Catheter ablation targeting the pulmonary veins has been reported as a potential curative method for atrial fibrillation (AF) treatment since the late 1990s. As techniques and technologies have improved, catheter ablation has become an effective treatment strategy for patients with drug-refractory AF, with continuous escalation of its popularity. Of note, recent ESC guidelines suggest including catheter ablation even as a first-line therapy for specific groups of AF patients. Although catheter ablation is superior to antiarrhythmic drugs, up to 30% to 50% of AF patients suffer recurrences within the first year. On the one hand, AF recurrences are associated with impaired quality of life, but on the other, they are also related to poor clinical outcomes such as increased morbidity and mortality due to cardio- and cerebrovascular events.

Several studies were performed to identify clinical predictors for AF recurrences after catheter ablation. Among those, persistent AF and enlarged left atrial (LA) diameter have reproducibly been shown to associate with AF recurrences, although CHADS$_2$ and CHA$_2$DS$_2$-VASC scores were found to be significant predictors in small cohorts. Similarly, the association between rhythm outcomes and renal dysfunction has been shown recently. The association between rhythm outcomes and the new R$_2$CHADS$_2$ score was not described previously. Therefore, the aim of this study was to evaluate the potential association between all 3 stroke risk stratification scores with early and late AF recurrences in a large contemporary AF ablation population.

**Background**—Recurrences of atrial fibrillation (AF) occur in up to 30% within 1 year after catheter ablation. This study evaluated the value of CHADS$_2$, R$_2$CHADS$_2$, and CHA$_2$DS$_2$-VASC scores for the prediction of rhythm outcomes after AF catheter ablation.

**Methods and Results**—Using the Leipzig Heart Center AF Ablation Registry, we documented rhythm outcomes within the first 12 months in 2069 patients (67% men; 60±10 years; 35% persistent AF) undergoing AF catheter ablation. AF recurrences were defined as any atrial arrhythmia occurring within the first week (early recurrences, ERAF) and between 3 and 12 months (late recurrences, LRAF) after ablation. ERAF and LRAF occurred in 36% and 33%, respectively. On multivariable analysis, R$_2$CHADS$_2$ (odds ratio [OR], 1.11; 95% confidence interval [CI], 1.02 to 1.21; P=0.016) and CHA$_2$DS$_2$-VASC (OR, 1.09; 95% CI, 1.017 to 1.17; P=0.015) scores as well as persistent AF and left atrial diameter were significant predictors for ERAF. Similarly, the same clinical variables remained significant predictors for LRAF even after adjustment for ERAF, which was the strongest predictor for LRAF (HR, 3.12; 95% CI, 2.62 to 3.71; P<0.001). However, using receiver operating characteristic curve analyses, both scores demonstrated relatively low predictive value for ERAF (area under the curve [AUC], 0.536 [0.510 to 0.563]; P=0.007; and AUC, 0.547 [0.521 to 0.573]; P<0.001 for R$_2$CHADS$_2$ and CHA$_2$DS$_2$-VASC, respectively) and LRAF (AUC, 0.548 [0.518 to 0.578]; P=0.002; and AUC, 0.550 [0.520 to 0.580]; P=0.001).

**Conclusions**—R$_2$CHADS$_2$ and CHA$_2$DS$_2$-VASC were associated with rhythm outcomes after catheter ablation. However, AF type, left atrial diameter, and especially ERAF are also significant predictors for LRAF that should be included into new clinical scores for the prediction of rhythm outcomes after catheter ablation.

(Circ Arrhythm Electrophysiol. 2014;7:281-287.)

**Key Words:** atrial fibrillation ▪ catheter ablation ▪ CHA$_2$DS$_2$-VASC score ▪ recurrences ▪ renal dysfunction
those scores and AF-related variables such as LA diameter and AF type was examined.

### Methods

#### Study Population

A total of 2069 patients from the Leipzig Heart Center AF Ablation Registry with follow-up at least 12 months were included in this study (Table 1). All patients underwent AF catheter ablation according to current guidelines at our institution between January 2007 and December 2011. Paroxysmal and persistent AF was defined according to current guidelines. Paroxysmal AF was defined as self-terminating <7 days after onset documented by previous routine ECGs or Holter-ECGs. Persistent AF was defined as any AF episode either lasting >7 days or requiring drug or direct current cardioversion for termination. In all patients, transthoracic and transesophageal echocardiography was performed before ablation. All class I or III antiarrhythmic medications with the exception of amiodarone were discontinued at least 5 half-lives before the procedure.

