

Predictive modeling and external validation of late atrial fibrillation recurrence following catheter ablation

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Table S1. Comparison of Baseline Characteristics Between the Training and External Validation Cohorts.

Variables	Total (n = 459)	Training cohort (n = 256)	External validation cohort (n = 203)	<i>P</i>
Sex, n(%)				0.957
Female	177 (38.56)	99 (38.67)	78 (38.42)	
Male	282 (61.44)	157 (61.33)	125 (61.58)	
Age (years)	64.00 (57.00, 70.00)	64.00 (57.00, 70.00)	64.00 (57.50, 70.00)	0.966
BMI (kg/m ²)	24.50 (22.40, 26.44)	24.55 (22.41, 26.44)	24.48 (22.39, 26.48)	0.941
SBP (mmHg)	126.00 (116.00, 138.50)	126.00 (116.00, 139.00)	126.00 (116.00, 138.00)	0.942
DBP (mmHg)	82.00 (74.00, 88.00)	82.00 (74.00, 88.00)	83.00 (74.00, 86.00)	0.913
Pulse (beats/min)	76.00 (67.00, 87.00)	76.00 (67.00, 88.00)	75.00 (67.00, 87.00)	0.765
LAD (cm)	4.31 ± 0.71	4.31 ± 0.71	4.31 ± 0.72	0.950
Hb (g/L)	137.00 (124.00, 147.00)	137.00 (124.00, 147.00)	137.00 (125.00, 148.00)	0.754
CHA2DS2-VASC	2.00 (1.00, 3.00)	2.00 (1.00, 3.00)	2.00 (1.00, 3.00)	0.860
Course of AF (months)	12.00 (3.00, 36.00)	12.00 (3.00, 36.00)	12.00 (5.00, 34.00)	0.981
Time of surgery (hours)	2.16 (2.00, 2.65)	2.16 (2.00, 2.60)	2.16 (2.00, 2.67)	0.899
CRP (mg/L)	1.10 (0.60, 2.05)	1.10 (0.60, 2.00)	1.10 (0.60, 2.15)	0.742
ALT (IU/L)	20.00 (16.00, 28.00)	20.00 (16.00, 28.00)	20.00 (16.00, 29.00)	0.852
AST (IU/L)	21.00 (18.00, 25.00)	21.00 (18.00, 25.00)	21.00 (18.00, 26.00)	0.980
NT-proBNP (pg/mL)	363.00 (166.00, 763.50)	363.00 (151.75, 730.75)	363.00 (185.00, 769.50)	0.585
Cr (μmol/L)	77.00 (68.00, 90.00)	77.00 (68.00, 90.25)	77.00 (68.00, 89.50)	0.833
TSH (μIU/mL)	2.04 (1.48, 2.78)	2.04 (1.47, 2.76)	2.04 (1.50, 2.79)	0.937
FT4 (pmol/L)	1.19 (1.02, 1.19)	1.19 (1.02, 1.19)	1.19 (1.02, 14.95)	0.761

	15.10)	15.22)		
FT3 (pmol/L)	2.83 (2.56, 4.26)	2.83 (2.57, 4.29)	2.83 (2.54, 4.18)	0.766
HbA1c	5.80 (5.50, 6.00)	5.80 (5.50, 6.00)	5.80 (5.50, 5.97)	0.872
EF (%)	59.00 (55.00, 64.00)	59.00 (55.00, 64.00)	59.00 (53.00, 62.00)	0.611
Late recurrence, n(%)				0.858
No	360 (78.43)	200 (78.12)	160 (78.82)	
Yes	99 (21.57)	56 (21.88)	43 (21.18)	
ECV, n(%)				0.739
No	309 (67.32)	174 (67.97)	135 (66.50)	
Yes	150 (32.68)	82 (32.03)	68 (33.50)	
Early recurrence, n(%)				0.838
No	410 (89.32)	228 (89.06)	182 (89.66)	
Yes	49 (10.68)	28 (10.94)	21 (10.34)	
HF, n(%)				0.532
No	395 (86.06)	218 (85.16)	177 (87.19)	
Yes	64 (13.94)	38 (14.84)	26 (12.81)	
Hypertension, n(%)				0.662
No	248 (54.03)	136 (53.12)	112 (55.17)	
Yes	211 (45.97)	120 (46.88)	91 (44.83)	
Diabetes, n(%)				0.815
No	380 (82.79)	211 (82.42)	169 (83.25)	
Yes	79 (17.21)	45 (17.58)	34 (16.75)	
Cerebral infarction/TIA, n(%)				0.946
No	394 (85.84)	220 (85.94)	174 (85.71)	
Yes	65 (14.16)	36 (14.06)	29 (14.29)	
CHD, n(%)				0.778
No	343 (74.73)	190 (74.22)	153 (75.37)	
Yes	116 (25.27)	66 (25.78)	50 (24.63)	
Type of AF, n(%)				0.660
Paroxysmal	290 (63.18)	164 (64.06)	126 (62.07)	
Non-paroxysmal	169 (36.82)	92 (35.94)	77 (37.93)	
AF duration, n(%)				0.966
<6 years	384 (83.66)	214 (83.59)	170 (83.74)	
≥6 years	75 (16.34)	42 (16.41)	33 (16.26)	
Cardiomyopathy, n(%)				0.944
No	411 (89.54)	229 (89.45)	182 (89.66)	
Yes	48 (10.46)	27 (10.55)	21 (10.34)	
Sleep apnea syndrome, n(%)				0.795
No	435 (94.77)	242 (94.53)	193 (95.07)	
Yes	24 (5.23)	14 (5.47)	10 (4.93)	

