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Comparisons of Procedural Characteristics and Clinical Outcomes between SMARTTOUCH® SURROUNDFLOW Catheter and Other Catheters for Atrial Fibrillation Radiofrequency Catheter Ablation: A Systematic Literature Review

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Abstract

Background: SMARTTOUCH® SURROUNDFLOW (STSF) catheter is the new generation of SMARTTOUCH (ST) catheter with an upgraded irrigation system for radiofrequency catheter ablation (RFCA) in patients with atrial fibrillation (AF). **Methods**: This systematic literature review searched the major English and Chinese bibliographic databases from 2016 to 2022 for any original clinical studies assessing the STSF catheter for RFCA in AF patients. Meta-analysis with random effects model was used for evidence synthesis. **Results**: Pooled outcomes from 19 included studies indicated that STSF catheter was associated with a significantly shorter procedure time [weighted mean difference (WMD): -17.4 minutes, $p<0.001$], shorter ablation time (WMD: -6.6 minutes, $p<0.001$), and lower catheter irrigation fluid volume (WMD: -492.7 ml, $p<0.001$) than ST catheter. Pooled outcomes from 4 included studies with paroxysmal AF patients reported that using the STSF catheter for RFCA was associated with a significantly shorter ablation time (WMD: -5.7 minutes, $p<0.001$) and a lower risk of one-year post-ablation arrhythmia recurrence (rate ratio: 0.504, $p<0.001$) than the SURROUNDFLOW (SF) catheter. Significant reductions in procedure time and ablation time associated with the STSF catheter were also reported in the other 4 studies using non-ST/SF catheters as the control. Overall complications of STSF catheter and control catheters were comparable. **Conclusions**: Using the STSF catheter was superior to using the ST catheter to conduct RFCA for AF by significantly reducing procedure time, ablation time, fluoroscopy time, and irrigation fluid volume. The superiority of the STSF catheter over the SF catheter and other non-ST/SF catheters for RFCA needs further confirmation.

Strengths and limitations of this study

This study was a comprehensive systemic literature review including published evidence assessing all existing catheters for radiofrequency catheter ablation in patients with atrial fibrillation. In addition, the literatures search was conducted in both English and Chinese bibliographic databases. This study conducted subgroup analysis to explore the sources of heterogeneity in the pooled outcomes and generated robust evidence for the comparisons of the outcomes associated with SMARTTOUCH® SURROUNDFLOW (STSF) catheter and SMARTTOUCH (ST) catheter. The existing evidence was insufficient to support full comparisons of ablation-related complications and long-term clinical outcomes associated with ablation catheters.

Keywords
atrial fibrillation; radiofrequency catheter ablation; SMARTTOUCH® SURROUNDFLOW; systematic literature review; meta-analysis

1. Introduction

Radiofrequency catheter ablation (RFCA) plays a critical role in managing atrial fibrillation (AF), which affects 1.6% of the Chinese adult population and is rising in prevalence along with the aging population in China [1]. RFCA was originally conducted using a non-contact force (CF)-sensing catheter, whose use is now discouraged due to the inadequate lesion formation caused by insufficient CF or complications (such as cardiac perforation and atrioesophageal fistula) caused by excessive CF [2]. Thus, a CF-sensing catheter was developed to improve ablation outcomes and safety. The THERMOCOOL SMARTTOUCH® (ST) catheter is one of the CF-sensing catheters widely used for RFCA. The ST catheter is equipped with a technology that can measure the CF generated by the catheter tip on the myocardium and an irrigation system that cools the tip of the electrode catheter during ablation and allows high radiofrequency energy ablation without overheating at the electrode-tissue interface [3]. To enhance the cooling effects on the tip of the catheter electrode, surround flow (SF) technology was developed by equipping the catheter porous tip with 56 tiny holes, which make conduits for optimal fluid pressure distribution in the catheter tip. As the new generation of a catheter with advanced irrigation technology, the STSF catheter combines both CF and SF technologies to optimize ablation outcomes, protect cardiac function, and reduce the risk of developing eschar during ablation [4]. According to a meta-analysis of four clinical trials published before 2020, the STSF catheter was superior to the ST catheter in procedure outcomes by reducing the procedure time, fluoroscopy time, and catheter irrigation infusion volume [5]. However, this meta-analysis was unable to assess the robustness of the pooled evidence due to the small number of included studies. With accumulated evidence from recently published studies assessing STSF catheter ablation in patients with AF, we conducted this systematic literature review (SLR) aiming to add more evidence from multiple sources (journals published in Chinese and recent conference proceedings) and including studies comparing STSF versus (vs.) catheters other than ST to better comprehend the values of STSF catheter for RFCA in AF patients.

2. Materials and Methods

This study was designed as an SLR using major English- and Chinese-language bibliographic databases to identify published, peer-reviewed clinical studies comparing the STSF catheter against other ablation catheters for procedural characteristics and clinical outcomes associated with RFCA in AF patients. This SLR was conducted by following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 Statement [6].

2.1 Study eligibility criteria

This SLR set both inclusion and exclusion criteria to identify clinical trials or observational studies comparing the STSF catheter with other ablation catheters for AF. The study inclusion criteria are as follows: (1) including AF patients who underwent RFCA; (2) assessing STSF against any other type of ablation catheter for RFCA in adult patients with AF; (3) reporting procedural characteristics and clinical outcomes associated with ablation catheter during and/after RFCA in AF patients; and (4) designed as a clinical trial or observational study. The exclusion criteria of this SLR are as follows: (1) preclinical (*in vivo* or *in vitro*) studies, case studies, case reports, non-original research articles (*e.g.* correspondence, editorials, commentaries, overviews, summaries, communications, consensus guidelines) and reviews; (2) any cohort that includes patients with ablation for arrhythmias other than AF; (3) single-arm studies assessing STSF without control; (4) inadequate information.

2.2 Information sources and search strategies

Given that RFCA has been implemented for AF treatment for over 20 years in China, many clinical studies assessing various ablation catheters for AF have been published in Chinese clinical journals. Therefore, this SLR explored major English bibliographic databases (MEDLINE, Embase, Web of Science, and the Cochrane Library) and three major Chinese bibliographic databases (WANFANG, VIP, and China National Knowledge Infrastructure) as the data sources. To align with the time of STSF approval in 2016, the literature search period was set from January 1, 2016, to the date when the literature search was first conducted (July 31, 2022). Grey literature search was conducted by searching the proceedings of the Heart Rhythm Society annual conference, the Society for Cardiovascular Angiography and Interventions annual conference, the European Heart Rhythm Association annual conference, and the Asia Pacific Heart Rhythm Society annual conference in 2021 and 2022 for any relevant but not fully published studies. To ensure that all relevant evidence is captured, this study only combined the keywords for AF and STSF to develop the search strategy for each bibliographic database and grey literature search.

2.3 Literature selection process

Two reviewers conducted the literature selection independently after which the search hits were pooled. Then, they deleted duplicate results and identified additional studies from the left references for further eligibility assessment, which included the exclusion of irrelevant references and retrieving full publications of the relevant references. The developed inclusion and exclusion criteria were used to determine the study eligibility after a full publication review. The exclusion reasons during the literature selection process were documented for records. Any disagreement on study eligibility between the two reviewers was resolved by consulting with the study lead.

2.4 Data collection process

Excel-based data extraction forms were developed specifically to guide the data collection from the full publications of included studies. The designed data extraction form was tested using one included study to align with definitions of the planned data items for extraction. Two reviewers were fully trained on how to use the data extraction forms and the definitions of data items. The two reviewers conducted data extraction independently. The extracted information from the two reviewers was further cross-checked by the third reviewer, which corrected any inconsistent information by verifying the information source. The study lead reviewed all extracted information for any abnormal information before evidence synthesis.

2.5 Data items

The full publication of the included studies was reviewed to collect the following information: (1) study characteristics such as country setting, study design, and patient inclusion and exclusion criteria; (2) study arm information including the arm definition, sample size, and patient baseline characteristics (demographics, AF-related clinical characteristics, and comorbidities); (3) ablation catheter type; (4) outcome measures that included procedural characteristics (procedure time, ablation time, fluoroscopy time, irrigation fluid volume), clinical

outcomes (acute procedural success of pulmonary vein isolation (PVI), one-year post-ablation cardiac arrhythmia recurrence, ablation-related complications); and other relevant outcomes (eschar, use of diuretics, and use of urinary catheter). Most of the included studies didn't provide adequate information for the definitions of outcome measures except catheter irrigation fluid volume, fluoroscopy time, and acute procedural success of PVI.

2.6 Study risk of bias assessment

This SLR used Newcastle-Ottawa Scale (NOS) [7] to assess the study quality of the included studies. Based on the recommendation from previous research [8], this SLR classified included studies as good quality (NOS 8-9), fair quality (NOS 5-7), and poor quality (NOS 0-4). This SLR included one randomized clinical trial, which was published as a conference abstract and didn't provide adequate information for the quality assessment using the Jadad score [9]. Two reviewers used NOS to assess the fully published studies independently. Any disagreement on assessment was discussed with the study lead to reach a consensus.

2.7 Effect measures

This SLR extracted any reported effect measures from the included studies. The extracted effect measures were standardized according to their original definitions in the included studies and the selected effect measures for evidence synthesis included procedural characteristics and clinical outcomes. This SLR used weighted mean difference (WMD) to present the pooled procedural characteristics for the comparisons of procedure time, ablation time, fluoroscopy time, and catheter irrigation fluid volume. The pooled clinical outcomes for the comparisons of acute procedural success of PVI, one-year post-ablation arrhythmia recurrence, and RFCA-related overall complications were presented with a rate ratio (RR).

2.8 Synthesis methods

The extracted data were standardized and categorized by AF types (paroxysmal AF, persistent AF, and unspecified AF); control catheter types (ST, SF, CELSIUS® catheter, DiamondTemp™, and NAVISTAR®); patient characteristics [age, gender distribution, AF type distribution, disease duration after the diagnosis of AF, left ventricular ejection fraction (LVEF), left atrium diameter, CHA_2DS_2 VASc, and comorbidities]; and effect measures for RFCA procedural characteristics and clinical outcomes. The reported outcomes from the included studies comparing STSF vs. the same control catheter were first pooled for evidence synthesis using a pairwise meta-analysis method, which used a random-effect model to consider the variance between the included studies and within each included study. Heterogeneity in the conducted meta-analysis was assessed using the I^2 method. The included studies were stratified by AF type for subgroup analysis if the heterogeneity in the pooled outcomes was significant. Further exploration of potential heterogeneity sources was conducted by excluding the studies reporting different patient characteristics if significant heterogeneity was still detected in the pooled outcomes from the subgroup analysis. The leave-one-out sensitivity analysis was conducted to determine the robustness of the overall pooled outcomes for the meta-analysis including 3 or more eligible results. The Egger's test was also performed to assess publication bias for overall pooled outcomes from 10 or more eligible results. This SLR used the statistical

software R to conduct the described analyses. Original results from included studies were reported when the meta-analysis was not feasible.

3. Results

3.1 Study selection

This study initially identified 373 unique references from the search of the included English and Chinese bibliographic databases. One-hundred-eighty-two were excluded due to irrelevance following the review of the titles and abstracts of the initial batch of papers. Following the study eligibility assessment of the full publications of the remaining 191 papers, 25 met the inclusion criteria. The search of conference proceedings and review articles identified two additional eligible studies. Thus, a total of 27 studies are included in our SLR. The flowchart of the study identification process is illustrated in Figure 1.

3.2 Characteristics and qualities of included studies

The included 27 studies assessed the procedural characteristics and clinical outcomes associated with STSF relative to ST (in 19 studies), SF (in 4 studies), and other four non-STSF/SF catheters (1 study for each non-STSF/SF catheter), respectively. This SLR only included one randomized clinical trial and the rest of the included studies were observational studies, including 13 retrospective studies and 13 prospective studies. This SLR included 4 studies published in Chinese. The studies published in English included 3 studies from the United States, 13 studies from Europe, and 7 studies from other regions. Among the included studies, 17 studies were fully published and 10 studies were published in conference proceedings. Even though all these studies included patients who underwent RFCA for AF, 7 studies solely included patients with paroxysmal AF, 1 study only included patients with persistent AF, and 19 studies included patients with either paroxysmal or persistent AF. According to the reported patient baseline characteristics in these included studies, the study patients were characterized with relatively old age (mean age range: 58.0-67.5 years), high CHA_2DS_2 VASc score (mean range: 1.3-2.7), and prevalent cardiovascular comorbidities, which included hypertension (30.4%-98.0%), coronary heart disease (8.3%-29.2%), and heart failure (17.8%-41.7%). Of the 17 studies assessed for study quality, 7 studies had good quality and 10 studies had fair quality. The study characteristics and main extracted information from these included 27 studies are summarized in Supplementary Table 1.

3.3 Synthesized evidence from the included studies comparing the STSF catheter with the ST catheter

Of the included 19 studies comparing STSF with ST, 13 studies [10-22] included patients with unspecified AF (persistent or paroxysmal AF) and 6 studies [23-28] included patients with paroxysmal AF. The synthesized outcomes included procedural characteristics (procedure time, ablation time, fluoroscopy time, and irrigation fluid volume), primary clinical outcomes (acute procedural success of PVI, one-year post-ablation arrhythmia recurrence, and overall complications), and other ablation-related clinical outcomes that included foley catheter use, diuretics use, and eschar development.

3.3.1 Procedural characteristics - Procedure time

Overall, nine included studies with 10 eligible results [10-15, 23-25] report RFCA procedure time (876 operated with STSF and 762 operated with ST). The overall pooled outcomes from nine included studies showed that STSF was associated with significantly shorter procedure time than ST (WMD: -17.4 minutes, 95% CI: -25.3 to -9.4 minutes, $p<0.01$); however, this pooled outcome has considerable heterogeneity [$I^2 = 76\%$, $p<0.01$]. The pooled outcomes from the stratified studies by AF types identified significantly shorter procedure time associated with the STSF catheter from the studies with unspecified AF patients (WMD: -18.7 minutes, 95% CI: -27.6 to -9.7 minutes, $p<0.001$) but not from the studies with paroxysmal AF patients (WMD: -14.7 minutes, 95% CI: -32.3 to 2.9 minutes, $p=0.101$). Because the heterogeneity of the pooled evidence from the 6 studies with unspecified AF patients was still significant, we reviewed these six studies to further explore the potential heterogeneity sources.

We found that 2 studies [10, 11] and a subgroup within one study [12] included patients who were likely to be different from those in other studies in AF duration, left atrial diameter/volume, the proportion of patients with paroxysmal AF, and proportion of patients with cardiomyopathy. After excluding the results from these four studies in the meta-analysis, the shorter procedure time of the STSF catheter remained statistically significant (WMD: -25.9 minutes, 95% CI: -33.0 to -18.8 minutes, $p<0.001$) with non-significant heterogeneity ($I^2=21\%$, $p=0.29$), suggesting that these characteristics are potential heterogeneity sources.

The leave-one-out sensitivity analysis indicated that the point estimation of the overall pooled difference in procedure time between the STSF catheter and the ST catheter had a relatively narrow range (from -15.2 minutes to -19.9 minutes). In addition, Egger's test did not detect significant publication bias for the reported difference in procedure time between the STSF catheter and the ST catheter from the included 9 studies ($p=0.768$). The pooled difference in the procedure time between the STSF catheter and the ST catheter is illustrated in Figure 2. The other reported outcomes are listed in Supplementary Files.

3.3.2 Procedural characteristics - Ablation time

Twelve included studies [10-17, 23-26] with 13 eligible results reported the ablation time associated with using STSF and ST to conduct RFCA in 1,870 patients with AF (992 operated with STSF and 878 with ST). The pooled differences in the ablation time of the two catheters favored the STSF catheter (WMD: -6.6 minutes, 95% CI: -12.5 to -0.6 minutes, $p=0.031$) with significant heterogeneity ($I^2=98\%$, $p<0.01$). To control the potential heterogeneity associated with AF type, this SLR performed a subgroup meta-analysis for this outcome by including the stratified studies by the AF types of study patients (paroxysmal AF vs. unspecified AF). The pooled difference in ablation time between the two catheters remained significant in the meta-analysis of the studies with unspecified AF patients (WMD: -8.6 minutes, 95% CI: -16.9 to -0.4 minutes, $p=0.039$) but was not for the studies with paroxysmal AF patients (WMD: -1.1 minutes, 95% CI: -4.8 to 2.6 minutes, $p=0.555$). However, heterogeneity in the subgroup meta-analysis of the studies with unspecified AF patients was still significant ($I^2=98\%$, $p<0.01$) and brought our attention to further explore the potential heterogeneity sources in these studies. By reviewing the reported patient baseline characteristics from these included studies, we found 4 studies [10-12, 16] with obviously

different patient characteristics (AF duration, left atrial diameter/volume, the proportion of paroxysmal AF, proportion of patients with myopathy, Ablation Index value, baseline CHA_2DS_2 VASc score, saline flow rate) from the other studies. After excluding these four studies from the subgroup meta-analysis, the pooled difference in ablation time still favored the STSF catheter with statistical significance (WMD: -22.5 minutes, 95% CI: -24.3 to -20.6 minutes, $p<0.001$) and low-level of heterogeneity ($I^2=0\%$, $p=0.69$), suggesting that these characteristics are potential heterogeneity sources.

The overall pooled difference in ablation time between the two catheters from the leave-one-out sensitivity analysis ranged from -7.5 minutes to -5.1 minutes. No significant publication bias was detected from the included 12 studies comparing the two catheters for ablation time during RFCA (Egger's test: $p=0.450$). The pooled difference in the ablation time between the STSF catheter and the ST catheter is illustrated in Figure 3. The other reported outcomes are listed in Supplementary Files.

