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Systematic Review

Early Recurrence of Atrial Arrhythmia Across Ablation Modalities for Atrial Fibrillation: A Systematic Review and Meta-Analysis

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Abstract

Background: Early recurrence of atrial arrhythmia after catheter ablation for atrial fibrillation (AF) has traditionally been considered transient. However, its prognostic significance, particularly in the era of pulsed field ablation (PFA), remains uncertain. We sought to evaluate the prognostic impact of early arrhythmia recurrence after catheter ablation for AF. **Methods:** A systematic review and meta-analysis of studies published before the 16th of January 2026 was conducted, including human studies that evaluated early (≤3 months) and late (>3 months) recurrence of atrial arrhythmia following catheter ablation. Random-effects modeling was used to generate pooled odds ratios (ORs) with 95% confidence intervals (CIs), and heterogeneity was assessed using I^2. Subgroup analyses were performed based on ablation modality, follow-up modality, and AF type at baseline. Meta-regression was performed to assess whether age, sex, ablation modality, and follow-up modality accounted for interstudy variation. **Results:** A total of 94 studies (63,113 patients; mean/median age, 60.4 ± 4.3 years; 32% female; 47% paroxysmal AF) were included. Six studies used PFA. Early arrhythmia recurrence within 3 months post-ablation was strongly predictive of later arrhythmia recurrence (after the blanking period) after 90 days (OR 3.86; 95% CI 3.72–4.01; I^2 = 86.9%; $p < 0.001$). The strength of this association numerically increased with later onset of early recurrence: 0–2 weeks, OR 3.24 (95% CI 2.76–3.79; I^2 = 76.7%; $p < 0.001$); 0–1 month, OR 2.88 (95% CI 2.69–3.08; I^2 = 89.2%; $p < 0.001$); 1–2 months, OR 4.64 (95% CI 4.05–5.31; I^2 = 85.3%; $p < 0.001$); 2–3 months, OR 7.18 (95% CI 6.41–8.04; I^2 = 88.6%; $p < 0.001$). This temporal gradient was consistent across radiofrequency and cryoballoon ablation. There were insufficient studies to assess individual time intervals within the 0–90-day range for PFA. No significant differences were observed by AF type (paroxysmal AF: OR 4.17, 95% CI 3.70–4.71; I^2 = 84.4%; $p < 0.001$; persistent AF: OR 3.65, 95% CI 3.02–4.40; I^2 = 90.1%; $p < 0.001$) or ablation modality (radiofrequency: OR 3.69, 95% CI 3.50–3.90; I^2 = 87.2%; $p < 0.001$; cryoballoon: OR 4.07, 95% CI 3.73–4.43; I^2 = 78.3%; $p < 0.001$; PFA: OR 5.67, 95% CI 4.66–6.90; I^2 = 70.6%; $p < 0.001$). **Conclusions:** Early arrhythmia recurrence predicts late recurrence following AF ablation, with the strength of association numerically increasing later in the conventional blanking period. These findings support an individualized, patient-centered, time-dependent approach to post-ablation management. **The PROSPERO Registration:** CRD420261288494, https://www.crd.york.ac.uk/PROSPERO/view/CRD420261288494.

Keywords: atrial fibrillation; catheter ablation; atrial arrhythmia; recurrence; blanking period

1. Introduction

Catheter ablation for atrial fibrillation (AF) is a cornerstone therapy associated with reduced recurrence of atrial arrhythmia and improved symptoms [1]. Historically, a blanking period after index ablation was adopted in clinical trials because of the perceived transient electrophysiological instability following thermal ablation, which might predispose patients to early recurrent atrial arrhythmia without necessarily affecting the longer-term clinical trajectory. However, growing clinical data suggest that early recurrence may still predict late recurrent tachyarrhythmia, and that the timing of recurrence within the blanking period is important [2]. This has become increasingly relevant in the era of pulsed field ablation (PFA), which is thought to have a less proinflammatory profile than conventional thermal ablation [3]. Therefore, this study conducted a systematic review and meta-analysis of clinical studies evaluating the association between early atrial arrhythmia recurrence and late recurrence after AF ablation, as well as the relevance of the timing of early recurrences.

