CHADS$_2$ and CHA$_2$DS$_2$-VASc Scores in the Prediction of Clinical Outcomes in Patients With Atrial Fibrillation After Catheter Ablation

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Objectives   This study aimed to evaluate whether CHADS$_2$ and CHA$_2$DS$_2$-VASc scores are useful for risk stratification in patients after catheter ablation of atrial fibrillation (AF).

Background   AF is associated with increased risk of cardiovascular events. However, limited data are available on the predictors of adverse events in patients with AF after catheter ablation.

Methods   A total of 565 patients with AF who underwent catheter ablation were enrolled in the study. The clinical endpoint was occurrence of thromboembolic events (ischemic stroke, transient ischemic attack, peripheral embolism, or pulmonary embolisms) or death during follow-up after catheter ablation.

Results   During a follow-up of 39.2 ± 22.6 months, 27 patients (4.8%) experienced adverse events. Both the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores were useful predictors of events in separate multivariate models. The areas under the receiver-operator characteristic curves based on the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores in predicting events were 0.785 and 0.830, respectively. Although the difference did not reach statistical significance (p = 0.116), the CHA$_2$DS$_2$-VASc score could be used to further stratify the patients with CHADS$_2$ scores of 0 or 1 into 2 groups with different event rates (7.1% vs. 1.1%, p = 0.003) at a cutoff value of 2.

Conclusions   The CHADS$_2$ and CHA$_2$DS$_2$-VASc scores are useful predictors of adverse events after catheter ablation of AF.   (J Am Coll Cardiol 2011;58:2380–5) © 2011 by the American College of Cardiology Foundation

Atrial fibrillation (AF) is a common arrhythmia that represents an independent risk factor for strokes and is associated

with marked morbidity and mortality (1). Recently, a newly developed scoring system, the CHA$_2$DS$_2$-VASc score, which extends the CHADS$_2$ scheme by considering addi-

tional stroke risk factors, was recommended to guide antithrombotic therapy in patients with AF (2,3). However, these 2 scoring systems were developed and validated in AF patients who did not receive catheter ablations. This study aimed to investigate whether the CHADS$_2$ or CHA$_2$DS$_2$-VASc score is useful for predicting thromboembolic events and mortality after catheter ablation for AF.

Methods

A total of 565 consecutive patients with symptomatic drug-refractory AF who received radiofrequency catheter ablation were enrolled in the study. The CHADS$_2$ score was calculated for each patient (4). The CHA$_2$DS$_2$-VASc score was calculated for every patient based on a point system in which 2 points were assigned for a history of stroke or transient ischemic attack (TIA) or age ≥75 years. One point was assigned for age between 65 and 74 years; history of hypertension, diabetes, recent cardiac failure, and

Table 1	Baseline Characteristics of the Patients With and Without Adverse Events		
Variable	With Events (n = 27)	Without Events (n = 538)	p Value
Age, yrs	67.8 ± 12.7	53.5 ± 12.0	<0.001
Age ≥65 yrs	59.3%	17.8%	<0.001
Age ≥75 yrs	40.7%	3.0%	<0.001
Male	77.8%	72.3%	0.534
Medical history			
Hypertension	74.1%	45.0%	0.003
Diabetes mellitus	25.9%	11.9%	0.065
Congestive heart failure	33.3%	6.5%	<0.001
Coronary artery disease	66.7%	27.1%	<0.001
Previous stroke/TIA	25.9%	4.1%	<0.001
Previous vascular disease	7.4%	1.1%	0.052
Long-term use of warfarin	7.4%	3.2%	0.216
Left atrial diameter, mm	45.5 ± 11.8	39.1 ± 6.7	<0.001
LVEF, %	52.7 ± 11.0	58.9 ± 7.7	0.008
AF type (paroxysmal AF)	48.1%	79.4%	<0.001
Recurrence rate after ablations	59.3%	28.1%	<0.001
CHADS$_2$ score	2 (1–3)	1 (0–1)	<0.001
CHA$_2$DS$_2$-VASc score	3 (2–4)	1 (0–2)	<0.001

Values are mean ± SD, %, or median (interquartile range).
AF = atrial fibrillation; LVEF = left ventricular ejection fraction; TIA = transient ischemic attack.

vascular disease (myocardial infarction, complex aortic plaque, or peripheral artery disease); and female sex (2).

