Comparison of effectiveness and safety between high-power short-duration ablation and conventional ablation: a systematic review and meta-analysis

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Abstract

Aims: We aimed to further evaluate the effectiveness and safety between high-power short-duration (HPSD) radiofrequency ablation (RFA) and conventional RFA in patients with atrial fibrillation (AF). Methods: Studies comparing HPSD and conventional applications from inception through December 2021 were searched on Pubmed, Medline, Cochrane and Clinicaltrials.gov. Results: The meta-analysis included seventeen studies with a total of 4934 patients. HPSD group decreased procedure duration [mean difference (MD) -38.28 min, 95% confidence interval (CI) -47.08 to -29.49, P¡0.001], RF duration (MD -20.51 min, 95% CI -25.96 to -15.06, P¡0.001) and fluoroscopy duration (MD -5.19 min, 95% CI -8.02 to -2.37, P¡0.001), while improving the rates of first-pass isolation [Odds Ratio (OR) 8.92, 95% CI 2.40-33.09, P=0.009]. Compared with conventional group, freedom from atrial arrhythmia at 1-year-followup was higher in the HPSD group with a power setting of 40-50W (OR 1.93, 95% CI 1.27-2.91, P=0.002), nevertheless, two groups had similar effectiveness with a power setting of 50W in the HPSD RFA (OR 1.10, 95% CI 0.83-1.46, P=0.52). Acute pulmonary vein reconnection (P¡0.001) was significantly lower in the HPSD group. There was no difference in complications between the two groups (P=0.71). Conclusion: HPSD RFA was associated with shorter procedure duration, higher freedom from atrial arrhythmia and comparable safety when compared with conventional RFA.

1 Introduction:

Catheter ablation for atrial fibrillation (AF) is recommended as an effective therapy, reducing the risk of stroke, heart failure and mortality to improve the quality of life[1]. As the cornerstone of AF catheter [2,3], pulmonary vein isolation (PVI) aims to produce continuous, transmural and durable lesions around the pulmonary vein. And remarkably, pulmonary vein reconnection (PVR) can be a key driver of AF recurrence[4,5]. High-power short-duration (HPSD) ablation strategy comprises the use of higher RF power ([?]40W) and shorter duration (5-15s) of each RF energy application, and HPSD applications result in larger lesion diameters and smaller lesion depths compared to conventional (20–35W, 10-30s) applications [6]. Recent studies [7-9] demonstrate that HPSD is safe and efficient for treating AF, reducing radiofrequency catheter ablation (RFA) and procedure times, without increasing major complication rates. Meta-analyses or randomized controlled studies comparing atrial arrhythmia recurrence and rates of PVR between HPSD and conventional RFA settings with or without the guidance of ablation Index (AI) or lesion size index (LSI) are lacking. Therefore, this meta-analysis aims to compare the effectiveness and safety of HPSD and LPLD settings in RFA for AF [10].

2 Methods

2.1 Search strategy and study selection

An all-round search was conducted in Pubmed, Medline, Cochrane, Clinicaltrials.gov from inception through December 2021 by two reviewers (Shuyu Jin and Yumei Xue) independently. The search involved the following key words: ("Atrial fibrillation"OR AF) AND ("High power"OR"High-power shorter-duration"OR HPSD).

2.2 Inclusion and exclusion criteria

The studies included fulfilled the following criteria: (1) Cohort study, case-control study, cross-sectional study, or randomized controlled trial (RCT) conducted in patients with age[?]18, with paroxysmal and/or persistent AF undergoing initial catheter ablation; (2) comparison between HPSD RFA and conventional RFA; (3) studies must meet the following for each ablation strategy: HPSD settings: Power[?]40 W, with ablation duration of 5 to 15s per site including the posterior wall; Conventional settings: Power[?]35 W, duration¿10 s for any ablation; (4) reported outcome data including but not limited to procedure time, freedom from atrial arrhythmia, total complications, redo-ablation procedure;(5) the follow-up duration was at least 6 months.

The exclusion criteria were as follows: (1) conference abstracts, case reports, review articles, meta-analysis, editorials or non-English articles;(2) an equivocal study design or group allocation.