Renal insufficiency, n(%)				0.890
No	417 (90.85)	233 (91.02)	184 (90.64)	
Yes	42 (9.15)	23 (8.98)	19 (9.36)	
Hyperlipidemia, n(%)				0.854
No	386 (84.10)	216 (84.38)	170 (83.74)	
Yes	73 (15.90)	40 (15.62)	33 (16.26)	
COPD, n(%)				1.000
No	455 (99.13)	254 (99.22)	201 (99.01)	
Yes	4 (0.87)	2 (0.78)	2 (0.99)	
Valvular regurgitation, n(%)				0.802
No	389 (84.75)	216 (84.38)	173 (85.22)	
Yes	70 (15.25)	40 (15.62)	30 (14.78)	
Smoking history, n(%)				0.830
No	219 (47.71)	121 (47.27)	98 (48.28)	
Yes	240 (52.29)	135 (52.73)	105 (51.72)	
Drinking history, n(%)				0.816
No	373 (81.26)	209 (81.64)	164 (80.79)	
Yes	86 (18.74)	47 (18.36)	39 (19.21)	
SGLT2i, n(%)				1.000
No	452 (98.47)	252 (98.44)	200 (98.52)	
Yes	7 (1.53)	4 (1.56)	3 (1.48)	
Statin, n(%)				0.855
No	242 (52.72)	134 (52.34)	108 (53.20)	
Yes	217 (47.28)	122 (47.66)	95 (46.80)	
Beta-blocker, n(%)				0.848
No	260 (56.64)	144 (56.25)	116 (57.14)	
Yes	199 (43.36)	112 (43.75)	87 (42.86)	
Amiodarone, n(%)				0.854
No	35 (7.63)	19 (7.42)	16 (7.88)	
Yes	424 (92.37)	237 (92.58)	187 (92.12)	
Propafenone, n(%)				0.995
No	398 (86.71)	222 (86.72)	176 (86.70)	
Yes	61 (13.29)	34 (13.28)	27 (13.30)	
Rivaroxaban, n(%)				0.344
No	260 (56.64)	150 (58.59)	110 (54.19)	
Yes	199 (43.36)	106 (41.41)	93 (45.81)	
Dabigatran, n(%)				0.577
No	292 (63.62)	160 (62.50)	132 (65.02)	
Yes	167 (36.38)	96 (37.50)	71 (34.98)	
ACEI/ARB/ARNI, n(%)				0.858
No	233 (50.76)	129 (50.39)	104 (51.23)	
Yes	226 (49.24)	127 (49.61)	99 (48.77)	

BMI: body mass index, LAD: left atrial diameter, CRP: C-reactive protein, SBP: systolic blood pressure, DBP: diastolic blood pressure, ALT: alanine aminotransferase, AST: aspartate

aminotransferase, NT-proBNP: N-terminal pro-B-type natriuretic peptide, Cr: creatinine, Hb: hemoglobin, TSH: thyroid-stimulating hormone, FT4: free thyroxine, FT3: free triiodothyronine, HbA1c: glycated hemoglobin, EF: ejection fraction, HF: heart failure, TIA: transient ischemic attack, CHD: coronary heart disease, SGLT2i: sodium-glucose co-transporter 2 inhibitor use, ACEI/ARB/ARNI: angiotensin-converting enzyme inhibitor/angiotensin receptor blocker/angiotensin receptor neprilysin inhibitor use.