3.3.3 Procedural characteristics - Irrigation fluid volume

Six included studies [10-12, 23-25] with 1229 AF patients (629 operated with STSF and 600 with ST) reported catheter irrigation fluid volume during RFCA. The meta-analysis of the reported irrigation fluid volume associated with the two catheters from the 6 studies indicated a significantly lower irrigation volume for using STSF to conduct RFCA (WMD: -492.7 mL, 95% CI -646.1 to -339.3 mL, $p<0.001$). However, this pooled outcome was associated with significant heterogeneity ($I^2=94\%$, $p<0.01$). These six included studies were stratified by patient AF type (paroxysmal AF vs. unspecified AF) to conduct a meta-analysis for the control of potential heterogeneity associated with AF types. The pairwise meta-analysis of the three studies with paroxysmal AF patients [23-25] confirmed the significant reduction of catheter irrigation fluid volume (WMD: -538.6 mL, 95% CI: -621.2 to -456.1 mL, $p<0.001$) with moderate but non-significant heterogeneity ($I^2=38\%$, $p=0.20$) for RFCA conducted by STSF catheter. However, significant heterogeneity ($I^2=94\%$, $p<0.01$) was found for the pooled difference in catheter irrigation fluid volume (WMD: -461.4 mL, 95% CI: -739.2 to -183.6 mL, $p=0.001$) between the two catheters from the left three studies with unspecified AF patients [10-12]. No further exploration of heterogeneity resources for this pooled outcome due to a limited number of studies reporting this outcome measure. The overall pooled difference in catheter irrigation fluid volume between the two catheters from the leave-one-out sensitivity analysis ranged from -532.1 mL to -427.3 mL.

The pooled difference in the catheter irrigation fluid volume between the STSF catheter and the ST catheter is illustrated in Figure 4. The other reported outcomes are listed in Supplementary Files.

3.3.4 Procedural characteristics - Fluoroscopy time

Eight included studies [10-13, 23, 25-27] compared fluoroscopy time between STSF catheter and ST catheter used to conduct RFCA (four studies [10-13] with unspecified AF patients and four studies [23, 25-27] with paroxysmal AF). The overall pooled difference in fluoroscopy time during RFCA between the two catheters showed that the STSF catheter was associated with significantly shorter fluoroscopy time than the ST catheter (WMD: -1.6 minutes, 95% CI: -2.8 to -0.3 minutes, $p=0.014$); however, this pooled outcome was associated with

significant heterogeneity (I^2=77%, p<0.014). The included studies were further stratified by the patient AF types (paroxysmal AF vs. unspecified AF) to conduct subgroup meta-analysis to explore potential heterogeneity associated with AF types. The subgroup meta-analysis including studies with paroxysmal AF patients confirmed the significantly shorter fluoroscopy time during RFCA conducted by STSF catheter (WMD: -1.4 minutes, 95% CI: -2.2 to -0.6 minutes, p<0.001) with a low level of heterogeneity (I^2=8%, p=0.35) [23, 25-27]. However, the pooled difference in fluoroscopy time between the two catheters from the subgroup meta-analysis of 5 eligible results from the four studies with unspecified AF patients [10-13] didn't reach statistical significance and also had substantial heterogeneity. No further exploration of heterogeneity sources for this subgroup meta-analysis due to a limited number of included studies reporting this outcome. The overall pooled difference in fluoroscopy time between the two catheters from all included studies in the leave-one-out sensitivity analysis ranged from -1.9 minutes to -1.4 minutes.

The results of the meta-analysis of the included 8 studies reporting fluoroscopy time associated with STSF catheter and ST catheter are illustrated in Figure 5. The other reported outcomes are listed in Supplementary Files.

3.3.5 Primary clinical outcomes

Thirteen studies [10-17, 22-24, 26, 28] reported primary clinical outcomes, including the acute procedural success of PVI, one-year post-ablation cardiac arrhythmia recurrence, and overall complications related to RFCA. The overall pooled RR for acute procedure success [10, 12, 14-17, 26, 28], one-year post-ablation cardiac arrhythmia recurrence [10, 13, 17, 22, 28], and overall complications [11, 14, 16, 17, 23, 24, 26, 28] from these studies were 0.995 (95% CI: 0.976 to 1.014, p=0.592), 0.727 (95% CI: 0.355 to 1.490, p=0.384), and 0.766 (95% CI: 0.299 to 1.959, p=0.578), respectively, without reaching statistical significance. Among these three pooled outcomes, only the pooled RR for one-year post-ablation arrhythmia recurrence between the two catheters was associated with significant heterogeneity (I^2 = 68%, p<0.01). Subgroup meta-analysis including stratified studies by patient AF types (paroxysmal AF vs. unspecified AF) was unable to homogenize the pooled RR for one-year post-ablation cardiac arrhythmia recurrence between the two catheters. The leave-one-out sensitivity analyses for the three pooled outcomes observed a narrow range for pooled RR for the acute procedural success of PVI (0.993 to 0.999) but wide ranges for one-year post-ablation cardiac arrhythmia recurrence (0.555 to 0.929) and overall complications (0.600 to 0.927). All reported outcomes are illustrated in Supplementary Files.

3.3.6 Other ablation-related clinical outcomes

Three included studies reported other ablation-related clinical outcomes. Two studies [23, 24] (502 paroxysmal AF patients) reported significantly lower utilizations of the foley catheter [RR: 0.506, 95% CI 0.393 to 0.651, p<0.001] without heterogeneity (I^2=0%, p=0.68). One study [25] with 47 paroxysmal AF patients reported STSF catheter was associated with a significantly lower risk of diuretics use (RR: 0.050, 95% CI: 0.003 to 0.819, p=0.036). In addition, one study [27] with 68 paroxysmal AF patients reported that STSF catheter was associated with a reduced risk of eschar formation during ablation without reaching statistical significance (RR: 0.143, 95% CI 0.008 to 2.663, p=0.192). The pooled outcomes are illustrated in Supplementary Files.

3.4 Synthesized evidence from the studies comparing the STSF catheter with the SF catheter

This SLR identified 4 studies [29-32] comparing STSF with SF for procedural characteristics and clinical outcomes in AF patients. One study [29] with a small sample size (26 using STSF catheter and 26 using SF catheter) reported significantly longer RFCA procedure time (mean difference: 20.0 minutes, 95% CI: 2.9 to 37.1 minutes, p=0.022) and fluoroscopy time (mean difference: 4.0 minutes, 95% CI: 1.1 to 6.9 minutes, p=0.007) in the STSF group. The meta-analysis including 2 studies [29, 30] with 252 patients did not identify significant differences in both acute procedure success of PVI and ablation-related complications between the two catheters. One study [31] with 395 patients with paroxysmal AF (298 using STSF and 97 using SF) reported significantly shorter ablation time (mean difference: -5.7 minutes, 95% CI: -8.4 to -3.1 minutes, p<0.001). The pooled RR for one-year post-ablation arrhythmia recurrence between the two catheters from the two studies [31, 32] favored the STSF catheter with statistical significance (RR: 0.503, 95% CI: 0.379 to 0.667, p<0.001, heterogeneity test: I^2=0%, p=0.98) when compared to SF catheter. The reported RFCA-related outcomes from the four studies are summarized in Table 1. The pooled outcomes are illustrated in Supplementary Files as well.

Table 1. Summary of the pooled differences in RFCA-related outcomes between STSF catheter and SF catheter in AF patients.

AF type	Outcome type	Outcome	Number of studies	Sample size	Outcome measure	Pooled outcomes			
						Point estimation	95%CI lower	95%CI upper	P value
Unspecified AF	Procedural characteristics	Procedure time (minutes) [29]	1	STSF: 26; SF: 26	WMD	20.0	2.9	37.1	***0.022***
		Fluoroscopy time (minutes) [29]	1	STSF: 26; SF: 26	WMD	4.0	1.1	6.9	***0.007***
	Clinical outcomes	Acute procedural success of PVI (%) [29]	1	STSF: 26; SF: 26	RR	1.000	0.928	1.078	1.000
		Any complications [29, 30]	2	STSF: 126; SF: 126	RR	0.745	0.052	10.574	0.828
Paroxysmal AF	Procedural characteristics	Ablation time (minutes) [31]	1	STSF: 298; SF: 97	WMD	-8.7	-8.4	-3.1	***<0.001***
		Radiofrequency energy use (J) [31]	1	STSF: 298; SF: 97	WMD	-3,432.5	-9,629.5	-1,235.5	***0.011***
	Clinical outcomes	Acute procedural success of PVI (%) [31]	1	STSF: 298; SF: 97	RR	1.000	0.985	1.015	1.000
		One-year post-ablation arrhythmia recurrence rate (%) [31]	1	STSF: 298; SF: 97	RR	0.504	0.368	0.689	***<0.001***
Persistent AF	Clinical outcomes	One-year post-ablation arrhythmia recurrence rate (%) [32]	1	STSF: 74; SF: 74	RR	0.500	0.262	0.956	***0.036***
		Any complications [32]	1	STSF: 74; SF: 74	RR	2.000	0.378	10.587	0.415

STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; WMD: Weighted mean difference; RR: Rate ratio; CI: Confidence interval.

3.5 Reported outcomes between STSF catheter and non-ST/SF catheter

This SLR identified 4 studies comparing STSF with four non-ST/SF catheters which were the CELSIUS® catheter [33], DiamondTemp™ catheter [34], DirectSense catheter guided by Rhythmia™ System [35], and NAVISTAR® catheter [36]. The 4 studies reported that the STSF catheter was associated with significantly shorter RFCA procedure time than the DiamondTemp™ catheter(mean difference: -20.6 minutes, 95% CI: -32.5 to -8.7 minutes, p<0.001) and NAVISTAR® catheter (mean difference: -30.0, 95% CI: -39.9 to -20.1 minutes, p<0.001); significantly shorter ablation time than NAVISTAR® catheter (mean difference: -15.0 minutes, 95% CI: -20.5 to -9.5 minutes, p<0.001); and significantly shorter fluoroscopy time than DirectSense catheter guided by Rhythmia™ System (mean difference: -7.0 minutes, 95% CI: -10.9 to -3.1 minutes, p<0.001) and NAVISTAR® catheter (mean difference: -2.0 minutes, 95% CI: -2.8 to -1.2 minutes, p<0.001). However, one study with 116 patients with persistent or paroxysmal AF [34] reported that the STSF catheter was associated with a significantly longer ablation time than the DiamondTemp™ catheter (mean difference: 4.1 minutes, 95% CI: 2.0 to 6.2 minutes, p<0.001). None of these 4 studies reported any significant differences in the rates of ablation-related overall complications between the STSF catheter and the four non-ST/SF catheters.

4. Discussion

Compared to a similar SLR published in 2020 [5], our SLR was designed with an expansive search period and search scope which has resulted in the inclusion of a larger pool of studies and much more robust evidence to demonstrate the values of STSF catheter for RFCA in AF patients. For example, our SLR captured and studied significantly more studies than the aforementioned SLR (27 studies vs. 4 studies). Additionally, not only did our SLR include studies comparing STSF with ST but also with SF and other ablation catheters in AF patients; in contrast, the other SLR only included studies comparing STSF with ST. Furthermore, our SLR synthesized evidence for more outcomes than the previous SLR and conducted additional heterogeneity analysis and publication bias assessment to make the pooled findings more robust. Therefore, our SLR should be more informative regarding the clinical values of STSF for RFCA in AF patients.

According to the studies reviewed in this SLR, the STSF catheter was mainly studied in comparison with the ST catheter in AF patients. As the STSF catheter evolved from the ST catheter by upgrading the irrigation system to improve procedural characteristics, the STSF catheter contains all the features of the ST catheter such as the contact force technology and advanced irrigation system that provides uniform cooling at half the flow rate of ST catheter and facilitates the process of fluid management [4]. The pooled evidence for the outcomes that were compared between the two catheters in our SLR aligned with the expected impact of the advanced irrigation system of STSF. For example, the pooled evidence showed that the STSF catheter significantly save RFCA procedure time (17.4 minutes, p<0.001), ablation time (6.6 minutes, p=0.031), and fluoroscopy time (1.6 minutes, p=0.016) with significantly reduced catheter irrigation fluid volume (492.7 mL, p<0.001) relative to ST catheter. These benefits could potentially improve the performance efficiency of RFCA and enhance the capacity of conducting RFCA in hospital settings. In addition, reduced fluoroscopy time could help with reducing occupational health hazards during RFCA. Moreover, the substantial reduction in the irrigation volume of STSF could substantially limit the cardiac burden due to catheter irrigation infusion and make ablation treatment safer to treat AF with heart failure.

The pooled evidence also indicates that primary clinical outcomes, including acute procedure success of PVI, one-year post-ablation arrhythmia recurrence, and overall complications, are comparable for the STSF catheter and ST catheter. A possible explanation is that both catheters use the same contact force technology, which is the primary driver of the ablation effects [37]. However, the advanced irrigation system of the STSF could bring more clinical benefits to AF patients with heart failure. According to the reported patient characteristics from the

included studies, AF patients are characterized by old age (mean age range: 58.0-67.5 years old) and a high prevalence of heart failure (17.8% to 41.7%). The fluid infusion through the catheter during RFCA could stress the heart and deteriorate the cardiac function in patients with heart failure. Even though RFCA has been proven to improve cardiac function (indicated by LVEF [38]), previous studies observed a high rate of developing acute heart failure (4.9% to 26.1%) after open-irrigated catheter ablation [39-41]; the development of acute heart failure after ablation in these studies was likely due to excessive infusion fluid during ablation procedure as patients with developed acute heart failure after ablation was associated with significantly higher net fluid infusion volume during ablation than those without developing acute heart failure. Thus, the substantial reduction of the catheter irrigation infusion volume of the STSF catheter could lower the burden of RFCA on the cardiac load and potentially reduce the risk of acute heart failure after RFCA [42]. In addition, the shortened ablation time through STSF could make RFCA more tolerable for AF patients with heart failure who are prone to developing respiratory distress with the flat position required by the ablation procedure [43]. Even though this SLR didn't identify any included studies directly assessing the impact of STSF on cardiac function and risk of acute heart failure, three of the included studies [23-25] did report that STSF catheter was associated with significantly reduced uses of diuretics and urinary catheter, the treatments often used to reduce fluid retention and the risk of acute heart failure after RFCA for AF. Since AF patients are often complicated with heart failure due to old age and other cardiovascular conditions, future research should be encouraged to confirm the cardiac function-related benefits of STSF and generate robust evidence to inform clinical practices and guidelines regarding the appropriate applications of STSF catheter ablation for AF. Another potential clinical benefit of the improved irrigation system of STSF is the reduction of the risk of eschar due to the amplified cooling effects. Eschar occurs more often with unipolar radiofrequency ablation that generates excessive local temperature leading to the formation of eschar on the tissue surface; carbonization; and thromboembolic complications; and even damage to the esophagus and atrium, which induces serious complications such as atrial esophageal fistula, atrial rupture, and pulmonary vein stenosis [44]. Because the STSF catheter has a more advanced irrigation system than the ST catheter, it is expected that the STSF catheter could be associated with a lower risk of eschar formation than the ST catheter. However, this SLT didn't identify robust evidence to support this clinical benefit of STSF as only one study with a small sample size reported a non-significant trend for the reduced risk of eschar for STSF catheter [27].

This SLR also identified 4 eligible studies comparing the STSF catheter with SF catheter and other 4 studies comparing the STSF catheter with non-ST/SF catheters. The pooled evidence from two eligible studies identified significantly reduced one-year post-ablation arrhythmia recurrence for STSF catheter relative to SF catheter. Because these SF catheters were equipped with a similar irrigation technology as the STSF catheter but without contact force technology, which mainly drives the ablation outcomes [37]. The reported outcomes from the four studies comparing the STSF catheter with contemporary non-ST/SF catheters suggested that the STSF catheter could be better than the non-ST/SF catheter regarding the procedure characteristics, which included procedural time, ablation time, and fluoroscopy time. However, these findings are not robust due to a limited number of studies (only one study comparing STSF with each non-ST/SF catheter) and the small sample size in each included study.

The generated evidence from this SLR should be interpreted with caution as most of the included studies were observational studies. The common limitations, such as selection bias, measurement bias, and unknown confounders, of observational studies could introduce heterogeneity in the pooled evidence. That might explain why most of the overall pooled outcomes in this SLR had significant heterogeneity. This SLR did recognize that AF type could an important heterogeneity source as the persistent AF usually requires additional substrate ablation beyond PVI than paroxysmal AF. Thus, this SLR stratified the included studies by patient AF types to control heterogeneity in the pooled outcomes. This strategy seems to work well with the studies only including paroxysmal AF patients as the pooled outcomes, including the differences in ablation time, irrigation fluid volume, fluoroscopy time, and overall complications from these studies don't have significant heterogeneity anymore. However, it is difficult to control the heterogeneity in the pooled outcomes from the studies which included both persistent AF patients and paroxysmal AF patients. Due to insufficient studies, this SLR only tried to explore heterogeneity resources for procedure time and ablation time by further excluding studies with obviously different patient

characteristics rather than conducting meta-regression analyses. The lack of definitions for some outcome measures in the included studies could introduce measurement bias and further increase the heterogeneity in the pooled evidence. In addition, this SLR doesn't have enough studies to explore the heterogeneity sources in other pooled outcomes. For the same reason, this SLR only assessed the publication bias for RFCA procedure time and ablation time. Given the fact that most of the included studies compared the STSF catheter with the ST catheter, the pooled evidence regarding the comparisons between STSF with non-ST catheters was not robust enough. Thus, this SLR didn't grade the pooled evidence because of the limitations discussed above. Future research with adequate quality is still needed to confirm the generated evidence from this SLR and further explore the potential clinical benefits of using the STSF catheter to conduct RFCA for AF (such as preventing eschar and acute heart failure).

