%)                           | 110 (32.7)     | 62 (26.5)                              | 48 (47.1)                                   | 0.00    |
| Floor ablation, n (%)                          | 21 (6.3)       | 9 (3.8)                                | 12 (11.8)                                   | 0.00    |
| Posterior wall ablation, n (%)                 | 60 (17.9)      | 37 (15.8)                              | 23 (22.5)                                   | 0.09    |
| Mitral isthmus line ablation, n (%)            | 49 (14.6)      | 11 (4.7)                               | 38 (37.3)                                   | 0.00    |
| CTI ablation, n (%)                            | 69 (20.5)      | 37 (15.8)                              | 32 (31.4)                                   | 0.00    |
| SVC ablation, n (%)                            | 13 (3.9)       | 11 (4.7)                               | 2 (2)                                       | 0.35    |
| CS ablation, n (%)                             | 10 (3)         | 4 (1.7)                                | 6 (5.9)                                     | 0.07    |
| Other, n (%)                                   | 15 (4.5)       | 12 (5.1)                               | 3 (2.9)                                     | 0.56    |
| Combination of ablation, n (%)                 | 93 (27.7)      | 46 (19.7)                              | 47 (46.1)                                   | 0.00    |

Abbreviations: CS, coronary sinus; CTI, cavotricuspid isthmus; LS, left superior; LI, left inferior; PV, pulmonary vein; RS, right superior; RI, right inferior; SVC, superior vena cava.
recurrent atypical AFL after index AF ablation on the success of the repeat ablation. Ammar et al.,14 in their small retrospective study, showed that recurrent atrial tachycardia after PsAF ablation is associated with a better success rate of repeat ablation procedure compared to recurrent persistent AF. In contrast, our study included both types of AF patients at the time of index ablation and comprised a greater proportion of PAF patients than PsAF patients. Additionally, we also demonstrated that patients undergoing repeat ablation for atypical AFL were older with dilated LA and higher LAVi compared to those presenting with recurrent AF; these factors are associated with poor ablation outcomes. Our results are interesting in demonstrating that despite the association with factors predictive of poor outcomes of the ablation procedure, patients undergoing repeat ablation for atypical AFL have a better success rate as compared to those for recurrent AF.

The findings of our study should be interpreted with attention to the associated limitations, including (1) Limitations inherent to a single-center, retrospective, and observational study; (2) We did not have index AF ablation details, including use of contact force-sensing catheters and high energy-short duration lesion delivery, for patients referred from outside institutions, precluding a meaningful analysis of how such factors predicted recurrent AF or atypical AFL; (3) Data related to mapping of focal gaps in the index ablation set was not available therefore relationship between the flutter circuit and the gaps in the previous lesion set could not be determined; (4) LA diameter and LA volume were not available for all the included patients; (5) Lack of continuous ECG monitoring during follow-up might have contributed to an underestimation of arrhythmia recurrence rate.

In conclusion, based on our experience, roof-dependent, and perimital flutter are the common forms of atypical AFL after index AF ablation. Patients developing atypical AFL after index AF ablation have dilated LA and higher LAVi and arrhythmia free survival rate of first repeat ablation is higher for patients presenting with recurrent atypical AFL as compared to recurrent AF.

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CONFLICT OF INTERESTS
The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.
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