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ORIGINAL ARTICLE

High power short duration versus low power long duration ablation in patients with atrial fibrillation: A meta-analysis of randomized trials

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Abstract

Background: High-power-short-duration (HPSD) radiofrequency (RF) ablation is a viable alternative to low-power-long-duration (LPLD) RF for pulmonary vein isolation (PVI). Nevertheless, trials showed conflicting results regarding atrial fibrillation (AF) recurrences and few data concerning complications. Therefore, we conducted a meta-analysis of randomized trials comparing HPSD versus LPLD.

Methods: We systematically searched the electronic databases for studies published from inception to March 31, 2023 focusing on HPSD versus LPLD. The study endpoints were AF recurrence, procedural times and overall complications.

Results: Five studies enrolling 424 patients met the inclusion criteria (mean age 61.1 years; 54.3% paroxysmal AF; mean LVEF 58.2%). Compared to LPLD, HPSD showed a significantly lower AF recurrence rate [16.3% vs. 30,1%; RR: 0.54 (95% CI: 0.38–0.79); $p = 0.001$] at a mean 10.9 months follow-up. Moreover, HPSD led to a significant reduction in total procedural time [MD: −26.25 min (95%CI: −42.89 to −9.61); $p = 0.002$], PVI time [MD: −26.44 min (95%CI: −38.32 to −14.55); $p < 0.0001$], RF application time [MD: −8.69 min (95%CI: −11.37 to −6.01); $p < 0.00001$] and RF lesion number [MD: −7.60 (95%CI: −10.15 to −5.05); $p < 0.00001$]. No difference was found in either right [80.4% vs. 78.2%; RR: 1.04 (95% CI: 0.81–1.32); $p = 0.77$] or left [92.3% vs. 90.2%; RR: 1.02 (95% CI: 0.94–1.11); $p = 0.58$] first-pass isolation and overall complications [6% vs. 3.7%; RR: 1.45 (95%CI: 0.53–3.99); $p = 0.47$] between groups.

Abbreviations: ACE, asymptomatic cerebral emboli; AF, atrial fibrillation; AI, ablation index; HPSD, higher power short duration; LPLD, lower power longer duration; LSI, lesion index; PVI, pulmonary vein isolation; RF, radiofrequency.

Conclusion: In our metanalysis of randomized trials, HPSD ablation appeared to be associated to a significantly improved freedom from AF and shorter procedures, without increasing the risk of complications.

KEYWORDS
atrial fibrillation, HPSD, LPLD, pulmonary vein isolation, radiofrequency

1 | INTRODUCTION

Ablation of atrial fibrillation (AF) has been proven to be superior to medical therapy in preventing atrial tachyarrhythmia recurrence.[1–3] Pulmonary vein isolation (PVI) is the main strategy for AF catheter ablation.[4] Successful PVI requires the creation of contiguous, transmural lesions surrounding the pulmonary vein ostia, while avoiding extracardiac injury.

For years, PVI was achieved with a point-by-point technique using low-power (25–30 W) radiofrequency (RF) over 30–90 s, often with difficulties in maintaining adequate catheter stability and an optimal contact force over time. The major drawback is a higher risk of non-durable, less transmural lesions, which may contribute to ineffective line of electrical block and longer procedure duration, with a higher risk of veins reconnection.[5]

Recent technological advances have paved the way to novel ablation strategies[6–8]; among these, high power (40–50 W) short duration (HPSD) has been proven to be a viable alternative in terms of efficacy and safety.[9] HPSD has been demonstrated to produce larger, more superficial lesions that should not increase complication rate.[10,11]

Nevertheless, trials showed conflicting results; specifically, Shin et al.,[12] Power-AF[13], and Pilot-AF[14] observed no significant differences between HPSD and low power long duration (LPLD) in contrast to the Short-AF[15] and Hi-Lo Heat[16] trials, regarding AF recurrences.

Moreover, it is not clear yet whether there are differences in terms of complications between the two ablation strategies.[17,18]

Therefore, we conducted a meta-analysis of randomized trials with the aim of comparing freedom from AF, procedural times and overall complication rate of HPSD versus LPLD.

2 | METHODS

2.1 | Data sources and searches

We systematically searched the Medline, Embase and Scopus electronic databases for studies published from the time of inception to March 31, 2023 and focusing on HPSD versus LPLD. Two investigators (A.P. and G.V.) independently performed searches including the following terms: "high power short duration atrial fibrillation". Detailed information of our literature search strategy is available in Supplemental Material in the Expanded Methods.

Ethical approval was not required because this study retrieved and synthesised data from already published studies.

2.2 | Study selection

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement for reporting systematic reviews and meta-analyses was used in this study.

The studies had to fulfil the following criteria to be included in the analysis: (1) presence of a direct comparison between HPSD and LPLD, (2) adult (>18 years old) study population, (3) ≥6-month follow-up, (4) persistent or paroxysmal AF, and (5) reported one or more clinical outcomes. Observational studies, case reports, editorials, reviews, expert opinions, and non-English studies were excluded.