Because of recently shown greater accuracy and lower bias, especially at an estimated glomerular filtration rate (eGFR) >60 mL/min per 1.73 m², eGFR was estimated using the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) equation:

\[
\text{eGFR} = 141 \times \min(\text{Scr}/\text{K}, 1)^{\alpha} \times \max(\text{Scr}/\text{K}, 1)^{\beta} \times 0.993^{\text{Scr}^{0.115}} \times 1.018 \times \text{Age}^{0.203} \times 0.993 \times \text{Age}^{0.018} \times \text{if female} \times 1.159 \times \text{if black},
\]

where Scr is serum creatinine, K is 0.7 for women and 0.9 for men, and α is −0.329 for women and −0.411 for men, min indicates the minimum of Scr/K or 1, and max indicates the maximum of Scr/K or 1.²

The study was performed according to the Declaration of Helsinki and institutional guidelines. Patients provided written informed consent.

#### Radiofrequency Catheter Ablation

LA catheter ablation was performed using a well-documented approach. Patients presenting with AF at the beginning of the procedure were electrically cardioverted, and ablation was performed during sinus rhythm (ie, AF termination with ablation was not attempted). In all patients, circumferential LA ablation lines were placed around the antrum of the ipsilateral pulmonary veins (irrigated tip catheter, presected tip temperature of 48°C, and maximum power of 30–50 W). In patients with persistent AF, additional linear lesions were added at the LA roof, the basal posterior wall, and the LA isthmus. At the end of the procedure, linear block was confirmed across the roof and the mitral isthmus. Ablation of complex fractionated electrograms was not performed.

After circumferential line placement, voltage and pace mapping along the ablation line were used to identify and close the gaps. The isolation of all pulmonary veins with bidirectional block was verified with a multipolar circular mapping catheter and was defined as the procedural end point.

After ablation, class I and III antiarrhythmic drugs were not reinitiated, and proton pump inhibitors were added for 4 weeks. According to the current guidelines, oral anticoagulation was prescribed for 3 to 6 months after catheter ablation and depending on risk stratification of stroke using the CHADS₂ or CHA₂DS₂-VASc score thereafter.

#### Follow-Up

All patients were followed in the outpatient clinic for ≥12 months after the catheter ablation. During this follow-up period, 7-day Holter recordings were performed (immediately, 3, 6, and 12 months after ablation). Additional ECGs and Holter recordings were obtained when patients’ symptoms were suggestive of AF. Early AF recurrences (ERAF) were defined as any atrial arrhythmia lasting >30 seconds and occurring within the first week after the procedure, which is in alignment with previous definitions. This definition was also chosen because continuous Holter-ECG monitoring was available for 98% patients for this time period. If recurrent AF was self-terminating <24 hours, no additional therapeutic measures were undertaken. In the case of sustained episodes, sinus rhythm was restored using external electric cardioversion. If patients had very early recurrence