2. Methods

A systematic literature search was conducted in PubMed and EMBASE to identify studies published up to 16 January 2026. Two investigators (F.H. and P.C.) independently searched the databases using the Medical Subject Headings (MeSH) terms “atrial fibrillation” and “catheter ablation”. A manual search of the reference lists of included articles was also performed to identify additional relevant studies. Articles were screened for eligibility by two investigators (F.H. and P.C.). The study protocol was prospectively registered with the PROSPERO international register

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(CRD420261288494). The inclusion criteria were as follows: (1) evaluation of atrial arrhythmia recurrence (AF, atrial flutter, or atrial tachycardia) after AF ablation; (2) catheter ablation; (3) studies involving humans; (4) publications in English; (5) full publication status. Articles were excluded if they did not report original data, were performed in animals or *in vitro*, explicitly included patients who had undergone repeat AF ablation, or used surgical ablation. Data collected included study design, patient demographics, type of AF, ablation modality, follow-up duration, definition of atrial arrhythmia recurrence, and the method used to monitor recurrence. Data were extracted by one investigator (P.C.) and verified by a second investigator (F.H.). The primary endpoint was the association between early recurrence, defined as recurrence occurring within 3 months post-ablation, and late recurrence, defined as any recurrence after 3 months through the end of the individual study follow-up period. A meta-analysis was performed using individual study data, including odds ratios (ORs) and 95% confidence intervals (CIs); the data were log-transformed, with priority given to the OR from the most adjusted model. Random-effects modeling was used to analyze the data and produce overall summary estimates with 95% CIs. Cochran's Q test was used to assess statistical heterogeneity, and the I^2 statistic was used to quantify the extent of heterogeneity. Tau was calculated using the restricted maximum likelihood method. Subgroup analyses were performed to compare various subgroups across different time points. Meta-regression with trend analysis was used to explore the temporal effects of early recurrence on the odds of late recurrence. Egger's test, along with visual inspection of funnel plots, was used to evaluate publication bias. Where evidence of publication bias was identified, trim-and-fill analysis was performed. An additional meta-regression was conducted to explore heterogeneity. Statistical analyses were conducted using Stata 19.0 (StataCorp LP, College Station, TX, USA).

3. Results

A total of 1157 studies were screened, of which 92 were deemed eligible for inclusion. Two additional studies were identified through snowball sampling, bringing the total number of included studies to 94 [2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96]. Of these, 68 were prospective studies, and 26 were retrospective. A total of 63,113 patients were included, with a mean age of 60.4 ± 4.3 years; 32% were female, and 47% had paroxysmal AF. Most studies used thermal ablation (89 studies using radiofrequency, cryoballoon, or both), whereas PFA was used in six studies. All but one study had a minimum follow-up period of 6 months. Meta-analysis showed that any early recurrence was associated with late recurrence (OR 3.86, 95% CI 3.72–4.01; I^2 = 86.9%; p < 0.001; Table 1).

The strength of the association between early recurrence and late recurrence depended on the timing of the initial recurrence (Fig. 1): very early recurrence at 0–2 weeks, OR 3.24 (95% CI 2.76–3.79; I^2 = 76.7%; p < 0.001); 0–1 month, OR 2.88 (95% CI 2.69–3.08; I^2 = 89.2%; p < 0.001); 1–2 months, OR 4.64 (95% CI 4.05–5.31; I^2 = 85.3%; p < 0.001); 2–3 months, OR 7.18 (95% CI 6.41–8.04; I^2 = 88.6%; p < 0.001). On trend analysis using random-effects meta-regression, the odds of late recurrence increased by 45% with each subsequent interval of the blanking period in which early recurrence occurred, OR 1.45 (95% CI 1.19–1.71; p < 0.001).

For radiofrequency ablation (RFA), the association between late recurrence and very early recurrence had an OR of 3.37 at 0–2 weeks (95% CI 2.86–3.97; I^2 = 77.2%; p < 0.001); 0–1 month, OR 3.38 (95% CI 3.03–3.76; I^2 = 88.7%; p < 0.001); 1–2 month, OR 6.42 (95% CI 5.44–7.58; I^2 = 83.9%; p < 0.001); 2–3 months, OR 8.71 (95% CI 7.45–10.18; I^2 = 82.0%; p < 0.001). For cryoballoon ablation (CBA), the corresponding associations had an OR of 1.99 at 0–2 weeks (95% CI 1.08–3.66; I^2 = 0.00%; p = 0.27); 0–1 month, OR 3.74 (95% CI 3.25–4.31; I^2 = 0.00%; p < 0.001); 1–2 months, OR 4.63 (95% CI 3.59–5.97; I^2 = 64.6%; p < 0.001); 2–3 months, OR 5.90 (95% CI 4.65–7.49; I^2 = 86.3%; p < 0.001). There were insufficient studies on PFA to provide a breakdown of recurrence timing within the blanking period.