HPSD and LPLD were defined according to the definition of the studies (Table 1). LPLD group delivered a power between 20–30 W in the posterior wall and between 30–50 W in the anterior wall. The HPSD group used power between 30–50 W throughout the atrium. All lesions were delivered up to the ablation index (AI)/lesion index (LSI)/time target. Trials with an HPSD arm > 50 W were excluded.

2.3 | Data extraction and quality appraisal

Data were extracted from each study using standardized protocols and reporting forms and quality items were independently assessed.

Disagreements were resolved by consensus. The quality of individual studies was assessed using the Cochrane Risk of Bias tool for Randomized Controlled Trials.

2.4 | Study endpoints

The study endpoints were:

AF recurrence, defined as any recurrent atrial arrhythmias (AF, atrial flutter or atrial tachycardia) lasting longer than 30 s during rhythm monitoring or clinical diagnosis after the initial 2–3 month blanking period post-ablation.[19]

TABLE 1 Study baseline characteristics of patients included in the analysis.

First author	Trial	Inclusion criteria	Ablation protocol		Patients		Age		Paroxysmal AF		CHA2DS2-VASc[a]		LVEF†		Follow-up (mo)
			LPLD	HPSD	LPLD	HPSD	LPLD	HPSD	LPLD	HPSD	LPLD	HPSD	LPLD	HPSD	
Wielandts et al. 2021	POWER-AF	Paroxysmal AF	25 W at the posterior wall and roof, and with 35 W at the anterior wall until AI	45 W for every lesion until AI	48	48	61 ± 11	64 ± 11	48 (100)	48 (100)	1 (0-3)	1 (0-3)	NA	NA	6
Shin et al. 2020		Paroxysmal and persistent AF	30 W/40s and 25–30 W/20s to the posterior segments of PV antra and posterior-inferior line between each lower PV	50 W/10s and 25–30 W/20s to the posterior segments of PV antra and posterior-inferior line between each lower PV	50	50	58.7 ± 11.1	58.5 ± 7.9	24 (48)	25 (50)	1.7 ± 1.6	1.6 ± 1.5	58.9 ± 8.3	55.7 ± 11.4	12
Lee et al. 2023	SHORT-AF	Paroxysmal and persistent AF	30 W on the ridge/septal aspect and 25 W on the posterior aspects of the PV antra until AI/LSI	50 W for every lesion until AI/LSI	29	27	63 (59-68)	67 (62-73)	17 (55)	17 (59)	2 (1-3)	2 (1-3)	60 (55-60)	60 (50-65)	12
Leo et al. LSI 4 2020	PILOT-AF	Paroxysmal and persistent AF	20 W at the posterior wall and 40 W at the roof, floor and anterior wall until LSI 4	40 W for every lesion until LSI 4	20	20	58.9 ± 9.2	60.1 ± 9.4	9 (45)	8 (40)	1 (0–2)	1 (1–3)	60.0 ± 11.5	60.0 ± 9.2	12
Leo et al. LSI 5 2020	PILOT-AF	Paroxysmal and persistent AF	20 W at the posterior wall and 40 W at the roof, floor and anterior wall until LSI 5	40 W for every lesion until LSI 5	20	20	55.7 ± 10	61.3 ± 9.6	6 (30)	8 (40)	1 (1–2)	2 (0–4)	60.0 ± 10.2	57.9 ± 6.4	12
Chieng et al. 2023	Hi-Lo HEAT	Paroxysmal and persistent AF	25 W at the posterior wall, 40 W anterior wall until AI/LSI	40-50 W for every lesion until AI/LSI	44	44	59.7 ± 10.0	62.9 ± 8.2	21 (48)	15 (34)	1.5 ± 1.5	2 ± 2	54.6 ± 11.4	55.4 ± 13.0	12

Abbreviations: AI, ablation index; AF, atrial fibrillation; HPSD, high power short duration; LPLD, low power long duration; LSI, lesion Index; NA, not available; LVEF, left ventricular ejection fraction; mo, months.
[a] mean ± SD (min–max); † mean ± SD.