Catheter ablation of AF and anticoagulant strategy. Before catheter ablation, every patient underwent transesophageal echocardiography to confirm the absence of a left atrial thrombus. Details of ablation procedures are provided in the Online Appendix.

Before catheter ablation, the use of oral anticoagulation therapy with an adjusted dose of warfarin was based on the patients' CHADS$_2$ scores. Warfarin was intended to be prescribed for patients whose CHADS$_2$ scores were ≥2 to maintain the international normalized ratio (INR) of the prothrombin time between 2 and 3 (3). After catheter ablation, warfarin was continued for 3 months for patients who were already receiving warfarin treatment before ablation. After 3 months, discontinuation of warfarin was generally not considered for patients with CHADS$_2$ scores of ≥2. However, if patients remained symptom free, and there was no evidence of AF recurrences, replacement of warfarin with antiplatelet agents was considered. This was

decided by the physicians responsible for treatment according to the individual characteristics of each patient.

Definitions of the clinical endpoints and follow-up. The clinical endpoint was the combined occurrence of clinical events, including thromboembolic events (ischemic stroke, TIA, peripheral embolism, or pulmonary embolism) and death. Patients were followed-up every 1 to 3 months at our cardiology clinic or by referring physicians after catheter ablation. During each follow-up, patients were carefully examined, and 24-h Holter monitoring and/or cardiac event recording for 1 week were performed. AF recurrence was defined as an episode lasting longer than 1 min and confirmed by electrocardiograms 2 months after ablation. The status of patients who did not receive regular follow-up was assessed by chart reviews and telephone consultations to determine whether adverse events occurred. Our database was linked with the National Death Registry, and mortalities were further validated through a unique, lifelong personal identification number given to every Taiwan citizen.

Statistical analysis. Differences between continuous values were assessed using an unpaired 2-tailed *t* test for normally distributed continuous variables, the Mann-Whitney *U* test for skewed variables, and the chi-square test for nominal variables. Cox regression analysis was used to identify factors associated with adverse events. Details of the statistical analysis are provided in the Online Appendix.

Results

Clinical characteristics, adverse events, and predictors. Baseline characteristics of patients with and without events are shown in Table 1. During the follow-up period of 39.2 ± 22.6 months, 27 patients (4.8%) experienced adverse events, including death in 9 patients, ischemic stroke in 9, TIA in 6, pulmonary embolisms in 2, and peripheral embolism in 1. Three of the 27 patients experienced events within the blanking period after catheter ablation. Significant predictors of adverse events based on the univariate

Table 2	Univariate Cox Regression Analysis for Predictors of Adverse Events After Catheter Ablation		
Variable	Hazard Ratio	95% CI	p Value
AF type (nonparoxysmal)	4.682	2.186–10.030	<0.001
Recurrence after multiple ablations	3.552	1.648–7.655	0.001
Left atrial diameter, mm	1.077	1.047–1.108	<0.001
LVEF, %	0.920	0.885–0.956	<0.001
CHADS$_2$ score	2.154	1.768–2.624	<0.001
CHA$_2$DS$_2$-VASc score	1.856	1.585–2.174	<0.001

CI = confidence interval; other abbreviations as in Table 1.

Table 3	Multivariate Cox Regression Analysis for Predictors of Adverse Events After Catheter Ablation Using the CHADS$_2$ Score		
Variable	Hazard Ratio	95% CI	p Value
AF type (nonparoxysmal)	1.804	0.752–4.328	0.186
Recurrence after multiple ablations	2.452	1.060–5.673	0.036
Left atrial diameter, mm	1.015	0.982–1.050	0.379
LVEF, %	0.977	0.936–1.021	0.308
CHADS$_2$ score	1.892	1.482–2.414	<0.001

Variables with p < 0.05 in Table 2 were adjusted with the CHADS$_2$ score in the multivariate Cox regression analysis.
Abbreviations as in Tables 1 and 2.