Table S2. Variance inflation factor and proportional hazards assumption test.

	Variance Inflation Factor	Proportional Hazards Assumption Test		
		χ^2	df	P
Early recurrence	1.09	2.1160	1	0.15
Left atrial diameter	1.13	0.1581	1	0.69
Electrical cardioversion	1.15	1.3264	1	0.25
Cr	1.11	0.0552	1	0.81
ACEI/ARB/ARNI	1.13	0.1730	1	0.68
Course of AF	1.12	0.0487	1	0.83
Global test		6.3250	6	0.39

Table S3. Predicted 18-month AF recurrence-free probability stratified by major risk factors.

Early relapse	ECV	LAD_high	N	Median	Q1	Q3
No early recurrence	No intra-procedural cardioversion	LAD \leq median	105	0.885	0.839	0.93
No early recurrence	No intra-procedural cardioversion	LAD $>$ median	54	0.832	0.747	0.887
No early recurrence	Intra-procedural cardioversion	LAD \leq median	22	0.768	0.706	0.821
No early recurrence	Intra-procedural cardioversion	LAD $>$ median	47	0.768	0.682	0.844
Early recurrence	No intra-procedural cardioversion	LAD \leq median	7	0.456	0.321	0.503
Early recurrence	No intra-procedural cardioversion	LAD $>$ median	8	0.178	0.095	0.347
Early recurrence	Intra-procedural cardioversion	LAD \leq median	2	0.253	0.158	0.349
Early recurrence	Intra-procedural cardioversion	LAD $>$ median	11	0.093	0.012	0.242

LAD was dichotomized at the cohort median of 4.3 cm.

Figure S1. Overview of Missingness in Variables with Missing Data.