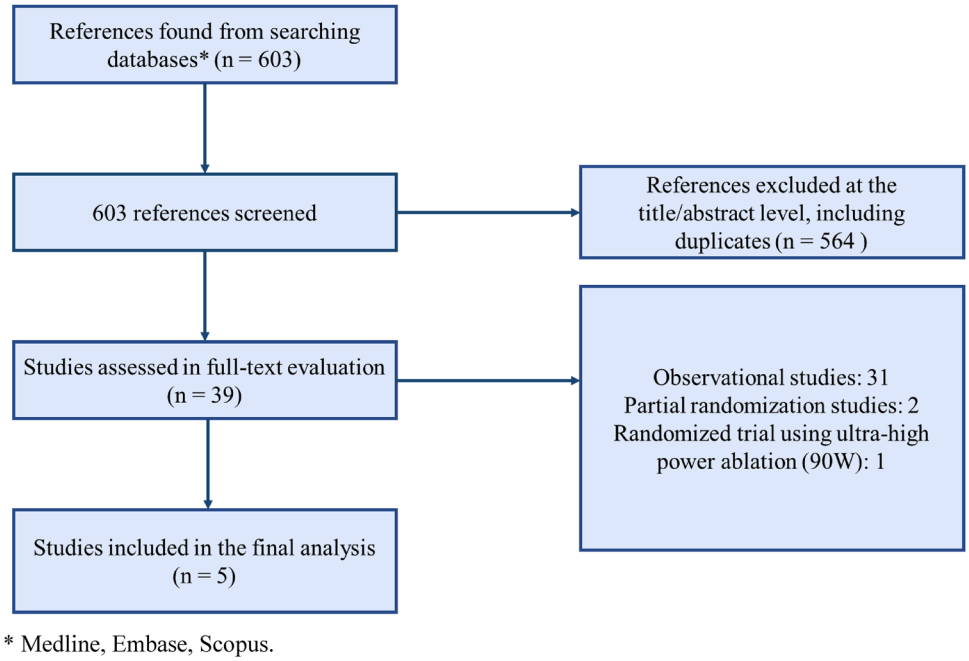

FIGURE 1 Evidence search and selection of the preferred reporting items for systematic reviews and meta-analyses (PRISMA). * Medline, Embase, Scopus. [Color figure can be viewed at wileyonlinelibrary.com]

Total procedure time (from initial femoral access to catheter withdrawal from all sheaths), PVI time (from the first to the final lesions applied to the pulmonary vein to achieve circumferential ablation and entrance/exit block), first pass right and left PVI, RF application time and number of RF lesions.

Overall complications included esophageal injury, stroke/TIA and pericardial tamponade.

2.5 | Statistical analysis

Descriptive statistics are presented as means and standard deviations (SD) for the continuous variables or a number of cases (n) and percentages (%) for the dichotomous and categorical variables. The Mantel–Haenszel risk ratio (RR) model was used to summarize the data for binary outcomes among the treatment arms. Summary estimates and 95% confidence intervals (CI) were reported for the continuous variables as the standardized mean difference. The heterogeneity across studies was evaluated by using the Chi^2, Tau^2, and Higgins-I^2 statistics and random effects models of DerSimonian and Laird was used. We performed a sensitivity analysis of AF recurrence, excluding a trial enrolling only paroxysmal AF patients, and a sensitivity analysis of total procedural time, excluding a trial AI blinded. The publication bias was assessed using the funnel plot. The statistical analysis was performed using Review Manager (RevMan) (computer program) Version 5.4.1, Copenhagen, Denmark: Nordic Cochrane Centre, the Cochrane Collaboration, 2020.

3 | RESULTS

3.1 | Study selection and baseline characteristics

Among 603 screened articles, 39 full texts were retrieved and reviewed for possible inclusion; a total of five randomized trials[12–16] fulfilled the selection criteria and were included in the final analysis (Figure 1).

The studies enrolled 424 patients (Group HPSD: 211 patients; Group LPLD: 213 patients). Overall, 71.4% (95% CI: 67.2–75.7) patients were male with an average age of 61.1 years (95% CI: 59.4–62.7); mean left ventricular ejection fraction (LVEF) was 58.2% (95% CI 56.9–59.5) and 54.3% (95% CI: 23.5–85.0) of patients had paroxysmal AF. The average follow-up time was of 10.9 months (95% CI: 8.3—12.0). In all trials, lesions were delivered up to the AI/LSI target, except for the study by Shin et al. which used a time target. The study by Leo et al. included four groups (two LPLD and two HPSD) with two different LSI targets, so they were divided according to the LSI target (four and five, respectively). In the LPLD group, energy below 35 W was delivered in all segments in three studies, while in the PILOT-AF and the Hi-Lo HEAT trial, energy below 35 W was only used in the posterior segments. In the HPSD group, four studies used an energy greater than 40 W in all segments except in the trial by Shin et al. which used a lower energy in the posterior segments. Further details on baseline characteristics of the studies population are reported in Table 1.