In summary, this SLR demonstrated that STSF is superior to ST catheter by reducing procedure time, ablation time, fluoroscopy time, and irrigation fluid volume. Because both catheters use contact force technology which is a key factor in determining ablation outcomes, it is not a surprise to see highly comparable acute procedure success of PVI and one-year post-ablation arrhythmia recurrence between STSF catheter and ST catheter from the pooled evidence. Due to the lack of sufficient and robust evidence to support other clinical benefits of the STSF catheter relative to other catheters, such as preventing eschar and acute heart failure, more future studies with appropriate study designs and sufficient sample size are needed in this field.

5. Figures

Figure 1. Literature search flowchart for identifying eligible studies (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; AF: Atrial fibrillation).

Figure 2. Forest plot for the paired meta-analysis of the included studies for the difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 3. Forest plot for the paired meta-analysis of the included studies for the difference in ablation time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 4. Forest plot for the paired meta-analysis of the included studies for the difference in catheter irrigation fluid volume (mL) between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 5. Forest plot for the paired meta-analysis of the included studies for the difference in fluoroscopy time between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval)

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Conflict of Interest

Liang Tan and Wendong Chen are employed by contract research organizations that receive industry funds to conduct health economics and outcomes research. Other 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.

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Availability of Data and Materials

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

Author Contributions

Jianyong Li, Guifang Zhou, Yuegang Wang, and Xiaobo Huang formulated the research idea. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Yuegang Wang, Xiaobo Huang, Liang Tan, and Wendong Chen developed the study protocol. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Hairuo Lin, Shaopeng Lin, and Liang Tan conducted the literature search, study quality assessment, data extraction, and evidence synthesis. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Xiaobo Huang, Yuegang Wang, and Wendong Chen drafted the manuscript based on the study findings. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

Not applicable.

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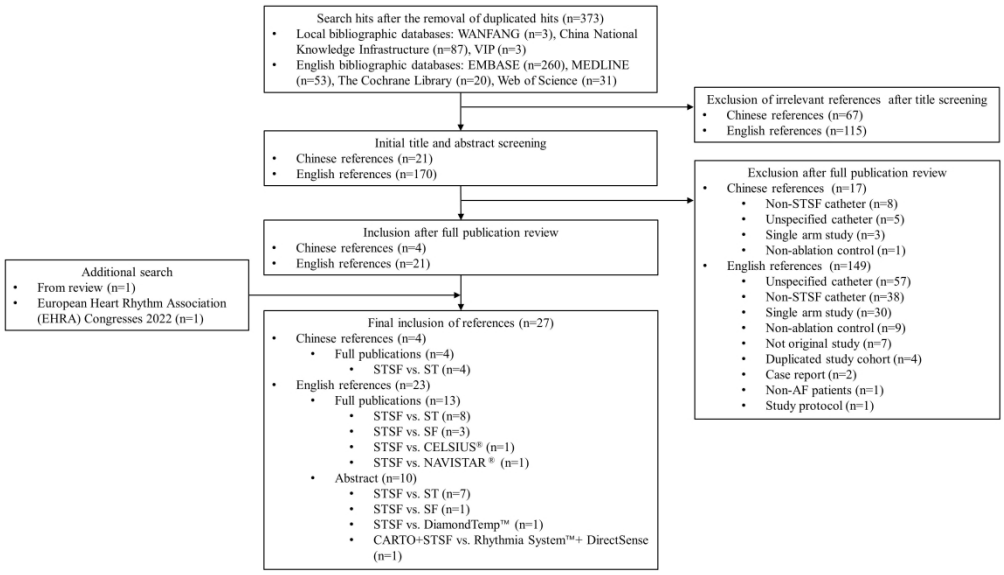

Figure 1. Literature search flowchart for identifying eligible studies (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; AF: Atrial fibrillation).

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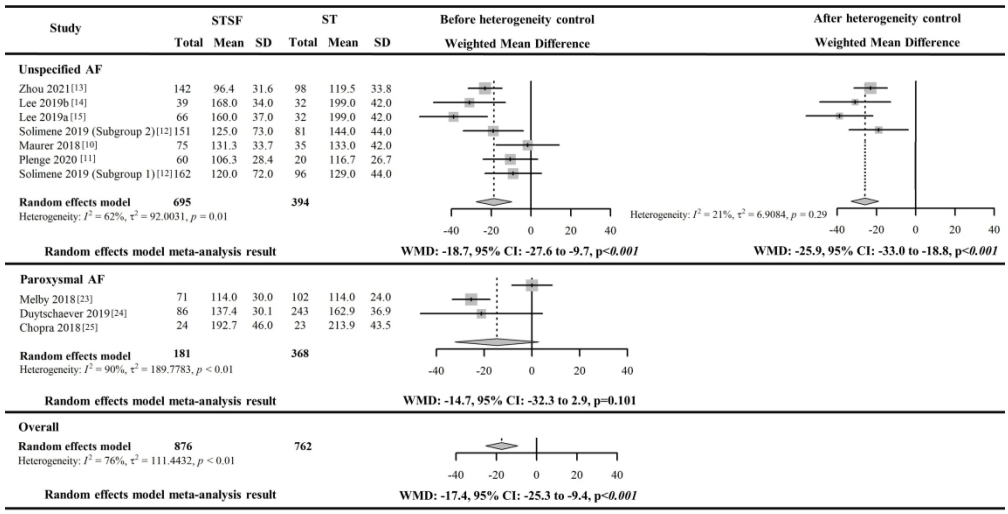

Figure 2. Forest plot for the paired meta-analysis of the included studies for the difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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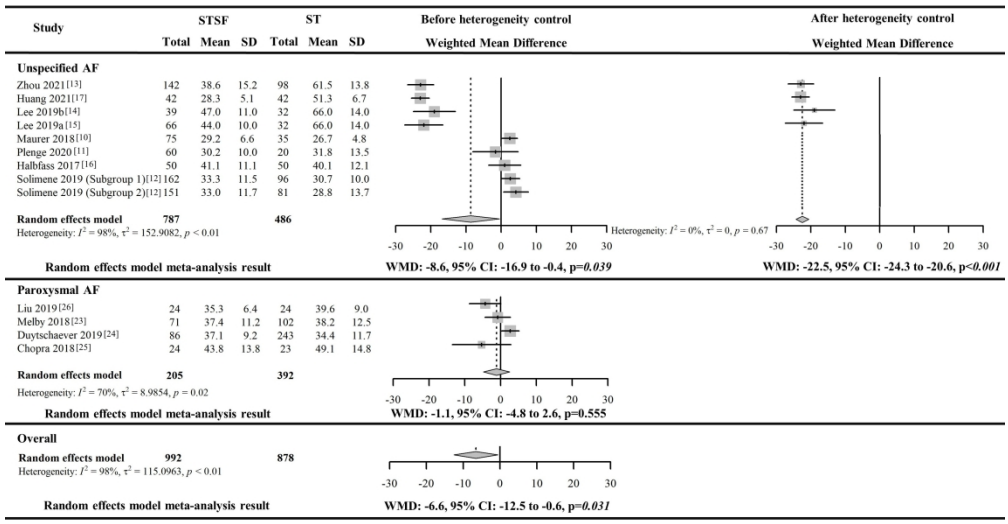

Figure 3. Forest plot for the paired meta-analysis of the included studies for the difference in ablation time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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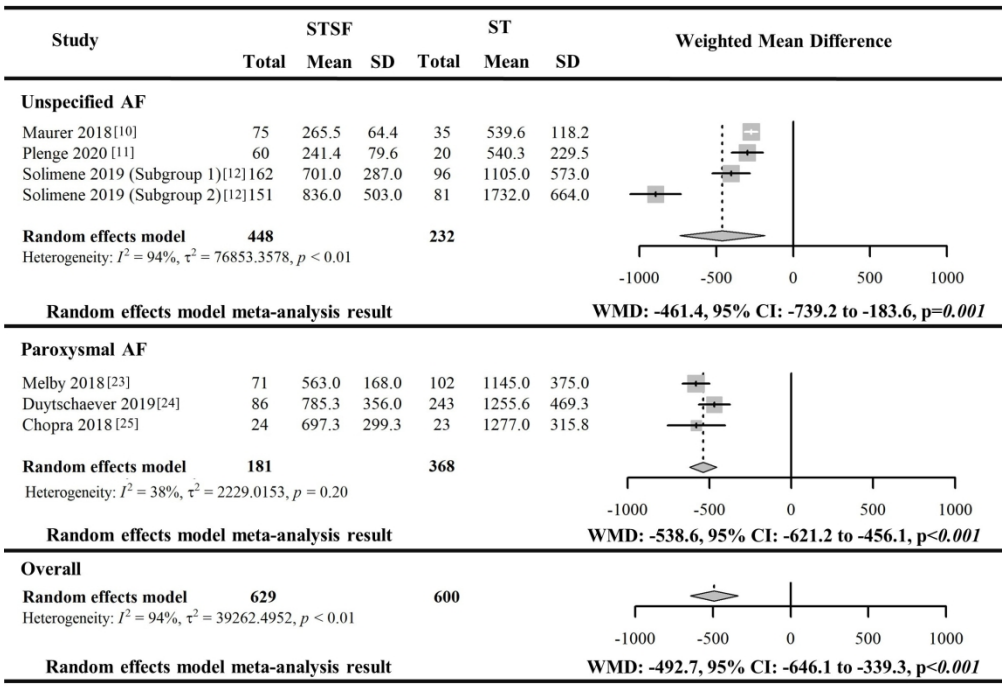

Figure 4. Forest plot for the paired meta-analysis of the included studies for the difference in catheter irrigation fluid volume (mL) between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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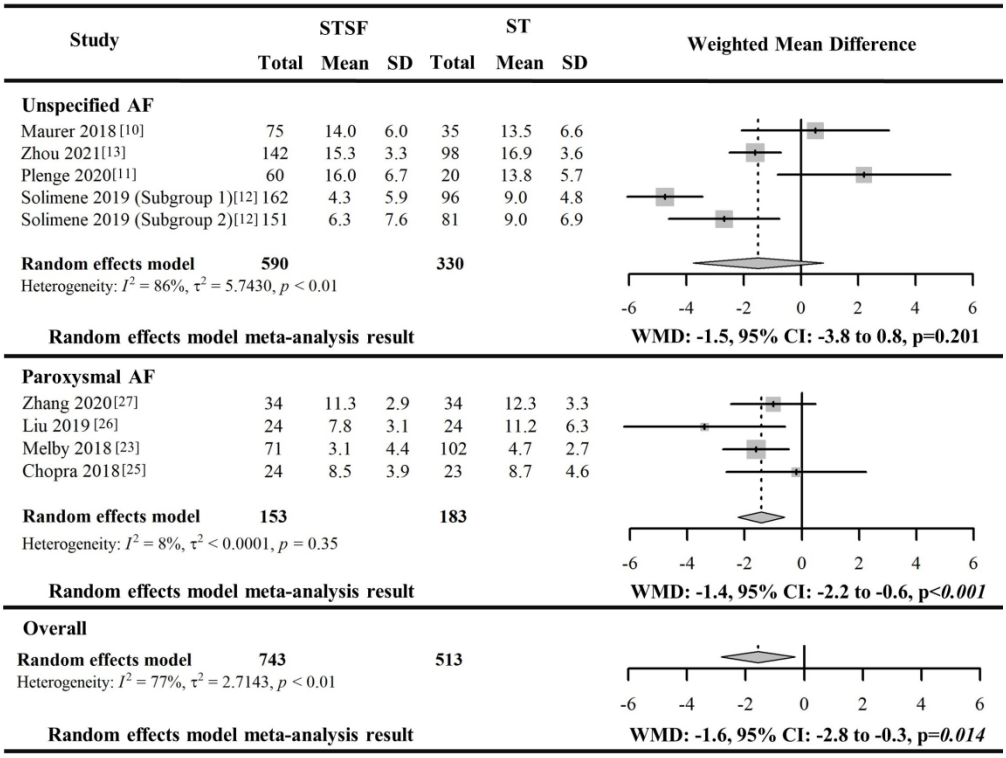
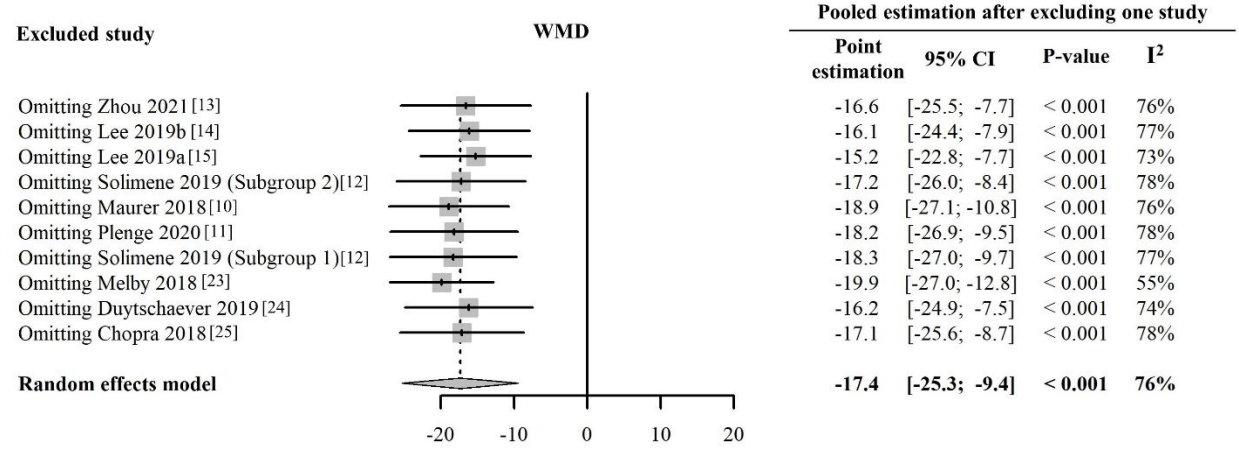


Figure 5. Forest plot for the paired meta-analysis of the included studies for the difference in fluoroscopy time between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval)

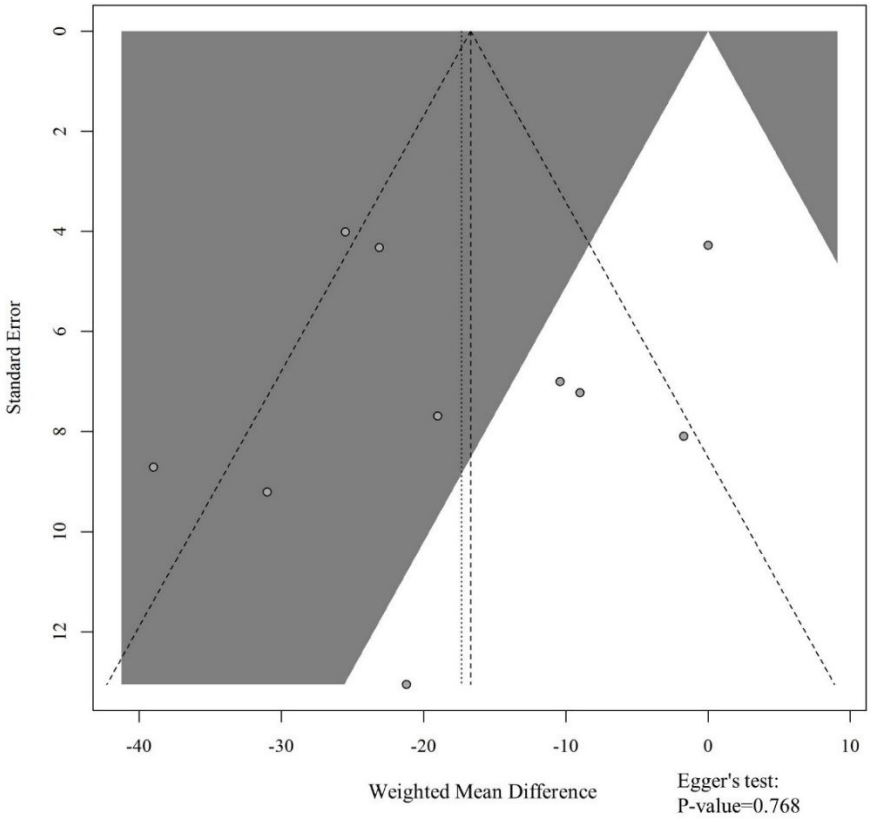
192x147mm (300 x 300 DPI)

Supplementary Figures

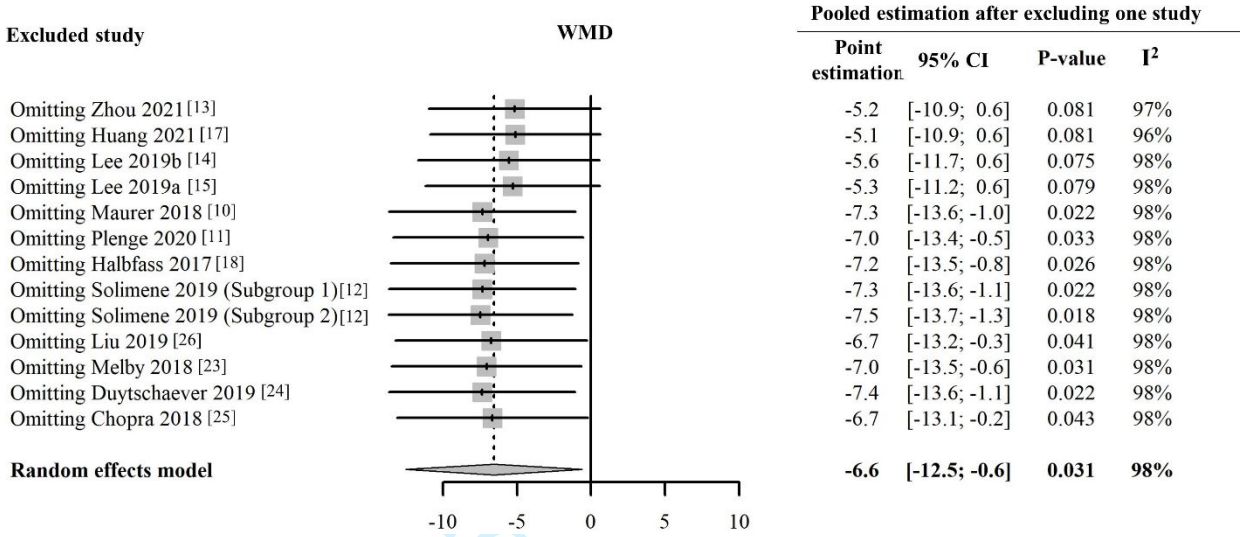
Supplementary Figure 1. Forest plot of the leave-one-out sensitivity analysis for pooled difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



