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Education of healthcare professionals to improve guideline adherence in atrial fibrillation: the STEEER-AF cluster-randomized clinical trial

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Guideline-adherent care is associated with better patient outcomes, but whether this can be achieved by professional education is unclear. Here we conducted a cluster-randomized controlled trial across 70 centers in six countries to understand if a program for the education of healthcare professionals could improve patient-level adherence to clinical practice guidelines on atrial fibrillation (AF). Each center recruited patients with AF seen in routine practice (total $N = 1{,}732$), after which the centers were randomized, accounting for baseline guideline adherence to class I and III recommendations from the European Society of Cardiology on stroke prevention and rhythm control. Healthcare professionals in the intervention centers received a 16-week structured educational program with an average of 9 h of online engagement, whereas those at control centers received no additional education beyond standard practice. For the co-primary stroke prevention outcome, guideline adherence was 63.4% and 58.6% at baseline and 67.5% and 60.9% at 6–9-months follow-up for the intervention and control groups, respectively (adjusted risk ratio 1.10; 95% confidence interval (CI) 0.97 to 1.24; $P = 0.13$). For the co-primary rhythm control outcome, guideline adherence was 21.4% and 20.4% at baseline and 33.9% and 22.9% at follow-up for the intervention and control groups, respectively (adjusted risk ratio 1.51; 95% CI 1.04 to 2.18; $P = 0.03$). The secondary outcome of patient-reported integrated AF management showed a 5.1% improvement in the intervention group compared with the control group (95% CI 1.4% to 8.9%; $P = 0.01$). Thus, while the education of healthcare professionals improved substantial gaps in implementation for rhythm control, it had no significant effect on stroke prevention. ClinicalTrials.gov registration: NCT04396418.

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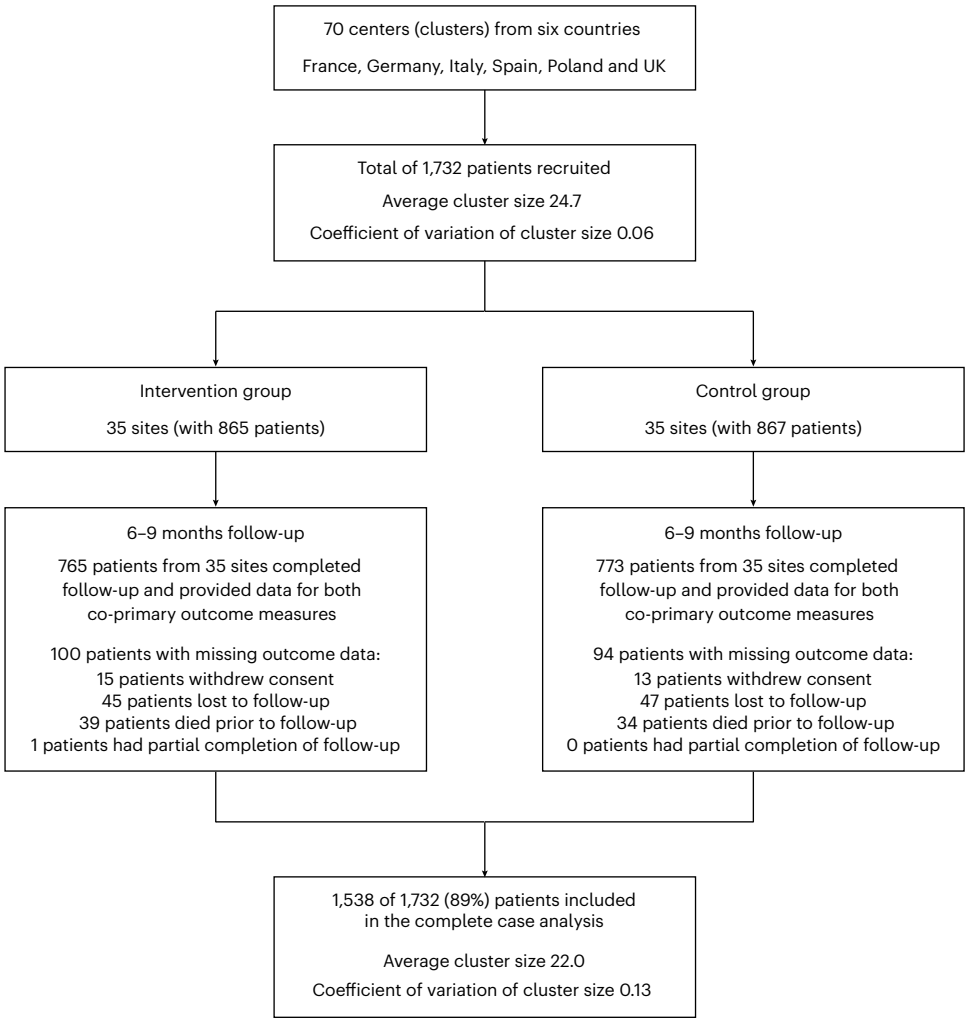

Fig. 1 | STEEER-AF trial flowchart. CONSORT diagram for the centers and patients enrolled in the trial. Each center was randomized only after patient recruitment had been completed, aiming for a maximum of 25 patients per center. A 1:1 randomization to intervention (additional education for healthcare professionals) or control (usual approaches to medical education) was performed using a minimization algorithm to account for country and the cluster-level values for the co-primary outcomes at baseline. All centers randomized to the intervention group received the educational program.

Considerable effort and resources are expended globally to educate and train healthcare professionals to improve outcomes for patients[1]. The effectiveness of these programs is highly variable and dependent on technique, interactivity and subject context[2,3]. Clinical practice guidelines are widely used around the world to standardize care and provide optimal patient management according to the current evidence base. However, implementation of guideline-adherent care is often challenging, especially in conditions with high patient heterogeneity where delivery of the optimal treatment pathway is dependent on individual clinical factors. One such condition is atrial fibrillation (AF), which is already one of the most common cardiovascular conditions and expected to double in prevalence in the coming decades[4,5]. There is a substantial risk of morbidity and mortality associated with AF[6,7], but this is highly variable and requires an individualized approach and often difficult decision-making on best-practice management[8]. Guideline-adherent care for anticoagulation therapy in patients with AF[9,10] has been associated with lower rates of stroke, bleeding and death[11–13].

The extent of guideline implementation is challenging to ascertain in observational research although typically thought to be poor, with numerous barriers implicated such as appropriate education[14–16]. Patient education has the potential to reduce serious adverse events and have a positive impact on quality of life in patients with AF[17]. However, educational interventions directed at healthcare professionals to improve the adherence to cardiovascular guidelines have had limited success[18]. The Stroke prevention and rhythm control Therapy Evaluation of an Educational Program of the European society of cardiology in a Cluster Randomized trial in patients with Atrial Fibrillation (STEEER-AF) trial was designed to robustly determine real-world adherence to clinical practice guidelines and examine the value of an educational intervention directed to a range of healthcare professionals treating patients with AF[19,20]. The primary objective was to establish if the addition of concise structured learning for healthcare professionals could improve patient-level adherence to guidelines for stroke prevention and rhythm control compared with standard practice.

Results

Seventy centers across France, Germany, Italy, Poland, Spain and the UK were included, with center characteristics summarized in Extended Data Table 1. A total of 1,732 patients with AF were recruited, with average cluster size of 24.7 patients (coefficient of variation in cluster size 0.06) (Fig. 1). The mean age of participants was 68.9 years (s.d. 11.7), with 647 (37.4%) women and similar baseline characteristics between the randomized groups (Table 1). The randomization of centers took place only after participant recruitment had closed (between May 2022 and February 2023), with 35 centers allocated to the intervention and 35 to the control. The minimization algorithm ensured that randomization

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Table 1 | Baseline characteristics

Characteristic	Intervention (*N*=865)	Control (*N*=867)	Total (*N*=1,732)
Age at enrollment, mean (s.d.), years	68.7 (11.6)	69.0 (11.7)	68.9 (11.7)
Women, *n* (%)	340 (39.3%)	307 (35.4%)	647 (37.4%)
Type of AF			
First diagnosed	147 (17.0%)	135 (15.6%)	282 (16.3%)
Paroxysmal	340 (39.3%)	316 (36.4%)	656 (37.9%)
Persistent	228 (26.4%)	256 (29.5%)	484 (27.9%)
Long-standing persistent	38 (4.4%)	28 (3.2%)	66 (3.8%)
Permanent	112 (12.9%)	132 (15.2%)	244 (14.1%)
Duration of AF			
≤1 year	346 (40.0%)	336 (38.8%)	682 (39.4%)
1–5 years	256 (29.6%)	286 (33.0%)	542 (31.3%)
>5 years	263 (30.4%)	245 (28.3%)	508 (29.3%)
Rhythm on electrocardiogram[a]			
Sinus rhythm	401 (46.4%)	359 (41.4%)	760 (43.9%)
AF	407 (47.1%)	436 (50.3%)	843 (48.7%)
Diagnosis of COVID-19	150 (17.3%)	122 (14.1%)	272 (15.7%)
Hypertension requiring treatment	588 (68.0%)	619 (71.4%)	1,207 (69.7%)
Diabetes mellitus	181 (20.9%)	205 (23.6%)	386 (22.3%)
History of stroke or TIA	74 (8.6%)	102 (11.8%)	176 (10.2%)
History of myocardial infarction	86 (9.9%)	80 (9.2%)	166 (9.6%)
Diagnosis of heart failure	272 (31.4%)	217 (25.0%)	489 (28.2%)
Left-ventricular ejection fraction			
Preserved (≥50%)	645 (74.6%)	643 (74.2%)	1,288 (74.4%)
Mildly reduced (40–49%)	104 (12.0%)	103 (11.9%)	207 (12.0%)
Reduced (<40%)	116 (13.4%)	121 (14.0%)	237 (13.7%)
Resting heart rate on ECG, beats min^{-1} (s.d.)[b]	78.8 (22.9)	79.7 (23.4)	79.2 (23.2)
Systolic blood pressure, mmHg (s.d.)[b]	131.7 (18.7)	132.0 (20.7)	131.8 (19.7)
Diastolic blood pressure, mmHg (s.d.)[b]	77.5 (11.8)	78.2 (13.1)	77.8 (12.5)
Body mass index, kg/m^2 (s.d.)[b]	28.9 (6.1)	28.3 (5.5)	28.6 (5.8)
Creatinine, μmol/L (s.d.); mg dL^{-1} (s.d.)[b]	121.7 (285.3); 1.38 (3.23)	124.0 (190.2); 1.40 (2.15)	122.8 (243.4); 1.39 (2.75)
Taking an oral anticoagulant at baseline	779 (90.1%)	764 (88.1%)	1543 (89.1%)
Receiving antiarrhythmic drugs at baseline	266 (30.8%)	285 (32.9%)	551 (31.8%)
Catheter ablation performed before baseline	201 (23.2%)	142 (16.4%)	343 (19.8%)

COVID-19, coronavirus disease 2019; TIA, transient ischemic attack. [a]129 patients had another rhythm or pacing at baseline. [b]Missing data: 20 patients for ECG heart rate, 52 for systolic blood pressure, 53 for diastolic blood pressure, 38 for body mass index and 205 for creatinine.

was balanced within each country for baseline guideline adherence (Extended Data Table 2).