2.3 Data extraction and quality assessment

A standardized data collection form was extracted by two investigators independently to obtain the following data from each study including name of the first author, year of publication, country of origin, study population, inclusion and exclusion criteria, demographic data of participants, ablation procedure details. Disagreements were arbitrated by a third person in re-review. The original author was contacted by mail for access if the full text could be obtained. For literature in which the same study populations were reported many times or repeatedly published, only one with the most complete data was included. The quality of these studies was evaluated by two investigators (Shuyu Jin and Yumei Xue) using NewCastle Ottawa scale (NOS) for observational studies and the Cochrane Collaboration tool for assessing risk of bias of randomized controlled studies (RCTs). The NOS system consisted of eight questions with nine possible points. Higher scores represent higher study quality[11,12].

2.4 Definitions

HPSD RFA: Ablation power[?]40W, including the posterior wall, with ablation duration of 5 to 15s per site.

Conventional RFA: Ablation power limited to 20-35W, with a longer ablation duration of 10-30s per site.

Procedure time: Time from the application of local anesthesia to the withdrawal of all catheters.

RF time: Total time from the first to the last ablation site.

Fluoroscopy time: Total time for fluoroscopy from the start to the end of the procedure.

First-pass PVI: Rate of complete PVI after first-pass circumferential RF delivery.

Atrial arrhythmia recurrence: Any symptomatic or asymptomatic atrial arrhythmia lasting >30s after completing the blanking period post ablation.

Acute PVR: Acute reconnection was assessed at 20–30 minutes post ablation, and adenosine was administered intravenously (dosed to achieve transient heart block) or waiting for 30 minutes following the last RF application to assess PV reconnection,including spontaneous reconnection and dormant conduction.

Major complication:Complications that required any intervention or prolonged hospital stay including pericarditis, complete atrioventricular block, sinus node dysfunction, phrenic nerve palsy, stroke, pericardial effusion, vascular access issues, steam pop, esophageal lesions and death.

2.5 Statistical analysis

Binary variables were expressed as odds ratios (ORs) with 95% confidence intervals (CIs). Continuous variables were analyzed using the mean difference (MD) and the corresponding 95% CI estimated using the inverse-variance method. A two-sided P-value[?]0.05 was considered statistically significant. The fixed-effects model and the random-effects model were considered based on the level of heterogeneity. The heterogeneity of studies was evaluated by Cochran's Q and the I^2 statistic. I^2 lies between 0% and 100% with larger values showing increasing heterogeneity. I^2 value >50% was considered high degrees of heterogeneity and the random model was used in the subgroup analysis or sensitivity analysis excluding the trials that potentially biased the results to avoid publication bias, otherwise, a fixed-effects model was used [13,14]. We performed sensitivity analysis by omitting one study successively to evaluate the impact of the individual studies on the pooled effect size. All statistical analyses were performed using the RevMan version 5.3 (Nordic Cochrane Center; The Cochrane Collaboration, 2014).

3 Results

3.1 Eligible studies

The flowchart of the detailed search progress is illustrated in Figure 1. After removing the duplicated articles and browsing the abstracts, titles or full texts, consequently, seventeen studies[15-31] with 4934 patients were enrolled in this meta-analysis. Among these studies, ten[15,17-20,22,23,26-28] were retrospective cohort studies and seven [16,21,24,25,29-31] were prospective studies in which only one study [29] was a randomized controlled trial (RCT).

3.2 Study characteristics

Baseline characteristics among these studies are shown in Table 1 and 2. There were 2397 underwent HPSD RFA and 2537 underwent conventional ablation procedures. In the HPSD group and conventional group, mean age was 63.53 and 61.88 years, with 67.58% and 70.40% male, respectively. The baseline characteristics were not significant difference between the two groups and the follow-up duration was at least 6 months. Study quality assessed by Newcastle Ottawa scale demonstrated that ten studies scored 9 and seven studies scored 8, which indicated good quality of the included studies (Table 3).

3.3 Primary pooled analysis

Total procedure duration was significantly shorter in the HPSD RFA group compared with conventional RFA group [MD -38.28 min (95% CI -47.08 to -29.49); P¡0.001] (Figure 2, A). Compared with the conventional RFA group, total RF duration [MD -20.51 min (95% CI -25.96 to -15.06); P¡0.001] (Figure 2, B) and total fluoroscopy duration [MD -5.19 min (95% CI -8.02 to -2.37); P¡0.001] (Figure 2, C) were also significantly shorter in the HPSD RFA group. First-pass isolation (OR 8.92, 95% CI 2.40-33.09, P=0.001) (Figure 3, A) and freedom from atrial arrhythmia at one year (OR 1.48, 95% CI 1.12-1.94, P=0.005) (Figure 3, B) were significantly higher in the HPSD RFA group when compared with the conventional group. Acute PVR was significantly lower in the HPSD RFA group (OR 0.40, 95% CI 0.23-0.69, P¡0.001) (Figure 3, C). There was no difference between the two groups regarding total complications (OR 0.95, 95% CI 0.72-1.25, P=0.71) (Figure 4, A). Among these studies, only four studies described PVR during redo procedures, and there was no difference in PVR between the two groups (OR 0.65, 95% CI 0.29-1.46, P=0.29) (Figure 4, B).