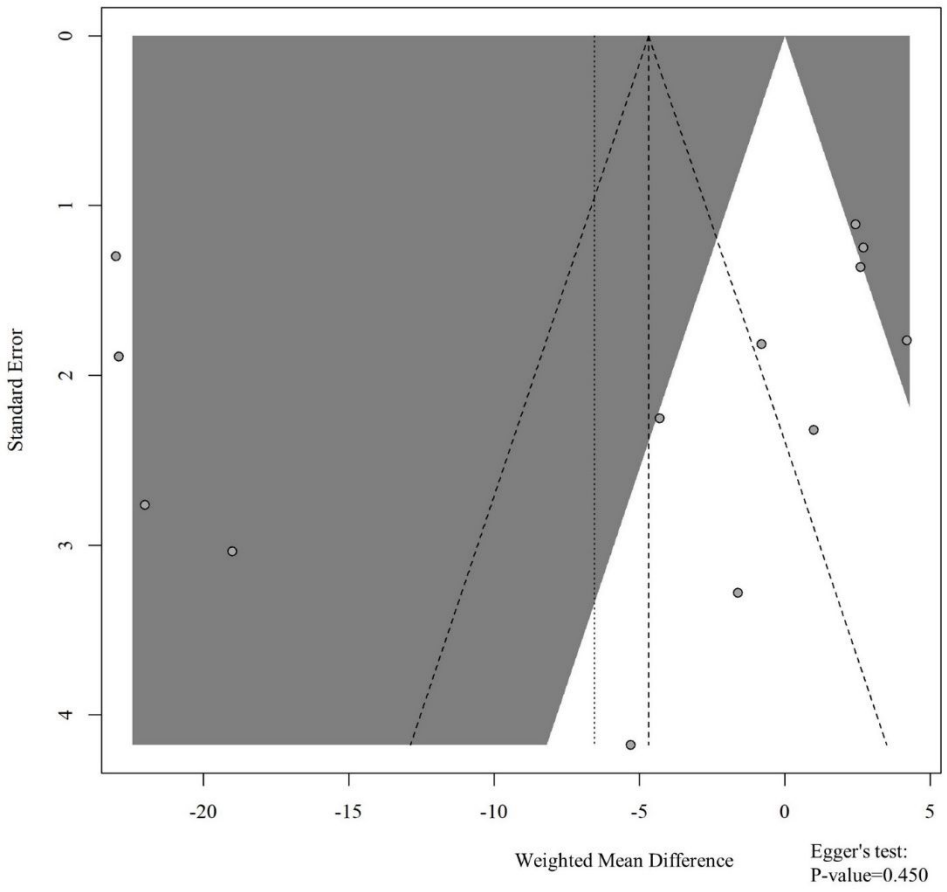
Supplementary Figure 2. Illustrated publication bias analysis for the included studies comparing STSF catheter with ST catheter for RFCA procedure time (minutes).



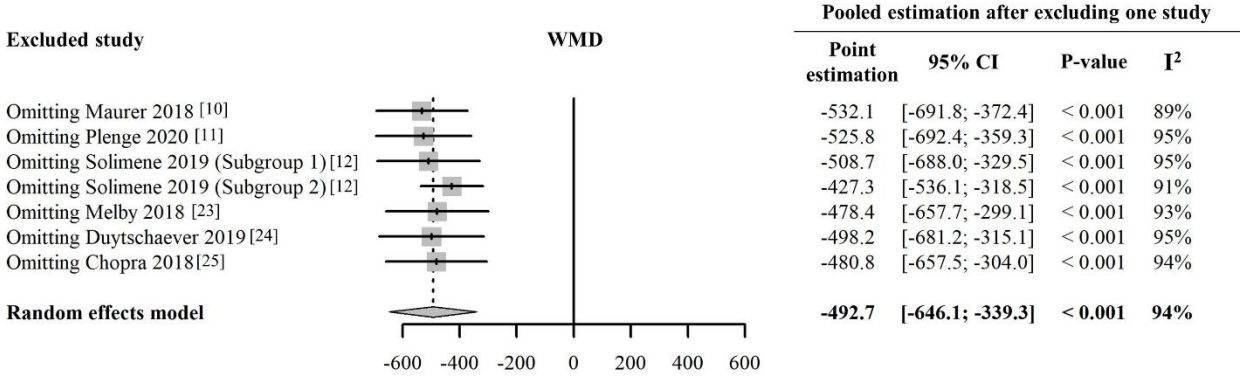
Supplementary Figure 3. Forest plot of the leave-one-out sensitivity analysis for pooled difference in ablation time (minutes) between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



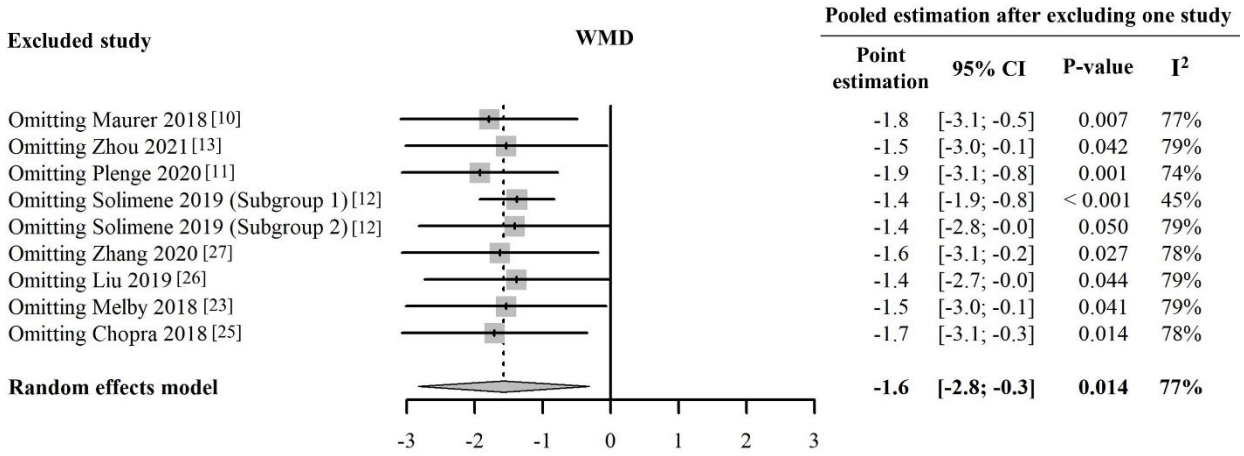
Supplementary Figure 4. Illustrated publication bias analysis for the included studies comparing STSF catheter with ST catheter for ablation time (minutes).



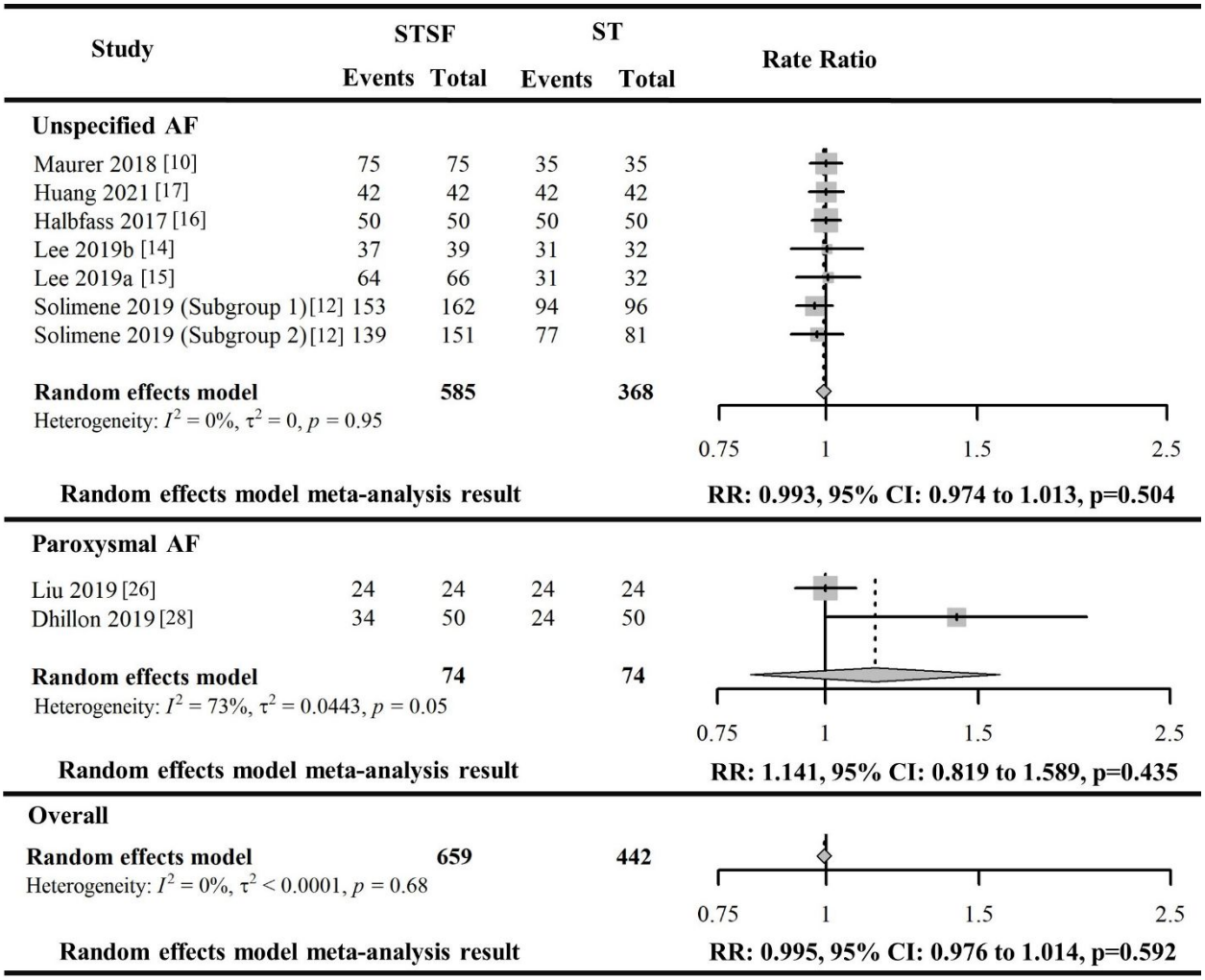
Supplementary Figure 5. Forest plot of the leave-one-out sensitivity analysis for pooled difference in irrigation fluid volume (mL) during RFCA between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



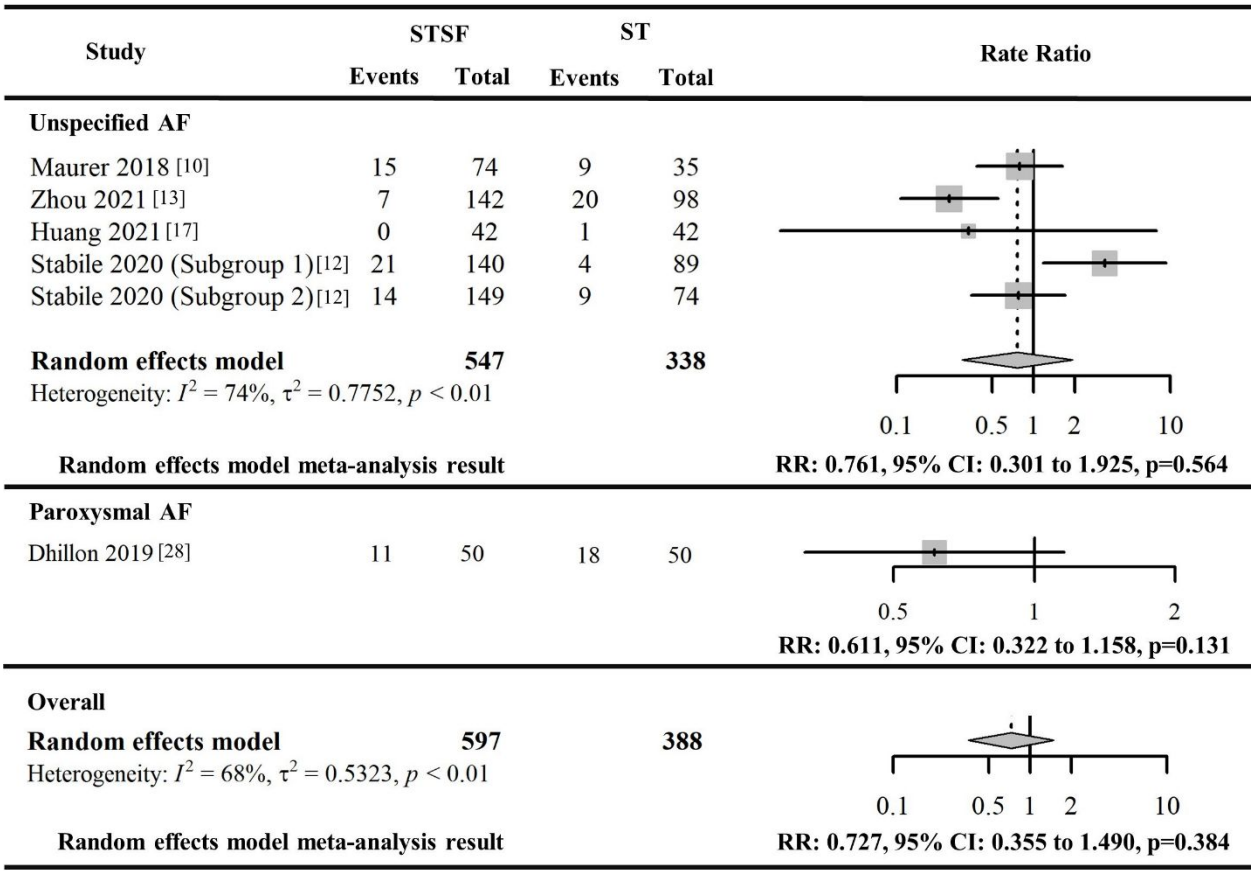
Supplementary Figure 6. Forest plot of the sensitivity analysis for pooled difference in fluoroscopy time (minutes) during RFCA between STSF and ST (WMD: Weighted mean difference; CI: Confidence interval).



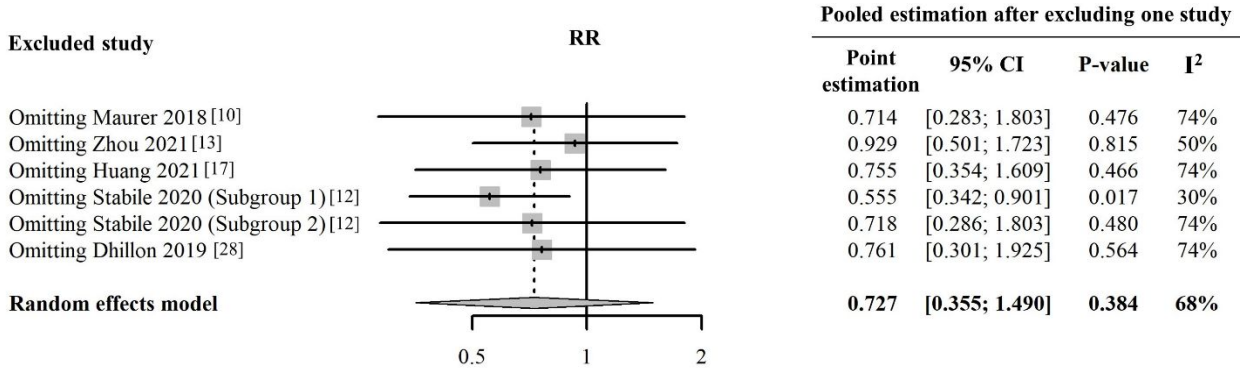
Supplementary Figure 7. Forest plot for the paired meta-analysis of the included studies comparing STSF vs. ST for acute procedural success of PVI (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