Baseline adherence to guidelines

Guideline adherence was evaluated for each individual patient using the pre-published decision tree algorithm[20]. The observed guideline adherence at baseline to all relevant class I and III European Society of Cardiology (ESC) recommendations for stroke prevention overall was 61.0% (intracluster correlation coefficient 0.11). In the intervention group, 548 patients (63.4%) were fully adherent for stroke prevention, with 508 (58.6%) in the control group. For rhythm control, overall guideline adherence at baseline was 21.0% (intracluster correlation coefficient 0.26); there were 185 patients (21.4%) in the intervention group fully adherent and 178 (20.5%) in the control group.

Co-primary outcomes

The median time between randomization and completion of the follow-up electronic case report forms (eCRF) was 7.7 months (interquartile range (IQR) 5.9–8.8 months). For stroke prevention at follow-up, guideline adherence increased to 516 patients (67.5%) in the intervention group and 471 (60.9%) for control (Table 2 and Fig. 2). The risk ratio for intervention versus control after adjusting for baseline values, country and clustering by center was 1.10 (95% confidence interval (CI) 0.97 to 1.24; $P = 0.13$). The corresponding adjusted risk difference was 6.0% (95% CI −1.5% to 13.4%; $P = 0.12$). For rhythm control at follow-up, guideline adherence increased to 259 patients (33.9%) in the intervention group and 177 (22.9%) for control. The adjusted risk ratio for intervention versus control was significant at 1.51 (95% CI 1.04 to 2.18; $P = 0.03$), with adjusted risk difference 11.2% (95% CI 1.6 to 20.7; $P = 0.02$).

Secondary outcomes

Prescriptions of oral anticoagulation according to class I and class I/IIa indications were high (94% and 92% at baseline) and not impacted by the intervention (risk ratio 1.02, 95% CI 0.99 to 1.05; $P = 0.26$ and 1.01, 95% CI 0.98 to 1.05; $P = 0.40$, respectively; Table 2 and Fig. 2). The proportions of class I and III stroke prevention and rhythm control guidelines with adherence were consistent with the co-primary outcomes (adjusted mean difference in proportions of 3.2% for stroke prevention, 95% CI −0.1% to 6.5%; $P = 0.06$ and 5.8% for rhythm control, 95% CI 0.4% to 11.3%; $P = 0.04$). The proportion of applicable patients failing at each point in the guideline decision tree was variable, with key factors for both stroke prevention (Extended Data Table 3) and rhythm control (Extended Data Table 4) being appropriate evaluation and patient indication(s) for the therapeutic approach. Patients in the intervention group reported a significant 5.1% improvement over control in the proportion attaining integrated AF management (95% CI 1.4% to 8.9%; $P = 0.01$). There were no differences between groups in patient-reported quality of life.

Process outcomes

Learners spent a median of 9.2 h (IQR 6.4–13.4 h) on the online platform (Extended Data Table 5), with a high level of involvement with required reading (mean 94.8%, s.d. 9.7) and with their commitment to change local practice (97.8% implemented). The expert trainer was engaged by 158 of 195 learners (81.0%). The proportion of correct answers to multiple-choice questions increased with the intervention, from a mean of 65.2% before the education (s.d. 18.3%) to 72.0% after (s.d. 19.9%) (post-hoc $P < 0.001$).

Subgroup and sensitivity analyses

Exploratory analyses indicated consistent effects for the co-primary outcomes across subgroups for patient age and baseline thromboembolic risk (Fig. 3). Effects were noted to vary by country for stroke prevention (P interaction = 0.01; Extended Data Table 6) and sex for rhythm control ($P_{interaction} = 0.01$; Extended Data Table 7). The sensitivity analysis confirmed robust findings for both co-primary outcomes (Extended Data Fig. 1).

Discussion

STEER-AF demonstrates that adherence to the 'must-do' and 'must-do not' guideline recommendations in routine practice is poor, in

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Table 2 | Primary and secondary outcomes

Outcome	Intervention		Control		Risk ratio (95% CI); *P* value	Risk or mean difference (95% CI); *P* value
	Baseline (*N*=865)	Follow-up (*N*=765)	Baseline (*N*=867)	Follow-up (*N*=773)		
Co-primary outcomes						
Stroke prevention guideline adherence, *n* (%)	548 (63.4%)	516 (67.5%)	508 (58.6%)	471 (60.9%)	1.10 (0.97 to 1.24), *P*=0.13	6.0% (−1.5% to 13.4%), *P*=0.12
Rhythm control guideline adherence, *n* (%)	185 (21.4%)	259 (33.9%)	178 (20.5%)	177 (22.9%)	1.51 (1.04 to 2.18), *P*=0.03	11.2% (1.6% to 20.7%), *P*=0.02
Secondary outcomes						
Anticoagulation class I indication, *n* (%)[a]	608 (94.4%)	559 (97.2%)	602 (92.8%)	556 (95.7%)	1.02 (0.99 to 1.05), *P*=0.26	1.6% (−1.1% to 4.3%), *P*=0.26
Anticoagulation class I and IIa, *n* (%)[b]	723 (93.1%)	649 (94.5%)	717 (91.2%)	653 (93.3%)	1.01 (0.98 to 1.05), *P*=0.40	1.3% (−1.7% to 4.3%), *P*=0.40
Proportion of relevant guidelines with adherence for stroke prevention, mean (s.d.)	0.86 (0.21)	0.87 (0.20)	0.82 (0.25)	0.83 (0.25)	–	3.2% (−0.1% to 6.5%), *P*=0.06
Proportion of relevant guidelines with adherence for rhythm control, mean (s.d.)	0.67 (0.27)	0.72 (0.28)	0.67 (0.25)	0.66 (0.27)	–	5.8% (0.4% to 11.3%), *P*=0.04
Patient-reported integrated AF management, mean (s.d.)	0.70 (0.28)	0.77 (0.26)	0.64 (0.29)	0.71 (0.26)	–	5.1% (1.4% to 8.9%), *P*=0.01
Patient-reported quality of life						
EQ-5D-5L index score, mean (s.d.)	0.84 (0.20)	0.81 (0.28)	0.83 (0.21)	0.80 (0.27)	–	0.00 (−0.03% to 0.03%), *P*=0.95
Visual analog scale, mean (s.d.)	67.3 (19.3)	71.6 (18.5)	68.6 (19.1)	71.6 (16.7)	–	0.3 (−1.7% to 2.2%), *P*=0.79

All risk ratios, risk differences and mean differences are for intervention versus control at follow-up, adjusted for baseline values, minimization criteria (country, baseline guideline adherence for stroke prevention and rhythm control) and clustering by center. Risk differences and differences in proportions are presented in percentage points. [a]The proportion of participants receiving anticoagulation according to the class I ESC recommendation (women with CHA_2DS_2-VASc score ≥3 and men ≥2); intervention *N*=644 at baseline and *N*=575 at follow-up control and *N*=649 at baseline and *N*=581 at follow-up. [b]The proportion of participants receiving anticoagulation according to Class I or IIa ESC recommendations (women with CHA_2DS_2-VASc score ≥2 and men ≥1) intervention; *N*=777 at baseline and *N*=687 at follow-up and control *N*=786 at baseline and *N*=700 at follow-up.

particular the implementation of rhythm control in patients with AF. The educational intervention for healthcare professionals in the STEEER-AF trial resulted in a 51% relative increase (11.2% absolute increase) in patient-level adherence to recommendations for rhythm management. This benefit resulted from a relatively short and targeted educational program in addition to, and compared against, existing approaches for continued medical education. We saw no significant difference for guideline adherence to recommendations on the prevention of stroke and thromboembolism in AF.

Findings for the secondary outcomes were consistent with the co-primary results and help explain the divergence in results of STEEER-AF across the two components of AF care. The prescription of oral anticoagulants, which form the basis of stroke prevention in the majority of patients, was high. A key patient-reported secondary outcome demonstrated the intervention improved integration of care, with education, shared decision-making and the empowerment of patients being important facets of delivering optimal and individualized rhythm control.

