Impact of early ablation of atrial fibrillation on long-term outcomes: results from phase II/III of the GLORIA-AF registry

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Abstract

Background First-line ablation for atrial fibrillation (AF) reduces the risk of recurrent atrial arrhythmias compared to medical therapy. However, the prognostic benefit of early AF ablation remains undetermined. Herein, we aimed to evaluate the effects of early AF ablation compared to medical therapy.

Methods Using data from phase II/III of the GLORIA-AF registry, we studied patients who were consecutively enrolled with newly diagnosed AF (< 3 months before baseline visit) and an increased risk of stroke (CHA2DS2–VASc ≥ 1). At baseline visit, 445 (1.7%) patients were treated with early AF ablation and 25,518 (98.3%) with medical therapy. Outcomes of interest were the composite outcome of all-cause death, stroke and major bleeding, and pre-specified outcomes of all-cause death, cardiovascular (CV) death, non-CV death, stroke, and major bleeding.

Results A total of 25,963 patients (11733 [45.2%] females; median age 71 [IQR 64–78] years; 17424 [67.1%] taking non-vitamin K antagonist oral anticoagulants [NOACs]) were included. Over a follow-up period of 3.0 (IQR 2.3–3.1) years, after adjustment for confounders, early AF ablation was associated with a significant reduction in the composite outcome of all-cause death, stroke, and major bleeding (HR 0.50 [95% CI 0.30–0.85]) and all-cause death (HR 0.45 [95% CI 0.23–0.91]). There were no statistical differences between the groups in terms of CV death, non-CV death, stroke, and major bleeding. Similar results were obtained in a propensity-score matched analysis of patients with comparable baseline variables.

Conclusions Early AF ablation in a contemporary prospective cohort of AF patients who were predominantly treated with NOACs was associated with a survival advantage compared to medical therapy alone.

Trial registration Clinical trial registration: http://www.clinicaltrials.gov. Unique identifiers: NCT01468701, NCT01671007 and NCT01937377.

Graphical abstract

Early Atrial Fibrillation Ablation Compared to Medical Therapy:
Results from ~26,000 patients in GLORIA-AF phase II/III

-50% Reduction in composite outcome of all-cause death, stroke, and major bleeding
aHR 0.50 (95% CI, 0.30–0.85)

-55% Reduction in all-cause death
aHR 0.45 (95% CI, 0.23–0.91)

Non-statistically significant benefit in terms of:
CV death (aHR 0.59 [95% CI, 0.16–1.56])
Non-CV death (aHR 0.48 [95% CI, 0.18–1.38])
Stroke (aHR 0.73 [95% CI, 0.30–1.78])
Major bleeding (aHR 0.59 [95% CI, 0.24–1.44])

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Extended author information available on the last page of the article
Introduction

Atrial fibrillation (AF) is a cardiac arrhythmia that is characterised by an irregular heart beat and has important interactions with numerous other conditions. It is associated with an increased risk of thromboembolic complications, heart failure and death [1–3], and excess healthcare costs [4]. The treatment of patients with AF includes the use of either rhythm or rate control management strategies to achieve symptom control, as per current international guidelines [5–7]. These strategies were accepted as equivocal on the basis of historical studies which demonstrated similar outcomes with both [8]. Nonetheless, this notion has been challenged by more recent evidence from the EAST–AFNET 4 (Early Treatment of Atrial Fibrillation for Stroke Prevention) trial suggesting that early rhythm control may offer a prognostic advantage over rate control [9].

Rhythm control may be achieved using either cardioversion with anti-arrhythmic drugs or electrical therapy, or AF ablation. Over the past decade, the superiority of AF ablation over anti-arrhythmic drugs for the prevention of atrial arrhythmia recurrence has been proven [10], such that there is now an increasing argument for its use as first-line treatment in patients with AF. Recently, we published a systematic review and meta-analysis of 6 randomised controlled trials demonstrating that first-line treatment with catheter AF ablation was associated with a 36% reduction in the recurrence of atrial arrhythmias and 47% reduction in healthcare resource utilisation compared to anti-arrhythmic drug therapy [11].