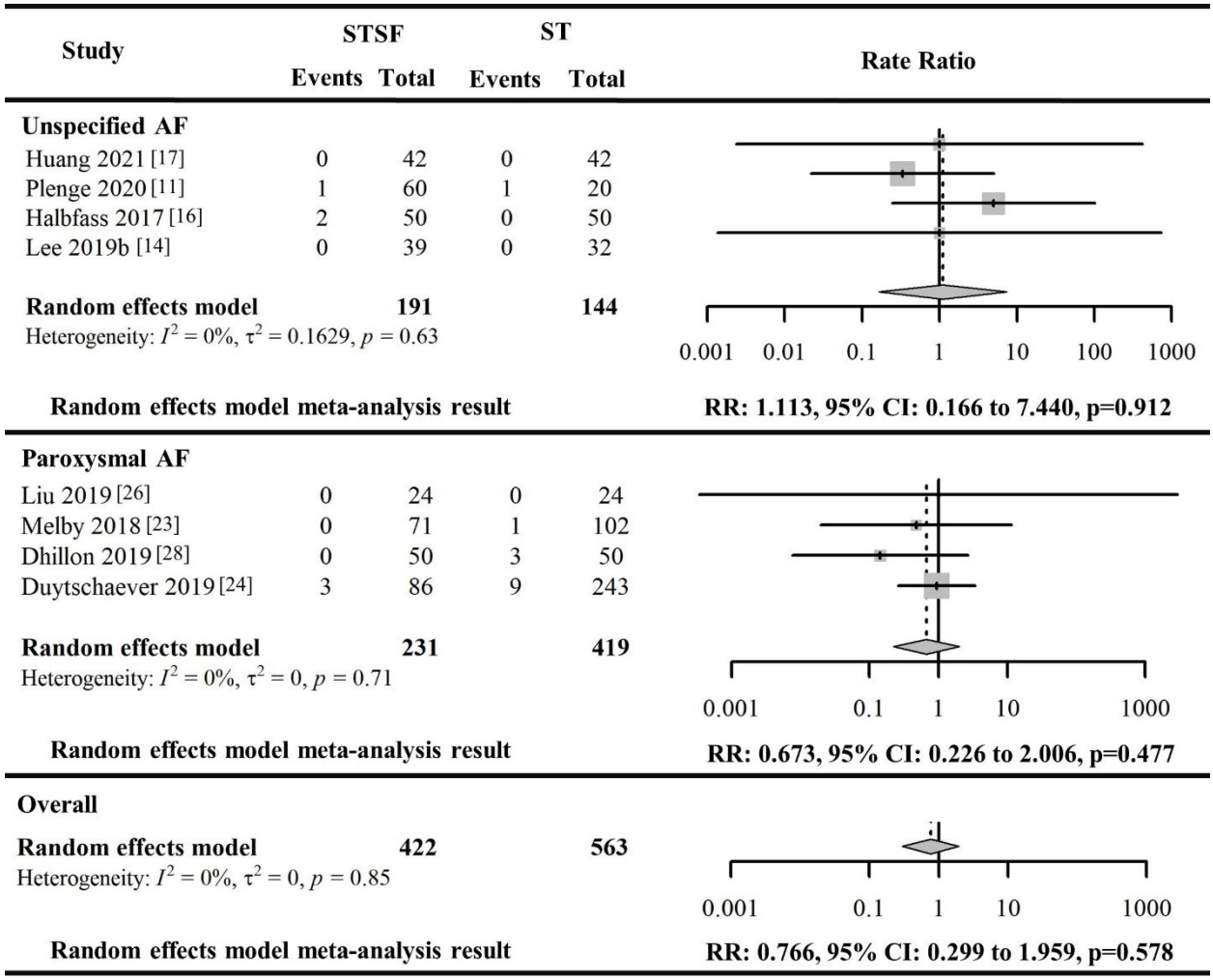
Supplementary Figure 8. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for one-year post-ablation cardiac arrhythmia recurrence (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



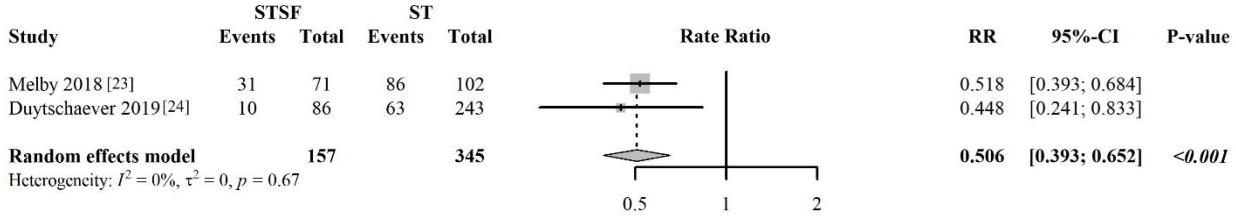
Supplementary Figure 9. Forest plot of the leave-one-out sensitivity analysis for pooled RR for one-year post-ablation cardiac arrhythmia recurrence between STSF catheter and ST catheter (RR: Rate ratio; CI: Confidence interval).



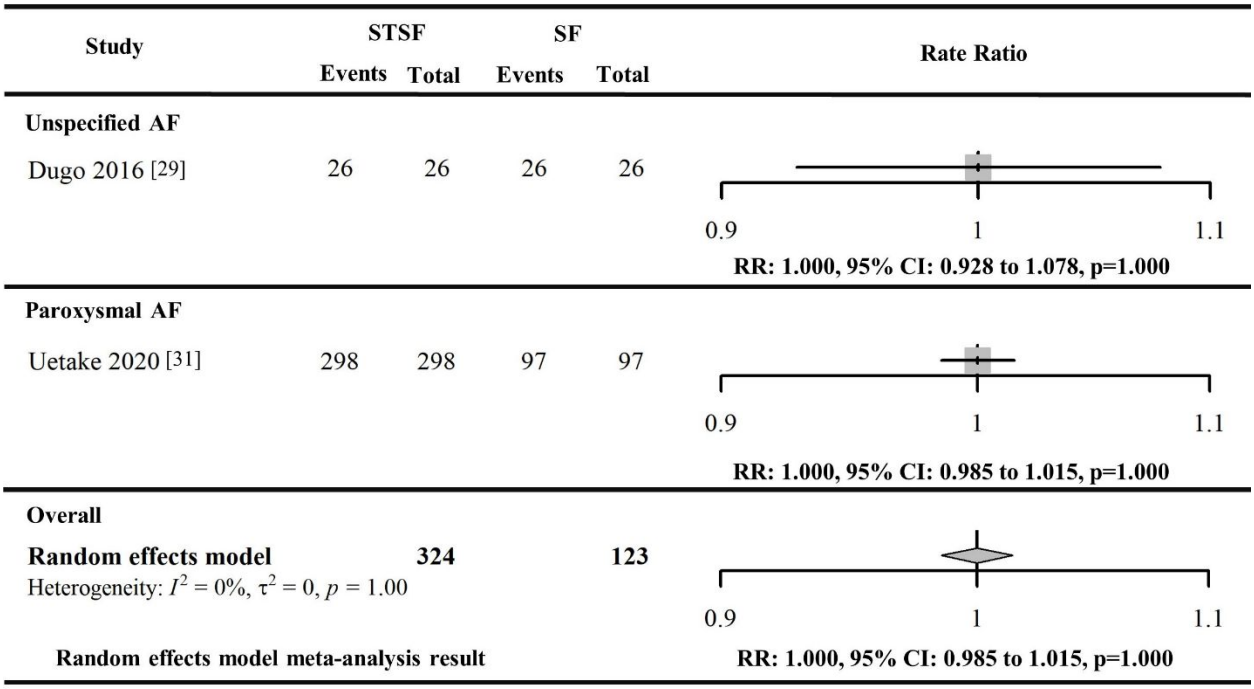
Supplementary Figure 10. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for the risk of overall complications related to RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



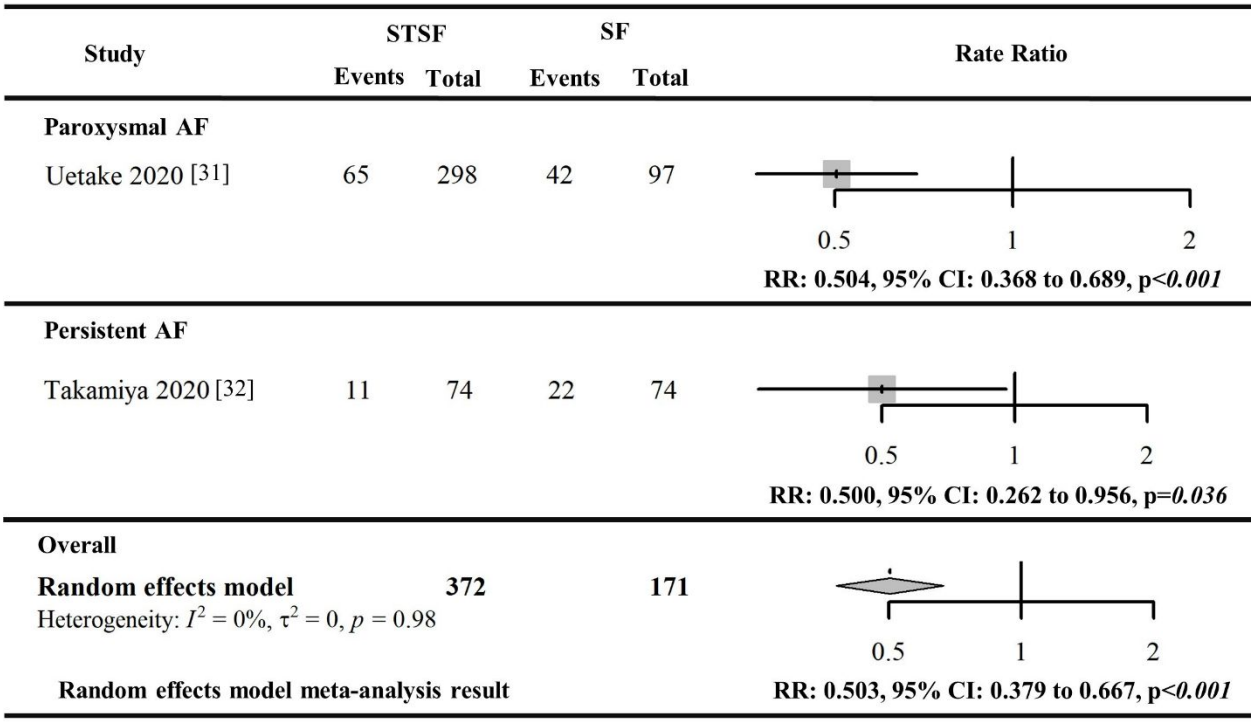
Supplementary Figure 11. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for foley catheter use (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; RR: Rate ratio; CI: Confidence interval).



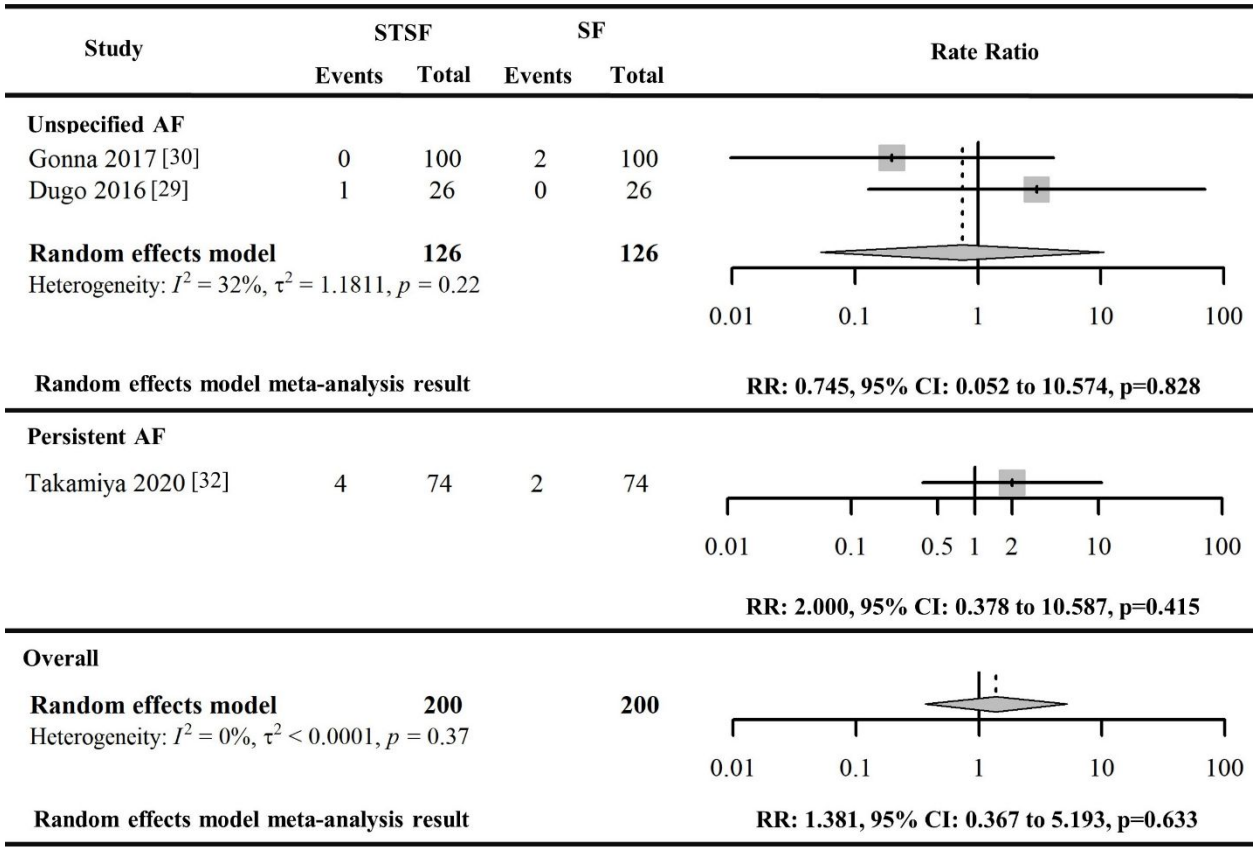
Supplementary Figure 12. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for acute procedure success of PVI (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



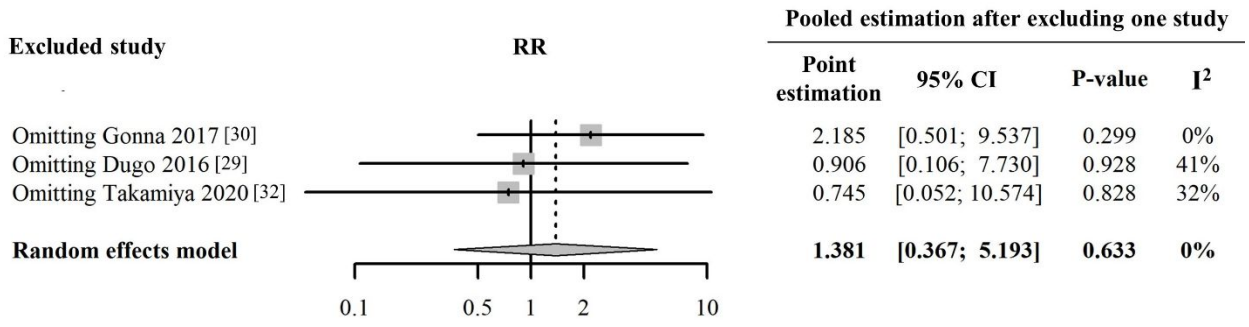
Supplementary Figure 13. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for one-year post-ablation arrhythmia recurrence (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



Supplementary Figure 14. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for the risk of overall complications related to RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



Supplementary Figure 15. Forest plot of the leave-one-out sensitivity analysis for pooled RR for the risk of overall complications related to RFCA between STSF catheter and SF catheter (RR: Rate ratio; CI: Confidence interval).



Supplementary Table

Supplementary Table 1. Study characteristics and main extracted information from the included studies.

Reference ID	Region	Publication type	Publication language	Study design	Patient inclusion and exclusion criteria	Catheter comparison and sample size	Patient characteristics	Main outcomes
Halbfass 2017 [16]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Patients with symptomatic, drug-refractory paroxysmal or persistent atrial fibrillation (AF) who underwent left atrial radiofrequency (RF) catheter ablation and post-procedural esophagogastroduodenoscopy (EGD) Exclusion criteria: Unspecified.	STSF (n=50) vs. ST (n=50)	Demographics • Mean age: STSF vs. ST (64.0±10.7 vs. 6[illegible].5 years, p=0.39); • Male: STSF vs. ST (58% vs. 58%, p=1.00); • BMI: STSF vs. ST (29.0±4.9 vs. 29.7±6.1 kg/m^2, p=0.[illegible]2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (44% vs. 38%, p=0.[illegible]); • Left ventricular ejection fraction: STSF vs. ST (55.6±11.0 vs. 56.5±9.8%, p=0.6[illegible]; • CHA_2DS_2 VASc Score: STSF vs. ST (2.3±1.5 vs. 2.[illegible]±1.4, p=0.20); Comorbidities • Hypertension: STSF vs. ST (90% vs. 98%, p=0.20[illegible]; • Coronary artery disease: STSF vs. ST (26% vs. 30%, p=0.82); • Diabetes: STSF vs. ST (14% vs. 20%, p=0.60); • Stroke/transient ischemic attack: STSF vs. ST (10[illegible] vs. 8%, p=1.00).	Procedural characteristics • Ablation time: STSF vs. ST (41.1±11.1 vs. 40.1±12.1 minutes, p=0.66); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%); • Any complications: STSF vs. ST (4% vs. 0%, p=0.49); • Cardiac tamponade: STSF vs. ST (2% vs. 0%); • Bleeding: STSF vs. ST (2% vs. 0%).
Horiuchi 2017 [18]	Japan	Abstract	English	Randomized controlled study	Inclusion criteria: Atrial fibrillation patients undergoing circumferential pulmonary vein isolation. Exclusion criteria: Unspecified.	STSF (n=20) vs. ST (n=20)	Pooled information of two groups Demographics • Mean age: 60±11 years; Clinical characteristics • Paroxysmal AF: 47.[illegible]%.	Procedural characteristics • Median radiofrequency time from superior to anterior sites: STSF vs. ST (9 vs. 22 seconds, p<0.01); • Median radiofrequency time at inferior and posterior sites: STSF vs. ST (9 vs. 8 seconds, p=NS);

