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Title: Pulsed-Field Ablation Versus Thermal Ablation for Atrial Fibrillation: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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20 **Clinical Question Box**

21 In patients undergoing catheter ablation for atrial fibrillation, how does pulsed-field ablation
22 compare with conventional thermal ablation in terms of efficacy, procedural efficiency, and
23 safety?

24 No statistically significant differences were detected in atrial arrhythmia recurrence, repeat
25 ablation, or overall safety outcomes, while pulsed-field ablation reduced procedure time and
26 left atrial dwell time. The certainty of evidence was low for atrial arrhythmia recurrence and
27 repeat ablation and moderate for phrenic nerve injury and procedural efficiency. The clearest
28 demonstrated advantage of pulsed-field ablation is greater procedural efficiency, while
29 precision and certainty remain limited for several clinical outcomes.

30

Abstract

Background: Pulsed-field ablation (PFA) has emerged as a nonthermal alternative to radiofrequency ablation (RFA) and cryoballoon ablation (CBA) for atrial fibrillation (AF). Randomized evidence has expanded rapidly, but its relative efficacy, procedural performance, and safety across thermal comparators remain uncertain.

Methods: We systematically searched PubMed, Embase, Web of Science, and the Cochrane Library from inception through June 30, 2026, for randomized controlled trials comparing PFA with thermal catheter ablation for AF. Random-effects meta-analyses were performed using odds ratios (ORs) for dichotomous outcomes and mean differences (MDs) for continuous outcomes. Prespecified subgroup analyses were conducted according to the thermal comparator. Risk of bias was assessed using RoB 2, and certainty of evidence was evaluated using GRADE.

Results: Seven randomized controlled trials including 2,076 participants were included. PFA was not associated with a significant reduction in atrial arrhythmia recurrence (OR, 0.83; 95% CI, 0.65–1.07) or repeat ablation (OR, 0.96; 95% CI, 0.55–1.66). PFA significantly reduced total procedure time (MD, –29.85 minutes; 95% CI, –41.03 to –18.66) and left atrial dwell time (MD, –30.95 minutes; 95% CI, –42.89 to –19.01), although heterogeneity was substantial. Phrenic nerve injury did not differ significantly overall (OR, 0.37; 95% CI, 0.12–1.15), and no statistically significant difference was detected in procedure-related adverse events (OR, 0.90; 95% CI, 0.66–1.21). No statistically significant difference was detected in post-blanking class I or III antiarrhythmic drug use (OR, 0.82; 95% CI, 0.58–1.17).

Conclusions: No statistically significant differences were detected in rhythm-control or overall safety outcomes, while PFA substantially reduced procedure time and left atrial dwell time.

54 These findings apply mainly to first-time ablation for paroxysmal AF, and precision and
55 certainty were limited for several clinical outcomes.

56 **Keywords:** atrial fibrillation; pulsed-field ablation; radiofrequency ablation; cryoballoon
57 ablation; randomized controlled trial; meta-analysis

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Just Accepted

59 **Introduction**

60 Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia and represents a
61 growing global public health burden.¹ Approximately 59.7 million individuals worldwide were
62 estimated to have AF or atrial flutter in 2019, and this number is expected to continue rising
63 because of population ageing, improved detection, and the increasing prevalence of
64 cardiovascular and metabolic comorbidities.² The prevalence of AF is projected to
65 approximately double by 2050.³ AF is associated with substantial morbidity and mortality,
66 including increased risks of ischemic stroke, heart failure, hospitalization, impaired quality of
67 life, and premature death.⁴

68 Contemporary AF management requires a comprehensive and integrated approach that extends
69 beyond control of the arrhythmia itself.⁵ The 2024 European Society of Cardiology guidelines
70 introduced the AF-CARE framework, which emphasizes management of comorbidities and
71 modifiable risk factors, prevention of stroke and thromboembolism, reduction of symptoms
72 through rate or rhythm control, and continued evaluation and reassessment.² Oral
73 anticoagulation remains the cornerstone of stroke prevention in patients at increased
74 thromboembolic risk, with direct oral anticoagulants generally preferred over vitamin K
75 antagonists except in specific settings, such as mechanical heart valves or mitral stenosis.⁶ Rate
76 control may be achieved with beta-blockers, digoxin, or nondihydropyridine calcium-channel
77 blockers in appropriately selected patients, whereas rhythm-control strategies include electrical
78 or pharmacological cardioversion, antiarrhythmic drug therapy, catheter ablation, and, in
79 selected cases, surgical or hybrid ablation.⁷