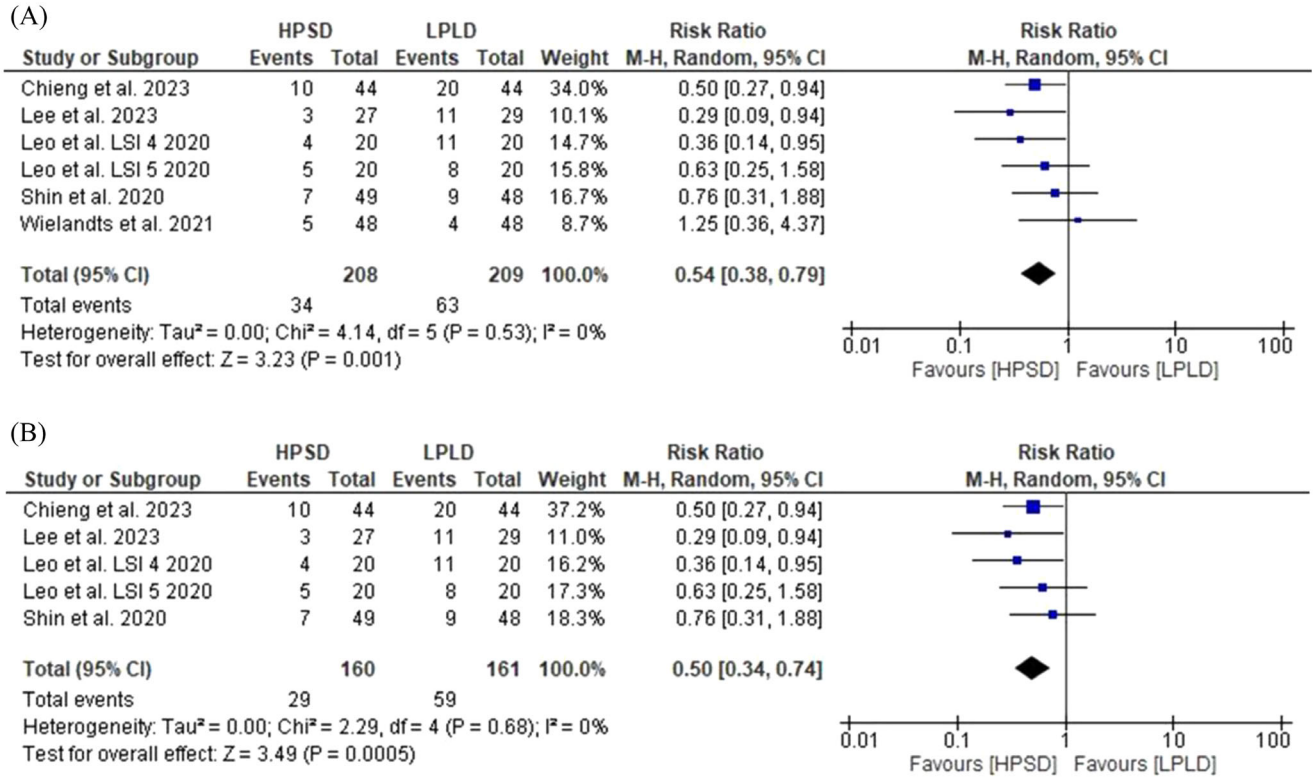

FIGURE 2 Forest plot comparing AF recurrence between high power short duration and low power long duration (A). Sensitivity analysis comparing high power short duration and low power long duration without power-AF trial (B). AF, atrial fibrillation; HPSD, high power short duration; LPLD, low power long duration. [Color figure can be viewed at wileyonlinelibrary.com]

3.2 | AF recurrence

All studies reported data on AF recurrence. HPSD showed a significantly lower AF recurrence rate compared to LPLD [16.3% vs. 30.1%; RR: 0.54 (95% CI: 0.38–0.79); $p = 0.001$; $I^2 = 0\%$] (Figure 2A).

As Wielandts et al.[13] included only paroxysmal AF patients with 6 months of follow-up, we performed a sensitivity analysis excluding this trial. An ablation strategy based on HPSD still presented fewer atrial tachyarrhythmia recurrences than LPLD [18.1% vs. 36.6%; RR: 0.50 (95% CI: 0.34–0.74); $p = 0.0005$; $I^2 = 0\%$] (Figure 2B).

3.3 | Total procedural time

Total procedural time was evaluated in all studies. HPSD showed a significantly shorter procedural time than LPLD [MD: −26.25 (95% CI: −42.89 to −9.61); $p = 0.002$] but with high heterogeneity ($I^2 = 77\%$) (Figure 3A). Therefore, we performed a sensitivity analysis excluding Shin et al.,[12] that was the only AI blinded study. After excluding this trial, HPSD maintained a shorter procedural time than LPLD [MD: −18.21 (95% CI: −26.52 to −9.91); $p < 0.0001$] and with no heterogeneity ($I^2 = 0\%$) (Figure 3B).

3.4 | PVI time

HPSD was characterized by a significant reduction in PVI time [MD: −26.44 min (95% CI: −38.32 to −14.55); $p < 0.0001$] with high heterogeneity ($I^2 = 71\%$) (Figure 4A). There was no change in heterogeneity after sequential exclusion of studies for this outcome.

3.5 | RF application time

Three studies reported data on RF application time. HPSD showed a significantly lower RF application time compared to LPLD [MD: −8.69 min (95% CI: −11.37 to −6.01); $p < 0.00001$; $I^2 = 34\%$] (Figure 4B).