Despite the advantages of AF ablation as described above, its benefits among the general AF population in terms of hard clinical outcomes including stroke, heart failure and long-term survival remain ill-defined. Several observational studies previously reported a prognostic benefit with AF ablation [12–15], though this was not found in the CABANA (Catheter Ablation vs. Antiarrhythmic Drug Therapy for Atrial Fibrillation) randomised controlled trial [10]. Nonetheless, the aforementioned studies were not designed to test for the effects of early AF ablation and only 8% of patients in the early rhythm control arm of EAST–AFNET 4 received such treatment [9]. Herein, we aimed to evaluate the effects of early AF ablation in patients from the contemporary prospective GLORIA-AF (Global Registry on Long-Term Oral Anti-thrombotic Treatment In Patients With Atrial Fibrillation) registry.

Methods

Study design and population

GLORIA-AF is a prospective, observational, global registry programme of patients from 935 centres across 38 participating countries in Asia, Europe, North America, Latin America, and Africa/Middle East. The study design has previously been described [16]. In brief, consecutive adults with newly diagnosed AF (<3 months before baseline visit) and an increased risk of stroke (CHA$_2$DS$_2$–VASc ≥ 1) were enrolled. This study focused on patients from GLORIA-AF phase II and III. These patients were enrolled between 2011 and 2020. Patients with known ablation status at baseline and follow-up data were included. Main exclusion criteria of GLORIA-AF registry were the presence of mechanical heart valve or valvular disease necessitating valve replacement, prior oral anticoagulation with vitamin K oral antagonist over 60 days, a reversible cause of AF, indication for anticoagulation other than AF, and life expectancy of less than 1 year. Ethics approval was obtained from the local institutional review boards, informed consent was obtained from patients, and the study was performed in accordance with the Declaration of Helsinki.

Data collection and definition

Data on demographics, comorbidities and therapies were collected at baseline with standardised, prospectively designed data collection tools. Early AF ablation was defined as AF ablation within 3 months from diagnosis. Creatinine clearance (CrCl) was assessed using the Cockcroft–Gault equation [17]. AF classification was determined according to the European Society of Cardiology recommendations [18]. Severity of AF-related symptoms was ascertained using the European Heart Rhythm Association classification [19]. CHADS$_2$, CHA$_2$DS$_2$–VASc and HAS–BLED scores were calculated as previously described [20–22].

Study outcomes and follow-up

Outcomes of interest were the composite outcome of all-cause death, stroke and major bleeding, and the pre-specified outcomes of all-cause death, cardiovascular (CV) death, non-CV death, stroke and major bleeding. Stroke was defined as an acute onset of a focal neurological deficit of presumed vascular origin lasting for 24 h or more, or resulting in death. Major bleeding was defined as either overt bleeding associated with a reduction in haemoglobin.
of at least 20 g/L or leading to a transfusion of at least 2 units of blood or packed cells; symptomatic bleeding in a critical area or organ (intraocular, intracranial, intraspinal or intramuscular with compartment syndrome, retroperitoneal bleeding, intra-articular bleeding or pericardial bleeding); or life-threatening bleeding. In phase II, follow-up for the dabigatran cohort was for 2 years, with scheduled visits at 3, 6, 12, and 24 months. In phase III, follow-up for all patients was conducted for 3 years, with scheduled visits at 6, 12, 24, and 36 months.

**Statistical analysis**

Continuous variables were described with median and interquartile range (IQR), and tested for differences with Kruskal–Wallis test. Categorical variables were described as count and percentage, and tested for differences with chi-squared test. Plots of Kaplan–Meier curves were performed for each outcome and survival distributions were compared using log-rank test. Cox proportional hazards analyses were performed to study the effects of early AF ablation on outcomes of interest. Potential confounders were accounted for using a multivariable model with forward selection of covariates including age, gender, body mass index, CrCl, type of AF, hypertension, hyperlipidaemia, diabetes mellitus, coronary artery disease, heart failure, left ventricular hypertrophy, prior thromboembolism, prior bleeding, peripheral artery disease, chronic obstructive pulmonary disease, oral anticoagulation use, antiplatelet use, anti-arrhythmic drug therapy, angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, beta-blocker, digoxin, statin and diuretic therapy.

Further analyses were undertaken after rigorous adjustment for baseline characteristics with propensity score matching (PSM) generated by logistic regression for all variables in Supplementary Table 1 in a 1:1 ratio using the nearest-neighbour technique without replacement. A two-sided p value of less than 0.05 was considered statistically significant. Statistical analyses were performed using RStudio (Version 1.3.1093).