80 The role of catheter ablation in rhythm control has expanded substantially. Current guidelines
81 recommend catheter ablation when antiarrhythmic drug therapy is ineffective, contraindicated,
82 or not preferred, and support its use as a first-line rhythm-control strategy in selected patients

with symptomatic paroxysmal AF.⁴ Pulmonary vein isolation (PVI) remains the cornerstone of catheter ablation for AF. Radiofrequency ablation (RFA) and cryoballoon ablation (CBA) are established thermal techniques that create myocardial lesions through heating and freezing, respectively.⁸ Although both approaches are effective, thermal energy may cause collateral injury to adjacent structures, including the esophagus, phrenic nerve, and pulmonary veins. In addition, procedural duration and the extent of left atrial instrumentation remain important considerations.⁹

Pulsed-field ablation (PFA) has emerged as a nonthermal alternative that uses high-voltage electrical pulses to induce irreversible electroporation.¹⁰ The greater susceptibility of cardiomyocytes to electroporation relative to surrounding noncardiac tissues may allow rapid and selective myocardial ablation while minimizing collateral injury.¹¹ PFA may therefore provide advantages in procedural efficiency and safety while maintaining effective PVI.¹² These characteristics have led to rapid clinical adoption and have prompted multiple randomized controlled trials (RCTs) directly comparing PFA with conventional thermal ablation.

However, the accumulating randomized evidence remains heterogeneous. Individual trials have used different thermal comparators, including CBA, RFA, or a combination of the two, and have assessed a broad range of efficacy, procedural, and safety outcomes. Determining whether the relative effects of PFA vary according to the comparator is clinically important because some proposed advantages of PFA, such as shorter procedural times or a lower risk of phrenic nerve injury, may depend on the thermal technique against which it is compared. Furthermore, individual RCTs may be insufficiently powered to evaluate relatively uncommon complications and clinically relevant downstream outcomes, including the need for repeat ablation.

A systematic review and meta-analysis of RCTs comparing PFA with thermal catheter ablation for AF was conducted. The primary efficacy outcomes included recurrence of atrial arrhythmias and repeat ablation. Procedural efficiency was assessed using total procedure time and left atrial dwell time, whereas safety outcomes included phrenic nerve injury and procedure-related adverse events. Post-ablation antiarrhythmic drug use was also evaluated. Prespecified subgroup analyses according to the thermal comparator were performed to determine whether the relative effects of PFA differed among CBA, RFA, and mixed thermal ablation strategies.

Methods

Study Design and Protocol Registration

This systematic review and meta-analysis was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.¹³ The review protocol was registered in the Open Science Framework (OSF; 10.17605/OSF.IO/AM7SW) before the literature search.¹⁴ Subsequent methodological clarifications were documented in the OSF record.

Literature Search

A systematic literature search was conducted in PubMed, Embase, Web of Science, and the Cochrane Library from database inception through June 30, 2026. Database-specific controlled vocabulary and free-text terms related to atrial fibrillation, pulsed-field ablation, irreversible electroporation, radiofrequency ablation, cryoballoon ablation, and catheter ablation were used. The reference lists of eligible studies and relevant systematic reviews were manually screened to identify additional potentially eligible studies. For included trials without complete peer-reviewed reports, conference presentations and ClinicalTrials.gov records were checked to verify study characteristics and outcome-specific data. The complete search strategies for all databases are provided in Supplementary Table S1.

Eligibility Criteria

Studies were eligible if they met all of the following inclusion criteria: (1) randomized controlled trial design; (2) inclusion of adult patients undergoing catheter ablation for atrial fibrillation; (3) direct comparison of pulsed-field ablation (PFA) with a thermal catheter ablation strategy, including radiofrequency ablation (RFA), cryoballoon ablation (CBA), or a comparator strategy permitting either RFA or CBA; and (4) reporting of at least one prespecified outcome of interest. Conference abstracts, trial presentations, and supplementary

reports were used when they provided additional comparative data for prespecified outcomes. When multiple reports described the same trial population, the most complete report was used as the primary source, with supplementary reports used as needed without double-counting participants.

Studies were excluded if they met any of the following criteria: (1) nonrandomized, single-arm, or observational study design; (2) case reports, case series, reviews, or editorials; (3) absence of a direct comparison between PFA and thermal catheter ablation; or (4) insufficient comparative data for extraction of at least one prespecified outcome.

Study Selection

Two reviewers F. L. and X. Z independently screened the titles and abstracts of all records identified through the literature search. Potentially eligible reports were subsequently assessed against the prespecified eligibility criteria using the full text or other available source material. Disagreements regarding study eligibility were resolved through discussion and consensus or, when necessary, consultation with a third reviewer J. Q. The study-selection process was documented using a PRISMA flow diagram.