Overall guideline adherence in the STEEER-AF trial was substantially lower than anticipated from prior observational research, where self-reporting can introduce response bias[21]. Our study suggests the need for a reappraisal of strategies to improve the delivery of patient care and enhance guideline adoption by guideline writers, professional associations, medical educators and policy makers. Prior evidence for improving guideline-adherent care is largely restricted to the use of oral anticoagulation in patients with AF, including a cluster trial which demonstrated higher rates of anticoagulant prescription with education compared with usual care (odds ratio 3.28, 95% CI 1.67 to 6.44), and lower rates of the secondary outcome of incident stoke in the intervention group (hazard ratio 0.48, 95% CI 0.23 to 0.99)[22]. Of note, that trial was performed in Argentina, Brazil, China, India and Romania, with 68% of patients prescribed an oral anticoagulant at baseline. On the basis of the findings from STEEER-AF and these other studies, implementing approaches to guideline-adherent management is likely to require focused education that is tailored not only to a specific delivery gap, but also the needs of the individual healthcare professional in the context of the local healthcare environment. Although we observed an improvement in rhythm control adherence, additional approaches are clearly needed to tailor education for patients and healthcare professionals, further improving guideline adherence and patient outcomes. A trial of shared decision-making did not identify any benefit for anticoagulation use in AF or related safety endpoints[23], although it could be argued that shared care is dependent on adequate levels of education for both patients and healthcare staff.

This trial was designed to test the value of education specifically for healthcare professionals, as prior trials have already demonstrated that patient education, with the right approach and format, can yield benefits for patients with AF[17,24]. We accounted for a range of inherent biases that are common when assessing the value of an educational intervention. Recruitment of participants at each site was completed before randomization could take place, and extraction of the clinical pathway for each patient was determined objectively rather than from the healthcare professional involved. Any imbalance in randomization was minimized using the cluster-level adherence of the co-primary outcomes calculated at baseline, and the algorithm to determine guideline adherence was pre-defined but not disclosed. Although we were unable to blind healthcare professionals to the randomized allocation at their center, all coordinating staff were kept blinded. Care was taken to avoid any contamination of trial groups by geographically dispersing sites across each country. The enrolled participants were a good reflection of patients with AF seen in real-world cohort studies[25–27]. Despite considerable external events (such as the coronavirus pandemic, which

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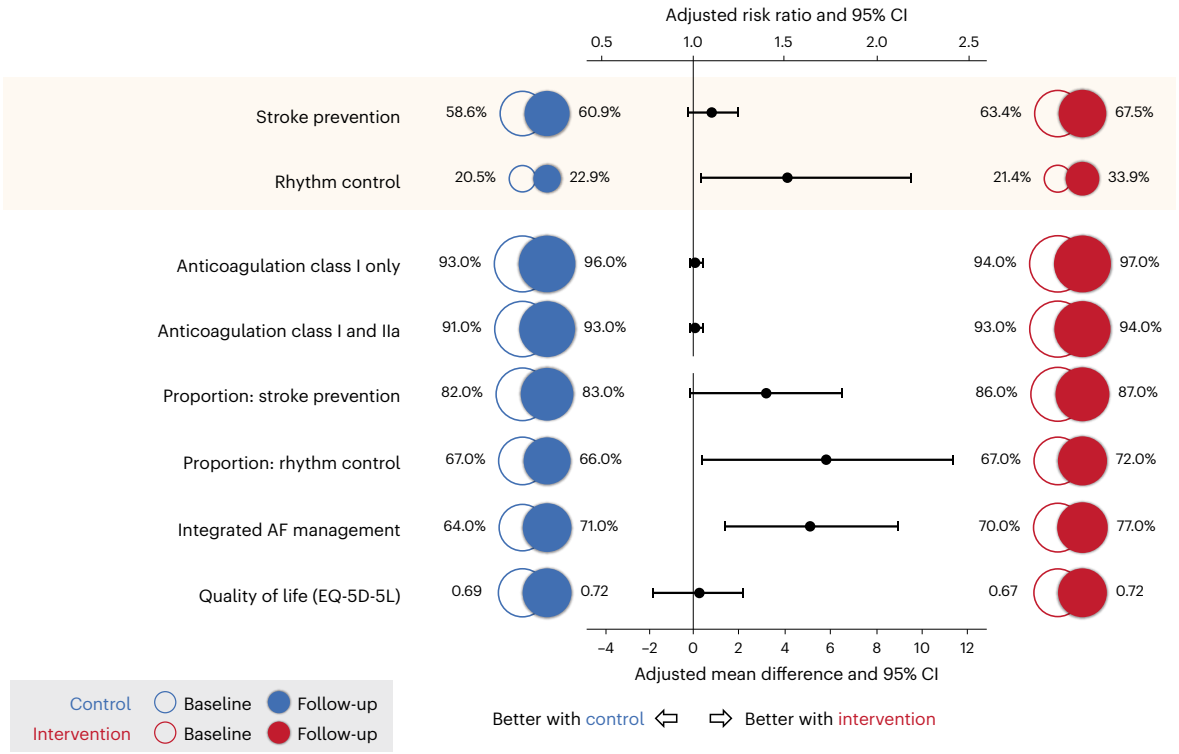

Fig. 2 | Co-primary and secondary outcomes. Outcomes are presented as a risk ratio or adjusted mean difference for intervention versus control, with circles for point estimates and capped lines for the 95% CI adjusted for baseline values, country and clustering by center. For each outcome, absolute values are indicated at baseline and follow-up for each of the groups. The shaded area indicates the co-primary trial outcomes.

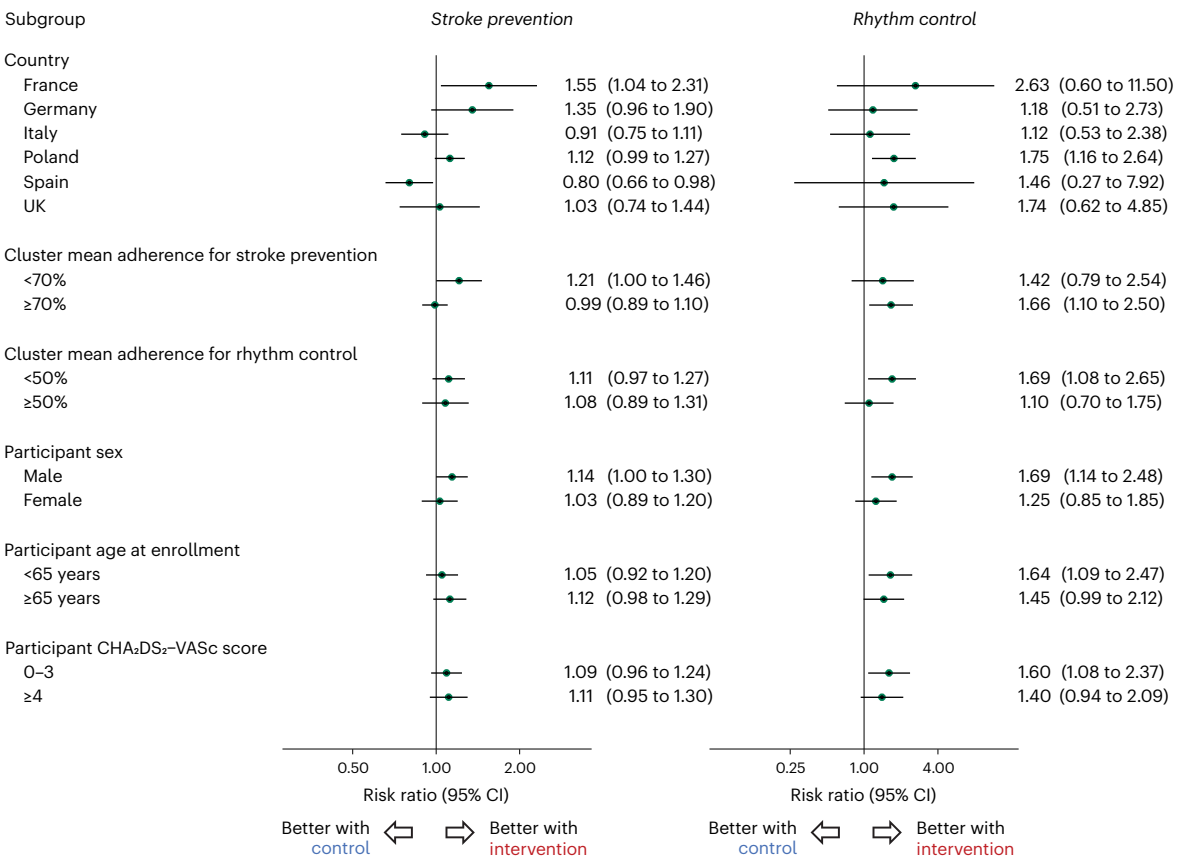

Fig. 3 | Subgroup analyses for co-primary outcomes. Prespecified subgroup analyses are presented for the two co-primary outcomes, with circles for point estimates of risk ratios and lines for the 95% CI.

precluded in-person training of healthcare professionals[20]), there was good engagement with the bespoke online educational platform that was specifically developed to achieve sustainable behavioral change, supported by national trained experts.

The findings of STEEER-AF on targeted education for healthcare professionals, combined with past research on targeted education of patients, would suggest an important opportunity to achieve clinical and societal benefit through scalable multifactorial interventions. These approaches need to be part of broader quality improvement efforts that are ongoing in local environments, national policy-making and also on the international level (for example, World Health Organization Quality of Care in line with the United Nations Sustainable Development Goals; the European Commission's European Education Area initiative; and various strategies on education and quality improvement by the Association of American Medical Colleges).

There are limitations that warrant consideration. First, the trial was established to ascertain the value of additional education; hence both intervention and control groups could engage in whatever usual approaches were available to meet their educational needs. As a pragmatic trial embedded within clinical practice, it was not possible to determine or account for varying levels of education within or across the six countries[20]. However, all the countries involved are members of the ESC and European Heart Rhythm Association (EHRA), which have the same core curriculum for cardiology that includes AF[28]. Second, the co-primary outcomes were focused on determining adherence to class I and III recommendations (that is, where there is no dispute that treatments are either effective or harmful). This leaves out many areas of routine practice that are important to patient care. Although the ESC guidelines have contribution from the national cardiac societies in each country, there can be different applications of best practice locally. The STEEER-AF was deployed across 70 centers in six countries so that regional or national differences in implementation were accounted for by design. Third, the trial was conducted in the European secondary care setting, and the findings may not apply to primary care, lower-income areas or environments with a different approach to professional development. Although care was taken to engage a broad range of centers within each country, these sites did agree to participate, which may indicate an existing interest in quality improvement. The trial was powered to detect clinically relevant changes in guideline adherence within the first year, rather than clinical outcomes, which will be explored in future reports. Finally, the sample size assumptions deviated from actuality (lower baseline adherence using our objective trial assessment than expected from available observational data), and so the trial may be underpowered to detect the anticipated differences in stroke prevention management.