Subgroup analysis found no statistically significant difference in the association between early and late recurrence according to ablation modality during the 3-month blanking period: RFA, OR 3.69 (95% CI 3.50–3.90; I^2 = 87.2%; p < 0.001); CBA, OR 4.07 (95% CI 3.73–4.43; I^2 = 78.3%; p < 0.001); PFA, OR 5.67 (95% CI 4.66–6.90; I^2 = 70.6%; p < 0.001) (p = 0.76). Subgroup analysis further demonstrated no statistically significant difference between RFA and CBA in the association between early and late recurrence across the following time periods: 0–2 weeks (p = 0.07), 0–1 month (p = 0.58), 1–2 months (p = 0.17), and 2–3 months (p = 0.3). On meta-regression trend analysis of the RFA subgroup, the odds of late recurrence increased by 54% with each interval of the blanking period, OR 1.54 (95% CI 1.19–1.89; p < 0.001). Similarly, trend analysis of the CBA cohort demonstrated a 50% increase per subsequent blanking period interval, OR 1.50 (95% CI 1.08–1.93; p = 0.006). There were insufficient data for each time interval to compare thermal ablation (RFA or CBA) with PFA.

Analysis by monitoring modality found that in studies using Holter monitoring, the association between late recurrence and very early recurrence had an OR of 3.68 at 0–2 weeks (95% CI 3.16–4.28; I^2 = 83.2%; p < 0.001); 0–1 month, OR 4.22 (95% CI 3.96–4.51; I^2 = 86.4%; p < 0.001);

Table 1. Odds of late recurrence of atrial fibrillation given early recurrence stratified by time, ablation modality, follow-up modality, and type of atrial fibrillation.

Comparison of recurrence rates based stratified by timing of early recurrence					
Timing of early recurrence		OR	95% CI	I^2	*p*-value
0–2 weeks		3.24	2.76–3.79	76.7%	<0.001
0–1 months		2.88	2.69–3.08	89.2%	<0.001
1–2 months		4.64	4.05–5.31	85.3%	<0.001
2–3 months		7.18	6.41–8.04	88.6%	<0.001
All 3 months		3.86	3.72–4.01	86.9%	<0.001
Comparison based on ablation modality					
Ablation modality	Timing of early recurrence	OR	95% CI	I^2	*p*-value
Radiofrequency ablation	0–2 weeks	3.37	2.86–3.97	77.2%	<0.001
	0–1 month	3.38	3.03–3.76	88.7%	<0.001
	1–2 months	6.42	5.44–7.58	83.9%	<0.001
	2–3 months	8.71	7.45–10.18	82.0%	<0.001
	All 3 months	3.69	3.50–3.90	87.2%	<0.001
Cryoballoon ablation	0–2 weeks	1.99	1.08–3.66	0.00%	0.27
	0–1 months	3.74	3.25–4.31	0.00%	<0.001
	1–2 months	4.63	3.59–5.97	64.6%	<0.001
	2–3 months	5.90	4.65–7.49	86.3%	<0.001
	All 3 months	4.07	3.73–4.43	78.3%	<0.001
Pulsed field ablation*	All 3 months	5.67	4.66–6.90	70.6%	0.002
Comparison based on monitoring modality					
Monitoring modality	Timing of early recurrence	OR	95% CI	I^2	*p*-value
Holter monitor	0–2 weeks	3.68	3.16–4.28	83.2%	<0.001
	0–1 month	4.22	3.96–4.51	86.4%	<0.001
	1–2 months	5.71	4.88–6.69	72.2%	0.001
	2–3 months	5.75	4.89–6.76	91.2%	<0.001
	All 3 months	4.14	3.97–4.32	86.4%	<0.001
Loop recorder	0–2 weeks	2.80	1.49–5.26	0.00%	0.001
	0–1 month	2.45	2.20–2.73	94.8%	0.002
	1–2 months	4.93	4.02–6.06	87.1%	<0.001
	2–3 months	7.69	6.50–9.09	82.3%	<0.001
	All 3 months	2.96	2.71–3.24	91.1%	<0.001
Comparison based on type of atrial fibrillation					
Type of atrial fibrillation	Timing of early recurrence	OR	95% CI	I^2	*p*-value
Paroxysmal	0–2 weeks	2.16	1.33–3.50	0.00%	0.563
	0–1 month	1.93	1.57–2.36	39.5%	0.116
	1–2 months	3.16	2.45–4.06	73.1%	0.005
	2–3 months	9.73	8.07–11.73	35.9%	0.167
	All 3 months	4.17	3.70–4.71	84.4%	<0.001
Persistent*	All 3 months	3.65	3.02–4.40	90.1%	<0.001