Data Extraction

The two reviewers independently extracted data using a standardized data-extraction form. Extracted study characteristics included study design and setting, patient population, sample size, age, sex, body mass index, left atrial diameter, PFA platform and ablation strategy, thermal comparator, blanking period, rhythm-monitoring strategy, and duration of follow-up. For dichotomous outcomes, event counts and outcome-specific denominators were extracted; missing outcome data were not imputed. For continuous outcomes, the mean, standard deviation (SD), and number of participants were extracted. When procedural-time outcomes were reported as medians and interquartile ranges (IQRs), means and SDs were estimated from

the reported quantiles.¹⁵ Procedural duration variables were standardized to minutes. When necessary, data were supplemented by additional reports from the same study. Discrepancies were resolved by discussion between the reviewers.

Outcomes

The principal outcomes were atrial arrhythmia recurrence after the trial-defined blanking period, repeat catheter ablation, total procedure time, and phrenic nerve injury. Atrial arrhythmia recurrence was defined according to each trial, including the duration threshold used to define an arrhythmic episode. Supplementary outcomes included procedure-related adverse events or complications, left atrial dwell time, and post-ablation antiarrhythmic drug use. Procedure-related adverse events or complications were defined as any event considered by the investigators of the individual trials to be related to the ablation procedure, irrespective of severity.

Statistical Analysis

For dichotomous outcomes, pooled effects were expressed as odds ratios (ORs) with 95% confidence intervals (CIs) using Mantel-Haenszel random-effects models. Continuous outcomes were summarized as mean differences (MDs) with 95% CIs using inverse-variance random-effects models. Between-study variance was estimated using the DerSimonian-Laird method, and pooled 95% CIs were calculated using the Wald-type method based on the standard normal distribution. Studies with no events in either treatment group did not contribute to pooled OR estimates; when a zero cell occurred in only one treatment group, the default continuity correction of 0.5 was applied. Statistical heterogeneity was assessed using Cochran's Q test and the I² statistic.¹⁶ All analyses were conducted using Review Manager (RevMan), version 5.4 (The Cochrane Collaboration), with two-sided P values <0.05 considered statistically significant.

Risk-of-Bias Assessment

Two reviewers independently assessed outcome-specific risk of bias using the Cochrane Risk of Bias 2 (RoB 2) tool across the five standard domains.¹⁷ Overall judgments were classified as low risk, some concerns, or high risk. Disagreements were resolved by consensus. Each assessment was applied to the specific result contributing to the corresponding prespecified meta-analytic outcome.

Certainty of Evidence

The certainty of evidence for each outcome was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.¹⁸ Evidence from randomized controlled trials was initially rated as high certainty and downgraded, when appropriate, for risk of bias, inconsistency, indirectness, imprecision, or publication bias. Certainty was categorized as high, moderate, low, or very low. Two reviewers independently performed the GRADE assessments, with disagreements resolved through discussion and consensus. A Summary of Findings table was prepared for the principal outcomes.

Results

Study Selection and Characteristics

The literature search identified 994 records. After removal of 73 duplicates, 921 records underwent title and abstract screening, of which 818 were excluded. The remaining 103 reports were assessed for eligibility. Ultimately, seven randomized controlled trials comprising 2,076 participants were included in the meta-analysis (Table 1).¹⁹⁻²⁵ The study-selection process and reasons for exclusion are shown in the PRISMA flow diagram.

Individual trials enrolled 65 to 607 participants. Most included patients with symptomatic paroxysmal atrial fibrillation undergoing first-time pulmonary vein isolation, whereas Osmancik et al. also included patients with nonparoxysmal atrial fibrillation. Six trials were multicenter studies, and one was conducted at a single center. PFA was predominantly performed using pentaspline catheter systems, whereas InsightPFA evaluated a nanosecond biphasic PFA system. Three trials compared PFA with cryoballoon ablation, three with radiofrequency ablation, and ADVENT permitted either radiofrequency or cryoballoon ablation in the control group. Baseline characteristics were generally comparable between treatment groups. Blanking periods ranged from 60 to 90 days, rhythm-monitoring strategies varied across trials, and most efficacy outcomes were assessed at approximately 12 months (Table S3).

Atrial Arrhythmia Recurrence

Six studies comprising 2,011 participants contributed to the analysis of atrial arrhythmia recurrence (Figure 1). Recurrence occurred in 209 of 1,006 patients treated with PFA and 238 of 1,005 patients undergoing thermal ablation. PFA was associated with a numerically lower risk of recurrence, although the overall difference was not statistically significant (OR, 0.83; 95% CI, 0.65–1.07; $P=0.150$), with low between-study heterogeneity ($I^2=22\%$).

In trials comparing PFA with cryoballoon ablation, PFA was associated with fewer recurrences (OR, 0.62; 95% CI, 0.44–0.87; $P=0.005$). No significant difference was observed in trials comparing PFA with radiofrequency ablation (OR, 1.04; 95% CI, 0.71–1.51) or in ADVENT, which permitted either radiofrequency or cryoballoon ablation in the control group (OR, 1.06; 95% CI, 0.69–1.63). The test for subgroup differences was not statistically significant ($P=0.070$).