There was significant heterogeneity with I^2>50% for the outcomes of procedure duration (93%), RF duration (98%), fluoroscopy duration (95%), first-pass isolation (81%), freedom from atrial arrhythmia (73%), and acute PVR (72%). All summary estimates from pooled analyses were made using a random-effects model rather than a fixed-effects model to reduce the influence of heterogeneity between studies. Sensitivity analysis demonstrated the robustness of the above results during the sequential exclusion of studies except first-pass isolation, freedom from atrial arrhythmia and acute PVR. Low heterogeneity following exclusion of one study[30] based on the follow-up monitoring for recurrence of AF demonstrated (I2=0), two studies[27,30]based on freedom from atrial arrhythmia (I2=2%) and one study[31] based on acute PVR (I^2=0). In spite of reduced heterogeneity, there were no changes in the results of differences between two groups.

3.4 Subgroup analysis

3.4.1 Studies with the guidance of AI/LSI in ablation

There were 5 studies [15,20,23,28,29] with a total of 739 patients (366 in HPSD group, 373 in conventional group) that ablated with the guidance of AI or LSI. Whether with the guidance of AI or LSI, total procedure duration [MD -21.08 min (95% CI -24.63 to -17.54); P¡0.001] and RF duration [MD -9.43 min (95% CI -12.21 to -6.65); P¡0.001] (Supplementary material online, Figure S1, A, B) were shorter in the HPSD RFA group. Guided by AI/LSI, there was no apparent difference in freedom from atrial arrhythmia at one year (OR 1.41, 95% CI 0.88-2.25, P=0.15) and PVR (OR 1.55, 95% CI 0.40-5.98, P=0.52) (Supplementary material online, Figure S1, C, D) between the two groups. However, the HPSD RFA group demonstrated higher freedom from atrial arrhythmia at one year (OR 1.66, 95% CI 1.12-2.47, P=0.01) and lower PVR (OR 0.32, 95% CI 0.17-0.61, P=0.008) (Supplementary material online, Figure S1, C, D) without the guidance of AI/LSI.

3.4.2 Studies with 50W vs 40-50W in the high-power short-duration radio frequency ablation group

In the HPSD RFA group, there were 9 studies[15,16,22-24,26-28,31] where ablation was performed with a setting of 50W, while 7 studies [17,18,20,21,25,29,30]with a power setting of 40-50W. In order to reduce heterogeneity, two studies [19,31] exceeding the power of 50 W were excluded. Without increased complication rates, freedom from atrial arrhythmia at one year was higher in the HPSD RFA group with the power setting of 40-50W (P=0.03), conversely, no difference was found in this endpoint between the two groups with the power setting of 50W (P=0.52) (Supplementary material online, Figure S2). At 50W or 40-50W, total procedure duration (P¡0.001), total RF duration (P¡0.001) and fluoroscopy duration (P¡0.001) (Supplementary material online, Figure S3) were both significantly shorter in the HPSD RFA group.

4 Discussion

This meta-analysis provides a more comprehensive assessment of HPSD RFA and conventional RFA in patients with AF. Our results suggest that HPSD RFA may be more effective with higher first-pass isolation and freedom from atrial arrhythmia and lower acute PVR when compared with conventional RFA. However, there was no difference in safety outcomes between two groups. Unlike previous studies[8,9,32], our study had more findings. In our study, there was no difference in PVR between the two groups that described redo procedures. In subgroup analysis, there was no difference between the two groups using AI/LSI guided ablation for freedom from atrial arrhythmia. And HPSD group with a power setting of 40-50W had better efficacy when compared with conventional group.