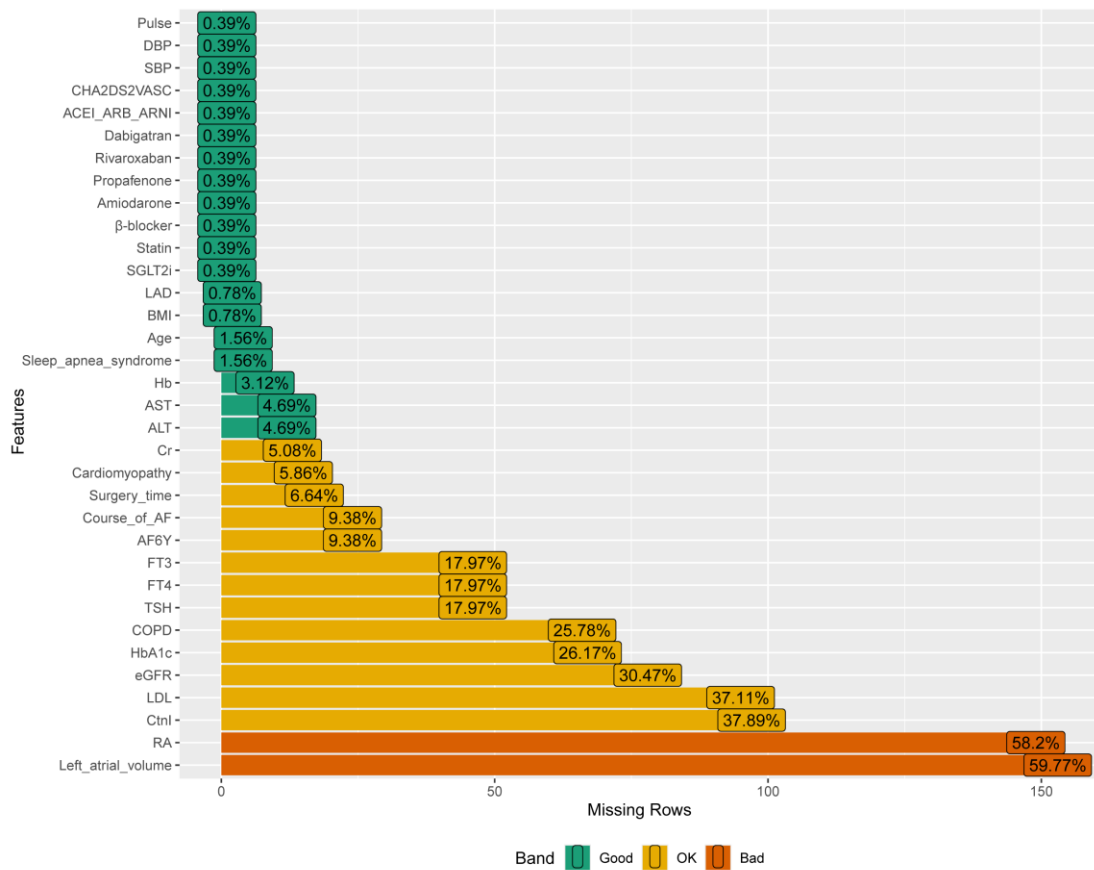


Figure S2. Bar Chart of Coefficients for Variables with Nonzero Coefficients Selected by Lambda.min.

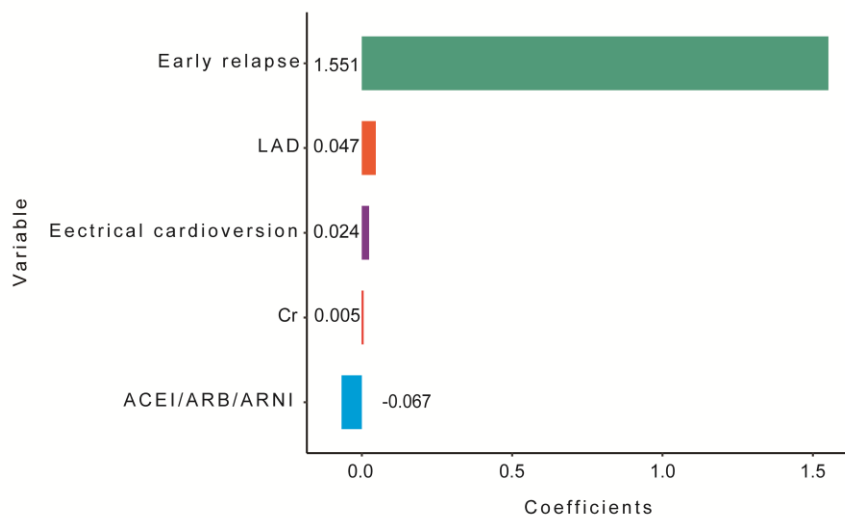
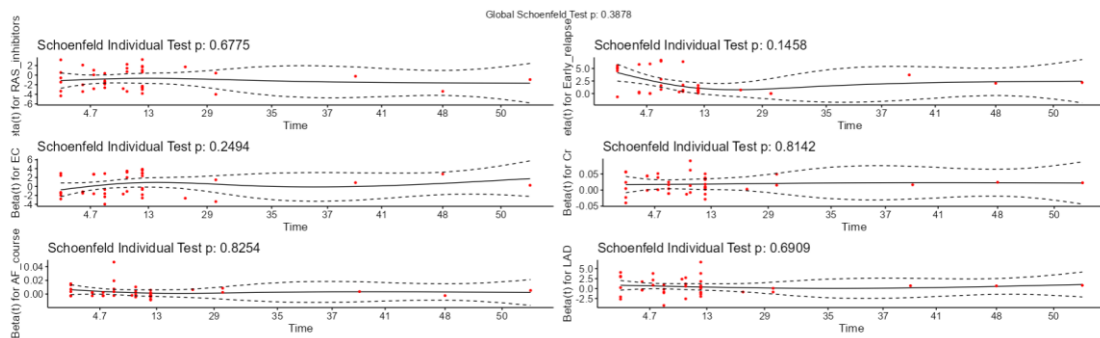


Figure S3. The Schoenfeld residuals test for proportional hazards assumption. The plot illustrates the temporal variation in the beta coefficient for six dependent predictors (Early recurrence, Left atrial diameter, Electrical cardioversion, Cr, ACEI/ARB/ARNI, Course of AF), with residuals depicted as red dots and a smoothed trend indicated by a black line. The confidence intervals are represented by dashed lines. The global Schoenfeld test was not statistically significant ($P = 0.3878$), indicating no evidence of violation of the proportional hazards assumption in the overall model, which included early recurrence, left atrial diameter, electrical cardioversion, creatinine, ACEI/ARB/ARNI use, and AF duration.



Abbreviation: LAD: Left atrial diameter; EC: Electrical cardioversion.