**Results**

A total of 25,963 patients (11,733 [45.2%] females; median age 71 [IQR 64–78] years) were included. A flow chart of the patient selection process is shown in Supplementary Fig. 1. The anticoagulation status of patients in this study cohort is demonstrated in Fig. 1. There were 445 (1.7%) patients treated with early AF ablation and 25,518 (98.3%) with medical therapy.

**Baseline characteristics**

Baseline characteristics are described in Table 1. Patients in the early AF ablation group were younger and had lower body mass index, higher CrCl, less advanced forms of AF and reduced burden of comorbidities including hypertension, hypercholesterolaemia, diabetes mellitus, prior myocardial infarction, heart failure, left ventricular hypertrophy, prior thromboembolism and chronic obstructive pulmonary disease compared to patients on medical therapy alone. As a result, patients treated with early AF ablation had a lower risk of stroke (median CHADS2 of 1 [IQR 1–2] vs. 2 [IQR 1–3]; CHA2DS2–VASc of 2 [IQR 1–3] vs. 3 [IQR 2–4]) and major bleeding (median HAS–BLED of 1 [IQR 0–1] vs. 1 [IQR 1–2]).

![Fig. 1](https://via.placeholder.com/150)

**Fig. 1** Anticoagulation status of patients in study cohort (n = 25,963). OAC oral anticoagulant, VKA vitamin K antagonist
Medication use

Oral anticoagulation was prescribed in 22,219 (85.6%) patients at baseline with 17,424 (67.1%) receiving non-vitamin K antagonist oral anticoagulants and 4795 (18.5%) vitamin K antagonist. In contrast to patients on medical therapy, those treated with early AF ablation had greater uptake of anticoagulation and anti-arrhythmic drug therapy but less frequent use of antiplatelet agent, angiotensin-converting enzyme inhibitor, beta-blocker, digoxin and diuretic therapy (Table 2).

Table 1 Baseline characteristics

| Baseline characteristics | Early AF ablation (n = 445) | Medical therapy (n = 25,518) | p value |
|--------------------------|-----------------------------|-----------------------------|---------|
| Age (years), median (IQR) | 63 (57–70)                  | 71 (64–78)                  | < 0.001 |
| Female sex, n (%)        | 186 (41.8%)                 | 11,450 (44.9%)              | 0.213   |
| Heart rate (bpm), median (IQR) | 75 (67–86) | 76 (65–90) | 0.394   |
| sBP (mmHg), median (IQR) | 130 (120–140)               | 130 (120–142)               | 0.003   |
| BMI (kg/m²), median (IQR) | 26.1 (23.6–29.1)            | 27.6 (24.5–31.5)            | < 0.001 |
| CrCl (mL/min), median (IQR) | 84.7 (68.6–107.0)          | 75.3 (56.9–98.3)            | < 0.001 |
| AF classification, n (%) |                            |                            |         |
| Paroxysmal               | 332 (74.6%)                 | 14,084 (55.2%)              | < 0.001 |
| Persistent               | 110 (24.7%)                 | 8807 (34.5%)                |         |
| Permanent                | 3 (0.7%)                    | 2627 (10.3%)                |         |
| EHRA classification, n (%) |                        |                            |         |
| I                        | 45 (10.7%)                  | 8732 (36.2%)                | < 0.001 |
| II                       | 177 (42.1%)                 | 9027 (37.4%)                |         |
| III                      | 179 (42.6%)                 | 4906 (20.3%)                |         |
| IV                       | 19 (4.5%)                   | 1471 (6.1%)                 |         |
| Comorbidities, n (%)     |                            |                            |         |
| Hypertension             | 308 (69.2%)                 | 19,218 (75.5%)              | 0.003   |
| Hypercholesterolaemia    | 125 (28.3%)                 | 10,171 (40.9%)              | < 0.001 |
| Diabetes mellitus        | 82 (18.4%)                  | 5937 (23.3%)                | 0.019   |
| Coronary artery disease  | 85 (19.3%)                  | 4810 (19.3%)                | 1.000   |
| Prior myocardial infarction | 12 (2.7%)              | 2457 (9.6%)                 | < 0.001 |
| Heart failure            | 63 (14.2%)                  | 5708 (22.5%)                | < 0.001 |
| Left ventricular hypertrophy | 51 (11.6%)           | 4735 (19.4%)                | < 0.001 |
| Prior thromboembolism    | 46 (10.3%)                  | 3805 (14.9%)                | 0.009   |
| Prior stroke             | 36 (8.1%)                   | 2783 (10.9%)                | 0.069   |
| Prior bleeding           | 17 (3.9%)                   | 1356 (5.4%)                 | 0.188   |
| Peripheral artery disease | 7 (1.6%)                   | 744 (2.9%)                  | 0.120   |
| COPD                     | 14 (3.2%)                   | 1546 (6.1%)                 | 0.013   |
| CHADS₂ score, median (IQR) | 1 (1–2)                    | 2 (1–3)                     | < 0.001 |
| CHA₂DS₂–VASc score, median (IQR) | 2 (1–3)     | 3 (2–4)                     | < 0.001 |
| HAS–BLED score, median (IQR) | 1 (0–1)                    | 1 (1–2)                     | < 0.001 |