PVI is the cornerstone of AF ablation [33], however, PVR is frequent and is mostly the result of catheter instability, tissue edema, and a reversible non-transmural injury [34]. One of the main reasons for AF recurrence is the recovery of the conduction between the pulmonary veins and left atrium [35], so continuous and transmural lines are key to the success of ablation. In animal studies, the lesions were wider and HPSD ablation resulted in 100% contiguous lines with transmural lesions which improved lesion-to-lesion uniformity [36]. In 6 swine, HPSD ablation was performed using the QDOT MICROTMCatheter at a setting of 90W for 4s and conventional ablation was delivered using a Thermocool Smarttouch SF Catheter at a setting of 30W for 30s, Barkagan et al found that all lines remained intact after 30 days in HPSD ablation, while none of the lines were continuous in conventional ablation[37]. Although there was variation in the definition of freedom from arrhythmia in each study and the use of AADs, our analysis favors the HPSD RFA strategy over LPLD RFA strategy for lower acute PVR, higher first-pass isolation and higher freedom from atrial arrhythmia. Nevertheless, in our analysis, there was no difference between two groups in PVR during the redo procedure. Some patients might have had recurrence during the follow-up period, but they did not undergo redo procedures. Furthermore, the follow-up was determined to one year, therefore all the reasons above may underestimate the rate of chronic PVR.

However, the appropriate power for the RF ablation is not clear. One study [31] used higher power of 70W for 5-7s and demonstrated significantly less arrhythmia recurrence during one-year follow-up (26.9% vs 34.9%, P < 0.013) with no major complications. The QDOT-FAST trial [38] used 90W for 4s per site in 52 patients with paroxysmal atrial fibrillation and 94.2% patients were in sinus rhythm at 3 months with one pseudoaneurysm

and one asymptomatic thromboembolism. In our meta-analysis, mostly half of studies of HPSD RFA used 50W and the others using 45-50W. For freedom from atrial arrhythmia at one year, the HPSD RFA group demonstrated higher efficacy with the power setting of 45-50W, whereas the two groups were similar with the power setting of 50W. To reduce complications when ablating with 50W on the posterior atrial wall, ablation duration was shorter than that of 40/45W. Less total energy and shallower lesions which possibly not reaching transmural, resulting in no difference in the recurrence rate between the two groups[39]. Winkle et al [40] reported that 6 independent predictors affected the outcomes for HPSD ablation including age, gender, type of AF, left atrial size, type of catheter and posterior wall isolation. Therefore, further studies will be required to explore the most optimal power and duration for HPSD RFA to bring the highest clinical value.

Previous studies indicate force time integral (FTI) as a target value to achieve permanent PVI, while not considering power settings. Consequently, only 72% of PVs remained isolated in 3 months[41]. AI is a novel ablation quality marker that incorporates contact force (CF), time and power in a weighted formula and LSI is a multi-parametric index incorporating CF and radiofrequency current data across time. Many reports demonstrated that AI or LSI can be used as the correlation index of pulmonary vein persistent isolation[42,43]. HPSD-AI or LSI groups had lower recurrence of atrial arrhythmia at 12 months, higher first-pass isolation, lower acute PVR and similar complication rates in the AI-guided group compared with non-AI-guided group [32,44]. Okamatsu et al[45] studied a group of persistent AF patients undergoing AI-guided PVI with target values of 550 for anterior and 400 for posterior left atrial regions, with 22% patients demonstrating late PVR during repeat procedures after 2 months and 95% patients were in sinus rhythm at 12 months. However, freedom from atrial arrhythmia and acute PVR failed to demonstrate a significant advantage with AI or LSI in our analysis. It is regrettable that only 5 studies were included in our subgroup analysis with AI or LSI guided procedure, of which only 4 studies and 2 studies respectively illustrated freedom from atrial arrhythmia at one year and acute PVR rates. We did not analyze first-pass isolation because only one study reported this data. Therefore, more well-designed and large-scale RCTs are required to confirm these findings.

Safety during elective PVI procedures is of worthwhile concern. Radiofrequency catheter ablation is a technique where conductive and resistive heating are delivered through electrode catheters to myocardial tissue creating a thermal lesion. Irreversible myocardial tissue injury with cellular death occurs once the temperature of approximately 50 has been reached, whereas conductive heating transfers thermal energy directly to deeper tissue [46]. Unlike conventional ablation, the HPSD ablation strategy results in a higher resistive heating and lower conductive heating, which may reduce collateral injury to surrounding structures such as the esophagus[36,47]. Late gadolinium enhancement MRI of the oesophagus in 574 patients following AF ablation using HPSD settings of 50 W for 5 seconds reported a 14.3% incidence of moderate to severe thermal oesophageal late gadolinium enhancement with no fistulas[22]. Takemoto et al [48] reported that high power settings based on the AI or LSI might reduce the collateral thermal damage comparing use of 20W and 40W with the same AI or LSI for RF applications. HPSD RFA strategies performed at 45-50W have very low complication rates [49]. Likewise, in our analysis, there was no difference between the two groups across each subgroup analysis.