*Insufficient data to stratify the category across all five time points. OR, odds ratio; CI, confidence interval.

1–2 months, OR 5.71 (95% CI 4.88–6.69; I^2 = 72.2%; p = 0.001); 2–3 months, OR 5.75 (95% CI 4.89–6.76; I^2 = 91.2%; $p < 0.001$). In studies using loop recorders, the corresponding associations at 0–2 weeks had an OR of 2.80 (95% CI 1.49–5.26; I^2 = 0.0%; p = 0.001); 0–1 month, OR 2.45 (95% CI 2.20–2.73; I^2 = 94.8%; p = 0.002); 1–2 months, OR 4.93 (95% CI 4.02–6.06; I^2 = 87.1%; $p <$ 0.001); 2–3 months, OR 7.69 (95% CI 6.50–9.09; I^2 = 82.3%; $p < 0.001$). On subgroup meta-analysis, the pooled association between early and late recurrence for Holter monitoring had an OR of 4.14 (95% CI 3.97–4.32; I^2 = 86.4%; $p < 0.001$), while for cohorts followed up by loop recorders, the OR was 2.96 (95% CI 2.71–3.24; I^2 = 91.1%; $p < 0.001$). There was no statistically significant difference in the strength of association between 0 and 3 months when comparing the two monitoring modalities (p = 0.81). Sub-