AF atrial fibrillation, BMI body mass index, COPD chronic obstructive pulmonary disease, CrCl creatinine clearance, EHRA European heart rhythm association, IQR interquartile range, sBP systolic blood pressure

Study outcomes

During a median follow-up period of 3.0 (IQR 2.3–3.1) years, there were 3237 (12.5%) events for the composite outcome of all-cause death, stroke and major bleeding, including 2305 (8.9%) all-cause deaths, 807 (3.1%) CV deaths, 989 (3.8%) non-CV deaths, 679 (2.6%) strokes and 870 (3.4%) major bleeding events. Kaplan–Meier survival analyses demonstrated that patients who were treated with early AF ablation had lower event rates for the composite outcome, all-cause death, CV death, non-CV death and
major bleeding with a trend for reduced stroke compared to patients on medical therapy alone (Fig. 2).

Early AF ablation was associated with a significant reduction in the composite outcome of all-cause death, stroke and major bleeding (HR 0.26 [95% CI, 0.16–0.43]), all-cause death (HR 0.22 [95% CI, 0.11–0.42]), CV death (HR 0.21 [95% CI, 0.07–0.65]), non-CV death (HR 0.28 [95% CI, 0.11–0.66]), stroke (HR 0.43 [95% CI, 0.18–1.00]) and

| Medication use | Early AF ablation \( (n = 445) \) | Medical therapy \( (n = 25,518) \) | \( p \) value |
|---------------|---------------------------------|-----------------------------|-------------|
| Anticoagulation, \( n \) (%) | 402 (90.5%) | 21,817 (85.5%) | 0.004 |
| Apixaban | 39 (8.8%) | 4429 (17.4%) | |
| Dabigatran | 216 (48.6%) | 8427 (33.0%) | |
| Edoxaban | 7 (1.6%) | 323 (1.3%) | |
| Rivaroxaban | 53 (11.9%) | 3930 (15.4%) | |
| VKA | 87 (19.6%) | 4708 (18.5%) | |
| Antiplatelet, \( n \) (%) | 68 (15.3%) | 6223 (24.4%) | < 0.001 |
| Anti-arrhythmic drug, \( n \) (%) | 215 (48.3%) | 6488 (25.4%) | < 0.001 |
| ACE-i, \( n \) (%) | 95 (21.3%) | 7814 (30.6%) | < 0.001 |
| Angiotensin receptor blocker, \( n \) (%) | 104 (23.4%) | 6572 (25.8%) | 0.278 |
| Beta-blocker, \( n \) (%) | 182 (40.9%) | 16,159 (63.3%) | < 0.001 |
| Digoxin, \( n \) (%) | 13 (2.9%) | 2135 (8.4%) | < 0.001 |
| Diuretic, \( n \) (%) | 81 (18.2%) | 9770 (38.3%) | < 0.001 |
| Statin, \( n \) (%) | 179 (40.2%) | 11,475 (45.0%) | 0.052 |

AF atrial fibrillation, ACE-i angiotensin-converting enzyme inhibitor, VKA vitamin K antagonist

Fig. 2 Kaplan–Meier survival curves for composite outcome of all-cause death, stroke and major bleeding, all-cause death, CV death, non-CV death, stroke and major bleeding
major bleeding (HR 0.39 [95% CI, 0.18–0.88]) (Table 3).
After adjustment for various confounders, the composite outcome (HR 0.50 [95% CI, 0.30–0.85]) and all-cause death (HR 0.45 [95% CI, 0.23–0.91]) remained significantly lower among patients who were treated with early AF ablation compared to those on medical therapy.