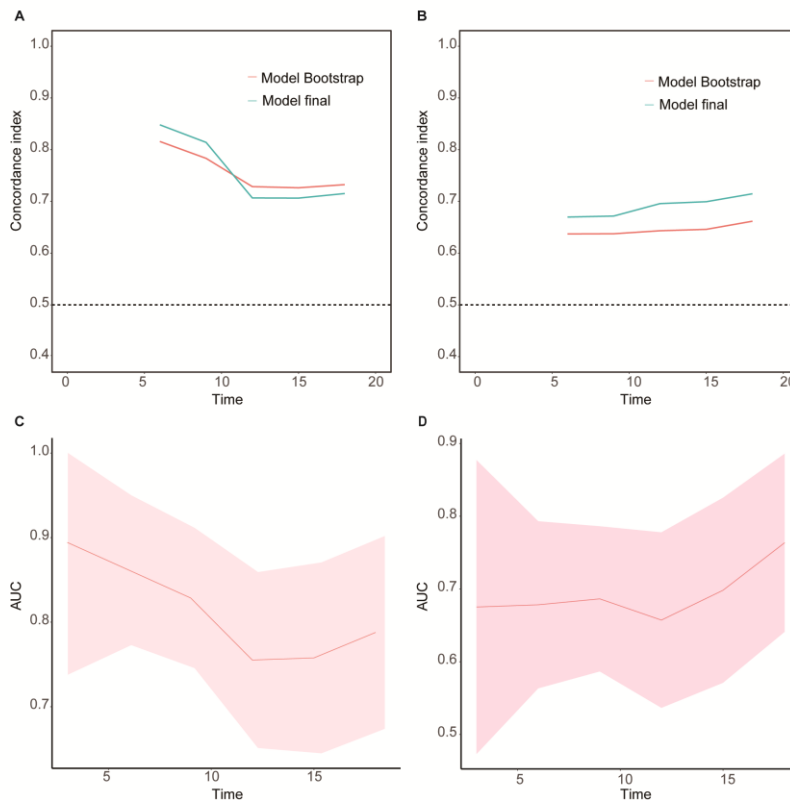


Figure S4. Sensitivity Analysis of Model Performance With and Without Early Recurrence.

Structured Follow-up Interview Questionnaire

Title: Structured Follow-up Interview Questionnaire for Post-Catheter Ablation Patients with Atrial Fibrillation

Purpose:

To assess recurrence of atrial fibrillation and post-procedural outcomes at follow-up intervals of 1, 3, 6, 12, and 18 months after radiofrequency catheter ablation.

Target Population:

Patients with atrial fibrillation who underwent catheter ablation.

Interview Format:

Conducted via telephone or outpatient visit by trained clinical staff.

Patient Identification

Full Name: _____

Medical Record Number: _____

Date of Interview: _____

Interviewer Name: _____

Section 1: General Status

1. Are you currently experiencing any chest discomfort, palpitations, dizziness, or shortness of breath?

Yes

No

If yes, please describe: _____

2. Since your last follow-up, have you visited the emergency department or been re-hospitalized for heart-related issues?

Yes

No

If yes, please provide date and reason: _____

Section 2: Cardiac Rhythm Monitoring

3. Have you undergone any of the following rhythm assessments since your last visit? (check all that apply)

12-lead ECG

24-hour Holter monitoring

Smart wearable ECG device (e.g., smartwatch)

Other: _____

None

4. Was atrial fibrillation or any other arrhythmia detected during these assessments?

Yes

No

If yes, what type and when? _____

Section 3: Arrhythmia Events

5. Have you experienced any episodes of irregular heartbeat lasting more than 30 seconds since ablation?

Yes

No

If yes:

- Number of episodes: _____

- Approximate date(s): _____

- Were you symptomatic? Yes No

6. Were any of these episodes confirmed by a healthcare provider or documented by ECG/Holter?

Yes

No

Section 4: Medication and Lifestyle

7. Are you currently taking any of the following medications? (check all that apply)

Antiarrhythmic drugs (e.g., amiodarone, propafenone)

Anticoagulants (e.g., rivaroxaban, dabigatran)

ACEI/ARB/ARNI

Beta-blockers

Others: _____

None

8. Have there been any recent changes to your medications?

Yes

No

If yes, please specify: _____

9. Are you currently smoking or consuming alcohol?

Smoking:

Never

Quit

Current

Alcohol:

Never

Occasionally

Regularly

Section 5: Additional Notes

10. Do you have any additional symptoms, concerns, or questions regarding your heart condition or treatment?

End of Interview

Thank you for your cooperation.