								• There was no difference between the two groups in the mean contact force at each of 6 sites (anterior, anterosuperior, anteroinferior, inferior, posteroinferior, and posterosuperior site); • Total number of residual conduction gaps: STSF vs. ST (1.0±1.1 vs. 0.9±1.1, *p*=NS).
Ullah 2017 [19]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Patients undergoing their first catheter ablation procedure for atrial fibrillation (AF) Exclusion criteria: Unspecified.	STSF (n=10) vs. ST (n=30)	Demographics • Mean age: STSF vs. ST (65.8±5.3 vs. 61±8.3 years, *p*=0.65); • Male: STSF vs. ST (70% vs. 70%, *p*=1); Clinical characteristics: • Paroxysmal AF: STSF vs. ST (50 % vs. 50%, *p*=1); • Duration of persistent AF: STSF vs. ST (11±3 vs. 20±7 months, *p*=0.13); • Left atrial diameter: STSF vs. ST (4.1±0.8 vs. 4.4±0.6 cm, *p*=0.17); • CHA_2DS_2 VASc score: STSF vs. ST (1.5±0.8 vs. 1.4±1.0, *p*=0.61).	Procedural characteristics • Median catheter tip temperature at the start of energy delivery: STSF vs. ST (28 vs. 36 °C, *p*<0.005); • Median impedance at start of energy delivery: STSF vs. ST (154 vs. 181 Ω, *p*<0.005); • Median minimum catheter tip temperature during RF delivery: STSF vs. ST (25 vs. 35 °C, *p*<0.005); • Median time to reach minimum catheter tip temperature: STSF vs. ST (8.4 vs. 1.2 seconds, *p*<0.005); • Median maximum catheter tip temperature during RF delivery: STSF vs. ST (29 vs. 41 °C, *p*<0.005); • Median time to reach maximum catheter tip temperature: STSF vs. ST (0 vs. 14.9 seconds, *p*<0.005); • Median time to reach maximum ablation power: STSF vs. ST (0.6 vs. 8.1 seconds, *p*<0.005).
Chopra 2018 [25]	United States	Full text	English	Retrospective study	Inclusion criteria: Patients aged between 18 and 81 years who had undergone a radiofrequency ablation procedure for the indication of	STSF (n=24) vs. ST (n=23)	Pooled information of two groups Clinical characteristics: • Left atrial diameter: 44.2±7.5 mm; • Left ventricular ejection fraction: 57.8%±7%; • CHADS VASc Score: 2.4±1.4.	Procedural characteristics • Procedure time: STSF vs. ST (192.7±46.6 vs. 213.9±43.5 minutes, *p*=0.11); • Ablation time: STSF vs. ST (43.8±13.8 vs. 49.1±14.8 minutes, *p*=0.18);

					paroxysmal AF at OhioHealth Riverside Methodist Hospital, Columbus, Ohio, USA, from May 1, 2017, to June 1, 2018. Exclusion criteria: Unspecified.			• Fluoroscopy time: STSF vs. ST (511.8±231.8 vs. 523.6±277.4 seconds, p=0.39); • Total fluid: STSF vs. ST (2,288.8±725.8 vs. 3,105±803 mL, p<0.001); • Fluid via ablation catheter: STSF vs. ST (697.3±299.3 vs. 1277±315.8 mL, p<0.001); • Fluid from sources other than ablation catheter: STSF vs. ST (1591±583.6 vs. 1828±689 mL, p=0.21); • Post-RFA Furosemide use (0% vs. 39%; p=0.0006).
Maurer 2018 [10]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Patients with symptomatic, drug-refractory paroxysmal, or short-term persistent AF (< 3 months in duration). Exclusion criteria: 1. Prior pulmonary vein isolation or left atrial surgery; 2. A left atrial (LA) diameter > 60 mm; 3. Severe valvular heart disease or contraindications to post-interventional oral anticoagulation.	STSF (n=75) vs. ST (n=35)	Demographics • Mean age: STSF vs. ST (65.4±11.5 vs. 66.6±9.0 years); • Male: STSF vs. ST (66.7% vs. 68.6%); • BMI: STSF vs. ST (28.5±6 vs. 26.3±4.3 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (52% vs. 43%); • Left atrial diameter: STSF vs. ST (45.2±6.6 vs. 44.2±6 mm); • Median CHA_2DS_2 VASc Score: STSF vs. ST (2 vs. 2); • Median CHADS Score: STSF vs. ST (1 vs. 1); Comorbidities • Coronary artery disease: STSF vs. ST (29.3% vs. 22.9%); • Congestive heart failure: STSF vs. ST (17.3% vs. 3%); • Arterial hypertension: STSF vs. ST (61.3% vs. 71.4%); • Diabetes mellitus: STSF vs. ST (9.3% vs. 11.4%); • Stroke/transient ischaemic attack: STSF vs. ST (4% vs. 14.3%).	Procedural characteristics • Procedure time: STSF vs. ST (131.3±33.7 vs. 133.0±42 minutes, p=0.995); • Ablation time: STSF vs. ST (1751±394.0 vs. 1604.6±287.8 seconds, p=0.201); • Fluoroscopy time: STSF vs. ST (14±6 vs. 13.5±6.6 minutes, p=0.559); • Total fluid: STSF vs. ST (265.5±64.4 vs. 539.6±118.2 mL, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%); • 12-month arrhythmia recurrence rate: STSF vs. ST (20.3% vs. 25.7%); • Audible steam pop: STSF vs. ST (0% vs. 0%).

Melby 2018 [23]	Unspecified	Abstract	English	Retrospective study	Inclusion criteria: Paroxysmal AF patients undergoing first-time ablation, guided by CARTO VISITAG™ Module. Exclusion criteria: Unspecified.	STSF (n=71) vs. ST (n=102)	Demographics • Mean age: STSF vs. ST (60±10 vs. 61±9 years, p=0.74); Clinical characteristics • Left ventricular ejection fraction: STSF vs. ST (60.2±7.6 vs. 59.5±7.9%, p=0.50); • CHADS VASc Score: STSF vs. ST (1.62±1.4 vs. 1.4, p=0.56); Comorbidities • Congestive heart failure: STSF vs. ST (0% vs. 4%).	Procedural characteristics • Procedure time: STSF vs. ST (1.9±0.5 vs. 1.9±0.4 hours, p=0.77); • Ablation time: STSF vs. ST (37.4±11.2 vs. 38.2±12.5 minutes, p=0.74); • Fluoroscopy time: STSF vs. ST (3.1±4.4 vs. 4.7±2.7 minutes, p<0.001); • Fluoroscopy dose: STSF vs. ST (12.4±16.7 vs. 27.3±18.6 mGy, p<0.001); • Total fluid: STSF vs. ST (1505±440 vs. 2353±605 mL, p<0.001); • Fluid via ablation catheter: STSF vs. ST (563±168 vs. 1145±375 mL, p<0.001); • Foley catheter usage (%): STSF vs. ST (43.7% vs. 84.3%, p<0.001); Clinical outcomes • Any complications: STSF vs. ST (0% vs. 1%); • Cerebrovascular accident: STSF vs. ST (0% vs. 1%).
Dhillon 2019 [28]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Consecutive patients with paroxysmal atrial fibrillation underwent pulmonary vein isolation guided by ablation index (AI) between January 2017 and October 2017. Exclusion criteria: Unspecified.	STSF (n=50) vs. ST (n=50)	Demographics • Mean age: STSF vs. ST (60.1±11.8 vs. 59.9±10.8 years, p=0.915); • Male: STSF vs. ST (70% vs. 48%, p=0.042); Clinical characteristics • Median duration of AF: STSF vs. ST (24 vs. 42 months, p=0.057); • Left atrial diameter: STSF vs. ST (37.6±5 vs. 38.7±4 mm, p=0.145); • CHA_2DS_2 VASc Score: STSF vs. ST (1.3±1.2 vs. 1.8±1.6, p=0.184);	Procedural characteristics • Mean procedure time: STSF vs. ST (156 vs. 199 minutes, p<0.001); • Mean ablation time: STSF vs. ST (27.2 vs. 43.2 minutes, p<0.001); • Mean left wide antral circumferential ablation Time: STSF vs. ST (29.5 vs. 38.5 minutes, p<0.001); • Mean right wide antral circumferential ablation Time: STSF vs. ST (32 vs. 38.5 minutes, p=0.001);

							Comorbidities • Hypertension: STSF vs. ST (38% vs. 34%, p=0.85); • Diabetes Mellitus: STSF vs. ST (12% vs. 6%, p=0.48); • Ischemic Heart Disease: STSF vs. ST (4% vs. 2%, p=0.291).	• Mean fluoroscopy time: STSF vs. ST (7.7 vs. 8.5 minutes, p=0.079); Clinical outcomes • Acute procedure success rate: STSF vs. ST (68% vs. 48%, p=0.068); • 12-month AF/AT recurrence rate: STSF vs. ST (6% vs. 34%); • Any complications: STSF vs. ST (0% vs. 6%); • Pericarditis: STSF vs. ST (0% vs. 4%); • Femoral venous hematoma: STSF vs. ST (0% vs. 2%).
Duytschaever 2019 [24]	Europe	Abstract	English	Prospective cohort study	Inclusion criteria: Patients underwent point-by-point paroxysmal atrial fibrillation ablations across 17 European centers in the VISTAX study. Exclusion criteria: Unspecified.	STSF (n=86) vs. ST (n=243)	Not reported	Procedural characteristics • Procedure time: STSF vs. ST (137.4±30.1 vs. 162.9±36.9 minutes); • Ablation time: STSF vs. ST (37.1±9.23 vs. 34.4±11.73 minutes); • Fluid via ablation catheter: STSF vs. ST (785.3±356.0 vs. 1,255.6±469.3 mL); • Foley catheter usage (%): STSF vs. ST (11.6% vs 25.9%); Clinical outcomes • Any complications: STSF vs. ST (3.5% vs. 3.7%).
Goldstein 2019a [20]	United States	Abstract	English	Retrospective study	Inclusion criteria: Patients with a primary diagnosis of AF (≥18 years) who underwent radiofrequency ablation between 09/01/2016–03/31/2018, identified from the Premier Healthcare database.	STSF (n=1,445) vs. ST (n=1,766)	Demographics • Age group ≥70: STSF vs. ST (35.09% vs. 30.18%, p=0.0031); Clinical characteristics • Paroxysmal AF: STSF vs. ST (63.32% vs. 67.21%, p=0.0210); • $CHADS_2VASc$ score ≥3: STSF vs. ST (43.39% vs. 35.08%, p<0.001);	Not reported

					Exclusion criteria: Unspecified.		Comorbidities • Obesity: STSF vs. ST (23.88% vs. 19.42%, p=0.0022); • Diabetes: STSF vs. ST (20.90% vs. 17.27%, p=0.0090); • Atrial flutter: STSF vs. ST (41.38% vs. 32.66%, p<0.0001); • Valvular disease: STSF vs. ST (21.87% vs. 12.31%, p<0.0001); • Cardiomyopathy: STSF vs. ST (12.87% vs. 9.68%, p=0.0042); • Hypertension: STSF vs. ST (69.48% vs. 63.03%, p=0.0001); • Heart failure: STSF vs. ST (20.69% vs. 17.85%, p=0.0407).	
Goldstein 2019b [21]	United States	Abstract	English	Retrospective study	Inclusion criteria: Patients with a primary diagnosis of AF (≥18 years) who underwent index (first occurrence) radiofrequency ablation in an outpatient setting (09/01/2016–03/31/2018), identified from the Premier Healthcare database. Exclusion criteria: Unspecified.	STSF (n=571) vs. ST (n=571)	Not reported	Hospital readmission outcomes • 4-6 months all-cause readmission rate: STSF vs. ST (2.78% vs. 2.78%, p=1.000); • 4-6 months cardiovascular-related inpatient readmission rate: STSF vs. ST (1.23% vs. 1.23%, p=1.000); • 4-6 months AF-related inpatient readmission rate: STSF vs. ST (0.93% vs. 0.62%, p=0.6535).
Lee 2019a [15]	South Korea	Abstract	English	Prospective cohort study	Inclusion criteria: Drug refractory symptomatic AF patients. Exclusion criteria: Unspecified.	STSF (n=66) vs. ST (n=32)	Pooled information of two groups Demographics • Mean age: 61±8 years; Clinical characteristics • Paroxysmal AF: 67%	Procedural characteristics • Procedure time: STSF vs. ST (160±37 vs. 199±42 minutes, p<0.001); • Ablation time: STSF vs. ST (44±10 vs. 66±14 minutes, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (96.3% vs. 95.8%, p=0.613).
Lee 2019b [14]	South Korea	Abstract	English	Retrospective study	Inclusion criteria: Drug refractory symptomatic AF patients.	STSF (n=39) vs. ST (n=32)	Pooled information of two groups Demographics Mean age: 61±10 years;	Procedural characteristics

					Exclusion criteria: Unspecified.		Male: 79%; Clinical characteristics Paroxysmal AF: 79%	• Procedure time: STSF vs. ST (168±34 vs. 199±42 minutes, p=0.001); • Ablation time: STSF vs. ST (47±11 vs. 66±14 minutes, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (96.0% vs. 95.8%, p=0.867); • Any complications: STSF vs. ST (0% vs. 0%).
Liu 2019 [26]	China	Full text	Chinese	Retrospective study	Inclusion criteria: Drug-refractory paroxysmal AF patients underwent pulmonary vein isolation. Exclusion criteria: Unspecified.	STSF (n=24) vs. ST (n=24)	Demographics • Mean age: STSF vs. ST (65.0±9.6 vs. 65.1±7.1 years, p=0.95); • Male: STSF vs. ST (37.5% vs. 37.5%, p=1.00); • BMI: STSF vs. ST (22.1±1.7 vs. 21.8±1.4 kg/m^2, p=0.53); Clinical characteristics • Duration of AF: STSF vs. ST (10.4±10.1 vs. 6.4±4.2 months, p=0.08); • Left atrial diameter: STSF vs. ST (34.1±13.9 vs. 39.6±5.4 mm, p=0.09); • Left ventricular ejection fraction: STSF vs. ST (55±6 vs. 53±8%, p=0.23); Comorbidities • Coronary heart disease: STSF vs. ST (8.3% vs. 29.2%, p=0.14); • Heart failure: STSF vs. ST (25.0% vs. 41.7%, p=0.22); • Hypertension: STSF vs. ST (41.7% vs. 50%, p=0.56); • Diabetes: STSF vs. ST (12.5% vs. 29.2%, p=0.16); • Stroke: STSF vs. ST (4.2% vs. 8.3%, p=1.00).	Procedural characteristics • Procedure time: STSF vs. ST (67 vs. 70 minutes, p=0.45); • Ablation time: STSF vs. ST (35.3±6.4 vs. 39.6±9.0 minutes, p=0.07); • Fluoroscopy time: STSF vs. ST (7.8±3.1 vs. 11.2±6.3 minutes, p=0.02); • Total infusion fluid: STSF vs. ST (356 vs. 700 mL, p<0.01); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%, p=1); • Any complications: STSF vs. ST (0% vs. 0%).

Solimene 2019 [12]	Italy	Full text	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF who underwent their first AF ablation. Exclusion criteria: 1. Age <18; 2. Longstanding persistent AF (AF was the sole rhythm for the last 12 months); 3. AF secondary to a transient or correctable abnormality, including electrolyte imbalance, trauma, recent surgery, infection, toxic ingestion, and endocrinopathy; 4. Intra-atrial thrombus, tumor, or other abnormality precluding catheter insertion; 5. Left ventricular ejection fraction <35%; 6. Women of childbearing potential who are or might be pregnant; 7. Hematological contraindications to ionizing radiation exposure; 8. Presence of complex congenital heart disease; 9. Cardiac surgery within 1 month from enrollment.	STSF (Subgroup with AI 330-450, n=162; Subgroup with AI 380-500, n=151) vs. ST (Subgroup with AI 330-450, n=96; Subgroup with AI 380-500, n=81)	The subgroup with AI 330-450 Demographics • Mean age: STSF vs. ST (60±12 vs. 58±10 years); • Male: STSF vs. ST (68% vs. 71%); • BMI: STSF vs. ST (27.5±4.3 vs. 27.2±3.8 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (79.6% vs. 81.3%); • Left ventricular ejection fraction: STSF vs. ST (58±8 vs. 52±10%); Comorbidities • Hypertension: STSF vs. ST (30.4% vs. 31.3%); • Ischemic heart disease: STSF vs. ST (5.3% vs. 7%); • Valvulopathy: STSF vs. ST (1.2% vs. 1%); • Dilated cardiomyopathy: STSF vs. ST (4.9% vs. 4.2%); • Previous transient ischemic attack/Stroke: STSF vs. ST (4.3% vs. 1%); • Diabetes mellitus: STSF vs. ST (11.1% vs. 2.1%); • Chronic renal failure: STSF vs. ST (1.9% vs. 0%); The subgroup with AI 380-500 Demographics • Mean age: STSF vs. ST (59±10 vs. 59±13 years); • Male: STSF vs. ST (72% vs. 77%); • BMI: STSF vs. ST (26.2±4 vs. 28.1±4.8 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (83.4% vs. 75.3%);	The subgroup with AI 330-450 Procedural characteristics • Procedure time: STSF vs. ST (120±72 vs. 129±44 minutes); • Ablation time: STSF vs. ST (33.3±11.5 vs. 30.7±10 minutes); • Fluoroscopy time: STSF vs. ST (257±356 vs. 542±285 seconds); • Total fluid: STSF vs. ST (701±287 vs. 1105±573 mL); Clinical outcomes • Acute procedure success rate: STSF vs. ST (94.5% vs. 97.5%); The subgroup with AI 380-500 Procedural characteristics • Procedure time: STSF vs. ST (125±73 vs. 144±44 minutes); • Ablation time: STSF vs. ST (33±11.7 vs. 28.8±13.7 minutes); • Fluoroscopy time: STSF vs. ST (379±454 vs. 540±416 seconds); • Total fluid: STSF vs. ST (836±503 vs. 1,732±664 mL); Clinical outcomes • Acute procedure success rate: STSF vs. ST (92.2% vs. 94.5%).