A comparison of early AF ablation to other risk factors for the composite outcome of all-cause death, stroke and major bleeding are shown in Fig. 3. Worse outcomes were seen in patients with increased age, reduced renal function, diabetes mellitus, coronary artery disease, heart failure, prior thromboembolism, prior bleeding, peripheral artery disease, chronic obstructive pulmonary disease, oral anticoagulation use, antiplatelet use, anti-arrhythmic drug therapy, angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, beta-blocker, digoxin, statin and diuretic therapy.

**Table 3** Effects of early AF ablation vs. medical therapy

| Outcomes                                              | Early AF ablation (n=445) | Medical therapy (n=25,518) | Early AF ablation vs. medical therapy                                      |
|-------------------------------------------------------|---------------------------|----------------------------|----------------------------------------------------------------------------|
|                                                       |                          |                            | Univariate HR (95% CI)   | aHR† (95%)   | p value       |
| Composite outcome of all-cause death, stroke and major bleeding | 21 (4.7%) | 3216 (12.6%) | 0.26 (0.16–0.43) | 0.50 (0.30–0.85) | 0.011  |
| All-cause death                                       | 13 (2.9%) | 2292 (9.0%) | 0.22 (0.11–0.42) | 0.45 (0.23–0.91) | 0.027  |
| CV death                                              | 5 (1.1%)  | 802 (3.2%)  | 0.21 (0.07–0.65) | 0.50 (0.16–1.56) | 0.232  |
| Non-CV death                                          | 6 (1.4%)  | 983 (3.9%)  | 0.28 (0.11–0.66) | 0.48 (0.18–1.30) | 0.149  |
| Stroke                                                | 6 (1.4%)  | 673 (2.6%)  | 0.43 (0.18–1.00) | 0.73 (0.30–1.78) | 0.489  |
| Major bleeding                                         | 8 (1.8%)  | 862 (3.4%)  | 0.39 (0.18–0.88) | 0.59 (0.24–1.44) | 0.247  |

**Fig. 3** Effects of early AF ablation in comparison to other risk factors for the composite outcome of all-cause death, stroke and major bleeding. AAD anti-arrhythmic drug, ACE-i angiotensin-converting enzyme inhibitor, AF atrial fibrillation, ARB angiotensin receptor blocker, BMI body mass index, CAD coronary artery disease, COPD chronic obstructive pulmonary disease, CrCl creatinine clearance, DM diabetes mellitus, HF heart failure, HTN hypertension, LVH left ventricular hypertrophy, OAC oral anticoagulation, PAD peripheral artery disease, TE thromboembolism.
disease, chronic obstructive pulmonary disease, antiplatelet use, digoxin and diuretic therapy. Protective factors were early AF ablation, female sex, oral anticoagulation use, angiotensin-converting enzyme inhibitor, angiotensin receptor blocker and anti-arrhythmic drug therapy.

PSM cohort

Using PSM, we identified 399 patients in each group with comparable baseline characteristics (Supplementary Table 1). Within this cohort, early AF ablation was related to a decrease in the composite outcome of all-cause death, stroke and major bleeding (HR 0.41 [95% CI, 0.22–0.77]) and all-cause death (HR 0.43 [95% CI, 0.19–0.99]) (Table 4). There was no statistically significant difference between the groups in terms of CV death, non-CV death, stroke and major bleeding.

Discussion

In this large, global, prospective registry of patients with newly diagnosed AF who were predominantly treated with non-vitamin K antagonist oral anticoagulants, we present novel findings demonstrating that early AF ablation was independently associated with a 51% decrease in the composite outcome of all-cause death, stroke and major bleeding, and a 59% decrease in all-cause death (HR 0.43 [95% CI, 0.19–0.99]) (Table 4). There was no statistically significant difference between the groups in terms of CV death, non-CV death, stroke and major bleeding.