Table 4	Multivariate Cox Regression Analysis for Predictors of Adverse Events After Catheter Ablation Using the CHA$_2$DS$_2$-VASc Score			
Variable		**Hazard ratio**	**95% CI**	**p Value**
AF type (nonparoxysmal)		1.927	0.800–4.644	0.144
Recurrence after multiple ablations		2.292	1.015–5.276	0.047
Left atrial diameter, mm		1.018	0.985–1.053	0.281
LVEF, %		0.973	0.931–1.017	0.219
CHA$_2$DS$_2$-VASc score		1.678	1.393–2.021	<0.001

Variables with p < 0.05 in Table 2 were adjusted with the CHA$_2$DS$_2$-VASc score in the multivariate Cox regression analysis.
   Abbreviations as in Tables 1 and 2.

Cox regression analysis are shown in Table 2. The CHADS$_2$ and CHA$_2$DS$_2$-VASc scores remained independent predictors of adverse events in separate multivariate models (Tables 3 and 4). Besides the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores, AF recurrence after multiple procedures was a significant predictor of adverse events. The event rate was higher in patients with recurrences than in patients without recurrences (9.6% vs. 2.8%, p = 0.001). When events were further divided into ischemic stroke/TIA, other embolic events, and death, the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores remained significant predictors. Hazard ratios of each increment of the CHADS$_2$ scores to predict ischemic stroke/TIA, other embolic events, and death were 1.893 (95% confidence interval [CI]: 1.364 to 2.627, p < 0.001), 2.306 (95% CI: 1.116 to 4.764, p = 0.024), and 1.786 (95% CI: 1.159 to 2.754, p = 0.009), respectively. Similarly, hazard ratios of