In summary, the STEEER-AF trial showed that guideline adherence in patients with AF is poor. Focused education for healthcare professionals did not demonstrate positive effects on guideline-adherent care for both co-primary outcomes. Improvement was noted in rhythm control where guideline implementation was particularly low, but with no significant effect on recommendations addressing stroke prevention where anticoagulation use was near-optimal.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgments, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41591-025-03751-2.

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Methods

Trial design and oversight

STEEER-AF is an international, pragmatic, two parallel group, cluster-randomized controlled trial, supported in its design by a patient and public involvement team[19,20]. The full protocol is available in the additional files (no changes after trial commencement). A cluster design was the most suitable approach for testing the educational program for healthcare professionals, as effect contamination could occur with individual patient-level randomization. The trial was sponsored by the ESC, with contribution from the EHRA and ESC Council on Stroke. A trial management group and trial steering committee directed the program, with oversight provided by an independent data monitoring committee and strategic oversight committee (Extended Data Table 8).

Ethics and inclusion statement

The trial was approved by ethical review committees in each country and local research governance authorities for each center. A patient and public involvement team aided with the design of the concept and drafting of patient-facing material to improve inclusivity. The trial was prospectively registered at clinicaltrials.gov (NCT04396418).

Participating centers, investigators and patients

The cluster-level selection criteria were a site that agreed to participation, enrollment and follow-up of patients and randomization of the site to the intervention or control for healthcare practitioners at that center. A national coordinator for each country was tasked with engaging a broad range of centers in their country that treat patients with AF and were representative of usual care, and selected a local principal investigator (PI) for each site. Healthcare professionals were nominated by the PI from across different specialties within each center to act as investigators, including trainee and experienced doctors, nurses and allied health professionals, with no more than a third of investigators seeing patients with AF on a daily basis. Each investigator recruited patients who were under their routine clinical care, with a maximum of 25 patients per center. Participants required a clinical diagnosis of AF and the ability to provide written informed consent. Patient-level exclusion criteria were age under 18 years, pregnancy or planning to be pregnant, breastfeeding at the time of consent, participation in another clinical trial of an investigational medicinal product or device and life expectancy of less than 2 years. Participants were followed up in routine practice by the same investigator at 6–9 months after each center was randomized. Where that was not possible (for example, the healthcare professional had left that institution), follow-up was performed by another investigator from that center.

Randomization and masking

Centers were randomized only after they had finished participant recruitment and fully completed baseline eCRF, managed by an independent contract research organization (Soladis). To provide objective assessment of the clinical care received, the eCRF was completed by the PI who was not involved in the care pathway for recruited participants. The eCRF was completed after the interaction between patient and investigator using all available clinical and/or electronic documentation. The PI received queries for any missing elements on the eCRF forms. Algorithms were used to objectively determine guideline adherence at the level of each patient. These algorithms were finalized and approved before the first randomization and are available in an open-access publication (https://doi.org/10.1093/europace/euae178)[20].

The algorithms were applied to the eCRF data for each participant. Guideline adherence was not disclosed to the PI or investigators to avoid influencing follow-up. Randomization was performed by the Birmingham Clinical Trials Unit (University of Birmingham), with a 1:1 ratio to intervention or control using a minimization algorithm to ensure balance by (1) country, (2) cluster-specific mean for class I and III guideline adherence to stroke prevention at baseline (<70 and ≥70%) and (3) cluster-specific mean for class I and III guideline adherence to rhythm control at baseline (<50 and ≥50%). The randomized allocation was performed by the trial statistician blinded to the identity of the centers. Owing to the nature of the intervention, it was not possible to blind investigators to the randomized allocation. The trial steering committee were blinded to the randomized allocation of centers during the entire trial.

Intervention and control

The educational intervention for healthcare professionals was targeted toward stroke prevention, rhythm control and integrated care in AF, with learning modules translated to the language for each participating country. Investigators from centers randomized to the intervention group were enrolled in an additional educational program lasting 16 weeks, primarily consisting of online resources. The intervention was designed by the ESC and EHRA, taking advantage of decades of work in methods applied to better educate healthcare professionals[1], and utilizing educational theory and learning frameworks to achieve sustainable behavioral change[29]. The educational intervention was developed with the assistance of an independent medical education agency (Liberum IME), with further details published previously[20].

The web-based platform included course materials, interaction with peers, case-based learning, videos and additional reading (providing direct educational benefit). Learners were supported by an expert trainer from that country that assisted with case-based examples of appropriate guideline-adherent care, and helped them to generate a 'commitment to change' plan that could be implemented locally to improve the management of patients with AF (indirect benefits from the educational program).

Centers randomized to the control group did not receive the additional educational intervention, but investigators were able to continue any existing healthcare professional development.

Outcomes

Full details on the outcomes are presented in the protocol. The co-primary outcomes were guideline adherence for stroke prevention and rhythm control on the basis of class I and III ESC recommendations from the 2016 and 2020 guidelines on the management of AF[9,10]. The prespecified secondary outcomes were the proportion of guidelines with adherence for stroke prevention and rhythm control, and the proportion of participants receiving anticoagulation according to class I and class I/IIa indications. The key patient-reported outcome was a score evaluating eight domains of integrated AF management, completed by the patient after their consultation with the investigator. Patient-reported quality of life was determined using the EuroQol EQ-5D-5L questionnaire (index values and visual analog scale). Process outcomes in the intervention group addressed the fidelity of the educational program. Ongoing follow-up is in process to collect future clinical outcomes.

Sample size

Sample size calculations for the stroke prevention co-primary outcome assumed that 80% of control patients expected to receive guideline-adherent care based on available observational studies[30,31]. A relative increase of 10% was considered clinically relevant (absolute increase from 80% to 88%). For this co-primary outcome, power was 85% based on an intracluster correlation coefficient of 0.04 (refs. 22,32), two-sided alpha 0.05, cluster size of 25 patients, coefficient of variation in cluster size 0.20, 70 clusters and 10% loss of patients to follow-up. For the rhythm control co-primary outcome, estimates of guideline-adherent care for rhythm control in the control group were 50% (refs. 30,33). Using the same assumptions as the stroke prevention co-primary outcome, the power to detect an absolute increase from 50% to 61% was 85%.

Statistical analysis

A statistical analysis plan was finalized and approved before unlocking the trial database (see additional file). All analyses were performed according to the intention-to-treat principle (according to the randomized allocation). The primary comparison was between the centers (clusters) randomized to the intervention group and those randomized to the control group. All model-based analyses were adjusted for minimization criteria (country and baseline guideline adherence for stroke prevention and rhythm control), the baseline of that variable (where appropriate) and clustering for center. All analyses were performed on patient-level data and used patient-level covariate adjustments. For each of the co-primary outcomes, we fitted a generalized linear mixed model using the binomial distribution and logit link (with robust standard error), followed by marginal standardization to estimate the risk ratio and risk difference. Type I error control is not required for co-primary endpoints[34]. Statistical analyses for the co-primary outcomes were double-coded by an independent statistician in a separate statistical package (Stata; StataCorp) to the analyses conducted by the senior statistician (SAS; SAS Institute). Prespecified subgroup analyses for the co-primary outcomes were the minimization variables and participant age, sex and CHA_2DS_2-VASc score at baseline (with 2 points for age ≥75 years and prior stroke, transient ischemic attack or systematic embolus, and 1 point for chronic heart failure, hypertension, diabetes mellitus, vascular disease, age ≥65 years or female sex). An additional planned subgroup analysis according to the modified EHRA symptom classification score was not pursued owing to missing data for this variable. Effects within these subgroups were examined by including the relevant subgroup by intervention interaction term. To examine the possible impact of any missing data on the co-primary outcome results, a prespecified sensitivity analysis explored whether missing outcomes were 'missing not at random' using a tipping point approach. Secondary outcomes with binary data were analyzed using the same methods as described for the co-primary outcomes, and differences in proportions were analyzed using a fractional regression model with logit link and cluster-robust standard errors. Secondary outcomes with continuous data were analyzed using mixed effects linear regression to estimate the adjusted mean difference.

Role of the funding source

The ESC and EHRA (not-for-profit professional organizations) contributed to the study design and data collection. The external funders provided educational grants to the ESC and had no role in study design, data collection, data analysis, data interpretation or writing of the report.

Reporting frameworks

The study is reported according to the cluster randomized trial extension of the CONSORT checklist (see additional file).

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

Anonymized summary data will be made available for noncommercial purposes on request to the corresponding author, after completion and publication of clinical follow-up and secondary paper (D.K.; d.kotecha@bham.ac.uk; 90-day response time for decisions following review by the STEEER-AF trial management group).

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Author contributions

Statistical analysis was performed by S.M. and Y.S., who had full access to the data and verified its integrity. The manuscript was drafted by D.K. and S.M. All other principal authors were members of the trial steering committee and edited the manuscript for intellectual content. D.K. and I.C.v.G. were the chief investigators and were responsible for the decision to submit. See Extended Data Tables 8 and 9 for all other contributions.