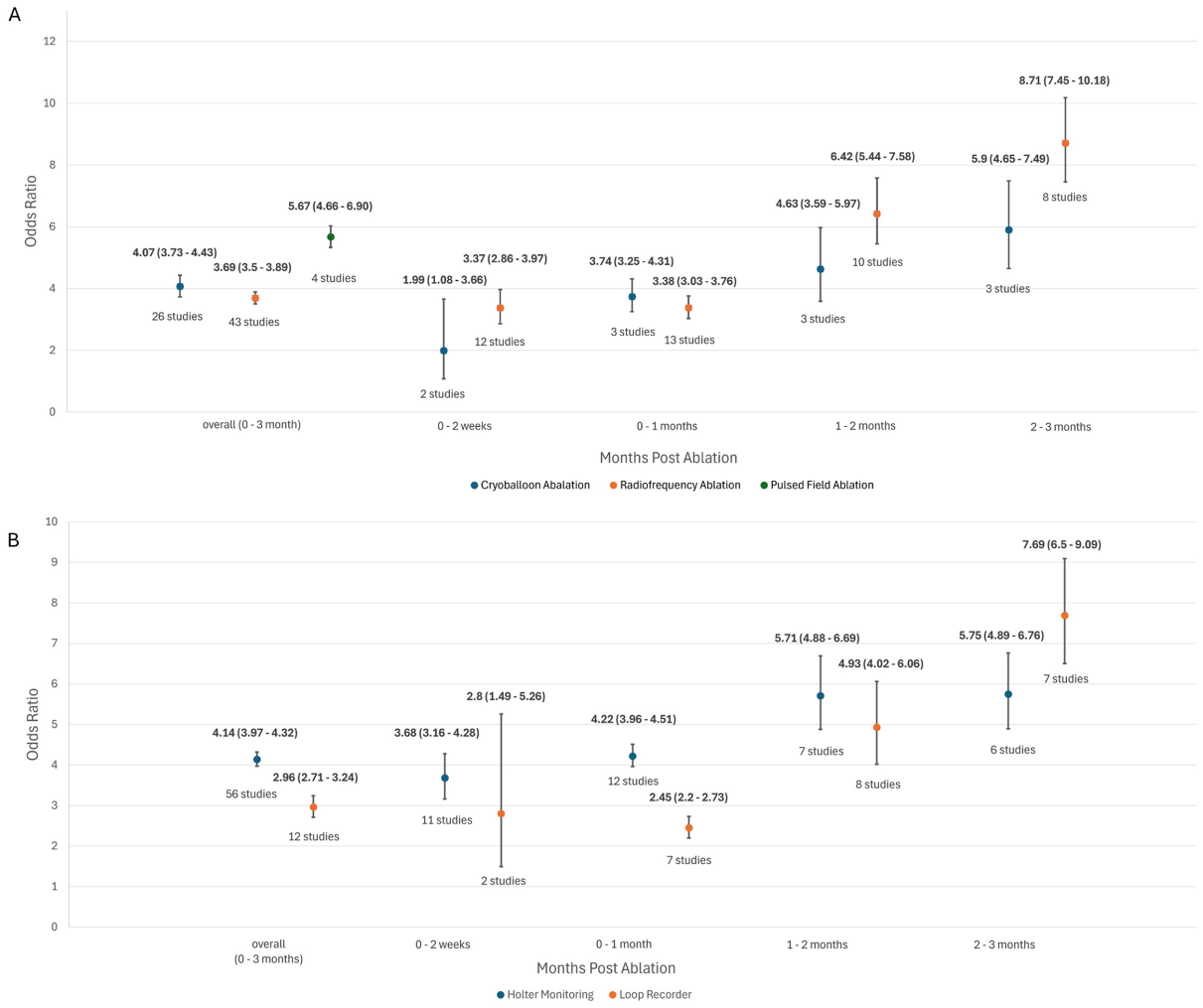


Fig. 1. Odds ratio of late recurrence stratified by: (A) ablation modality and timing of early recurrence, and (B) monitoring modality and timing of early recurrence.

group analyses also found no difference in the pooled association between early and late recurrence across follow-up modalities in the following time frames: 0–2 weeks (p = 0.53), 0–1 month (p = 0.993), 1–2 months (p = 0.88), and 2–3 months (p = 0.34). For Holter monitoring, trend analysis showed that the odds of late recurrence increased by 32% for each subsequent interval of the blanking period during which early recurrence occurred (OR 1.32; 95% CI 1.08–1.56; $p < 0.001$). Similarly, for loop recorders, the odds of recurrence increased by 71% with each subsequent interval of the blanking period on trend analysis (OR 1.71; 95% CI 1.02–2.41; $p < 0.001$).

The OR for late recurrence given early recurrence during the 3-month blanking period in patients with paroxysmal AF was 4.17 (95% CI 3.70–4.71; I^2 = 84.4%; $p < 0.001$); for persistent AF, the OR was 3.65 (95% CI 3.02–4.40; I^2 = 90.1%). Subgroup analysis demonstrated no statistically significant difference based on AF type (p = 0.37).

Egger's analysis of publication bias demonstrated data asymmetry across all 3-month and 2–3-month recurrence categories ($p < 0.001$ for both), whereas the 0–2-week, 0–1-month, and 1–2-month categories showed no evidence of asymmetry (Fig. 2). The funnel plot demonstrated asymmetry in both the 3-month and 2–3-month analyses. Trim-and-fill analysis found no evidence of missing studies in either cohort. A meta-regression of all 3-month categories, accounting for age, sex, AF type, ablation modality, and follow-up modality, found that these variables collectively did not explain the inter-study variation identified (R^2 = 0.00%, Omnibus Wald $\chi^2(10) = 12.8$; p = 0.23).