### Table 1. Baseline Characteristics of the Study Population (n=2069)

<table>
<thead>
<tr>
<th>Total (n=2069)</th>
<th>Early AF Recurrences (n=2025)</th>
<th>Late AF Recurrences (n=1631)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No (n=1315)</td>
<td>Yes (n=710)</td>
</tr>
<tr>
<td>Age, y</td>
<td>60±10</td>
<td>60±10</td>
</tr>
<tr>
<td>Female sex</td>
<td>34</td>
<td>32</td>
</tr>
<tr>
<td>Persistent AF</td>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>Previous ablation</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>29±5</td>
<td>28±4.5</td>
</tr>
<tr>
<td>eGFR, mL/min per 1.73 m²</td>
<td>80±17</td>
<td>82±17</td>
</tr>
<tr>
<td>eGFR &lt;60 mL/min per 1.73 m²</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>Hypertension</td>
<td>71</td>
<td>69</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Chronic heart failure</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Peripheral artery disease</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Previous thromboembolic events</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>CHADS₂</td>
<td>1.2±0.9</td>
<td>1.1±0.9</td>
</tr>
<tr>
<td>R₂CHADS₂</td>
<td>1.3±1.1</td>
<td>1.2±1.1</td>
</tr>
<tr>
<td>CHA₂DS₂-VASc</td>
<td>2.1±1.4</td>
<td>2.0±1.4</td>
</tr>
<tr>
<td>EF, %</td>
<td>59±10</td>
<td>59±10</td>
</tr>
<tr>
<td>LVEDd, mm</td>
<td>49±7</td>
<td>49±6</td>
</tr>
<tr>
<td>LA diameter, mm</td>
<td>43±6</td>
<td>42±6</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; BMI, body mass index; EF, ejection fraction; eGFR, estimated glomerular filtration rate; LA, left atrial; and LVEDd, left ventricular end-diastolic function.
before discharge, the antiarrhythmic therapy was continued for >1 month. Late AF recurrences (LRAF) were any atrial arrhythmia between 3 and 12 months after ablation. If electric or pharmacological cardioversion or repeat procedure were needed after 3 months of blanking period, this was considered as late AF recurrences, that is, study end point.

Statistical Analysis

Data are presented as mean and standard deviation for normally distributed continuous variables and as proportions for categorical variables. Continuous variables were tested for normal distribution using the Kolmogorov–Smirnov test. The differences between continuous values were assessed using an unpaired 2-tailed t-test for normally distributed continuous variables, a Mann–Whitney test for skewed variables, and a χ² test for nominal variables.

Multivariable logistic regression analysis (MV) for ERAF and Cox regression analyses for LRAF, which included variables with a P value <0.1 found on univariable analysis, were performed to identify the predictors for AF recurrences. We performed multivariable analyses separately for every stroke risk stratification score (MV model 1 for CHADS², MV model 2 for R²CHADS², and MV model 3 for CHA²DS²-VASc).

Receiver operating characteristic curves were generated for the analysis of CHADS², R²CHADS², and CHA²DS²-VASc scores’ performance in predicting rhythm outcomes, with the area under the curve (AUC) being equivalent to the c-index for determining the predictive value for a score.

A P value <0.05 was considered statistically significant. All statistical analyses were performed with SPSS statistical software (version 17).

Results

AF Recurrences

Seven hundred ten (35%) out of 2025 patients (98%) with continuous ECG monitoring within the first week after ablation suffered ERAF. Clinical and complete Holter-ECG follow-up was available in 1631 patients (79%), whereas 169, 201, and 68 patients were lost to follow-up at 3, 6, and 12 months, respectively. Of those, 540 patients (31.8%) experienced LRAF between 3 and 12 months after catheter ablation.

Repeat procedures within the 3 months of blanking period were necessary in 18 patients (1.1%).

Table 2. Clinical and Echocardiographic Characteristics Associated With Early AF Recurrences (n=2025)

<table>
<thead>
<tr>
<th>Variables</th>
<th>UV OR 95% CI</th>
<th>P Value</th>
<th>MV Model 1 OR 95% CI</th>
<th>P Value</th>
<th>MV Model 2 OR 95% CI</th>
<th>P Value</th>
<th>MV Model 3 OR 95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>1.02 (1.01–1.03)</td>
<td>&lt;0.001</td>
<td>1.41 (1.14–1.74)</td>
<td>0.002</td>
<td>1.41 (1.14–1.74)</td>
<td>0.002</td>
<td>1.41 (1.14–1.74)</td>
<td>0.002</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.31 (1.09–1.59)</td>
<td>0.005</td>
<td>1.10 (1.10–1.66)</td>
<td>0.005</td>
<td>1.09 (1.09–1.65)</td>
<td>0.005</td>
<td>1.07 (1.07–1.62)</td>
<td>0.009</td>
</tr>
<tr>
<td>Persistent AF</td>
<td>1.51 (1.25–1.82)</td>
<td>&lt;0.001</td>
<td>1.35 (0.95–1.98)</td>
<td>0.093</td>
<td>1.34 (0.92–1.94)</td>
<td>0.129</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Clinical and Echocardiographic Characteristics Associated With Late AF Recurrences