Repeat Ablation

Four studies comprising 1,375 participants reported repeat ablation (Figure 2). Repeat procedures were performed in 52 of 689 patients receiving PFA and 55 of 686 patients receiving thermal ablation. There was no significant difference between the two strategies (OR, 0.96; 95% CI, 0.55–1.66; $P=0.880$), with moderate heterogeneity ($I^2=45\%$).

No significant differences were observed within the cryoballoon ablation subgroup (OR, 0.96; 95% CI, 0.31–2.99), radiofrequency ablation subgroup (OR, 1.48; 95% CI, 0.61–3.57), or mixed radiofrequency/cryoballoon subgroup (OR, 0.68; 95% CI, 0.34–1.37). There was no evidence of a subgroup difference according to thermal ablation modality ($P=0.400$).

Procedural Efficiency

Seven studies comprising 2,076 participants provided data on total procedure time (Figure 3). PFA significantly shortened procedure time compared with thermal ablation, with a pooled mean difference of –29.85 minutes (95% CI, –41.03 to –18.66; $P<0.001$). Substantial between-study heterogeneity was observed ($I^2=96\%$).

Compared with cryoballoon ablation, PFA shortened procedure time by 16.13 minutes (95% CI, –18.59 to –13.66; $I^2=0\%$). The pooled reduction versus radiofrequency ablation was 50.95 minutes (95% CI, –87.50 to –14.41), with considerable heterogeneity ($I^2=98\%$). In ADVENT, which permitted either radiofrequency or cryoballoon ablation, the mean difference was –17.30

minutes (95% CI, -23.08 to -11.52). The test for subgroup differences was not statistically significant ($P=0.170$).

Left atrial dwell time was also significantly shorter with PFA (Figure S2). Across six studies comprising 1,806 participants, the pooled mean difference was -30.95 minutes (95% CI, -42.89 to -19.01; $P<0.001$), with substantial heterogeneity ($I^2=97\%$). The mean reduction was 12.44 minutes versus cryoballoon ablation (95% CI, -17.26 to -7.63), 46.82 minutes versus radiofrequency ablation (95% CI, -69.04 to -24.61), and 24.30 minutes in ADVENT (95% CI, -28.29 to -20.31). The magnitude of the reduction differed significantly among comparator subgroups ($P<0.001$).

Safety Outcomes

Phrenic nerve injury was reported in seven studies comprising 2,076 participants (Figure 4). Events occurred in 8 of 1,039 patients treated with PFA and 25 of 1,037 patients treated with thermal ablation. The overall difference was not statistically significant (OR, 0.37; 95% CI, 0.12–1.15; $P=0.090$), with low-to-moderate heterogeneity ($I^2=35\%$).

In trials using cryoballoon ablation as the comparator, PFA was associated with a lower risk of phrenic nerve injury (OR, 0.14; 95% CI, 0.04–0.55; $P=0.005$). No significant difference was observed in the radiofrequency subgroup (OR, 2.00; 95% CI, 0.18–22.30) or in the mixed-comparator subgroup (OR, 0.56; 95% CI, 0.16–1.93). The test for subgroup differences was not statistically significant ($P=0.120$).

For overall procedure-related adverse events or complications, six studies comprising 1,727 participants were included (Figure S3). Events occurred in 113 of 864 patients receiving PFA and 123 of 863 patients receiving thermal ablation. There was no significant difference between groups (OR, 0.90; 95% CI, 0.66–1.21; $P=0.480$), with no observed heterogeneity ($I^2=0\%$). No significant subgroup difference according to comparator modality was detected ($P=0.200$).

275 *Post-Blanking Antiarrhythmic Drug Use*

276 Post-blanking class I or III antiarrhythmic drug use was reported in four studies comprising
277 1,389 participants (Figure S4). Antiarrhythmic drugs were used in 67 of 696 patients treated
278 with PFA and 79 of 693 patients treated with thermal ablation. There was no significant
279 difference between groups (OR, 0.82; 95% CI, 0.58–1.17; $P=0.280$), with no observed
280 heterogeneity ($I^2=0\%$). Results were consistent across cryoballoon, radiofrequency, and mixed-
281 comparator subgroups, with no evidence of subgroup interaction ($P=0.930$).

282 *Risk of Bias and Certainty of Evidence*

283 Overall RoB 2 judgments were low risk for two trials and some concerns for five trials, with
284 no trial rated as high risk of bias (Figure S5). GRADE certainty was moderate for total
285 procedure time, left atrial dwell time, procedure-related adverse events, and phrenic nerve
286 injury, and low for atrial arrhythmia recurrence, repeat ablation, and post-blanking
287 antiarrhythmic drug use (Table S2). Downgrading was mainly due to risk of bias, imprecision,
288 and inconsistency; phrenic nerve injury was downgraded by one level for serious imprecision
289 because of the small number of events and wide confidence interval.