4. Discussion

This meta-analysis demonstrates that early atrial arrhythmias during the 3-month blanking period predict late recurrence. The strength of the association between early and late recurrence appeared, at least numerically, to be

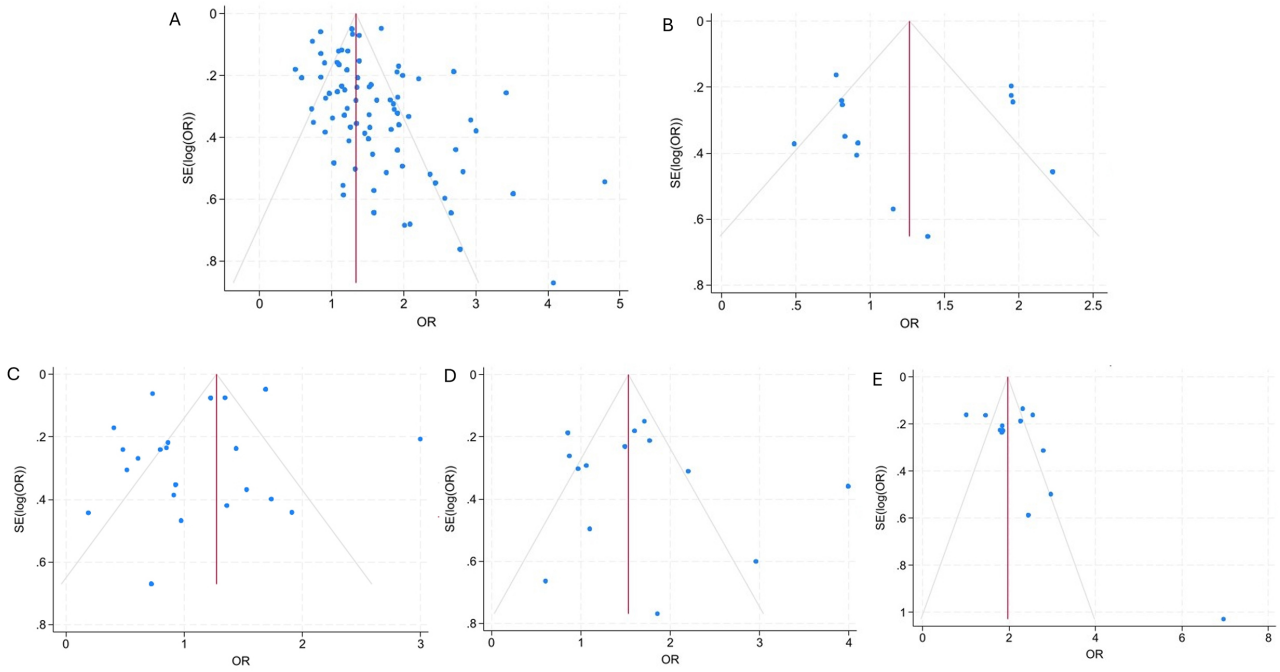


Fig. 2. Funnel plot for late recurrence according to early recurrence stratified by the timing of early recurrence. (A) Early recurrence occurring within the first 3 months. (B) Early recurrence within 0–2 weeks. (C) Early recurrence within 0–1 month. (D) Early recurrence within 1–2 months. (E) Early recurrence within 2–3 months.

time-dependent; that is, the later the onset of recurrence within the typical 3-month blanking period, the stronger the association with subsequent arrhythmia recurrence. In subgroup analyses, the association between early and late recurrence was consistent across ablation modalities (RFA, CBA, and PFA), follow-up monitoring methods (Holter monitor versus loop recorder), and AF type (paroxysmal versus persistent).

Recent guidelines have recommended reducing the blanking period to eight weeks, which is consistent with our findings that recurrence occurring 2–3 months post-ablation is associated with increased odds of late recurrence compared with recurrence occurring at the beginning of the blanking period [97]. However, eight weeks remains an arbitrary threshold because, in our meta-analysis, arrhythmia recurrence within eight weeks post-ablation was still associated with later recurrence. Meanwhile, very early recurrences are generally more likely to result from myocardial ischemia, edema, and post-procedural inflammation from ablation. In contrast, later recurrences are more likely to represent true disease recurrence due to pulmonary vein reconnections, non-pulmonary vein triggers, or simply substrate progression associated with atrial myopathy [97,98]. This is supported by a study of patients with AF undergoing RFA, in which elevated C-reactive protein and fibrinogen levels were associated with early recurrence within 3 days post-procedure [99]. The similar association between early and late atrial arrhythmia recurrence in the CBA and RFA cohorts may reflect the promotion of thermal injury by both modalities, leading to localized inflammation and myocardial injury. Interestingly, PFA appears to produce less inflammation in the 36 hours post-ablation, despite causing greater myocardial ischemia than both RFA and CBA [100].