<table>
<thead>
<tr>
<th>Variables</th>
<th>HR 95% CI</th>
<th>P Value</th>
<th>HR 95% CI</th>
<th>P Value</th>
<th>HR 95% CI</th>
<th>P Value</th>
<th>HR 95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>1.01 (1.003–1.02)</td>
<td>0.007</td>
<td>1.01 (1.003–1.02)</td>
<td>0.007</td>
<td>1.01 (1.003–1.02)</td>
<td>0.007</td>
<td>1.01 (1.003–1.02)</td>
<td>0.007</td>
</tr>
<tr>
<td>Female sex</td>
<td>1.11 (0.93–1.33)</td>
<td>0.231</td>
<td>1.03 (1.02–1.05)</td>
<td>0.001</td>
<td>1.03 (1.02–1.05)</td>
<td>0.001</td>
<td>1.03 (1.02–1.05)</td>
<td>0.001</td>
</tr>
<tr>
<td>Persistent AF</td>
<td>1.82 (1.53–2.15)</td>
<td>&lt;0.001</td>
<td>1.51 (1.25–1.82)</td>
<td>&lt;0.001</td>
<td>1.51 (1.25–1.82)</td>
<td>&lt;0.001</td>
<td>1.51 (1.25–1.82)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>eGFR &lt;60 mL/min per 1.73 m²</td>
<td>1.11 (1.05–1.01)</td>
<td>0.001</td>
<td>1.11 (1.05–1.01)</td>
<td>&lt;0.001</td>
<td>1.11 (1.05–1.01)</td>
<td>&lt;0.001</td>
<td>1.11 (1.05–1.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EF, %</td>
<td>0.99 (0.98–1.00)</td>
<td>&lt;0.001</td>
<td>1.00 (1.01–1.02)</td>
<td>0.001</td>
<td>1.00 (1.01–1.02)</td>
<td>0.001</td>
<td>1.00 (1.01–1.02)</td>
<td>0.001</td>
</tr>
<tr>
<td>LA diameter, mm</td>
<td>1.04 (1.03–1.06)</td>
<td>&lt;0.001</td>
<td>1.04 (1.03–1.06)</td>
<td>&lt;0.001</td>
<td>1.04 (1.03–1.06)</td>
<td>&lt;0.001</td>
<td>1.04 (1.03–1.06)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CHADS²</td>
<td>1.17 (1.07–1.27)</td>
<td>0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>0.001</td>
</tr>
<tr>
<td>R²CHADS²</td>
<td>1.17 (1.09–1.26)</td>
<td>&lt;0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>&lt;0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>&lt;0.001</td>
<td>1.17 (1.09–1.26)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CHA²DS²-VASc</td>
<td>1.11 (1.05–1.18)</td>
<td>&lt;0.001</td>
<td>1.11 (1.05–1.18)</td>
<td>&lt;0.001</td>
<td>1.11 (1.05–1.18)</td>
<td>&lt;0.001</td>
<td>1.11 (1.05–1.18)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; CI, confidence interval; EF, ejection fraction; eGFR, estimated glomerular filtration rate; LA, left atrial; MV, multivariable analysis; HR, hazards ratio; and UV, univariable analysis.
Predictors for AF Recurrences After Catheter Ablation

Patients with recurring AF are compared with patients without recurring AF in Table 1. Patients with ERAF or LRAF were older, had more often persistent AF, lower eGFR, larger LA diameter, as well as higher stroke risk stratification scores (all \( p < 0.005 \)). Patients with ERAF were often women and had hypertension, whereas more patients with chronic heart failure suffered LRAF. One hundred eighty-four patients with ERAF (26%) developed LRAF during longer follow-up.