Discussion

Across seven RCTs, PFA significantly reduced procedure and left atrial dwell times compared with thermal ablation. No statistically significant overall differences were detected in atrial arrhythmia recurrence, repeat ablation, post-blanking antiarrhythmic drug use, or procedure-related adverse events. The confidence intervals and low certainty of evidence for several clinical outcomes preclude claims of equivalence. These findings are consistent with previous randomized studies and meta-analyses reporting no clear overall difference in rhythm-control outcomes between PFA and thermal ablation, together with a procedural efficiency advantage for PFA.^{12,26} Differences in blanking periods, rhythm-monitoring strategies, and recurrence definitions may affect interpretation of rhythm outcomes.^{19,25} Fewer recurrences were observed in the cryoballoon subgroup, but the subgroup interaction was not statistically significant.

The clearest advantage of PFA was procedural efficiency. The reduction in procedure time was greater relative to radiofrequency ablation than to cryoballoon ablation, which itself provides a relatively rapid single-shot approach.²⁶ However, the substantial heterogeneity in procedure and left atrial dwell times indicates that the magnitude of time reduction varies across technologies and procedural settings. The small Osmercik trial contributed the largest procedure-time difference and included a mixed AF population with potentially more extensive left atrial ablation. The pooled estimates should therefore be interpreted as evidence of an overall efficiency advantage rather than a fixed expected time saving. The leave-one-out and conference-report exclusion analyses did not remove the direction or statistical significance of the total procedure-time effect, although the magnitude remained variable.

Safety findings require cautious interpretation. Although the tissue selectivity of electroporation provides a rationale for reducing collateral injury,¹¹ the overall analysis did not

demonstrate a statistically significant safety advantage for PFA, and estimates for uncommon complications were imprecise. PFA-associated intravascular hemolysis and hemoglobinuria-related acute kidney injury have also been reported, particularly after extensive energy delivery, but these outcomes were not consistently assessed in the included randomized trials.²⁷ Larger registries and post-marketing surveillance remain important for evaluating rare adverse events.²⁸ For phrenic nerve injury, significance differed between the prespecified random-effects analysis and the fixed-effect sensitivity analysis, further supporting cautious interpretation of the sparse-event estimate.

The choice of ablation technology should therefore reflect procedural requirements in addition to efficacy and safety. Radiofrequency ablation offers flexibility for tailored lesion placement, cryoballoon ablation provides an established single-shot workflow, and PFA offers rapid nonthermal lesion delivery.²⁹ Evidence remains limited for persistent AF and more extensive substrate modification. Cardiac magnetic resonance may help characterize atrial cardiomyopathy and fibrosis in this setting, although the benefit of imaging-guided substrate ablation remains uncertain.³⁰ Shorter procedure duration should also not be interpreted as demonstrated cost-effectiveness, because economic outcomes were not evaluated.³¹ Moreover, rhythm outcomes alone do not fully capture patient benefit; symptoms, quality of life, and patient preferences remain important measures of treatment success.³²

Several limitations should be acknowledged. The number of randomized trials was limited, particularly for uncommon safety outcomes, and some recent studies were available only as conference reports. Follow-up was generally approximately 1 year, rhythm-monitoring strategies and recurrence definitions varied, and substantial heterogeneity affected procedural outcomes. The small number of studies limited reliable prediction intervals and extensive sensitivity analyses, particularly for left atrial dwell time and rare safety outcomes; quality-of-life and other patient-reported outcomes could not be synthesized consistently.

339 **Conclusion**

340 In patients predominantly undergoing first-time ablation for paroxysmal AF, PFA was
341 associated with shorter procedure and left atrial dwell times than conventional thermal ablation.
342 No statistically significant differences were detected in atrial arrhythmia recurrence, repeat
343 ablation, overall procedure-related adverse events, or post-blanking antiarrhythmic drug use.
344 Phrenic nerve injury was less frequent with PFA in comparisons with cryoballoon ablation, but
345 an overall safety advantage was not established. Longer-term studies are needed to clarify
346 outcomes in persistent AF, repeat procedures, and uncommon complications.

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Consent to participate: Not applicable because no participants were directly enrolled in this study.

Data availability: All data analyzed in this meta-analysis were extracted from the published reports and supplementary materials of the included studies. The extracted data used for the analyses are available from the corresponding author upon reasonable request.

Generative AI Declaration : OpenAI was used for language editing. All outputs were independently reviewed and verified by the authors against the original sources. Generative AI was not used to generate or alter study data or to perform the statistical analyses..