Competing interests

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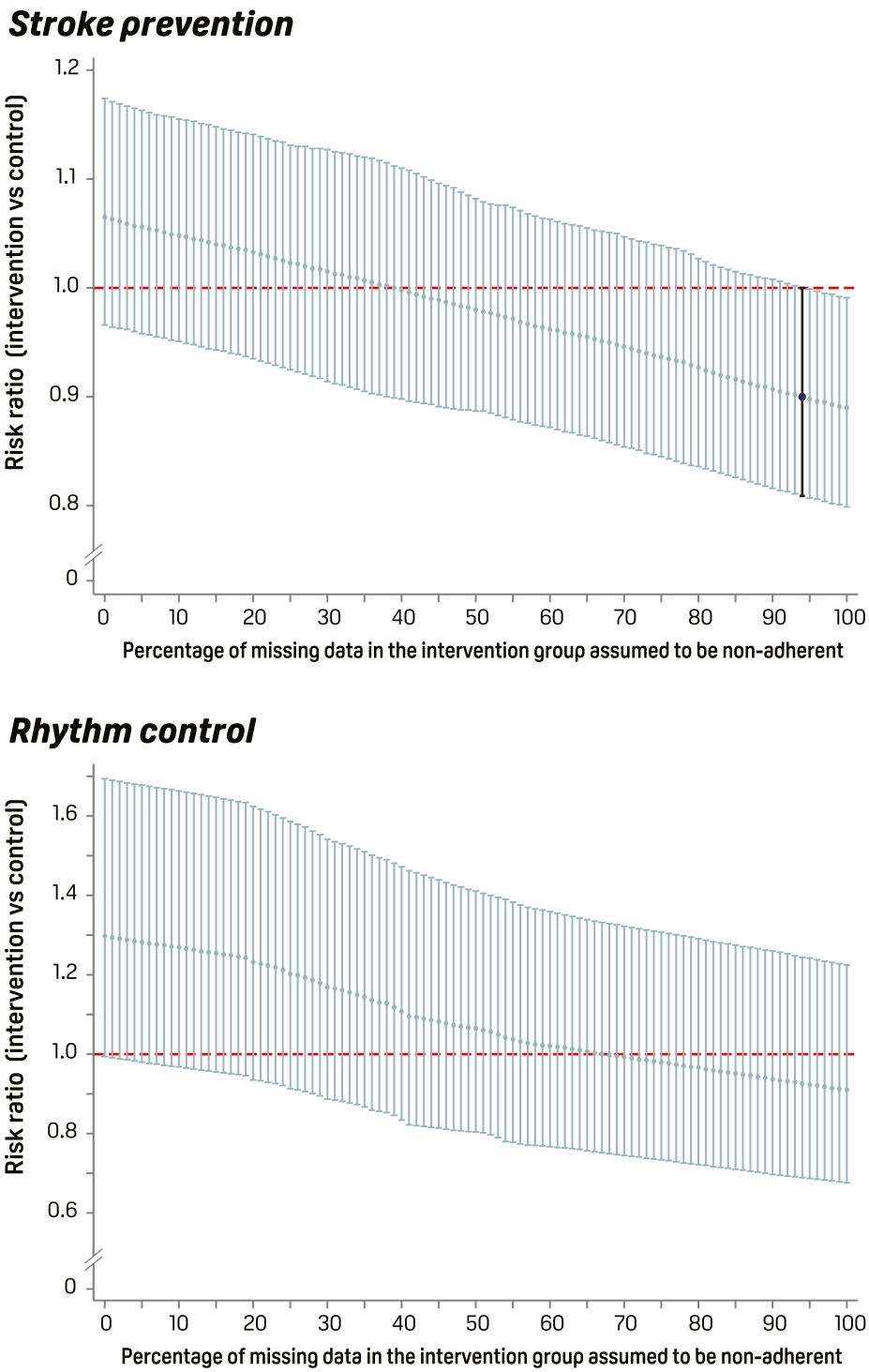

Extended Data Fig. 1 | Tipping Point Sensitivity Analyses. Graphs show the tipping point at which results will favor the control arm if participants with missing data at follow-up are imputed as being non-adherent to guidelines in the intervention arm and adherent in the control arm. Panel A for the stroke prevention co-primary outcome demonstrates that the tipping point only occurs after 95% of the missing data is imputed as non-adherent, and all of the missing data in the control arm are imputed as adherent. Panel B for the rhythm control co-primary outcome demonstrates that even if all missing data is imputed as non-adherent in the intervention arm and adherent in the control arm, this will still not provide a result that statistically favors the control group.

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Extended Data Table 1 | Characteristics of Included Centers

Centre characteristic	N=70
Number of beds for overnight stay, median (interquartile range)	700 (177 to 1180)
Centre status [1]	
General or secondary care hospital, n (%)	28 (40.0%)
Tertiary care hospital, n (%)	18 (25.7%)
University Hospital, n (%)	39 (55.7%)
Other or not a hospital, n (%)	4 (5.7%)
Facilities at center [1]	
Intensive care unit, n (%)	64 (91.4%)
Coronary care unit, n (%)	57 (81.4%)
Cardiac surgery, n (%)	41 (58.6%)
AF services at center [1]	
AF unit/clinic, n (%)	55 (78.6%)
AF 'Heart Team' [2], n (%)	43 (61.4%)
Catheter ablation for AF, n (%)	52 (74.3%)
Thoracoscopic AF ablation, n (%)	19 (27.1%)
Maze open surgery AF ablation, n (%)	33 (47.1%)

[1]Not mutually exclusive; multiple possible for each center. [2]Multidisciplinary complex case review by cardiologists, electrophysiologists, AF surgeons or other relevant specialists. AF = atrial fibrillation.

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Extended Data Table 2 | Randomization of Centers

Minimization variable	Intervention (N=35)	Usual care (N=35)	Total centers (N=70)	Total patients (N=1732)
Country				
France	7	8	15	375 (21.7%)
Germany	6	5	11	275 (15.9%)
Italy	4	4	8	200 (11.5%)
Poland	6	6	12	300 (17.3%)
Spain	5	6	11	275 (15.9%)
UK	7	6	13	307 (17.7%)
Cluster-specific mean for class I and III guideline adherence to stroke prevention at baseline				
<70%	21	21	42	1032 (59.6%)
≥70%	14	14	28	700 (40.4%)
Cluster-specific mean for class I and III guideline adherence to rhythm control at baseline				
<50%	30	30	60	1492 (86.1%)
≥50%	5	5	10	240 (13.9%)

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Extended Data Table 3 | Guideline Non-Adherence For Stroke Prevention

Decision tree failure point description	n/N (%) failed	Applicable guidance [1]
Stroke prevention in patients with a CHA_2DS_2-VASc score ≤2 in women or ≤1 in men		
CHA_2DS_2-VASc score was not used for stroke risk prediction and there was no additional indication for anticoagulation besides AF	60/368 (16%)	For stroke risk assessment, a risk-factor-based approach is recommended, using the CHA_2DS_2-VASc clinical stroke risk score to initially identify patients at 'low stroke risk' (CHA_2DS_2-VASc score = 0 in men, or 1 in women) who should not be offered antithrombotic therapy.
Patients not on anticoagulation but taking antiplatelets which was not due to "Acute coronary syndrome", "Recent PCI" or "Other acute vascular event"	7/8 (88%)	Antiplatelet therapy alone (monotherapy or aspirin in combination with clopidogrel) is not recommended for stroke prevention in AF.
Patients on anticoagulation without additional stroke risk factors (i.e., not scheduled to receive cardioversion or ablation; no additional indication besides AF for anticoagulation; CHA_2DS_2-VASc score 0 if male or 1 if female; not having a mechanical heart valve).	40/241 (17%)	For stroke risk assessment, a risk-factor-based approach is recommended, using the CHA_2DS_2-VASc clinical stroke risk score to initially identify patients at 'low stroke risk' (CHA_2DS_2-VASc score = 0 in men, or 1 in women) who should not be offered antithrombotic therapy.
Patients on anticoagulation and taking antiplatelets but not due to "Acute coronary syndrome", "Recent PCI" or "Other acute vascular event"	1/2 (50%)	There is limited evidence to support the combination therapy solely for stroke prevention in AF, with no effect on reductions in stroke, myocardial infarction, or death, but with a substantial increase in the risk of major bleeding and intracranial hemorrhage.
Patient on VKA where TTR was kept as high as possible and closely monitored but when examining the INR values, at least one value was <2.0.	3/7 (43%)	If a VKA is used, a target INR of 2.0 - 3.0 is recommended, with individual TTR≥70%.
Patient on VKA where TTR was not kept as high as possible and closely monitored, and less than 3 values for INR were provided.	6/6 (100%)	If a VKA is used, a target INR of 2.0 - 3.0 is recommended, with individual TTR≥70%.
Patients taking DOAC therapy when they have either moderate-to-severe mitral stenosis or have a mechanical heart valve.	2/228 (1%)	DOACs are contraindicated in patients with a prosthetic mechanical valve. Use of DOACs is not recommended in patients with AF and moderate-to-severe mitral stenosis.
Patient given incorrect dose of apixaban.	6/99 (6%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of dabigatran.	1/21 (5%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of edoxaban.	5/32 (16%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of rivaroxaban.	3/76 (4%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Stroke prevention in patients with a CHA_2DS_2-VASc score ≥3 in women or ≥2 in men		
CHA_2DS_2-VASc score was not used for stroke risk prediction and there was no additional indication besides AF for anticoagulation.	237/1170 (19%)	For stroke risk assessment, a risk-factor-based approach is recommended, using the CHA_2DS_2-VASc clinical stroke risk score to initially identify patients at 'low stroke risk' (CHA_2DS_2-VASc score = 0 in men, or 1 in women) who should not be offered antithrombotic therapy.
Taking antiplatelets for stroke prevention and not on anticoagulation.	8/16 (50%)	Antiplatelet therapy alone (monotherapy or aspirin in combination with clopidogrel) is not recommended for stroke prevention in AF.
Patients not on anticoagulation with no absolute contraindication to anticoagulation and existing left atrial appendage occlusion/excision which was either performed with thoracoscopic clipping/excision or open surgery clipping/excision.	1/3 (33%)	OAC is recommended for stroke prevention in AF patients with CHA_2DS_2-VASc score ≥2 in men or ≥3 in women. Long-term OAC is recommended in patients after AF surgery and appendage closure, based on the patient's thrombo-embolic risk assessed with the CHA_2DS_2-VASc score.
Patients not on anticoagulation that also have no absolute contraindication to anticoagulation and were not hospitalized due to stroke or TIA.	41/41 (100%)	OAC is recommended for stroke prevention in AF patients with CHA_2DS_2-VASc score ≥2 in men or ≥3 in women.
Patients on anticoagulation and were hospitalized due to stroke but then anticoagulated with heparin or low-molecular-weight heparin.	2/4 (50%)	In AF patients presenting with acute ischemic stroke, very early anticoagulation (<48 h) using UFH, LMWH, or VKAs is not recommended.
Patient on VKA where TTR was kept as high as possible and closely monitored, but when examining the INR values, at least one value was <2.0.	12/61 (20%)	If a VKA is used, a target INR of 2.0 - 3.0 is recommended, with individual TTR≥70%.
Patient on VKA where TTR was not kept as high as possible and closely monitored, and less than 3 values for INR were provided.	54/54 (100%)	If a VKA is used, a target INR of 2.0 - 3.0 is recommended, with individual TTR≥70%.
Patient on VKA where TTR was not kept as high as possible and closely monitored, but where at least 3 INR values were given, not all INR values were within range (taking into account whether patient had a mechanical heart valve or not).	4/4 (100%)	If a VKA is used, a target INR of 2.0 - 3.0 is recommended, with individual TTR≥70%.
Patients taking DOAC when they have either moderate-to-severe mitral stenosis or have a mechanical heart valve.	10/998 (1%)	DOACs are contraindicated in patients with a prosthetic mechanical valve. Use of DOACs is not recommended in patients with AF and moderate-to-severe mitral stenosis.
Patient given incorrect dose of apixaban.	70/513 (14%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of dabigatran.	4/94 (4%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of edoxaban.	22/128 (17%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.
Patient given incorrect dose of rivaroxaban.	56/263 (21%)	DOAC therapy should be optimized based on the efficacy and safety profile of each DOAC in different patient subgroups.