Clinical and echocardiographic predictors for ERAF and LRAF were evaluated using uni- and multivariable analyses (Tables 2–4). On multivariable analysis, female sex, persistent AF, larger LA diameter, as well as \( R^2 \text{CHADS}_2 \) (odds ratio [OR], 1.11; 95% confidence interval [CI], 1.02–1.21; \( p = 0.016 \)) and \( \text{CHA}_2 \text{DS}_2 \text{-VASc} \) (OR, 1.09; 95% CI, 1.01–1.18; \( p = 0.022 \)), but not the \( \text{CHADS}_2 \) score, remained significant predictors for ERAF. Although eGFR <60 mL/min per 1.73 m\(^2\) was not associated with ERAF, it was associated with LRAF in model 1 (hazards ratio [HR], 1.57; 95% CI, 1.16–2.12; \( p = 0.004 \)) and in model 3 (HR, 1.48; 95% CI, 1.08–2.01; \( p = 0.015 \); Table 3). On multivariable analysis, persistent AF, larger LA diameter, as well as \( R^2 \text{CHADS}_2 \) (HR, 1.14; CI, 1.05–1.23; \( p = 0.001 \)) and \( \text{CHA}_2 \text{DS}_2 \text{-VASc} \) scores (HR, 1.08; 95% CI, 1.02–1.16; \( p = 0.013 \)) remained significant predictors for LRAF. Of note, after adjustment of ERAF, only the \( R^2 \text{CHADS}_2 \) score remained significant predictor for LRAF on multivariable analysis (Table 4).

However, both scores showed only low predictive values using receiver operating characteristic curve analyses (ERAF: AUC, 0.541, 0.551; LRAF: AUC, 0.541, 0.545 for \( R^2 \text{CHADS}_2 \) and \( \text{CHA}_2 \text{DS}_2 \text{-VASc} \) scores, respectively).

In a subgroup of patients with ERAF (n=710), persistent AF (HR, 1.39; CI, 1.12–1.74; \( p = 0.003 \)) and larger LA diameter (OR, 1.05; CI, 1.01–1.10; \( p = 0.044 \)) were significant predictors for LRAF (Table 5).

Discussion

Main Findings

To the best of our knowledge, this is the first study comparing the value of \( \text{CHADS}_2 \), \( R^2 \text{CHADS}_2 \), and \( \text{CHA}_2 \text{DS}_2 \text{-VASc} \) scores for the prediction of rhythm outcomes in a...
large contemporary AF ablation population. The main findings are as follows: (1) for the first time we demonstrated the predictive value of the R\textsubscript{CHADS\textsuperscript{2}} score; (2) despite relatively poor predictive value, both ERAF and LRAF are significantly associated with the R\textsubscript{CHADS\textsuperscript{2}} and CHA\textsubscript{2}DS\textsubscript{2}-VASc, but not the CHADS\textsubscript{2} scores; (3) together with persistent AF and LA diameter, ERAF was the strongest predictor for LRAF; (4) one quarter of patients with ERAF had LRAF, which was also associated with persistent AF and LA diameter in this subgroup.

CHADS\textsubscript{2} and CHA\textsubscript{2}DS\textsubscript{2}-VASc Scores as Predictors for AF Recurrences

Both CHADS\textsubscript{2} and CHA\textsubscript{2}DS\textsubscript{2}-VASc scores are important in the daily routine to predict the risk of thromboembolic events in AF patients.\textsuperscript{15} However, there is an emerging role of these scores in the prediction of rhythm outcomes after AF catheter ablation.\textsuperscript{7,8,10} First, Saad et al\textsuperscript{10} demonstrated that a CHADS\textsubscript{2} score \(\geq 2\) was a predictor for LRAF, which was later confirmed by several small studies.\textsuperscript{7,18} Recently, Letas et al\textsuperscript{8} showed that both CHADS\textsubscript{2} and CHA\textsubscript{2}DS\textsubscript{2}-VASc scores are associated with rhythm outcomes after catheter ablation. In accordance to previous studies, they demonstrated that a score \(\geq 2\) for both CHADS\textsubscript{2} and CHA\textsubscript{2}DS\textsubscript{2}-VASc had the highest predictive value for AF recurrences (AUC, 0.644 and 0.627, respectively). However, those studies were relatively small, compared different ablation techniques,\textsuperscript{18} included selected cohorts with paroxysmal AF, and used different antiarrhythmic drug therapies.\textsuperscript{8}