each increment of the CHA$_2$DS$_2$-VASc scores to predict ischemic stroke/TIA, other embolic events, and death were 1.694 (95% CI: 1.321 to 2.173, p < 0.001), 2.088 (95% CI: 1.1865 to 3.6789, p = 0.011), and 1.551 (95% CI: 1.108 to 2.171, p = 0.010), respectively. The usefulness of these 2 scoring systems in predicting strokes/TIAs was consistent in patients with and without recurrences.
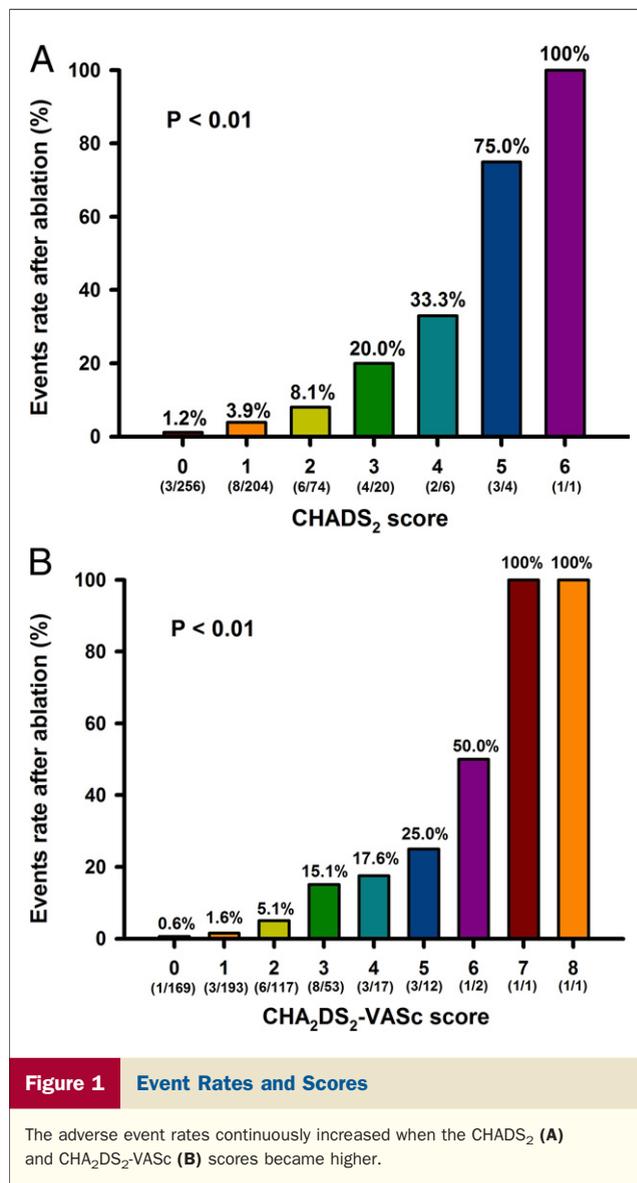
CHADS$_2$ and CHA$_2$DS$_2$-VASc scores for prediction of adverse events. The event rates of patients continuously increased with increases in the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores (Fig. 1). Figure 2 shows the receiver-operator characteristic (ROC) curves for predicting events after catheter ablation based on the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores. At a cutoff point of 2 identified by the ROC curve, Kaplan-Meier survival analysis showed that patients with CHADS$_2$ scores of ≥2 (sensitivity, 59.3%; specificity, 83.5%) were associated with a higher event rate than the patients with CHADS$_2$ scores of <2 (15.2% vs. 2.4%, p < 0.001) during the follow-up period (Fig. 3A). Furthermore, a CHA$_2$DS$_2$-VASc score of ≥2 identified by the ROC curve (sensitivity, 85.2%; specificity, 66.5%) also significantly predicted occurrences of events (11.3% vs. 1.1%, p < 0.001) (Fig. 3B).
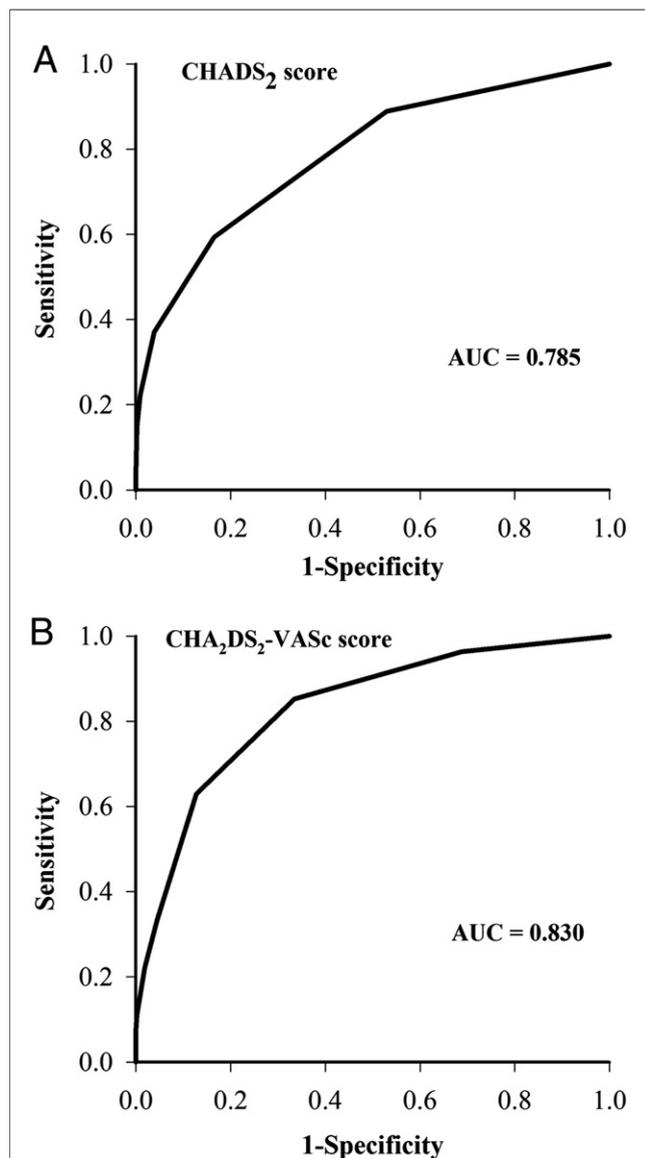
CHA$_2$DS$_2$-VASc scores and adverse events in low-risk patients with CHADS$_2$ scores of 0 or 1. In the subgroup analysis of 460 patients with CHADS$_2$ scores of 0 or 1, 11