Nevertheless, there may be a case for shortening the blanking period further to better delineate the risk of later recurrence. A systematic review of 13 studies reported that the optimal cutoff for the blanking period for RFA was 39 days, with an area under the curve (AUC) of 0.63 [101]. The same review also found that the optimal blanking period for CBA was 30 days, with an AUC of 0.76; however, only three studies were included in that analysis [101]. Another recent systematic review and meta-analysis reported that atrial arrhythmia recurrence within 90 days after PFA had a positive predictive value (PPV) of 66%, while recurrence within 60 days post-PFA had a PPV of 63% to 81% for late recurrence [98]. However, data remain limited on whether a 30-day blanking period would reduce the PPV to an acceptable level without resulting in overtreatment [98]. Our understanding of the long-term biophysics of PFA also remains incomplete, particularly regarding lesion durability, the effects of lesion overlap and associated tissue depth, and the distinction between reversible and irreversible electroporation, thereby making recommendations for a definitive blanking period challenging [102]. Furthermore, some may argue on philosophical grounds that the concept of a blanking period diminishes the role of the clinician in assessing the clinical context of arrhythmia recurrence and the appropriateness of further intervention for individual pa-

tients, whether that involves changing antiarrhythmic therapy, performing electrical cardioversion, or undertaking a repeat procedure [103].

Our study found no difference in the association between early and late recurrence of atrial arrhythmia across monitoring modalities. This may be due to similar intra-cohort detection rates of atrial arrhythmias during and after the blanking period, as Holter monitors are worn only intermittently and are less sensitive than continuous cardiac monitoring [104]. Notably, the overall predictive ability of recurrence at any time during the first 3 months after ablation was higher with Holter monitoring than with loop recorder data (OR 4.14 versus 2.96, respectively). This could reflect subclinical arrhythmias incidentally detected by loop recorders, which might be short-lived and asymptomatic. Studies in patients with stroke or at high risk of stroke have shown that implantable loop recorders are associated with nearly a four-fold increase in AF detection compared with standard care [105]. Although prolonged continuous monitoring undoubtedly detects more AF, the more pertinent issue is the clinical relevance of these episodes and the overall arrhythmia burden. Indeed, the CAPLA trial showed no significant difference in arrhythmia recurrence between pulmonary vein isolation alone and pulmonary vein isolation with or without posterior wall isolation in patients with persistent AF. However, the median AF burden remained 0% in both groups at 12 months [106]. Nevertheless, the absence of observed differences across time points within the first 3 months between monitoring modalities is subject to significant heterogeneity, and this meta-analysis remains observational; therefore, any apparent numerical differences at specific time points should be interpreted cautiously.

5. Limitations

This study has several limitations. First, this review did not account for arrhythmia burden. A sub-analysis of the DECAAF II trial demonstrated that AF burden during the blanking period predicted disease recurrence [107]. Second, Egger's analysis showed evidence of asymmetry, suggesting publication bias or heterogeneity. Since the trim-and-fill analysis showed no imputed studies, the asymmetry is more likely attributable to interstudy heterogeneity than to publication bias. This is consistent with the significant heterogeneity observed in the meta-analysis. Third, a formal evaluation of study quality was not conducted; therefore, potential bias should be considered when interpreting the findings of this review.

6. Conclusions

This study highlights the temporal relationship between early and late recurrence of atrial arrhythmia after catheter ablation for AF. This relationship should be considered when stratifying the risk of later recurrence in a patient, as this could influence subsequent monitoring, follow-up, and the potential need for repeat ablation. Further research is needed to determine the temporal association between early and late recurrence in patients undergoing PFA across different time intervals.

Availability of Data and Materials

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

FJH designed the review and contributed the conception of the manuscript. PC designed the tables, figures and analyzed the data. PC, FJH, HCH, AJB, NN and EK drafted the manuscript and contributed to the conception of the study. PC, FJH, HCH, AJB, NN, and EK contributed to critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work according to ICMJE guideline criteria and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

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Conflicts of Interest

E.K. reports serving on the medical advisory boards for Medtronic, Boston Scientific, and Biotronik. Other authors do not have relevant disclosures.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/RCM53232.

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