In contrast to other studies, our study included a larger patient number with serial rhythm monitoring. We failed to demonstrate the role of CHADS\textsubscript{2} score in predicting both ERAF and LRAF. However, the CHA\textsubscript{2}DS\textsubscript{2}-VASc score remained significantly associated with rhythm outcomes after catheter ablation. Hypertension,\textsuperscript{20} diabetes mellitus,\textsuperscript{21} and heart failure\textsuperscript{22} are associated with the level of activated inflammatory status, which plays a crucial role in AF per se and after catheter ablation. Although acute inflammatory responses after invasive treatment would explain ERAF,\textsuperscript{21} the components of thromboembolic scores indicate the association with LRAF. Of note, some components of stroke stratification scores are also presented in metabolic syndrome, which is associated with AF recurrences after catheter ablation.\textsuperscript{19,24,25} All components of metabolic syndrome (overweight/obesity, hypertension, impaired glucose tolerance/diabetes mellitus, dyslipidemia) are closely associated with inflammation. Thus, their relation to atrial remodeling, powered by inflammation, fibrosis, and oxidative stress, is unsurprising.

Renal Dysfunction and R\textsubscript{CHADS\textsuperscript{2}} Score as Predictors for AF Recurrences

Several studies were able to demonstrate an association between nonparoxysmal AF, LA size, renal dysfunction, and poor rhythm outcomes.\textsuperscript{7,10,18} Because the increased LA diameter or volume is considered as advanced structural remodeling, and persistent AF is rather an advanced disease stage with failing ability for self-termination, the association between AF recurrences and these clinical important markers is unsurprising. Recently, Chao et al\textsuperscript{11} showed an association between electroanatomic LA remodeling and renal dysfunction. This group demonstrated that even a mildly decreased GFR was associated with an arrhythmogenic LA substrate, which could be an explanation for AF susceptibility and, therefore, AF recurrences.

Although we found an association between AF recurrences and renal dysfunction on univariable analyses, eGFR <60 mL/min per 1.73 m\(^2\) was only borderline significant on multivariable analyses. This could be explained by only a small number (14%) of patients with renal dysfunction. Importantly, for the first time we demonstrated the predictive value of the R\textsubscript{CHADS\textsuperscript{2}} score. Similar as with CHA\textsubscript{2}DS\textsubscript{2}-VASc, both scores showed only mediocre predictive value. However, it has been previously recognized that stroke risk stratification scores cannot be used as standalone prognosticators for rhythm outcomes.\textsuperscript{8} The fact that R\textsubscript{CHADS\textsuperscript{2}}, and CHA\textsubscript{2}DS\textsubscript{2}-VASc remained significant predictors for AF recurrences even after adjustment for LA diameter and AF type indicates that scores could be taken into account together with other clinical AF-relevant variables.

Interestingly, after adjustment for ERAF into multivariable models, CHA\textsubscript{2}DS\textsubscript{2}-VASc score lost its predictive value, whereas R\textsubscript{CHADS\textsuperscript{2}}, persistent AF, LA enlargement, and ERAF remained significantly associated with AF recurrences between 3 and 12 months. Whether renal dysfunction is a stronger predictor for AF recurrences as impaired cardiovascular profile (peripheral artery disease, coronary artery disease) remains unclear, but we would speculate that the 2-point adjustment for impaired renal function in the R\textsubscript{CHADS\textsuperscript{2}} score could make this difference.

Late AF Recurrences in Patients With ERAF

Overall, patients with ERAF are less likely to have long-term freedom from AF recurrences, which is a common observation.\textsuperscript{17} Nevertheless, more than half of patients with ERAF experience delayed cure during subsequent follow-up.\textsuperscript{24,26} Hence, a blanking period of 3 months is considered as meaningful to avoid unnecessary repeat procedures. Although Saad et al\textsuperscript{10} found that 66.7% of patients with ERAF suffered LRAF during longer follow-up, Chao et al\textsuperscript{11} demonstrated recurrence freedom rate in nonparoxysmal AF after single procedure only in 28%, and multiple procedures were necessary to raise the AF freedom rate up to 57%. In our study, however, only 26% of patients with ERAF developed later LRAF. A possible explanation for these discrepant findings is the longer follow-up in the study by Saad et al\textsuperscript{10} (range 13–82 versus 12–29 months in our study) and no LRAF <12 months after initial procedure as in our study.