3.6 | RF lesions number

In the four studies reporting data on the number of RF lesions, HPSD resulted in fewer RF lesions than LPLD [MD: −7.60 (95% CI: −10.15 to −5.05); $p < 0.00001$; $I^2 = 0\%$] (Figure 4C).

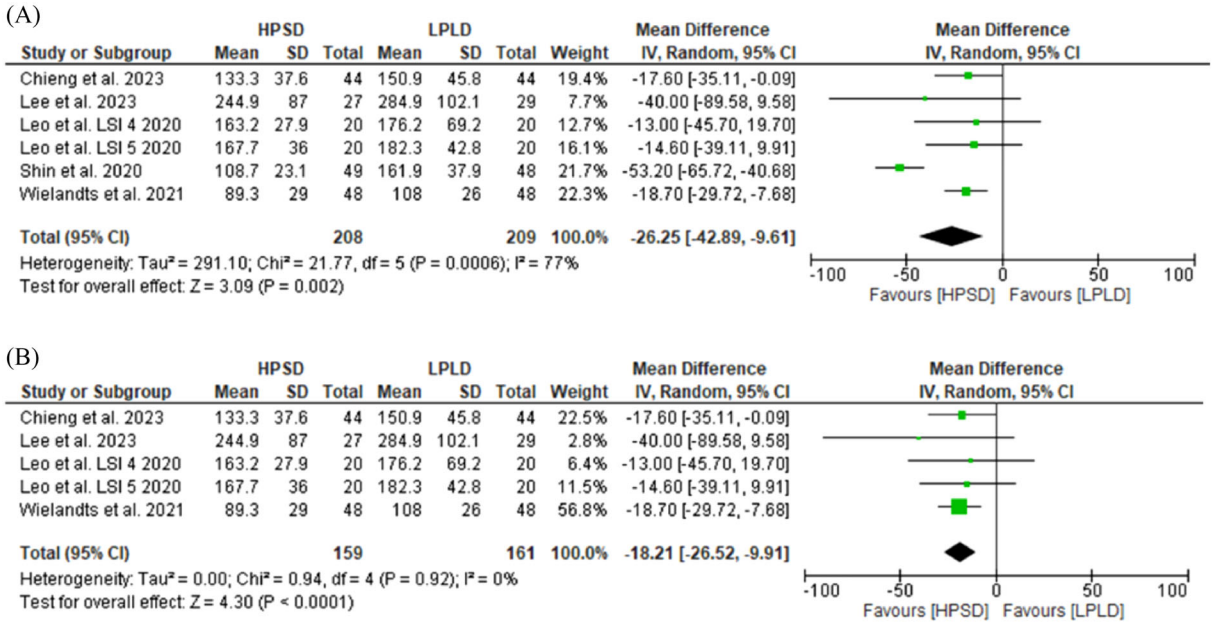

FIGURE 3 Forest plot comparing total procedural time between high power short duration and low power long duration (A). Sensitivity analysis comparing high power short duration and low power long duration without Shin et al. study (B). AF, atrial fibrillation; HPSD, high power short duration; LPLD, low power long duration. [Color figure can be viewed at wileyonlinelibrary.com]