							• Left ventricular ejection fraction: STSF vs. ST (60±7 vs. 57±7%); Comorbidities • Hypertension: STSF vs. ST (45.7% vs. 39.5%); • Ischemic heart disease: STSF vs. ST (5.5% vs. 3.4%); • Valvulopathy: STSF vs. ST (2.6% vs. 6.2%); • Dilated cardiomyopathy: STSF vs. ST (0.7% vs. 0%); • Previous transient ischemic attack/Stroke: STSF vs. ST (2.6% vs. 1.2%); • Diabetes mellitus: STSF vs. ST (4% vs. 6.2%); • Chronic renal failure: STSF vs. ST (0.7% vs. 3.7%);	
Plenge 2020 [11]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Consecutive patients with symptomatic paroxysmal or persistent AF scheduled for pulmonary vein isolation. Exclusion criteria: Age younger than 18 years, reversible causes of AF, prior pulmonary vein isolation, and intracardiac thrombus.	STSF (n=60) vs. ST (n=20)	Demographics • Mean age: STSF vs. ST (63.0±9.1 vs. 65.1±10.7 years, p=0.33); • Male: STSF vs. ST (53.3% vs. 65.0%, p=0.56); • BMI: STSF vs. ST (27.4±5.1 vs. 25.7±4.3 kg/m^2, p=0.24); Clinical characteristics • Duration of AF: STSF vs. ST (79.6±97.2 vs. 8.8±10.7 months, p=0.82); • Left atrial diameter: STSF vs. ST (41.2±7.0 vs. 42.7±6.3 mm, p=0.64); • Left ventricular ejection fraction: STSF vs. ST (61.3±8.4 vs. 62.2±5.3 %, p=0.68); Comorbidities • Hypertension: STSF vs. ST (65% vs. 73.3%, p=0.56); • Hyperlipoproteinemia: STSF vs. ST (33.3% vs. 40%, p=0.42);	Procedural characteristics • Procedure time: STSF vs. ST (106.3±28.4 vs. 116.7±26.7 minutes, p=0.2); • Ablation time: STSF vs. ST (25.9±7.3 vs. 32.1±16 minutes, p=0.045); • RF time for PVI left veins: STSF vs. ST (836.5±296.3 vs. 1,086.6±523.0 seconds, p=0.08); • RF time for PVI right veins: STSF vs. ST (913.5±1,435.8 vs. 1,002.8±544.6 seconds, p=0.8); • Fluoroscopy time: STSF vs. ST (16.0±6.7 vs. 13.8±5.7 minutes, p=0.25) • Fluoroscopy dose: STSF vs. ST (1,854.7±1,247.9 vs. 1,756.7±822.6 µGym2, p=0.77); • Fluid via ablation catheter: STSF vs. ST (241.4±79.6 vs. 540.3±229.5 mL, p<0.01);

							• Cardiovascular disease: STSF vs. ST (20% vs. 30%, p=0.10); • Cardiomyopathy: STSF vs. ST (15% vs. 13.3%, p=0.82); • Diabetes mellitus: STSF vs. ST (15% vs. 13.3%, p=0.72); • Renal failure: STSF vs. ST (11.7% vs. 0%, p=0.02); • Sleep-disordered breathing: STSF vs. ST (8.8% vs. 26.7%, p=0.63).	Clinical outcomes • Any complications: STSF vs. ST (1.7% vs. 5%); • Audible steam pop: STSF vs. ST (1.7% vs. 0%); • Bleeding: STSF vs. ST (0% vs. 5%).
Stabile 2020 [22]	Italy	Full text	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF who underwent their first AF ablation. Exclusion criteria: 1. Age <18; 2. Longstanding persistent AF (AF was the sole rhythm for the last 12 months); 3. AF secondary to a transient or correctable abnormality, including electrolyte imbalance, trauma, recent surgery, infection, toxic ingestion, and endocrinopathy; 4. Intra-atrial thrombus, tumor, or other abnormality precluding catheter insertion; 5. Left ventricular ejection fraction <35%; 6. Women of childbearing potential who are or might be pregnant; 7. Hematological contraindications to	STSF (Subgroup with AI 330-450, n=140; Subgroup with AI 380-500, n=149) vs. ST (Subgroup with AI 330-450, n=89; Subgroup with AI 380-500, n=74)	Duplicate with Scherr 2019.	The subgroup with AI 330-450 Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (14.9% vs. 4.5%); The subgroup with AI 380-500 Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (9.4% vs. 12.2%).

					ionizing radiation exposure; 8. Presence of complex congenital heart disease; 9. Cardiac surgery within 1 month from enrollment.			
Zhang 2020 [27]	China	Full text	Chinese	Retrospective study	Inclusion criteria: 1. Recurrent paroxysmal atrial fibrillation (defined as paroxysmal atrial fibrillation that can be terminated by itself or intervention within 7 days after the attack), which does not respond to antiarrhythmic drugs. 2. Preoperative echocardiography showed left atrial diameter <55mm and left ventricular ejection fraction (LVEF) > 35%. Exclusion criteria: Stroke, heart valve disease, heart failure (cardiac function Ⅳ level), atrial thrombus, cardiomyopathy (including hypertrophic cardiomyopathy and dilated cardiomyopathy), acute coronary syndrome, hyperthyroidism, hypothyroidism, coronary heart disease, chronic renal insufficiency (chronic kidney disease stage 4-5)	STSF (n=34) vs. ST (n=34)	Demographics • Mean age: STSF vs. ST (66.63±7.59 vs. 67.53±7.53 years, p>0.05); • Male: STSF vs. ST (55.9% vs. 58.8%, p>0.05); Clinical characteristics • Duration of AF: STSF vs. ST (9.6±3.6 vs. 8.7±4.6 months, p>0.05); • Left atrial diameter: STSF vs. ST (36.8±3.7 vs. 34.9±5.3 mm, p>0.05); • Left ventricular ejection fraction: STSF vs. ST (60.1±3.7 vs. 59.3±3.4%, p>0.05).	Procedural characteristics • Right PVI time: STSF vs. ST (23.30±5.53 vs. 28.65±4,95 minutes, p<0.05); • Left PVI time: STSF vs. ST (28.25±9.67 vs. 33.25±5.60 minutes, p<0.05); • Fluoroscopy time: STSF vs. ST (11.30±2.91 vs. 12.30±3.31 minutes, p>0.05); • Total fluid: STSF vs. ST (930.00±319.70 vs. 1,770.00±482.43 mL); Clinical outcomes • Unilateral PVI success rate: STSF vs. ST (88.23% vs. 58.82%, p<0.05); • Cardiac tamponade: STSF vs. ST (2.9% vs. 2.9%); • Eschar: STSF vs. ST (0.0% vs. 8.8%, p<0.05).

Huang 2021 [17]	China	Full text	Chinese	Retrospective study	Inclusion criteria: 1. Aged between 18 and 75 years; 2. ECG examination confirmed AF attack. Exclusion criteria: 1. Patients with cardiac thrombosis; 2. Patients complicated with active hemorrhagic disease, severe organic disease, or advanced chronic wasting disease; 3. Left atrial diameter > 55mm; 4. Patients with valvular heart disease or vascular disease requiring surgical treatment.	STSF (n=42) vs. ST (n=42)	Demographics • Mean age: STSF vs. ST (62.3±8.8 vs. 61.1±10.9 years, p=0.510); • Male: STSF vs. ST (69.0% vs. 64.3%, p=0.643); Clinical characteristics • Paroxysmal AF: STSF vs. ST (45.2% vs. 54.8%, p=0.383); • Left atrial diameter: STSF vs. ST (4.38±0.48 vs. 4.40±0.62 cm, p=0.854); • Left ventricular ejection fraction: STSF vs. ST (59.45±4.72 vs. 58.40±10.91%, p=0.340); Comorbidities • Hypertension: STSF vs. ST (54.8% vs. 52.4%, p=0.827); • Coronary heart disease: STSF vs. ST (21.4% vs. 21.4%, p=1.000); • Cardiac insufficiency: STSF vs. ST (9.5% vs. 9.5%, p=1.000); • Diabetes: STSF vs. ST (4.8% vs. 11.9%, p=0.266); • Cerebral infarction: STSF vs. ST (7.1% vs. 19.0%, p=0.106).	Procedural characteristics • Ablation time: STSF vs. ST (28.3±5.1 vs. 51.3±6.7 minutes, p<0.001); Clinical outcomes • Circumferential pulmonary vein isolation success rate: STSF vs. ST (100.0% vs. 100.0%, p=1.000); • Complement ablation rate in CPVI: STSF vs. ST (45.2% vs. 85.7%, p=0.087); • 12-month arrhythmia recurrence rate: STSF vs. ST (0% vs. 2.4%, p=0.314); • Any complications: STSF vs. ST (0% vs. 0%).
Zhou 2021 [13]	China	Full text	Chinese	Retrospective study	Inclusion criteria: Patients undergoing first-time percutaneous radiofrequency catheter ablation. Exclusion criteria: Unspecified.	STSF (n=142) vs. ST (n=98)	Demographics • Mean age: STSF vs. ST (63.2±9.2 vs. 63.1±10.6 years, p=0.950); • Male: STSF vs. ST (59.2% vs. 65.3%, p=0.491); Clinical characteristics • Paroxysmal AF: STSF vs. ST (59.9% vs. 66.3%, p=0.335); • Left atrial diameter: STSF vs. ST (43.4±4.4 vs. 44.4±5.5 mm, p=0.193);	Procedural characteristics • Procedure time: STSF vs. ST (96.4 ±31.6 vs. 119.5±33.8 minutes, p=0.021); • Ablation time: STSF vs. ST (38.6±15.2 vs. 61.5±13.8 minutes, p=0.013); • Fluoroscopy time: STSF vs. ST (15.3±3.3 vs. 16.9±3.6 minutes, p=0.144); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (4.9% vs. 20.4%, p=0.025).

							• Left ventricular ejection fraction: STSF vs. ST (61.4±5.7 vs. 61.2±5.1%, p=0.849); • CHA_2DS_2 VASc Score: STSF vs. ST (2.3±1.7 vs. 1.3±1.7, p=0.243).	
Dugo 2016 [29]	Germany	Abstract	English	Retrospective study	Inclusion criteria: Patients with AF underwent ablation between July 2014 and May 2015, with a minimum follow-up of 6 months. Exclusion criteria: Unspecified.	STSF (n=26) vs. SF (n=26)	Demographics • Mean age: STSF vs. SF (66±9 vs. 67±10 years); • Male: STSF vs. SF (54% vs. 50%); Clinical characteristics • Paroxysmal AF: STSF vs. SF (96% vs. 81%); • Left atrial diameter: STSF vs. SF (40±7 vs. 42±4 mm).	Procedural characteristics • Procedure time: STSF vs. SF (98±32 vs. 78±31 minutes, p< 0.05); • Fluoroscopy time: STSF vs. SF (11±7 vs. 7±3 minutes, p< 0.05); Clinical outcomes • Acute procedure success rate: STSF vs. SF (100% vs. 100%); • Any complications: STSF vs. SF (0% vs. 0%); • Cardiac tamponade: STSF vs. SF (0% vs. 0%); • Stroke: STSF vs. SF (0% vs.0%); • Atrial-esophageal fistula: STSF vs. SF (0% vs. 0%); • Vascular access: STSF vs. SF (3.8% vs. 0%);
Gonna 2017 [30]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Atrial fibrillation patients undergoing ablation, Between May and December 2015. Exclusion criteria: Unspecified.	STSF (n=100) vs. SF (n=100)	Demographics • Mean age: STSF vs. SF (60.5±14.0 vs. 62.4±13.3 years, p=0.38); • Male: STSF vs. SF (73% vs. 71%, p=0.75).	Procedural characteristics • Mean procedure time: STSF vs. SF (225.5 vs. 221.4 minutes, p=0.55); • Mean fluoroscopy time: STSF vs. SF (25.8 vs. 30.0 minutes, p=0.03); Clinical outcomes • Any complications: STSF vs. SF (0% vs. 2%, p=0.16); • Pericardial effusion: STSF vs. SF (0% vs. 1%, p=0.32); • Atrioventricular block: STSF vs. SF (0% vs. 1%, p=0.32).
Takamiya 2020 [32]	Japan	Full text	English	Retrospective study	Inclusion criteria: Patients who underwent	STSF (n=74) vs. SF (n=74)	Demographics	Procedural characteristics

					first catheter ablation for drug-refractory persistent AF. Exclusion criteria: Unspecified.		• Mean age: STSF vs. SF (63±10 vs. 63±12 years, p=0.5); • Male: STSF vs. SF (76% vs. 80%, p=0.69); • BMI: STSF vs. SF (25±4 vs. 25±4 kg/m^2, p=0.98); Clinical characteristics • Median duration of persistent AF: STSF vs. SF (6 vs. 6 months, p=0.30); • Left atrial diameter: STSF vs. SF (43±6 vs. 43±7 mm, p=0.96); • Left ventricular ejection fraction: STSF vs. SF (59±11 vs. 58±14%, p=0.57); Comorbidities • Heart failure: STSF vs. SF (18% vs. 20%, p=0.83); • Hypertension: STSF vs. SF (61% vs. 54%, p=0.5); •Diabetes mellitus: STSF vs. SF (20% vs. 19%, p=1.0).	• Procedure time: STSF vs. SF (180 vs. 200 minutes, p=0.150); • Fluoroscopy time: STSF vs. SF (67 vs. 76 minutes, p=0.026); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. SF (15% vs. 30%); • Any complications: STSF vs. SF (5% vs. 3%, p=1.0); • Pericardial effusion: STSF vs. SF (1.4% vs. 1.4%); • Esophageal gastroparesis: STSF vs. SF (1.4% vs. 0%); • Phrenic nerve injury: STSF vs. SF (1.4% vs. 0%); • Aspiration pneumonia: STSF vs. SF (1.4% vs. 0%); • Sinus node injury as a result of superior vena cava isolation: STSF vs. SF (0% vs. 1.4%).
Uetake 2020 [31]	Japan	Full text	English	Prospective cohort study	Inclusion criteria: Paroxysmal AF patients who underwent their first radiofrequency catheter ablation procedure. Exclusion criteria: 1. Severe valvular disease; 2. Left ventricular ejection fraction < 35%; 3. Left atrial dimension > 55 mm; 4. Active thyroid disease; 5. Hypertrophic cardiomyopathy; 6. Hemodialysis;	STSF (n=298) vs. SF (n=97)	Demographics • Mean age: STSF vs. SF (65.3±9.9 vs. 63.2±9.2 years, p=0.085); • Male: STSF vs. SF (78.8% vs. 79.4%, p=0.028); • BMI: STSF vs. SF (24.1±3.5 vs. 24.0±3.1 kg/m^2, p=0.985); Clinical characteristics • Duration of AF: STSF vs. SF (32.1±33.5 vs. 29.9±40.2 months, p=0.023); • Left atrial diameter: STSF vs. SF (41.0±6.0 vs. 40.6±5.9 mm, p=0.709); • Left ventricular ejection fraction: STSF vs. SF (65.8±7.7 vs. 65.5±8.4%, p=0.86);	Procedural characteristics • Ablation time: STSF vs. SF (2,056.8±534.5 vs. 2,401.1±733.4 seconds, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. SF (100% vs. 100%); • 12-month arrhythmia recurrence rate: STSF vs. SF (21.8% vs. 43.3%, p<0.001).

					7. Use of antiarrhythmic drugs during the blanking period.		• CHA_2DS_2 VASc Score: STSF vs. SF (1.94±1.2[illegible] vs. [illegible].51±1.13, *p*=0.010); Comorbidities • Hypertension: STSF vs. SF (53.4% vs. 52.6%, *p*=0.493); • Congestive heart failure: STSF vs. SF (4.7% vs. [illegible]%, *p*=0.203); • Diabetes mellitus: STSF vs. SF (10.1% vs. 13.4%, *p*=0.230); • Previous stroke or transient ischemic attack: STSF vs. SF (3.4% vs. 1.0%, *p*=0.202); • Vascular disease: STSF vs. SF (5.7% vs. 1.0%, *p*=0.055).	
Ikeda 2021 [33]	Japan	Full text	English	Retrospective study	Inclusion criteria: 1. Age of > 20 years and provision of informed consent to undergo a second AF ablation at our institute, the performance of the second AF ablation using high-density mapping or the conventional method (CARTO® mapping system; Biosense Webster, Irvine, CA, USA) during that period; 2. ≥ 3 months of follow-up at the outpatient clinic in our institute. Exclusion criteria: 1. Refusal to participate in the study; 2. An inability to undergo follow-up for any reason; 3. The lack of use of a 3D mapping system.	STSF (n=51) vs. CELSIUS® (n=49)	Demographics • Mean age: STSF vs. CELSIUS® (63.5±8.54 vs. 64.2±9.97 years, *p*=0.98); • Male: STSF vs. CELSIUS® (63% vs. 73%, *p*=0.25); Clinical characteristics • Paroxysmal AF: STSF vs. CELSIUS® (59% vs. 65%, *p*=0.5); • Median $CHADS_2$ VASc Score: STSF vs. CELSIUS® 0.8 vs. 0.8, *p*=0.91); Comorbidities • Sick sinus syndrome: STSF vs. CELSIUS® (14% vs. 16%, *p*=0.72); • Cerebrovascular disease: STSF vs. CELSIUS® (12% vs. 4%, *p*=0.16); • Congestive heart failure: STSF vs. CELSIUS® (16% vs. 22%, *p*=0.39); • Hypertension: STSF vs. CELSIUS® (35% vs. [illegible]3%, *p*=0.78);	Procedural characteristics • Procedure time: STSF vs. CELSIUS® (260.5±82.7 vs. 255.8±45.3 minutes, *p*=0.82); • Fluoroscopy dose: STSF vs. CELSIUS® (313.2±187.9 vs. 363.4±257.3 mGy, *p*=0.28); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. CELSIUS® (33% vs. 16%, *p*=0.017); • Cardiac tamponade: STSF vs. CELSIUS® (0% vs. 0%); • Cerebral infarction: STSF vs. CELSIUS® (0% vs. 0%); • Bleeding: STSF vs. CELSIUS® (13.7% vs. 10.2%); • Congestive heart failure: STSF vs. CELSIUS® (2% vs. 0%, *p*=0.32); • Pericarditis: STSF vs. CELSIUS® (2% vs. 0%, *p*=0.32).