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Table 1. Characteristics of randomized trials comparing pulsed-field ablation with thermal ablation

Study	Design and setting	Population	PFA strategy	Comparator	Patient s, n	Age, y	Male, %	BMI, kg/m ²	LAD, mm	Blanking period	Rhythm monitoring	Follow-up
ADVENT (Reddy et al., 2023)	Multicenter, randomized, single- blind, noninferiority trial	Symptomatic, drug-refractory PAF; age ≤75 y; first PVI	Pentaspine PFA; PVI	RFA or CBA	305 / 302	62.4 / 62.5	66.2 / 64.6	28.3 / 29.0	39 / 40 [†]	90 d	Weekly transtelephonic ECG; 72-h Holter at 6 and 12 mo; symptom- triggered recordings	12 mo
BEAT PAROX- AF (Jais et al., 2026)	9-center European, randomized, open-label, superiority trial	Symptomatic, drug-resistant PAF; age 18–80 y; no prior AF ablation	FARAPULSE pentaspine PFA; PVI	Contact- force RFA; CLOSE protocol	145 / 144 [§]	65 / 62 [†]	57 / 59	27 / 27 [†]	41 / 40 [†]	60 d	12-lead ECG and 24-h Holter; weekly Kardia ECG; symptom- triggered recordings	12 mo
FACIL-AF (Venier et al., 2026) [¶]	7-center French, randomized, prospective, noninferiority trial	PAF; age ≥18 y; first AF ablation	FARAPULSE PFA; PVI	CBA	175 / 174	NR	NR	NR	NR	90 d	ECG/Holter and connected-device monitoring; schedule NR	12 mo
InsightPFA (Lin et al., 2025)	13-center Chinese, randomized, prospective, noninferiority trial	Symptomatic PAF; age 18–75 y; first AF ablation	LotosPFA nanosecond biphasic PFA; PVI	AI-guided RFA	142 / 145	58.8 / 60.7 [‡]	66.9 / 57.9	24.5 / 24.8 [‡]	36.6 / 37.0	90 d	12-lead ECG and 24-h Holter at 1, 3, 6, and 12 mo; symptom-triggered ECG	12 mo
Osmancik et al., 2024	Single-center Czech, randomized, prospective trial	Paroxysmal or nonparoxysmal AF; first ablation	FARAWAVE pentaspine PFA; PVI ± additional LA ablation	Contact- force RFA	33 / 32	60.5 / 64.0	63.6 / 78.1	28.9 / 30.5	41.7 / 43.3	NA	No longitudinal rhythm- monitoring protocol	24 h biomarker assessment
PERFECT-PAF (Chierchia et al., 2026) [¶]	6-center European, randomized, prospective, noninferiority trial	PAF; age 18–75 y; first PVI	Pentaspine PFA; PVI	CBA	134 / 135	NR	NR	NR	NR	60 d	NR	12 mo
SINGLE SHOT CHAMPION (Reichlin et al., 2025)	2-center Swiss, randomized, investigator-initiated, noninferiority trial	Symptomatic PAF; first PVI; no prior LA ablation	FARAPULSE pentaspine PFA; PVI	CBA	105 / 105	64.0 / 63.3	73 / 70	27.0 / 27.3	39 / 38	90 d	Continuous ICM with daily remote transmission	12 mo

Values are shown as PFA / control. [†] Median values reported in the original study; [‡] Mean values were estimated from median (IQR) using the Wan et al. method; [§] BEAT PAROX-AF arm counts correspond to the analyzed population; [¶] Data available from conference reports.

Abbreviations: AF, atrial fibrillation; AI, artificial intelligence; BMI, body mass index; CBA, cryoballoon ablation; ECG, electrocardiography; ICM, implantable cardiac monitor; IQR, interquartile range; LA, left atrial; LAD, left atrial diameter; NA, not applicable; NR, not reported; PAF, paroxysmal atrial fibrillation; PFA, pulsed-field ablation; PV, pulmonary vein; PVI, pulmonary vein isolation; RFA, radiofrequency ablation; SD, standard deviation

Figure Legends

Figure 1. Atrial Arrhythmia Recurrence After Pulsed-Field Versus Thermal Ablation

Figure 2. Repeat Ablation After Pulsed-Field Versus Thermal Ablation

Figure 3. Procedure Time with Pulsed-Field Versus Thermal Ablation

Figure 4. Phrenic Nerve Injury After Pulsed-Field Versus Thermal Ablation

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Figure 1. Atrial Arrhythmia Recurrence After Pulsed-Field Versus Thermal Ablation