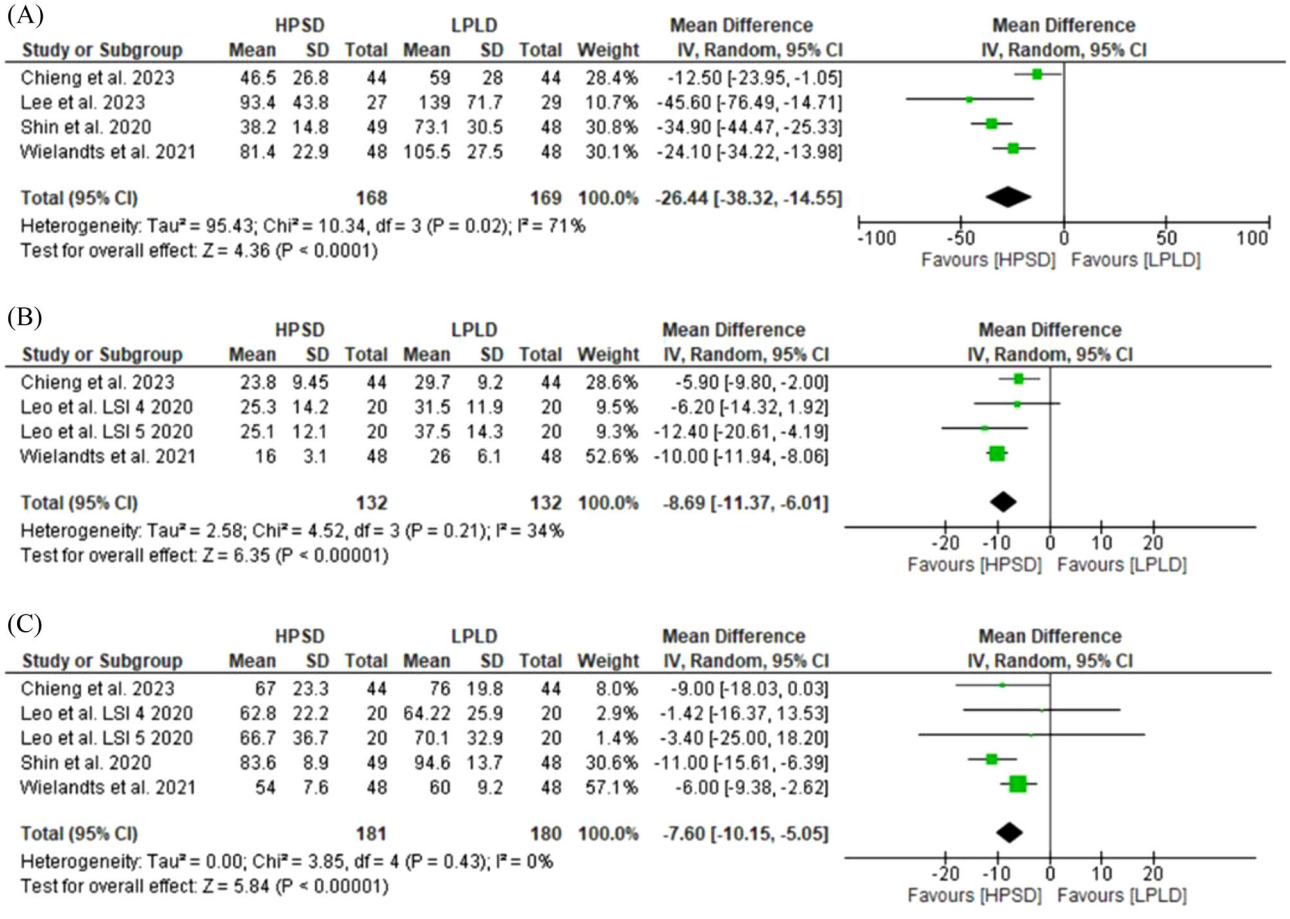

FIGURE 4 Forest plot comparing PVI time (A), RF application time (B) and Number of RF lesions (C) between high power short duration and low power long duration. HPSD, high power short duration; LPLD, low power long duration; PVI, pulmonary vein isolation; RF, radiofrequency. [Color figure can be viewed at wileyonlinelibrary.com]