In accordance with recent studies, we also found a strong association between ERAF and LRAF.\textsuperscript{24,26} Patients with ERAF had almost 4-fold risk for LRAF occurrence during follow-up. However, although all stroke risk stratification scores were associated with LRAF in the whole study population, we did not find an association between those and LRAF in the subgroup of patients with ERAF. Our results confirm the data from previous studies and demonstrate persistent AF
and LA size as significant predictors for LRAF in this subgroup as well.

**Clinical Implications**

The stroke risk stratification scores CHADS₂ and CHA₂DS₂-VASc were designed to predict thromboembolic risk in patients with AF. Despite only modest predictive value of these scores in high-risk patients (AUC, 0.650–0.700), recent studies, including the current study, demonstrated the predictive value of these scores for the prediction of rhythm outcomes. However, we found relatively poor predictive power for R₂CHADS₂ and CHA₂DS₂-VAS scores, and in contrast to previous studies, we failed to demonstrate the role of CHADS₂ score for predicting AF recurrences. These findings indicate the necessity to include other clinical relevant markers to create a new rhythm outcome scoring system that should also include AF-related variables such as LA diameter and AF type.¹⁷

**Limitations**

This study is limited by its retrospective nature and registry design, although we had careful follow-up data in a large consecutive series. Although 98% patients had complete ERAF follow-up, data of late recurrences between 3 and 12 months were available only in 79%. Despite several definitions for early AF recurrences, in the current study ERAF was considered as any atrial arrhythmia lasting >30 seconds and occurring within the first week after ablation. This definition is based on continuous in-hospital and Holter-ECG monitoring, thereby providing a very accurate prevalence of ERAF, which moreover seems to affect LRAF. Although the rate of ERAF could be underestimated because of noninclusion of AF recurrences within the whole 3 months of blanking period, from a practical point this seems to be an ideal scenario because alterations in management can be provided quite early.

Of note, despite the fact that during the course of the study newer ablation tools became available, yearly recurrence rates were stable during the whole study period.

Nevertheless, this study is the first and largest one analyzing the correlation between all 3 stroke risk stratification scores and renal dysfunction with rhythm outcomes. As long as AF recurrences could be asymptomatic and underdetected, further studies with continuous rhythm control during long-term follow-up are needed to confirm our findings.

Because of multiple testing, the type I error rate might be inflated. Findings with modest P values should be interpreted with caution.

**Conclusions**

R₂CHADS₂ and CHA₂DS₂-VASc were associated with rhythm outcomes after catheter ablation. However, AF type, LA diameter, and especially ERAF are also significant predictors for LRAF that should be included into new clinical scores for the prediction of rhythm outcomes of AF catheter ablation.

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**Disclosures**

None.

**References**

13. Lig GY, Nieuwlaat R, Pisters R, Lane DA, Crijns HJ. Refining clinical risk stratification for predicting stroke and thromboembolism in atrial


**CLINICAL PERSPECTIVE**

Catheter ablation has become an important treatment option for atrial fibrillation (AF), but recurrences are still common and often warrant another procedure if they persist >3 months. Better identification of patients at risk for recurrences is of interest to help individualize therapy, and the CHADS2, R_CHWADS2, and CHA2DS2-VASc scores have been suggested as predictors. We assessed predictors of early (within 1 week after ablation) and late (3–12 months) arrhythmia recurrences in 2069 patients in the Leipzig Heart Center AF Ablation Registry. Persistent AF and left atrial diameter were predictors for both early and late arrhythmia recurrences. R_CHHADS2 and CHA2DS2-VASc had only poor or moderate predictive value, and the CHADS2 score was not a predictor. Early recurrence was a predictor of late recurrence. These findings should inform prediction of the post-AF ablation course and development of prediction models.
Comparison of CHADS\textsubscript{2}, R\textsuperscript{2}CHADS\textsubscript{2}, and CHA\textsubscript{2}DS\textsubscript{2}-VASc Scores for the Prediction of Rhythm Outcomes After Catheter Ablation of Atrial Fibrillation: The Leipzig Heart Center AF Ablation Registry

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