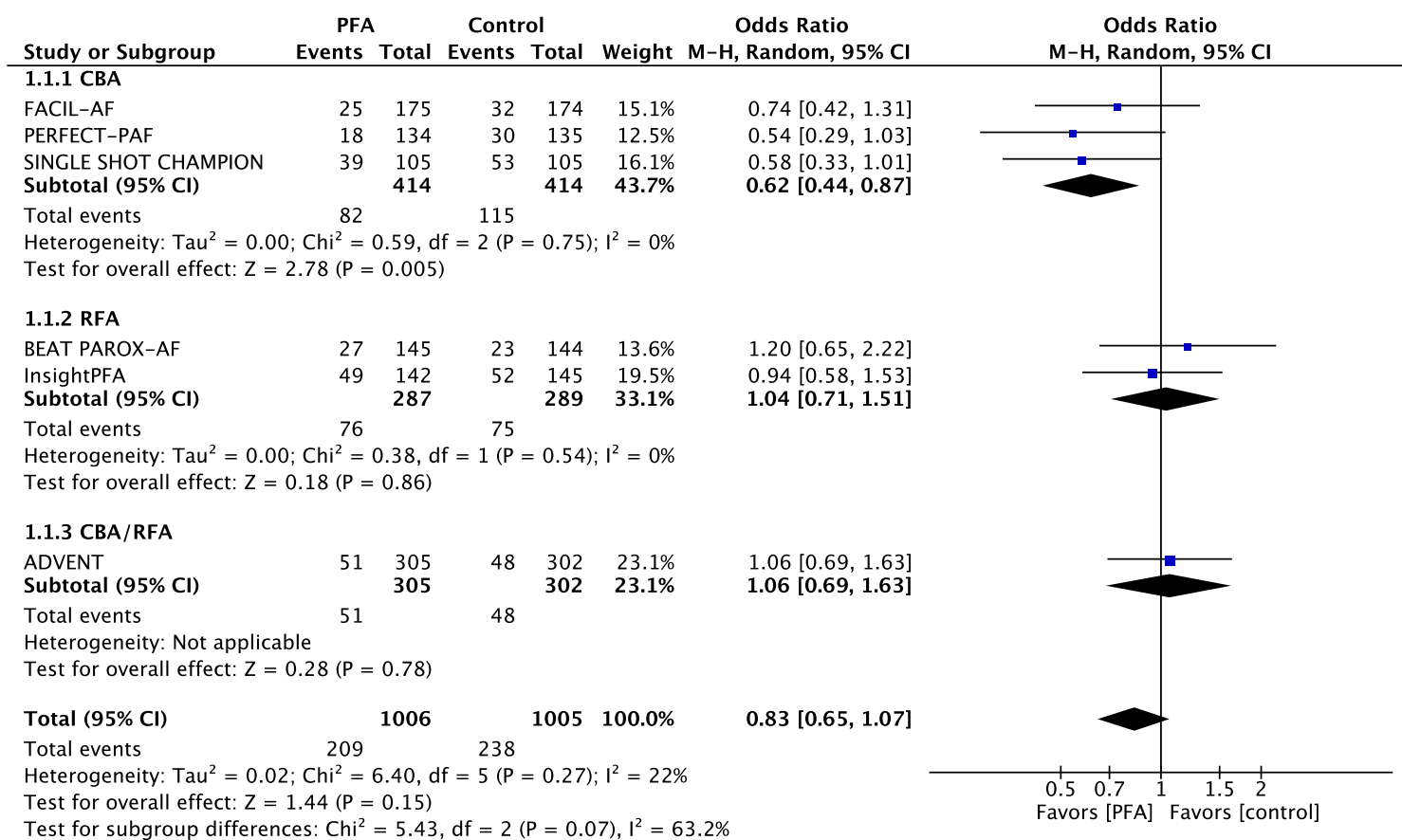


Figure 2. Repeat Ablation After Pulsed-Field Versus Thermal Ablation

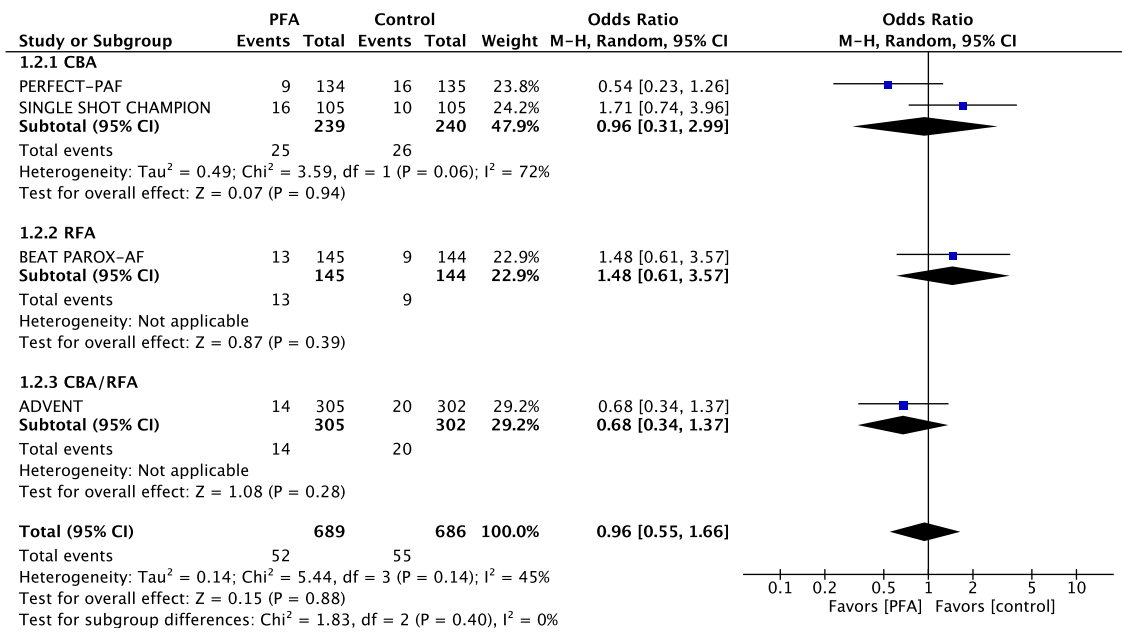