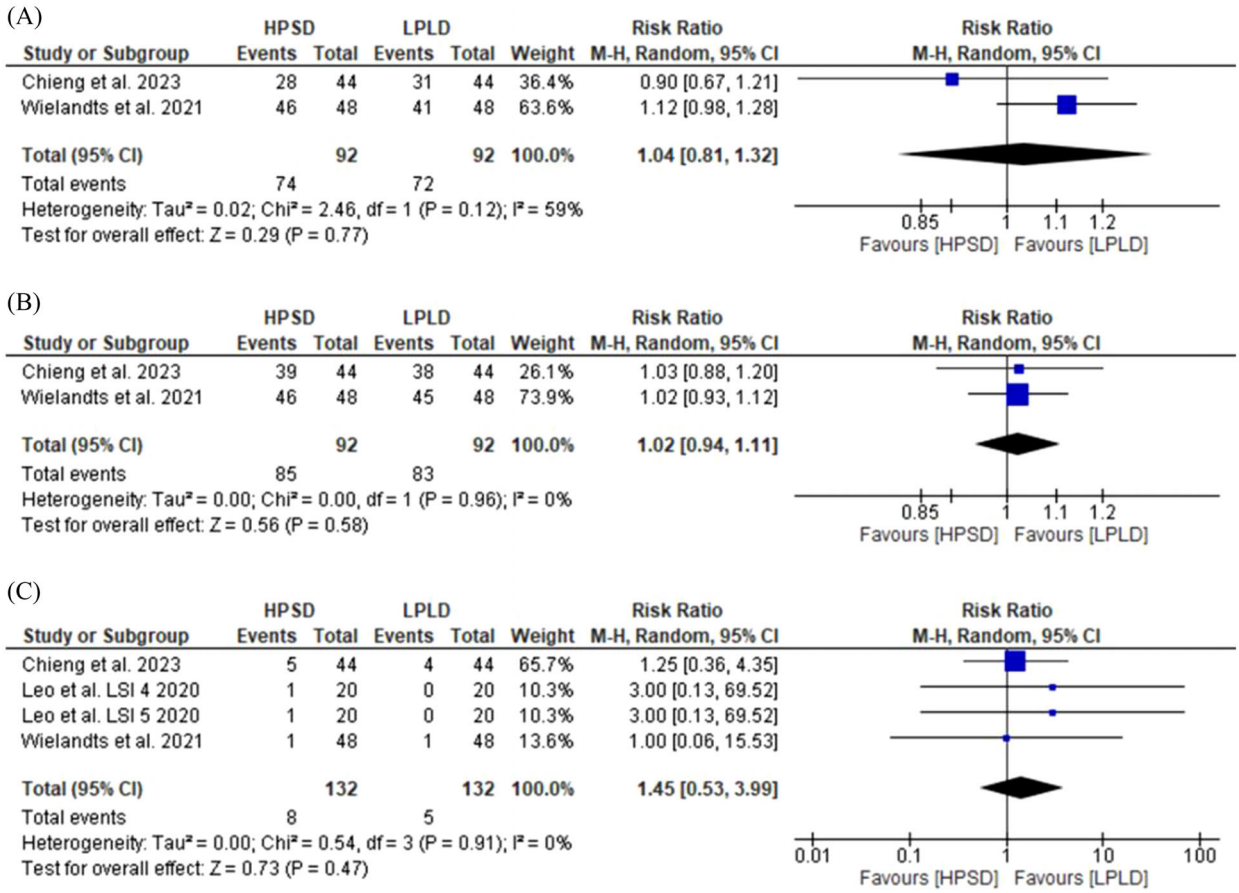

FIGURE 5 Forest plot comparing right first pass isolation (A), Left first pass isolation (B) and Overall complications (C) between high power short duration and low power long duration. HPSD, high power short duration; LPLD, low power long duration. [Color figure can be viewed at wileyonlinelibrary.com]

3.7 | First pass isolation

Two trials reported comparable data on first-pass isolation. No difference was found in either right [80.4% vs. 78.2%; RR: 1.04 (95% CI: 0.81–1.32); $p = 0.77$; $I^2 = 59\%$] or left [92.3% vs. 90.2%; RR: 1.02 (95% CI: 0.94–1.11); $p = 0.58$; $I^2 = 0\%$] first-pass isolation (Figure 5A,B).

3.8 | Overall complications

No differences were found in overall complication rate between the two groups [6% vs. 3.7%; RR: 1.45 (95% CI: 0.53–3.99); $p = 0.47$; $I^2 = 0\%$] (Figure 5C). The most common complication was esophageal injury in both groups. A summary of the overall complications is shown in Table 2.

3.9 | Publication bias

A graph and summary of Cochrane Risk of Bias tool for Randomized Controlled Trials is reported in Figure S1. The funnel plots for visual inspection of the bias showed no bias (Figure S2).

4 | DISCUSSION

This meta-analysis provides a comprehensive overview of the outcomes of HPSD and LPLD ablation for AF. The main findings are:

1. HPSD appeared to be associated with greater freedom from AF than LPLD.
2. HPSD seemed to reduce procedural time, PVI time, RF application time and the number of RF lesions.
3. There were no differences in first-pass isolation and in the overall complication rate between the two ablative strategies.

To the best of our knowledge, this is the first meta-analysis of randomized trials between HPSD and LPLD. Previous meta-analyses,[17,20] although with similar results, largely involved observational studies.

However, to understand our findings, it is useful to approach biophysics.

The irrigated RF ablation catheter tip induces a thermal lesion consisting of a resistive and a conductive phase. During the resistive phase, the electric current causes immediate heating of the surface tissue layer. This heat extends passively to the deeper tissue layers

TABLE 2 Summary of overall complications in the included studies.

Complications									
		Patients		Esophageal lesions		Stroke/TIA		Pericardial tamponade	
First author	Trial	LPLD	HPSD	LPLD	HPSD	LPLD	HPSD	LPLD	HPSD
Wielandts et al. 2021	POWER-AF	48	48	1	1	0	0	0	0
Chieng et al. 2023	Hi-Lo HEAT	44	44	4	5	0	0	0	0
Shin et al. 2020		50	50	0	0	0	0	0	0
Lee et al. 2023	SHORT-AF	31	29	0	0	0	0	0	0
Leo et al. LSI 4 2020	PILOT-AF	20	20	0	0	0	1	0	0
Leo et al. LSI 5 2020	PILOT-AF	20	20	0	0	0	0	0	1

Abbreviations: HPSD, high power short duration; LPLD, low power long duration.

during the conductive phase. Conductive heating is time-dependent and the result of the current applied and heat produced in the resistive phase.[21] Theoretically, the shorter power delivery of HPSD reduces the temperature rise in deeper tissues, resulting in a reduction in the depth of HPSD lesions compared to LPLD,[22] with the possibility of not performing transmural lesions.