Table presents data for failure points with any number of applicable patients, as determined using the pre-published guideline decision tree algorithm [https://doi.org/10.1093/europace/euae178][20]. [1]From the European Society of Cardiology guidelines for the management of atrial fibrillation [https://doi.org/10.1093/eurheartj/ehw210 and https://doi.org/10.1093/eurheartj/ehaa612][9,10]. AF = atrial fibrillation; CHA_2DS_2-VASc = stroke/thromboembolism risk score [Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes mellitus, Stroke or previous thromboembolism (2 points), Vascular disease, Age 65–74 years, Sex category (female)]; INR = International normalized ratio; LMWH = low molecular weight heparin; DOAC = direct oral anticoagulant; OAC = oral anticoagulation; PCI = percutaneous coronary intervention; TIA = transient ischemic attack; TTR = time in therapeutic range; UFH = unfractionated heparin; VKA = vitamin K antagonist oral anticoagulant.

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Extended Data Table 4 | Guideline Non-Adherence for Rhythm Control

Decision tree failure point description	n/N (%) failed	Applicable guidance [1]
Patient is not scheduled to have an electrical cardioversion (or had in the previous month) when they have evidence of hemodynamic instability.	50/56 (89%)	Emergency electrical cardioversion is recommended in AF patients with acute or worsening hemodynamic instability.
The modified EHRA scale was not used in patients (when there is no evidence of hemodynamic instability).	727/1482 (49%)	In patients with AF, it is recommended to evaluate AF-related symptoms (including fatigue, tiredness, exertional shortness of breath, palpitations, and chest pain) and quantify the patient symptom status using the modified EHRA symptom scale before and after initiation of treatment.
Attention not paid to blood pressure control, lifestyle risk factors and concomitant diseases.	242/1538 (16%)	Strict control of risk factors and avoidance of triggers are recommended as part of a rhythm control strategy. Attention to good blood pressure control is recommended in AF patients with hypertension to reduce AF recurrences and risk of stroke and bleeding.
Patients with previous electrical or pharmacological cardioversion, in which the indication for rhythm control was not to improve symptoms.	114/574 (20%)	Rhythm control therapy is recommended for symptom and QoL improvement in symptomatic patients with AF.
Patients with previous electrical or pharmacological cardioversion who did not receive a minimum of 3 weeks of effective anticoagulation before the procedure and a TEE was not performed to exclude cardiac thrombus.	43/87 (49%)	For cardioversion of AF/AFL, effective anticoagulation is recommended for a minimum of 3 weeks before cardioversion. TEE is recommended to exclude cardiac thrombus as an alternative to 3-week pre-procedural anticoagulation when early cardioversion is planned.
Patients with previous pharmacological cardioversion who had an atrioventricular node dysfunction or history of prolonged QT interval (>0.5s) without anti-bradycardia pacing.	3/167 (2%)	AAD therapy is not recommended in patients with advanced conduction disturbances unless anti-bradycardia pacing is provided.
Patients with previous pharmacological cardioversion who have heart valve disease, heart failure diagnosis with LVEF <40% or coronary artery disease, and were taking AAD other than amiodarone.	16/68 (24%)	Amiodarone is recommended for cardioversion of AF in patients with heart failure or structural heart disease, if delayed cardioversion is consistent with the clinical situation.
Patients with scheduled electrical cardioversion, but the indication for rhythm control was not to improve symptoms.	7/35 (20%)	Rhythm control therapy is recommended for symptom and QoL improvement in symptomatic patients with AF.
Patients with scheduled electrical cardioversion, not currently taking oral anticoagulation and procedure to be done without TEE guidance.	1/1 (100%)	For cardioversion of AF/AFL, effective anticoagulation is recommended for a minimum of 3 weeks before cardioversion. TEE is recommended to exclude cardiac thrombus as an alternative to 3-week pre-procedural anticoagulation when early cardioversion is planned.
Patient currently receiving any AAD, but the indication for rhythm control was not to improve symptoms.	108/425 (25%)	Rhythm control therapy is recommended for symptom and QoL improvement in symptomatic patients with AF.
Patient currently taking Flecainide or Propafenone in the presence of: diagnosis of HF, coronary artery disease, current valve disease, left-ventricular hypertrophy or LVEF<50%.	113/236 (48%)	Flecainide or propafenone are recommended for long-term rhythm control in AF patients with normal LV function and without structural heart disease, including significant LVH and myocardial ischemia .
Patient currently receiving any AAD but reason for this did not account for at least 2 out of the following criteria; 1) presence of comorbidities, 2) cardiovascular risk and potential for serious proarrhythmic effects, 3) potential extra-cardiac toxic effects, 4) patient preference, and 5) symptom burden.	236/425 (56%)	The decision to initiate long-term AAD therapy needs to balance symptom burden, possible adverse drug reactions, and patient preferences. Drug-induced proarrhythmia or extracardiac side-effects are frequent; safety rather than efficacy considerations should primarily guide the choice of AAD.
Catheter ablation was performed, but the indication for rhythm control was not to improve symptoms.	124/337 (37%)	AF catheter ablation for PVI is recommended for rhythm control after one failed or intolerant class I or III AAD, to improve symptoms of AF recurrences.
Catheter ablation was performed but without pulmonary vein isolation.	27/337 (8%)	Complete electrical isolation of the pulmonary veins is recommended during all AF catheter-ablation procedures.
Catheter ablation was performed but patients were not encouraged to take part in decisions being made about the management of their condition.	85/337 (25%)	For the decision on AF catheter ablation, it is recommended to take into consideration the procedural risks and the major risk factors for AF recurrence following the procedure and discuss them with the patient
Catheter ablation was performed in patients with Wolff–Parkinson–White syndrome but the accessory pathway was not ablated.	1/3 (33%)	Catheter ablation of the accessory pathway in Wolff–Parkinson–White patients with AF and rapid conduction over the accessory pathway is recommended to prevent sudden cardiac death
Catheter ablation was performed in patients with CHA_2DS_2-VASc score ≥3 for women or ≥2 for men but they did not receive therapeutic OAC for at least 3 weeks before the ablation.	6/206 (3%)	In AF patients with stroke risk factors not taking OAC before ablation, it is recommended that pre-procedural management of stroke risk includes initiation of anticoagulation and, preferably, therapeutic OAC for at least 3 weeks before ablation.
Catheter ablation is scheduled, but the indication for rhythm control was not to improve symptoms.	25/75 (33%)	AF catheter ablation for PVI is recommended for rhythm control after one failed or intolerant class I or III AAD, to improve symptoms of AF recurrences.
Catheter ablation is scheduled but will not be performed in an experienced center by an electrophysiologist who has received appropriate training.	2/75 (3%)	Catheter ablation is recommended…, when performed by an electrophysiologist who has received appropriate training and is performing the procedure in an experienced center.
Catheter ablation is scheduled but patients were not encouraged to take part in decisions being made about the management of their illness.	20/75 (27%)	For the decision on AF catheter ablation, it is recommended to take into consideration the procedural risks and the major risk factors for AF recurrence following the procedure and discuss them with the patient.
Catheter ablation is scheduled in patients with CHA_2DS_2-VASc ≥3 for women or ≥2 for men but they are not currently taking anticoagulation.	2/49 (4%)	In AF patients with stroke risk factors not taking OAC before ablation, it is recommended that pre-procedural management of stroke risk includes initiation of anticoagulation and, preferably, therapeutic OAC for at least 3 weeks before ablation.

Table presents data for failure points with any number of applicable patients, as determined using the pre-published guideline decision tree algorithm [https://doi.org/10.1093/europace/euae178][20]. [1]From the European Society of Cardiology guidelines for the management of atrial fibrillation [https://doi.org/10.1093/eurheartj/ehw210 and https://doi.org/10.1093/eurheartj/ehaa612][9,10]. AF = atrial fibrillation; CHA_2DS_2-VASc = stroke/thromboembolism risk score [Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes mellitus, Stroke or previous thromboembolism (2 points), Vascular disease, Age 65–74 years, Sex category (female)]; INR = International normalized ratio; LMWH = low molecular weight heparin; DOAC = direct oral anticoagulant; OAC = oral anticoagulation; PCI = percutaneous coronary intervention; TIA = transient ischemic attack; TTR = time in therapeutic range; UFH = unfractionated heparin; VKA = vitamin K antagonist oral anticoagulant.