Figure 3. Procedure Time with Pulsed-Field Versus Thermal Ablation

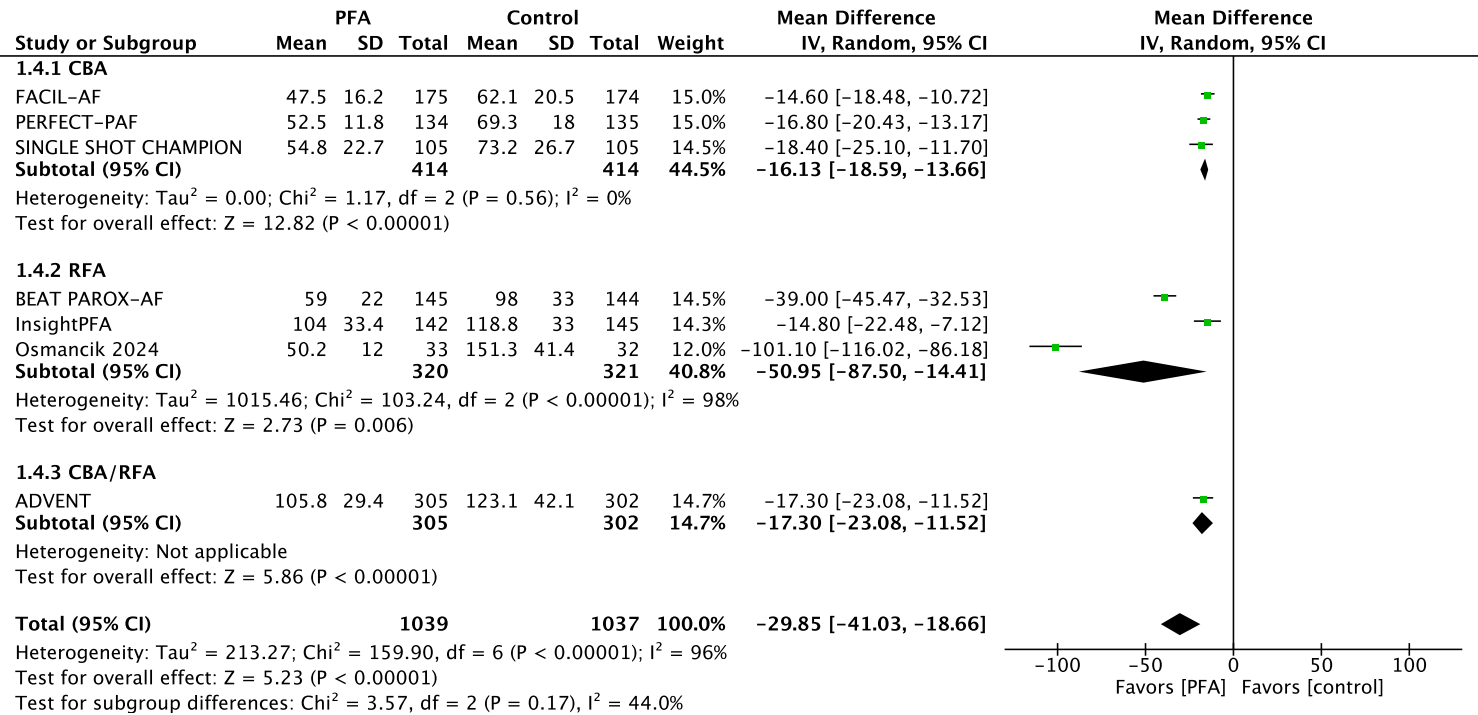


Figure 4. Phrenic Nerve Injury After Pulsed-Field Versus Thermal Ablation