Recurrence of AF is associated with non-transmural lesions.[23] However, the average thickness of the left atrial wall is 1.5–2 mm, ranging from 0.5–4 mm.[24] HPSD has been shown to reach a minimum depth of 2.1 mm.[25] Therefore, HPSD, despite producing a less deep lesion, ensures transmural lesions and lower risk of extracardiac injury. Indeed, porcine studies observed transmural endocardial lesions and more superficial esophageal adventitia injury with HPSD compared with LPLD.[10,26] Power AF and Hi-Lo HEAT trial showed that HPSD had a similarly low incidence of esophageal thermal injuries to LPLD ablation.[13,16]

Furthermore, the relatively increased ratio between irrigation and power with LPLD results in greater conductive cooling than with HPSD. Hence, high power delivery is expected to increase lesion diameters compared to LPLD.[27,28]

Increasing the diameter of lesions means improving contiguity between adjacent lesions, promoting complete encirclement of pulmonary veins. Histological studies showed that the width of the lesions on the endocardium was significantly greater after ablation with HPSD than after ablation with LPLD.[10,26]

Although observational studies have shown a lower frequency of PV reconnection with HPSD,[29] no randomized trial or this meta-analysis has confirmed this result.[17] In the swine model, Leshem et al.[27] observed that both HPSD and LPLD resulted in PV first-pass isolation in all cases, but gross pathology revealed gaps and partial-thickness lesions only in animals subjected to LPLD, whereas 100% contiguity of lesions was found in swine subjected to HPSD. Furthermore, Yavin et al.[11] showed that at redo procedures HPSD ablation led to much lower rates of chronic PV reconnections than LPLD.

Therefore, these studies suggest that, in addition to the contiguity of the lesions, their durability is also crucial for the success of ablation.[15]

Indeed, shorter duration of delivery promotes catheter stability and contact force during respiratory acts, resulting in a reduction in the transient suppression of the electrical excitability of tissue oedema, leading to optimal and durable lesions.[5,30]

There are concerns about the use of HPSD ablation and ischemic brain lesions. In the studies included in our meta-analysis only one stroke occurred in the HPSD arm, but Short AF showed a non-significantly increased incidence of asymptomatic cerebral emboli (ACE).[15] These could be due to char, thrombus, steam pops or air/gas embolism from the RF lesion site and from manipulation of ablation devices, especially in high velocity saline/contrast injections.[31–33] An animal study by Takami et al. showed that ablation with 50 W was more likely to produce microparticles in blood filters in an extra-corporeal circulation loop than ablation with 30 W since it induced excessive heating of tissue and blood with a higher risk of coagulum formation. Indeed, RF energy injures the endothelium, exposing subendothelial components such as collagen and tissue factors, leading to platelet activation and thrombus formation. Furthermore, blood at the electrode-endothelium interface can form char or thrombi due to overheating. These clots are not derived from the coagulation cascade, so anticoagulants do not prevent their formation.[33]

Takami et al. also observed that drag ablation tended to cause more microparticles than point-by-point ablation, due to greater overlapping of lesions resulting in overheating of the tissue.[32] This suggests that not only the power but also RF application time is relevant in the formation of ACE.

The clinical significance of ACE is unclear, as von Bary et al[34] did not find any difference in neurocognitive function between patients with or without ACE following ablation. Furthermore, MACPAF Study showed that ACE tend to disappear at follow-up.[35]

However, Power Fast III trial[18] observed not only an increase in ACE but also more symptomatic embolic events.

Power Fast III is an ongoing randomized trial using 70 W for 9—10 s in high power arm versus 25—40 W guided by LSI/AI in low power arm, with a one-year follow-up. It showed HPSD and persistent AF were predictors of ischemic brain lesions. Furthermore, it observed a non-significant lower recurrence of AF with HPSD with the same procedural times compared to LPLD.

The results of these trials and our meta-analysis give us elements to reflect on the right compromise to use in HPSD. To test whether decreasing the power and time of RF applications ensures equal

efficacy with less embolic risk should be the goal of the next randomized trial.

4.1 | Limitations

Although this meta-analysis of randomized trials showed a reduction in the recurrence of AF in patients undergoing ablation with HPSD, several factors may influence this outcome that represent relevant limitations. Indeed, (1) a relatively small population was included in the trials, with the risk of over- or underestimating events of interest. (2) Patients selected for a randomized trial of catheter ablation may be healthier than those in real-life situations and therefore do not reflect clinical practice. (3) The power parameters, duration and type of catheter used in the HPSD and LPLD of the trials differ and could lead to bias in the efficacy and safety of the two groups. (4) Further ablations outside the pulmonary veins may affect clinical outcomes.[36] (5) There is a great heterogeneity in the methodology used for the evaluation of AF recurrences among the different studies, which could potentially misestimate AF recurrence rates. (6) Different AF phenotypes have been enrolled and there are not enough data to perform a subgroup analysis between persistent and paroxysmal AF, not allowing us to assess whether there were differences in outcomes between the two populations.

5 | CONCLUSIONS

In our meta-analysis of randomized studies, HPSD seemed to be superior to LPLD in improving freedom from AF, total procedural time, PVI time, RF application time and number of RF lesions, without differences in terms of complications.

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CONFLICTS OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

The data underlying this article are available in the article and in its online supplementary material.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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