In terms of procedure duration, RF duration and fluoroscopy time, the HPSD RFA strategy represents distinct advantages compared with the conventional RFA strategy whether in the subgroup analysis or not. Additionally, the reduction in procedure times can decrease the intravenous fluid volumes administered to patients which may benefit patients with cardiac insufficiency. Finally, less radiation exposure will also benefit both patients and physicians [9].

To conclude, our results of the pooled analysis favour the use of HPSD settings over conventional settings. However, more RCT studies are needed to further assess the above results.

Limitations

We acknowledge several limitations in our study. First, we have only one RCT included in our meta-analysis

while the rest were non-randomized comparative studies. Although, all included studies were of good quality based on NewCastle Ottawa scale, reflecting a real-world experience, more randomized controlled trials would provide better evidence for the difference in outcomes between two groups. Second, there were variations in each study in terms of power, types of catheters, contact force, target temperature, and the definition of freedom from atrial arrhythmia, resulting in significant heterogeneity between groups. And seldom included studies analyzed total energy during ablation procedure which we could not compare between two groups. Third, on account of included studies not only performed PVI but also additional linear ablation, different surgical methods might affect the maintenance of sinus rhythm. At last, we have a limited number of studies that reported PVR during redo procedures and with the guidance of AI/LSI. Finally, exact anatomical locations of PVR were not clearly described in each study, so we could not analyze the specific locations of PVR.

Conclusions

High-power short-duration RFA was related to better procedural effectiveness and higher freedom from atrial arrhythmia with comparable safety when compared with conventional RFA. Additionally, HPSD RFA decreases procedural, RF and fluoroscopy durations. Meanwhile, in the subgroup analysis, HPSD RFA demonstrates a feasible, effective and safe approach for AF ablation.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

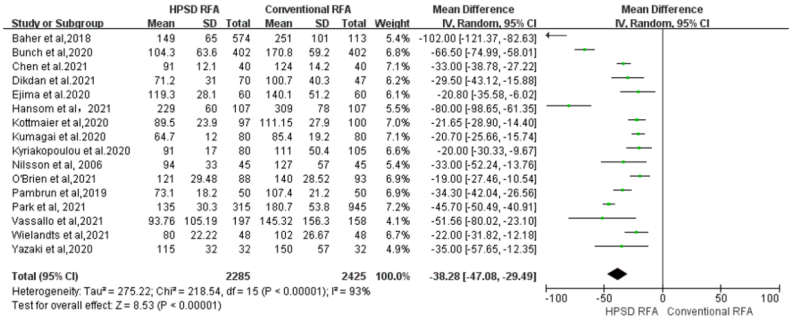
Author contributions

All authors participated in writing and editing of the manuscript.

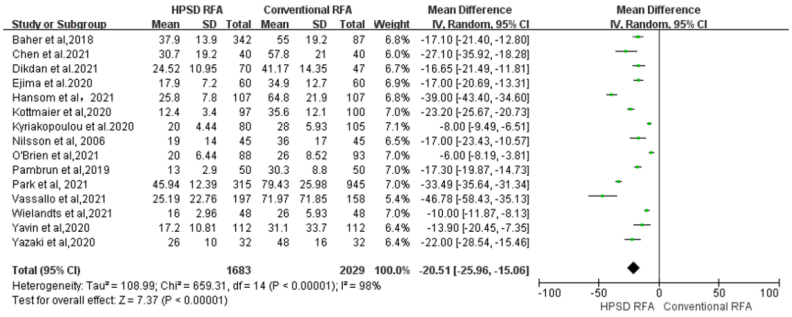
Figure 1 The flowchart of detailed search progress

Figure 2

(A) Total procedure duration



(B) Total RF duration



(C) Total fluoroscopy duration

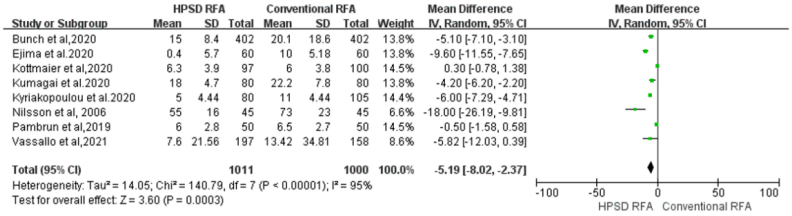
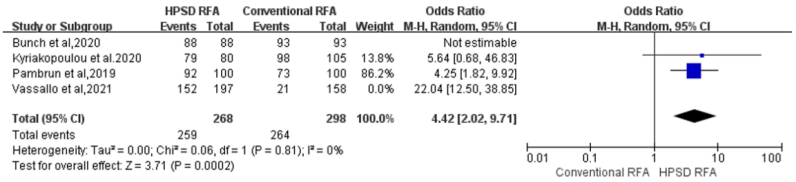