Table 4 Effects of early AF ablation vs. medical therapy after propensity score matching

| Outcomes                              | Early AF ablation (n = 399) | Medical therapy (n = 399) | HR (95% CI) | p value |
|---------------------------------------|-----------------------------|---------------------------|-------------|---------|
| Composite outcome of all-cause death, stroke and major bleeding | 18 (4.5%)                   | 33 (8.3%)                 | 0.41 (0.22–0.77) | 0.006   |
| All-cause death                       | 10 (2.5%)                   | 18 (4.5%)                 | 0.43 (0.19–0.99) | 0.046   |
| CV death                              | 4 (1.0%)                    | 8 (2.0%)                  | 0.36 (0.10–1.40) | 0.130   |
| Non-CV death                          | 5 (1.3%)                    | 9 (2.3%)                  | 0.43 (0.13–1.40) | 0.160   |
| Stroke                                | 5 (1.3%)                    | 9 (2.3%)                  | 0.60 (0.20–1.80) | 0.370   |
| Major bleeding                        | 7 (1.8%)                    | 11 (2.8%)                 | 0.42 (0.15–1.20) | 0.110   |

AF atrial fibrillation, CI confidence interval, CV cardiovascular, HR hazard ratio
but failed to alter the risk of all-cause death and stroke or transient ischaemic attack [25]. Another meta-analysis of 13 randomised controlled trials comprised of 3856 patients without heart failure also reported no significant difference between catheter AF ablation and medical therapy in terms of all-cause death and stroke [26]. However, patients who received catheter AF ablation had reduced cardiac hospitalisation and less frequent atrial arrhythmia recurrence, at the expense of procedural complications, such as pericardial tamponade; highlighting the need to recognise the invasive nature of AF ablation and to balance any intended benefits with the risk of potential complications [27]. Conversely, a meta-analysis of 9 studies (8 matched population studies and 1 randomised controlled trial) with 241,372 patients with AF found that catheter ablation decreased the risk of death, stroke and hospitalisation for heart failure compared to medical therapy alone [28].

Unlike the aforementioned studies, we investigated the effects of early AF ablation (i.e., within 3 months from diagnosis) in a prospectively enrolled global AF population with a high uptake of oral anticoagulation and found a significant survival benefit in these patients compared to those who received medical therapy alone. While we found a reduction in the risk of all-cause death with early AF ablation, we were unable to attribute this to CV or non-CV death likely owing to the low event rates. Notably, only a minority of patients were treated with early AF ablation and there were significant differences between the groups at baseline. Nonetheless, our results provide further support for the emerging role of early AF ablation and complements existing evidence from the EAST-AFNET 4 trial [9].

Current recommendations from international guidelines advocate that AF ablation should be reserved for patients who have failed at least 1 anti-arrhythmic drug therapy, though it may be considered in selected patients with early forms of AF or heart failure with reduced ejection fraction [5–7]. Healthcare structures in most countries are such that there is often a delay between the diagnosis of AF and specialist review, and/or subsequent referral for consideration of AF ablation. As a result, adoption of early AF ablation is associated with a survival advantage compared to medical therapy alone. Moreover, early AF ablation appeared to provide the greatest benefit compared to other treatments.

**Limitations**

The main limitations of this study are linked to possible misclassification and selection bias due its observational nature; though consecutive enrolment of patients was performed to reduce selection bias. As only a small proportion of patients were treated with early AF ablation, the results of this highly selected group may not be generalisable to the wider AF population. Despite rigorous model adjustment and propensity matching to ensure a balance of comorbidities and medication use between the groups, some residual unmeasured confounders may exist. Therefore, we are unable to prove a cause–effect relationship. In addition, outcomes were analysed according to variables collected at baseline. In this regard, a proportion of patients in the medical therapy group may have been treated with AF ablation following enrolment. This may have attenuated any differences between the groups but serves to provide further strength to our positive findings. Overall, the results of this post-hoc analysis should be treated as hypotheses-generating.

**Conclusions**

Early AF ablation within 3 months from initial diagnosis in a contemporary cohort of patients who were predominantly treated with non-vitamin K antagonist oral anticoagulants was associated with a survival advantage compared to medical therapy alone. Moreover, early AF ablation appeared to provide the greatest benefit compared to other treatments.

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