(2.4%) patients experienced adverse events. The event rate progressively increased from 0.6% in patients with CHA$_2$DS$_2$-VASc scores of 0 to 11.8% in patients with CHA$_2$DS$_2$-VASc scores of 3 (Fig. 4). Using a CHA$_2$DS$_2$-VASc score of 2 as the cutoff point, patients with CHA$_2$DS$_2$-VASc scores of ≥2 were associated with a higher event rate as compared with patients whose CHA$_2$DS$_2$-VASc scores were <2 (7.1% vs. 1.1%, p = 0.003) (Fig. 5).

Discussion

Main findings. The main findings were as follows: CHADS$_2$ and CHA$_2$DS$_2$-VASc scores were useful parameters for predicting adverse events after catheter ablation of AF; and the CHA$_2$DS$_2$-VASc score was helpful in further risk stratifications among patients with CHADS$_2$ scores of 0 or 1.


| Figure 1 | Event Rates and Scores |

The adverse event rates continuously increased when the CHADS$_2$ **(A)** and CHA$_2$DS$_2$-VASc **(B)** scores became higher.

Figure 2 ROC Curves for the CHADS$_2$ and CHA$_2$DS$_2$-VASc Scores for Predicting Events

The areas under the curves (AUCs) for the CHADS$_2$ **(A)** and CHA$_2$DS$_2$-VASc **(B)** scores for predicting adverse events were 0.785 and 0.830, respectively (p = 0.116). ROC = receiver-operator characteristic.

CHADS$_2$ and CHA$_2$DS$_2$-VASc scores and adverse events after catheter ablation. In the current study, both scores proved to be useful predictors of events after catheter ablation of AF in separate multivariate models. These results provide evidence for extending the usefulness of CHADS$_2$ and CHA$_2$DS$_2$-VASc scores to predict adverse events in AF patients who have received catheter ablation. In view of the ROC curves based on the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores in predicting events, the differences between the areas under the curves did not reach statistical significance (p = 0.116). This may be because of the low event rate of the current study. Therefore, further trials with a larger sample size may be

able to demonstrate a significant statistical difference with sufficient power.

Although the predictive accuracies of the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores assessed by the ROC curves did not differ significantly, the CHA$_2$DS$_2$-VASc scores could further stratify the patients with CHADS$_2$ scores of 0 or 1 into 2 groups with different risks of events at the cutoff value of 2. According to the flowchart of the current guidelines of the European Society of Cardiology on the use of oral anticoagulants after catheter ablations, the CHADS$_2$ scheme should be used as a simple initial means of assessing stroke risk, and chronic oral anticoagulant therapy is recommended for patients with CHADS$_2$ scores of ≥2. For patients with a CHADS$_2$ score of 0 or 1, it is recommended that the CHA$_2$DS$_2$-VASc scoring system be used for a more comprehensive assessment of the risks (3). However, this recommendation was mainly based on consensus among experts, and the data in patients who received catheter ablation of AF were insufficient. The results
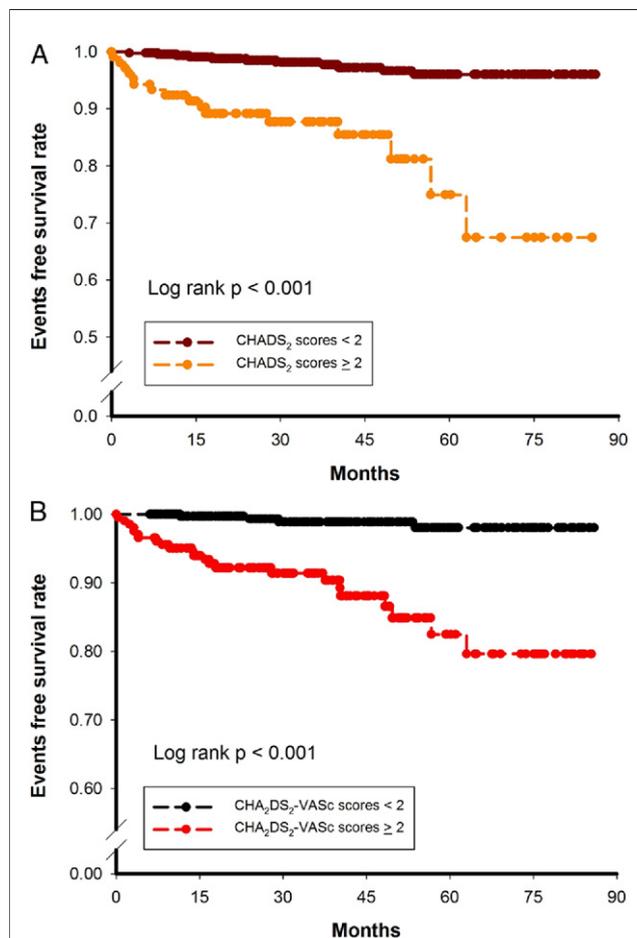
Figure 3 Event-Free Survival Curves for Patients With Different CHADS$_2$ and CHA$_2$DS$_2$-VASc Scores