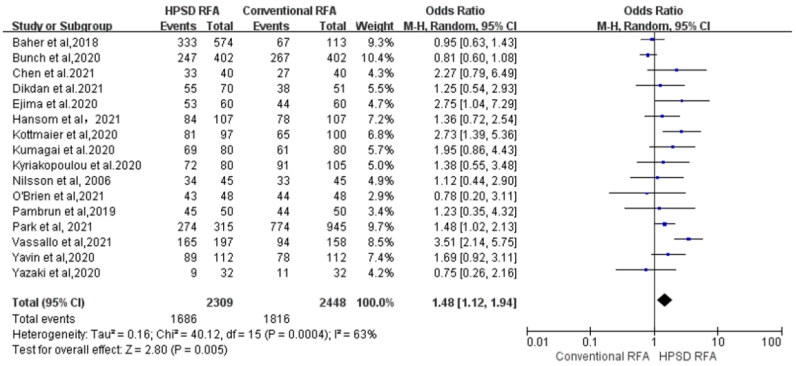
Figure 2: Forest plots of the primary pooled analysis demonstrating the effect of high-power short-duration RFA vs. conventional RFA in patients with atrial fibrillation. Data are mean duration and standard deviation in each group and weighted mean difference. The horizontal line is the 95% CI. The diamond shape is the pooled mean difference of all studies. CI: confidence interval; RFA: radiofrequency ablation.

Figure 3

(A) First-pass isolation



(B) Freedom from atrial arrhythmia at one year



(C) Acute PVR

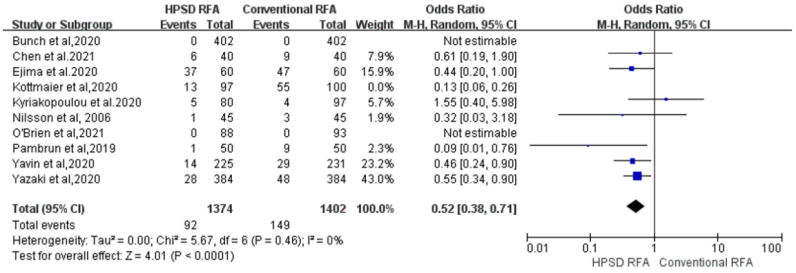
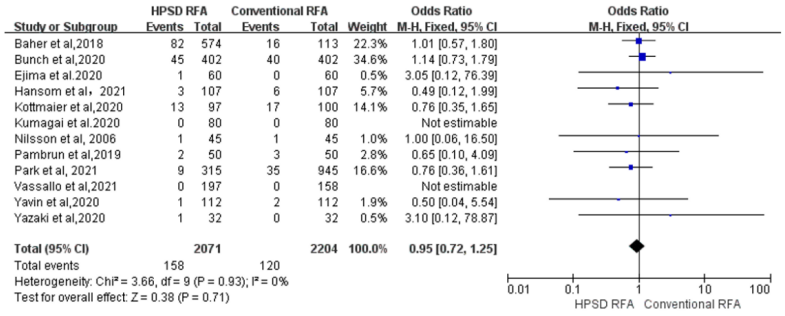


Figure 4

(A) Total complications



(B) PVR during redo procedures

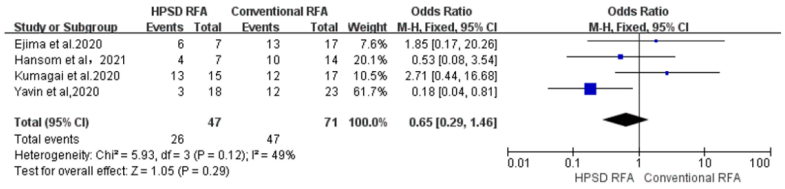


Figure 3,4: Forest plots of the primary pooled analysis demonstrating the effect of high-power short-duration RFA vs. conventional RFA in patients with atrial fibrillation. Data are events in each group and weighted odds ratios. The horizontal line is the 95% CI. The diamond shape is the pooled mean difference of all studies. CI: confidence interval; RFA: radiofrequency ablation, PVR: pulmonary vein reconnection.

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