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Extended Data Table 5 | Process Outcomes in the Intervention Group

Process outcome	N (%), mean (SD) or median (IQR)
Time spent on the online platform	N=195
Median hours (IQR)	9.2 (6.4 to 13.4)
Percentage of required reading links accessed	N=195
Mean % (SD)	94.8 (9.7)
Commitment to change plan	N=139 [1]
Successfully implemented, N (%)	136 (97.8%)
Interaction of learner with expert trainer	N=195
Successful interaction, N (%)	158 (81.0%)
Multiple choice questionnaire	
Pre-education test	N=190
Mean (SD)	65.2 (18.3)
Post-education test	N=188
Mean (SD)	72.0 (19.9) [2]

[1]56 learners were excluded from this analysis as they did not commit to at least two items, or there were missing data at baseline or follow-up. If all the excluded learners are assumed to have failed their commitment to change, then successful implementation is 69.7%. [2]post-hoc comparison against pre-education test, $p<0.0001$ (2-sided paired t-test not adjusted for multiple comparisons).

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Extended Data Table 6 | Subgroup Analyses on Stroke Prevention

Subgroup for stroke prevention outcome	Intervention		Control		Risk ratio (95% CI)	Risk difference (95% CI)	Interaction p-value
	Baseline	Follow-up	Baseline	Follow-up			
Country							***0.01***
France	93 (53.1%); N=175	96 (62.3%); N=154	87 (43.5%); N=200	69 (38.5%); N=179	1.55 (1.04, 2.31)	23.35 (3.89, 42.82)	
Germany	105 (70.0%); N=150	95 (72.5%); N=131	87 (69.6%); N=125	59 (56.2%); N=105	1.35 (0.96, 1.90)	17.96 (0.23, 35.70)	
Italy	78 (78.0%); N=100	63 (71.6%); N=88	69 (69.0%); N=100	71 (77.2%); N=92	0.91 (0.75, 1.11)	-6.41 (-19.76, 6.93)	
Poland	95 (63.3%); N=150	98 (76.6%); N=128	103 (68.7%); N=150	95 (70.9%); N=134	1.12 (0.99, 1.27)	8.34 (-0.51, 17.18)	
Spain	84 (67.2%); N=125	73 (64.0%); N=114	93 (62.0%); N=150	109 (77.9%); N=140	0.80 (0.66, 0.98)	-15.44 (-29.04, -1.85)	
United Kingdom	93 (56.4%); N=165	91 (60.7%); N=150	69 (48.6%); N=142	68 (55.3%); N=123	1.03 (0.74, 1.44)	1.90 (-18.44, 22.24)	
Cluster-specific mean for guideline adherence to stroke prevention at baseline							***0.08***
<70%	268 (52.0%); N=515	283 (61.0%); N=464	232 (44.9%); N=517	216 (48.2%); N=448	1.21 (1.00, 1.46)	11.18 (0.65, 21.71)	
≥70%	280 (80.0%); N=350	233 (77.4%); N=301	276 (78.9%); N=350	255 (78.5%); N=325	0.99 (0.89, 1.10)	-0.80 (-8.25, 6.64)	
Cluster-specific mean for guideline adherence to rhythm control at baseline							***0.94***
<50%	466 (62.1%); N=750	433 (65.1%); N=665	424 (57.1%); N=742	395 (59.0%); N=669	1.11 (0.97, 1.27)	6.34 (-1.83, 14.50)	
≥50%	82 (71.3%); N=115	83 (83.0%); N=100	84 (67.2%); N=125	76 (73.1%); N=104	1.08 (0.89, 1.31)	5.73 (-8.94, 20.40)	
Participant gender							***0.18***
Male	338 (64.4%); N=525	322 (69.4%); N=464	338 (60.4%); N=560	306 (60.5%); N=506	1.14 (1.00, 1.30)	8.45 (0.05, 16.84)	
Female	210 (61.8%); N=340	194 (64.5%); N=301	170 (55.4%); N=307	165 (61.8%); N=267	1.03 (0.89, 1.20)	2.04 (-7.32, 11.41)	
Participant age at enrolment							***0.37***
<65 years	185 (64.5%); N=287	177 (67.6%); N=262	185 (65.8%); N=281	175 (67.0%); N=261	1.05 (0.92, 1.20)	3.20 (-5.26, 11.66)	
≥65 years	363 (62.8%); N=578	339 (67.4%); N=503	323 (55.1%); N=586	296 (57.8%); N=512	1.12 (0.98, 1.29)	7.35 (-1.21, 15.92)	
Participant CHA_2DS_2-VASc score at baseline							***0.99***
0-3	309 (65.7%); N=470	302 (70.7%); N=427	321 (64.6%); N=497	303 (66.7%); N=454	1.09 (0.96, 1.24)	5.94 (-2.44, 14.33)	
≥4	239 (60.5%); N=395	214 (63.3%); N=338	187 (50.5%); N=370	168 (52.7%); N=319	1.11 (0.95, 1.30)	6.29 (-2.82, 15.40)	

CHA_2DS_2-VASc = stroke/thromboembolism risk score [Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes mellitus, Stroke or previous thromboembolism (2 points), Vascular disease, Age 65–74 years, Sex category (female)].

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Extended Data Table 7 | Subgroup Analyses on Rhythm Control

Subgroup for rhythm control outcome	Intervention		Control		Risk ratio (95% CI)	Risk difference (95% CI)	Interaction p-value
	Baseline	Follow-up	Baseline	Follow-up			
Country							***0.89***
France	6 (3.4%); N=175	22 (14.3%); N=154	32 (16.0%); N=200	14 (7.8%); N=179	2.63 (0.60, 11.50)	10.20 (-5.25, 25.64)	
Germany	51 (34.0%); N=150	64 (48.9%); N=131	22 (17.6%); N=125	43 (41.0%); N=105	1.18 (0.51, 2.73)	6.82 (-27.94, 41.57)	
Italy	20 (20.0%); N=100	37 (42.0%); N=88	41 (41.0%); N=100	43 (46.7%); N=92	1.12 (0.53, 2.38)	4.88 (-24.68, 34.44)	
Poland	55 (36.7%); N=150	68 (53.1%); N=128	34 (22.7%); N=150	36 (26.9%); N=134	1.75 (1.16, 2.64)	21.13 (7.86, 34.39)	
Spain	16 (12.8%); N=125	13 (11.4%); N=114	20 (13.3%); N=150	14 (10.0%); N=140	1.46 (0.27, 7.92)	3.96 (-12.60, 20.52)	
United Kingdom	37 (22.4%); N=165	55 (36.7%); N=150	29 (20.4%); N=142	27 (22.0%); N=123	1.74 (0.62, 4.85)	15.90 (-14.21, 46.02)	
Cluster-specific mean for guideline adherence to stroke prevention at baseline							***0.60***
<70%	74 (14.4%); N=515	126 (27.2%); N=464	88 (17.0%); N=517	93 (20.8%); N=448	1.42 (0.79, 2.54)	8.94 (-5.23, 23.10)	
≥70%	111 (31.7%); N=350	133 (44.2%); N=301	90 (25.7%); N=350	84 (25.8%); N=325	1.66 (1.10, 2.50)	14.78 (2.32, 27.24)	
Cluster-specific mean for guideline adherence to rhythm control at baseline							***0.39***
<50%	112 (14.9%); N=750	189 (28.4%); N=665	98 (13.2%); N=742	125 (18.7%); N=669	1.69 (1.08, 2.65)	12.39 (2.68, 22.11)	
≥50%	73 (63.5%); N=115	70 (70.0%); N=100	80 (64.0%); N=125	52 (50.0%); N=104	1.10 (0.70, 1.75)	4.67 (-17.71, 27.05)	
Participant gender							***0.01***
Male	117 (22.3%); N=525	165 (35.6%); N=464	111(19.8%); N=560	107 (21.1%); N=506	1.69 (1.14, 2.48)	14.41 (4.22, 24.59)	
Female	68 (20.0%); N=340	94 (31.2%); N=301	67 (21.8%); N=307	70 (26.2%); N=267	1.25 (0.85, 1.85)	6.00 (-4.09, 16.08)	
Participant age at enrolment							***0.37***
<65 years	62 (21.6%); N=287	84 (32.1%); N=262	57 (20.3%); N=281	57 (21.8%); N=261	1.64 (1.09, 2.47)	12.90 (3.08, 22.73)	
≥65 years	123 (21.3%); N=578	175 (34.8%); N=503	121 (20.6%); N=586	120 (23.4%); N=512	1.45 (0.99, 2.12)	10.28 (0.14, 20.41)	
Participant CHA_2DS_2-VASc score at baseline							***0.38***
0-3	95 (20.2%); N=470	134 (31.4%); N=427	101 (20.3%); N=497	99 (21.8%); N=454	1.60 (1.08, 2.37)	12.40 (2.71, 22.09)	
≥4	90 (22.8%); N=395	125 (37.0%); N=338	77 (20.8%); N=370	78 (24.5%); N=319	1.40 (0.94, 2.09)	9.45 (-1.39, 20.30)	

CHA_2DS_2-VASc = stroke/thromboembolism risk score [Congestive heart failure, Hypertension, Age ≥75 years (2 points), Diabetes mellitus, Stroke or previous thromboembolism (2 points), Vascular disease, Age 65–74 years, Sex category (female)].

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Extended Data Table 8 | STEEER-AF Central Teams

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EORP = EURObservational Research Programme; EHRA = European Heart Rhythm Association; ESC = European Society of Cardiology.