Kaplan-Meier survival analysis showed that the patients with CHADS$_2$ scores of ≥2 were associated with a higher event rate compared with the patients with CHADS$_2$ scores of <2 (15.2% vs. 2.4%, p < 0.001) **(A)**. Furthermore, a CHA$_2$DS$_2$-VASc score of ≥2 identified by the receiver-operator characteristic curve also significantly predicted occurrences of events (11.3% vs. 1.1%, p < 0.001) **(B)**.
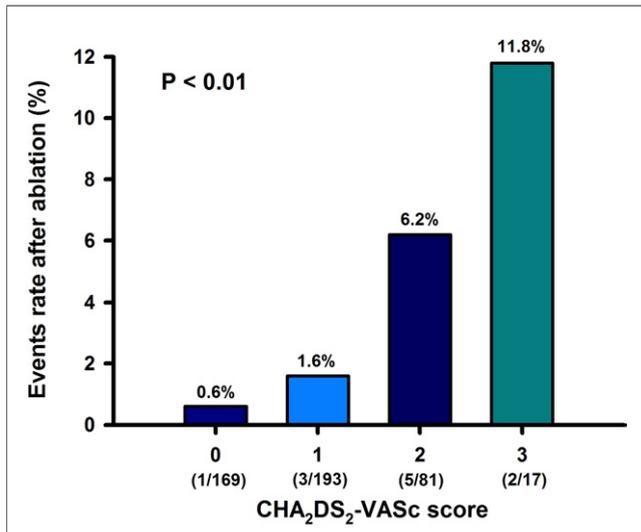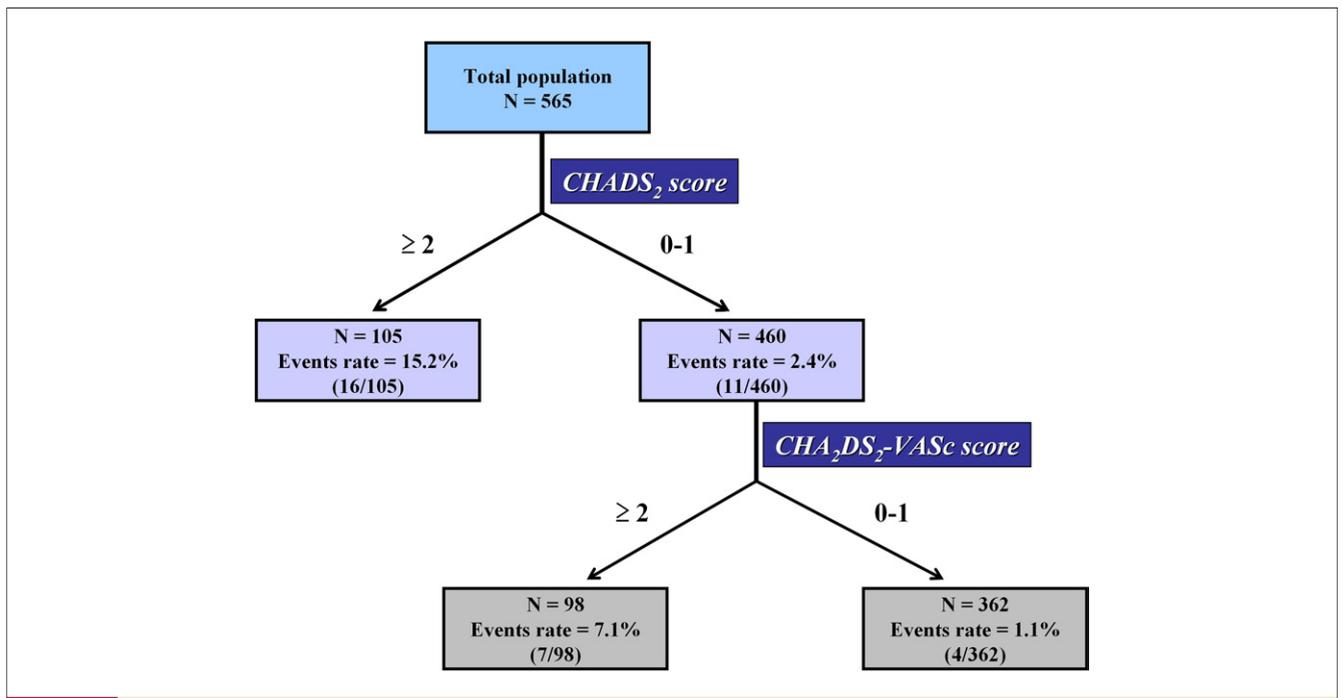
Figure 4   Event Rates in the Patients With CHADS$_2$ Scores of 0 or 1