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Extended Data Table 9 | STEEER-AF Local Teams

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Poland	Sylwia Sawicka; Jacek Szalewski; Agata Donczyk; Artur Kobus; Karina Chorazewicz; Katarzyna Jutkiewicz; Barbara Kwiatkowska; Natalia Wasilewska; Daria Koszelnik; Małgorzata Niedzielska; Paulina Wierzbinska-Kornek; Ryszard Gluszczyk; Pawel Harpula; Joalnata Krupa; Bartosz Olajossy; Rafal Szewczuk; Karolina Adamczyk; Sylwia Jedrej; Iwona Lagoda; Michal Miszczak; Michal Jasionka; Emilia Zablocka; Marta Sondej; Paulina Deleskiewicz; Natalia Dudzinska; Maciej Cholewinski; Aneta Kowalczyk-Rutkowska; Agnieszka Fil; Robert Ciesielski; Paulina Kulczyńska; Jewgienija Holovatska; Marcin Barzak; Piotr Barzak; Monika Kujawiak ; Krzysztof Cieślik; Piotr Szubielski; Dorota Stańczuk; Anna Janiszewska; Kamil Zenderowski; Artur Rok; Marcin Oglodek; Krystyna Moskal; Jacek Karasinski; Wojciech Dziadek; Krzysztof Bielamowicz; Bogdan Janus; Alicja Zajac Lesniak; Anna Szwiec; Rafal Witkowski; Tomasz Kozioł; Wiesław Banaś; Agnieszka Pasiowiec; Grzegorz Skonieczny; Maria Jaworska-Drozdowska; Mikolaj Strakowski; Lukasz Deptula; Magdalena Lewandowska; Agnieszka Fabisiak; Tomasz Fiderewicz; Monika Landzberg; Alicja Borowska.
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For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed
☐	☒ The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
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☐	☒ For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐ For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐ For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐ Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	Participant data were collected using electronic case report forms (eCRF), managed by an independent contract research organization (Soladis; France). To provide objective assessment of the clinical care received, the eCRF was completed by the PI who was not involved in the care pathway for recruited participants. Data from investigators using the online platform were extracted by staff at the European Society of Cardiology.
Data analysis	Algorithms were used to determine guideline adherence at the level of each patient, which were finalized and approved prior to the first randomization and have been published:https://doi.org/10.1093/europace/euae178. Statistical analyses for the co-primary outcomes were double-coded by an independent statistician in a separate statistical package (Stata; StataCorp, Texas) to the analyses conducted by the senior statistician (SAS; SAS Institute, North Carolina).

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Portfolio guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
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- For clinical datasets or third party data, please ensure that the statement adheres to our policy

Anonymized summary data will be made available for non-commercial purposes on request to the corresponding author, after completion and publication of clinical follow-up and secondary manuscripts (Prof Dipak Kotecha; d.kotecha@bham.ac.uk; 90-days response time for decisions following review by the STEEER-AF Trial Management Group).

Research involving human participants, their data, or biological material

Policy information about studies with human participants or human data. See also policy information about sex, gender (identity/presentation), and sexual orientation and race, ethnicity and racism.

Reporting on sex and gender	Gender used as this was self-identified by participants on enrollment. Gender reported in main results and table 1. Prespecified subgroup analyses for the co-primary outcomes included gender.
Reporting on race, ethnicity, or other socially relevant groupings	Ethnicity information on patients or healthcare staff were not collected.
Population characteristics	The mean age of participants was 68.9 years (SD 11.7), with 647 (37.4%) women. The median number of beds for overnight stay per center was 700 (IQR 177 to 1180), with 40.0% general or secondary care hospitals, 25.7% tertiary care hospitals, 55.7% University hospitals and 5.7% other units.
Recruitment	70 centers across France, Germany, Italy, Poland, Spain and the United Kingdom were included, with centers recruiting a total of 1732 patients with AF, with average cluster size of 24.7 patients (coefficient of variation in cluster size 0.06). To minimize selection bias, investigators were asked to approach consecutive patients under their care that met the inclusion criteria. The requirement for participant consent means there is potential for patient self-selection bias. Investigators were a broad range of multidisciplinary healthcare professionals at that site in order to further mitigate such biases.
Ethics oversight	The trial was approved by ethical review committees and research governance authorities: France: Comité de Protection des Personnes Est-II Siège : CHRU – Hôpital Saint Jacques Réf SIRIPH : 20.09.30.40105. Germany: Hamburg Medical Chamber 2021-200011-BO-bet; Universität Zu Lübeck 20-403; Universität Leipzig 274/21-1k; Medizinische Hochschule Hannover Nr.9774_BO_K_2021; Schleswig-Holstein Medical Association EK/AH/EN 052/21 m; Sächsische Landesärztekammer EK-BR-59/21-1. Italy: Comitato Etico di Area Vasta Emilia Centro 1285/2020/SPER/AOUMO SIRER ID2030; Comitato Etico Regionale - CER Umbria 4052/19; Comitato Etico di Area Vasta Emilia Centro della Regione Emilia-Romagna (CE-AVEC) Ethics 448/2021/Sper/AOUFe; Comitato Etico Regionale delle Marche n. cerm 2021 393; Comitato Etico Universita Federico II 186/21. Poland: Heart Rhythm Disorders Clinic, National Institute of Cardiology. Spain: el Comité de Ética de Investigación con Medicamentos del Hospital Universitario Vall d'Hebron PR(AG)613/2020; el Comité de ética de Investigación con medicamentos y comision dCEIM GIRONA PR(AG)613/2020. United Kingdom: NHS Health Research Authority 21/PR/0040.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

Field-specific reporting

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Life sciences study design

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Sample size	Sample size calculations for the stroke prevention co-primary outcome assumed 80% of control patients expected to receive guideline-adherent care, based on available observational studies. A relative increase of 10% was considered clinically-relevant (absolute increase from 80% to 88%). Power was 85% for this co-primary outcome, based on an intracluster correlation coefficient of 0.04, two-sided alpha 0.05, cluster size of 25 patients, coefficient of variation in cluster size 0.20, 70 clusters, and 10% loss to patient follow-up. For the rhythm control co-primary outcome, estimates of guideline-adherent care for rhythm control in the control group were 50%. Power was 85% to detect an

absolute increase from 50% to 61% using the same assumptions as the stroke prevention co-primary outcome.

Data exclusions	Intervention group: 15 patients withdrew consent, 45 lost to follow-up, 39 died prior to follow-up, 1 partial completion of follow-up. Control group: 13 patients withdrew consent, 47 lost to follow-up, 34 died prior to follow-up, 0 partial completion of follow-up. No cluster drop-outs.
Replication	All statistical analyses for the co-primary outcomes were double-coded by an independent statistician in a separate statistical package (Stata; StataCorp, Texas) to the analyses conducted by the senior statistician (SAS; SAS Institute, North Carolina). In addition, exploratory analyses indicated consistent effects for the co-primary outcomes across subgroups. The sensitivity analysis confirmed robust findings for both of the co-primary outcomes using a tipping point approach (presented in extended data figure 1).
Randomization	Centers were randomized only after they had finished participant recruitment and fully completed baseline electronic case report forms (eCRF), managed by an independent contract research organization (Soladis; France). To provide objective assessment of the clinical care received, the eCRF was completed by the PI who was not involved in the care pathway for recruited participants. The eCRF was completed after the interaction between patient and investigator using all available clinical and/or electronic documentation. Algorithms were used to determine guideline adherence at the level of each patient, which were finalized and approved prior to the first randomization and have been published. Randomization was performed by the Birmingham Clinical Trials Unit (University of Birmingham), with a 1:1 ratio to intervention or control using a minimization algorithm to ensure balance by (1) country; (2) cluster-specific mean for class I and III guideline adherence to stroke prevention at baseline (<70 and ≥70%); and (3) cluster-specific mean for class I and III guideline adherence to rhythm control at baseline (<50 and ≥50%).
Blinding	Guideline adherence at patient-level using the algorithms was not disclosed to the PI or investigators to avoid influencing follow-up. The randomized allocation was performed by the trial statistician blinded to the identity of the centers. Due to the nature of the intervention, it was not possible to blind investigators to the randomized allocation. The Trial Steering Committee were blinded to the randomized allocation of centers during the entire trial.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☐	☒ Clinical data
☒	☐ Dual use research of concern
☒	☐ Plants

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Clinical data

Policy information about clinical studies

All manuscripts should comply with the ICMJE guidelines for publication of clinical research and a completed CONSORT checklist must be included with all submissions.

Clinical trial registration	clinicaltrials.gov (NCT04396418)
Study protocol	attached as a supplemental file
Data collection	Data were collected from 70 centers across France, Germany, Italy, Poland, Spain and the United Kingdom. These centers included general or secondary care hospitals [28 (40.0%)], tertiary care hospitals [18 (25.7%)], University hospitals [39 (55.7%)] and other non-hospital sites [4 (5.7%)]. Data were collected on in-patients and out-outpatients that met selection criteria using a standardized electronic case report form. Randomization took place between May 2022 and February 2023 after completion of patient recruitment, with follow-up at 6-9 months post-randomization in the same 70 centers by the same investigators, and using the same standardized electronic case report form.
Outcomes	The co-primary outcomes were guideline-adherence for stroke prevention and rhythm control, based on class I and III ESC recommendations from the 2016 and 2020 guidelines on the management of AF. Prespecified secondary outcomes were the proportion of guidelines with adherence for stroke prevention and rhythm control, and the proportion of participants receiving anticoagulation according to class I and class I/IIa indications. The key patient-reported outcome was a score evaluating 8 domains of integrated AF management, completed by the patient after their consultation with the investigator. Patient-reported quality of life was determined using the EuroQol EQ-5D-5L questionnaire (index values and visual analogue scale). Process outcomes in the intervention group addressed the fidelity of the educational program.

Plants

Seed stocks	n/a
Novel plant genotypes	n/a
Authentication	n/a