The event rates progressively increased from 0.6% to 11.8% in patients with different CHA$_2$DS$_2$-VASc scores.

of the present study may provide the evidence for the basis of the previously mentioned flowchart.

Clinical applications of CHADS$_2$ and CHA$_2$DS$_2$-VASc scores. Oral et al. (5) reported that discontinuation of anticoagulant therapy appears to be safe after successful ablation of AF. Recently, Bunch et al. (6) reported that among patients with AF, the stroke risk was lower in

patients who underwent catheter ablation than in those who did not. The 3-year stroke rate (2% to 3%) was similar to that of our study. However, these previous studies did not provide a useful method to identify patients with high risk of events. According to the results of the present study, the CHADS$_2$ scoring scheme can be used to screen patients with CHADS$_2$ scores of ≥ 2 who are predisposed to adverse events after catheter ablation. Furthermore, a more detailed CHA$_2$DS$_2$-VASc scoring scheme can further identify patients with risk of events among patients with CHADS$_2$ scores of <2. The clinical use of CHA$_2$DS$_2$-VASc scores should be emphasized because among patients with CHADS$_2$ scores of 0 or 1 who were traditionally assumed to be at low risk, those with CHA$_2$DS$_2$-VASc scores of 3 can have an event rate as high as 11.8%. Among the 9 patients who experienced stroke, 2 patients were receiving long-term medication with warfarin and had an INR within the therapeutic range at the time the events occurred. Five and 8 patients had CHADS$_2$ and CHA$_2$DS$_2$-VASc scores of ≥ 2, respectively. Of the 4 patients with CHADS$_2$ scores of 0 or 1, 3 had CHA$_2$DS$_2$-VASc scores of ≥ 2. This may further demonstrate the important role of the CHA$_2$DS$_2$-VASc score in identifying low-risk patients who are at risk of stroke; an anticoagulant should be prescribed to lower this risk. Furthermore, for patients with scores indicating a high risk of stroke and who are receiving warfarin treatment, it may be helpful to monitor the INR level more closely to avoid suboptimal treatment. However, a further prospective and large-scale trial is necessary to prove this supposition.

Figure 5   Flowchart of Event Rates and Scores

A flowchart demonstrating the event rates in the patients stratified according to the CHADS$_2$ and CHA$_2$DS$_2$-VASc scores.

Study limitations. First, although the follow-up was not uniform for every patient, more than 70% of the study population underwent follow-up regularly at the cardiology clinics, and the remaining patients were completely assessed through telephone consultations. The accuracy of mortality events was further confirmed through the National Death Registry of Taiwan. Second, the strategy about the use of warfarin was determined by the physicians responsible for treatment according to the individual characteristics of each patient. However, the management was based on the same principle for individuals with similar risk. Moreover, long-term use of warfarin after catheter ablation was not a significant predictor of adverse events based on the analysis and therefore may not confound the results of the present study. Last, although only 18.6% of the patients in the study had $CHADS_2$ scores ≥ 2, the mean person-years of follow-up was $>1,500$, which was sufficient to show statistical significance in a population with low event rates.

Conclusions

$CHADS_2$ and CHA_2DS_2-VASc scores can provide an estimate of the risk of adverse events in patients who undergo catheter ablation of AF. Among patients with $CHADS_2$ scores of 0 or 1, CHA_2DS_2-VASc scores were useful to further identify which patients were predisposed to adverse events.

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Key Words: atrial fibrillation ■ catheter ablation ■ $CHADS_2$ score ■ CHA_2DS_2-VASc score.

▶ **APPENDIX**

**For an expanded Methods section,
please see the online version of this article.**