							• Diabetes mellitus: STSF vs. CELSIUS® (2% vs. 8%, *p*=0.15); • Chronic kidney disease: STSF vs. CELSIUS® (9% vs. 16%, *p*=0.19).	
Reinsch 2021 [36]	Germany	Full text	English	Retrospective study	Inclusion criteria: Atrial fibrillation patients undergoing ablation at the Alfried Krupp Krankenhaus, Essen, Germany from October 2014 to June 2019. Exclusion criteria: Unspecified.	STSF (n=690) vs. Thermocool NAVISTAR® (n=99)	Demographics • Mean age: STSF vs. Thermocool NAVISTAR® (67.5±10.6 vs. 62.6±9.9 years); • Male: STSF vs. Thermocool NAVISTAR® (58.4% vs. 59.6%); Clinical characteristics • Paroxysmal AF: STSF vs. Thermocool NAVISTAR® (43.5% vs. 48.5%); • Duration of AF: STSF vs. Thermocool NAVISTAR® (50.1±57.5 vs. 53.5±73.4 months); • Left ventricular ejection fraction≥55%: STSF vs. Thermocool NAVISTAR® (77.5% vs. 81.8%); • CHA_2DS_2 VASc Score≥3: STSF vs. Thermocool NAVISTAR® (57.0% vs. 46.9%); Comorbidities • Hypertension: STSF vs. Thermocool NAVISTAR® (69.9% vs. 57.6%).	Procedural characteristics • Procedure time: STSF vs. Thermocool NAVISTAR® (160±48 vs. 190±47 minutes); • Ablation time: STSF vs. Thermocool NAVISTAR® (43±19 vs. 58±27 minutes); • Fluoroscopy time: STSF vs. Thermocool NAVISTAR® (5±3 vs. 7±4 minutes); Clinical outcomes • Cardiac tamponade: STSF vs. Thermocool NAVISTAR® (1.7% vs. 2.9%).
Di 2020 [35]	Italy	Abstract	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF underwent point-by-point pulmonary vein isolation. Exclusion criteria: Unspecified.	CARTO+STSF (n=59) vs. Rhythmia System™ + DirectSense (n=57)	Pooled information of two groups Clinical characteristics • Paroxysmal AF: 63%	Procedural characteristics • Procedure time: CARTO+STSF vs. Rhythmia System™ + DirectSense (180±56 vs. 180±89 minutes, *p*=0.590); • Fluoroscopy time: CARTO+STSF vs. Rhythmia System™ + DirectSense (13±9 vs. 20±12 minutes, p=0.002); Clinical outcomes

								• Acute procedure success rate: CARTO+STSF vs. Rhythmia System™ + DirectSense (100% vs. 100%); • 9-month arrhythmia recurrence rate: CARTO+STSF vs. Rhythmia System™ + DirectSense(14% vs. 25%, *p*=0.2); • Any complications: CARTO+STSF vs. Rhythmia System™ + DirectSense (0% vs. 0%); • Audible steam pop: CARTO+STSF vs. Rhythmia System™ + DirectSense (0% vs. 0%).
Guckel 2022 [34]	Germany	Abstract	English	Prospective cohort study	Inclusion criteria: Patients undergoing radiofrequency ablation for AF. Exclusion criteria: Unspecified.	STSF (n=69) vs. DiamondTemp ™ (n=33)	Not reported	Procedural characteristics • Procedure time: STSF vs. DiamondTemp™ (78.2±25.6 vs. 98.8±30.1 minutes, *p*=0.002); • Ablation time: STSF vs. DiamondTemp™ (1,035.5±287.2 vs.792.1±311.2 seconds, *p*<0.001); • Fluoroscopy time: STSF vs. DiamondTemp™ (5.5±2.5 vs.4.6±2.1 minutes, p<0.006); • Fluoroscopy dose: STSF vs. DiamondTemp™ (295.8±247.5 vs. 183.8±178.1 yGym2, *p*<0.013); Clinical outcomes • Acute procedure success rate: STSF vs. DiamondTemp™ (100% vs. 100%); • Acute stroke: STSF vs. DiamondTemp™ (0% vs. 3%).

STSF: SMARTTOUCH® SURROUNDFLOW; ST: ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; BMI: Body mass index.

Supplementary Table 2. Search strategies for all databases of systematic literature retrieval.

Embase, run on July 31, 2022		
#	**Searches**	**Results**
1	exp atrial fibrillation/	100,822
2	atrial fibrillation.ti,ab,kw.	149,900
3	1 or 2	175,990
4	(Smart Touch or Smarttouch or ST).af.	2,039,661
5	(Surround Flow or Surroundflow or SF).af.	147,154
6	4 and 5	9,825
7	STSF.af.	81
8	6 or 7	9,875
9	3 and 8	336
10	limit 9 to yr="2016 -current"	263
11	limit 10 to english language	260
Medline, run on July 31, 2022		
#	**Searches**	**Results**
1	exp atrial fibrillation/	65,749
2	atrial fibrillation.ti,ab,kw.	83,864
3	1 or 2	96,391
4	(Smart Touch or Smarttouch or ST).af.	1,566,840
5	(Surround Flow or Surroundflow or SF).af.	58,697
6	4 and 5	4,937
7	STSF.af.	29
8	6 or 7	4,953
9	3 and 8	75
10	limit 9 to yr="2016 -current"	53
11	limit 10 to english language	53
The Cochrane library, run on July 31, 2022		

#	Searches	Results
1	exp atrial fibrillation/	5,190
2	atrial fibrillation.ti,ab,kw.	14,561
3	1 or 2	14,959
4	(Smart Touch or Smarttouch or ST).af.	66,732
5	(Surround Flow or Surroundflow or SF).af.	26,824
6	4 and 5	2,022
7	STSF.af.	9
8	6 or 7	2,027
9	3 and 8	38
10	limit 9 to yr="2016 -current"	21
11	limit 10 to english language	20
Web of Science, run on July 31, 2022		
#	**Searches**	**Results**
1	TS=atrial fibrillation	109,124
2	TS=(Smart Touch or Smarttouch or ST)	179,345
3	TS=(Surround Flow or Surroundflow or SF)	102,686
4	#2 AND #3	973
5	TS=STSF	56
6	#4 OR #5	1,018
7	#1 AND #6	34
8	PY="2016-2022"	21,184,249
9	#7 AND #8	31
WANFANG, run on July 31, 2022		
#	**Searches**	**Results**
1	主题:("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤")	15,732
2	全部:("Smart Touch" or "Smarttouch" or "ST")	32,844
3	全部:("Surround Flow" or "Surroundflow" or "SF")	28,101

4	2 AND 3	125
5	全部:("STSF")	3
6	4 OR 5	127
7	1 AND 6	3
CNKI, run on July 31, 2022		
#	**Searches**	**Results**
1	TKA=('房颤' + '心房颤动' + '心房纤维颤动' + '心房纤颤')	13,497
2	FT=('Smart Touch' + 'Smarttouch' + 'ST')	426,266
3	FT=('Surround Flow' + 'Surroundflow' + 'SF')	155,221
4	2 AND 3	18,007
5	FT=('STSF')	71
6	4 OR 5	18,070
7	1 AND 6	87
VIP, run on July 31, 2022		
#	**Searches**	**Results**
1	M=("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤") OR R=("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤")	13,437
2	U=("Smart Touch" or "Smarttouch" or "ST") OR R=("Smart Touch" or "Smarttouch" or "ST")	43,133
3	U=("Surround Flow" or "Surroundflow" or "SF") OR R=("Surround Flow" or "Surroundflow" or "SF")	52,374
4	2 AND 3	288
5	U=("STSF") OR R=("STSF")	4
6	4 OR 5	291
7	1 AND 6	3

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Line 1 to 4
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	See abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Line 58 to 61
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Line 61 to 65
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Line 73 to 80
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Line 84 to 92
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary Table 2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Line 94 to 99, and Figure 1
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Line 101 to 107, and Figure 1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Line 112 to 116
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Line 109 to 111
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Line 119 to 124
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Line 126 to 132
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Line 134 to 138
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Not applicable
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Supplementary Table 1
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Line 138 to 141, and Line 147 to 149
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Line 142 to 145

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Line 145 to 146
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Line 146 to 147
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Line 138 to 141
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Line 152 to 157, and Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	Line 159 to 162, and Supplementary Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Line 171 to 173, and Supplementary Table 1
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Line 283 to 285, Line 288 to 290, Line 293 to 294, and Line 302 to 314
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Line 175 to 180
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Line 183 to 185, Line 206 to 207, Line 229 to 231, Line 248 to 251, Line 267 to 270, Line 279 to 281, Line 291 to 292, and Line 295 to 297
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Line 186 to 196, Line 208 to 221, Line

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
			232 to 240, Line 251 to 259, and Line 271 to 274
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Line 197 to 199, Line 222 to 223, Line 241 to 242, Line 259 to 261, and Line 274 to 277
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Line 199 to 202, and Line 223 to 224
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Figure 2, 3, 4, and 5, and Table 1
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Line 316 to 324
	23b	Discuss any limitations of the evidence included in the review.	Line 379 to 399
	23c	Discuss any limitations of the review processes used.	Line 389 to 391
	23d	Discuss implications of the results for practice, policy, and future research.	Line 358 to 360, and Line 397 to 399
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Not applicable
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Not applicable
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Line 436
Competing interests	26	Declare any competing interests of review authors.	Line 432 to 434
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Upon request

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/updatedguideline.aspx

PRISMA 2020 Checklist

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Comparisons of Procedural Characteristics and Clinical Outcomes between SMARTTOUCH® SURROUNDFLOW Catheter and Other Catheters for Atrial Fibrillation Radiofrequency Catheter Ablation: A Systematic Literature Review

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Comparisons of Procedural Characteristics and Clinical Outcomes between SMARTTOUCH® SURROUNDFLOW Catheter and Other Catheters for Atrial Fibrillation Radiofrequency Catheter Ablation: A Systematic Literature Review

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Abstract

Background: SMARTTOUCH® SURROUNDFLOW (STSF) catheter is the new generation of SMARTTOUCH (ST) catheter with an upgraded irrigation system for radiofrequency catheter ablation (RFCA) in patients with atrial fibrillation (AF). **Methods**: This systematic literature review searched the major English and Chinese bibliographic databases from 2016 to 2022 for any original clinical studies assessing the STSF catheter for RFCA in AF patients. Meta-analysis with random effects model was used for evidence synthesis. **Results**: Pooled outcomes from 19 included studies indicated that STSF catheter was associated with a significantly shorter procedure time [weighted mean difference (WMD): -17.4 minutes, $p<0.001$], shorter ablation time (WMD: -6.6 minutes, $p<0.001$), and lower catheter irrigation fluid volume (WMD: -492.7 ml, $p<0.001$) than ST catheter. Pooled outcomes from 4 included studies with paroxysmal AF patients reported that using the STSF catheter for RFCA was associated with a significantly shorter ablation time (WMD: -5.7 minutes, $p<0.001$) and a lower risk of one-year post-ablation arrhythmia recurrence (rate ratio: 0.504, $p<0.001$) than the SURROUNDFLOW (SF) catheter. Significant reductions in procedure time and ablation time associated with the STSF catheter were also reported in the other 4 studies using non-ST/SF catheters as the control. Overall complications of STSF catheter and control catheters were comparable. **Conclusions**: Using the STSF catheter was superior to using the ST catheter to conduct RFCA for AF by significantly reducing procedure time, ablation time, fluoroscopy time, and irrigation fluid volume. The superiority of the STSF catheter over the SF catheter and other non-ST/SF catheters for RFCA needs further confirmation.

Strengths and limitations of this study

- Improve the generalizability of the pooled evidence by updating the published evidence and including studies published in Chinese journals.
- Conduct heterogeneity analyses, sensitivity analysis, and publication bias analysis to confirm the robustness of the pooled evidence.
- Most of the included studies in this review were observational studies that could introduce heterogeneity in the pooled evidence.
- The pooled evidence is robust for the comparisons between SMARTTOUCH® SURROUNDFLOW catheter and SMARTTOUCH® catheter but not for the comparisons between the other catheter types due to paucity of existing evidence.

Keywords
atrial fibrillation; radiofrequency catheter ablation; SMARTTOUCH® SURROUNDFLOW; systematic literature review; meta-analysis

1. Introduction

Radiofrequency catheter ablation (RFCA) plays a critical role in managing atrial fibrillation (AF), which affects 1.6% of the Chinese adult population and is rising in prevalence along with the aging population in China [1]. RFCA was originally conducted using a non-contact force (CF)-sensing catheter, whose use is now discouraged due to the inadequate lesion formation caused by insufficient CF or complications (such as cardiac perforation and atrioesophageal fistula) caused by excessive CF [2]. Thus, a CF-sensing catheter was developed to improve ablation outcomes and safety. The THERMOCOOL SMARTTOUCH® (ST) catheter is one of the CF-sensing catheters widely used for RFCA. The ST catheter is equipped with a technology that can measure the CF generated by the catheter tip on the myocardium and an irrigation system that cools the tip of the electrode catheter during ablation and allows high radiofrequency energy ablation without overheating at the electrode-tissue interface [3]. To enhance the cooling effects on the tip of the catheter electrode, surround flow (SF) technology was developed by equipping the catheter porous tip with 56 tiny holes, which make conduits for optimal fluid pressure distribution in the catheter tip. As the new generation of a catheter with advanced irrigation technology, the STSF catheter combines both CF and SF technologies to optimize ablation outcomes, protect cardiac function, and reduce the risk of developing eschar during ablation [4]. According to a meta-analysis of four clinical trials published before 2020, the STSF catheter was superior to the ST catheter in procedure outcomes by reducing the procedure time, fluoroscopy time, and catheter irrigation infusion volume [5]. However, this meta-analysis was unable to assess the robustness of the pooled evidence due to the small number of included studies. Additionally, this review didn't perform any analysis to address the heterogeneity and publication bias in the pooled evidence. With accumulated evidence from recently published studies assessing STSF catheter ablation in patients with AF, we conducted this systematic literature review (SLR) aiming to add more evidence from multiple sources (journals published in Chinese and recent conference proceedings) and including studies comparing STSF versus (vs.) catheters other than ST to better comprehend the values of STSF catheter for RFCA in AF patients. Thus, this SLR could be a timely evidence source to support the management of AF with catheter ablation in the countries where STSF was considered a new technology to improve ablation outcomes in AF patients.

2. Materials and Methods

This study was designed as an SLR using major English- and Chinese-language bibliographic databases to identify published, peer-reviewed clinical studies comparing the STSF catheter against other ablation catheters for procedural characteristics and clinical outcomes associated with RFCA in AF patients. This SLR was reported by following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 Statement [6].

2.1 Study eligibility criteria

This SLR set both inclusion and exclusion criteria to identify randomized clinical trials or observational studies (retrospective or prospective cohort studies) comparing the STSF catheter with other ablation catheters for AF. The study inclusion criteria are as follows: (1) including AF patients who underwent RFCA; (2) assessing STSF against any other type of ablation catheter for RFCA in adult patients with AF; (3) reporting procedural characteristics and clinical outcomes associated with ablation catheter during and/after RFCA in AF patients; and (4) designed as a clinical trial or observational study. The exclusion criteria of this SLR are as follows: (1) preclinical (*in vivo* or *in vitro*) studies, case studies, case reports, non-original research articles (*e.g.*

correspondence, editorials, commentaries, overviews, summaries, communications, consensus guidelines) and reviews; (2) any cohort that includes patients with ablation for arrhythmias other than AF; (3) single-arm studies assessing STSF without control; (4) inadequate information.

2.2 Information sources and search strategies

Given that RFCA has been implemented for AF treatment for over 20 years in China, many clinical studies assessing various ablation catheters for AF have been published in Chinese clinical journals. Therefore, this SLR explored major English bibliographic databases (MEDLINE, Embase, Web of Science, and the Cochrane Library) and three major Chinese bibliographic databases (WANFANG, VIP, and China National Knowledge Infrastructure) as the data sources. To align with the time of STSF approval in 2016, the literature search period was set from January 1, 2016, to the date when the literature search was first conducted (July 31, 2022). Grey literature search was conducted by searching the proceedings of the Heart Rhythm Society annual conference, the Society for Cardiovascular Angiography and Interventions annual conference, the European Heart Rhythm Association annual conference, and the Asia Pacific Heart Rhythm Society annual conference in 2021 and 2022 for any relevant but not fully published studies. The trial registry databases, including ClinicalTrials.gov, European Union Clinical Trials Register, and International Clinical Trials Registry Platform, were searched as well for any missing studies. To ensure that all relevant evidence is captured, this study only combined the keywords for AF and STSF to develop the search strategy for each bibliographic database and grey literature search. Search strategies is shown in Supplementary Table 1.

2.3 Literature selection process

Two reviewers conducted the literature selection independently after which the search hits were pooled. Then, they deleted duplicate results and identified additional studies from the left references for further eligibility assessment, which included the exclusion of irrelevant references and retrieving full publications of the relevant references. The source references reporting relevant outcome information from clinical guidelines, literature review, and health economic research were cross checked with the identified references to avoid missing studies. The developed inclusion and exclusion criteria were used to determine the study eligibility after a full publication review. The exclusion reasons during the literature selection process were documented for records. Any disagreement on study eligibility between the two reviewers was resolved by consulting with the study lead.

2.4 Data collection process

Excel-based data extraction forms were developed specifically to guide the data collection from the full publications of included studies. The designed data extraction form was tested using one included study to align with definitions of the planned data items for extraction. Two reviewers were fully trained on how to use the data extraction forms and the definitions of data items. The two reviewers conducted data extraction independently. The extracted information from the two reviewers was further cross-checked by the third reviewer, which corrected any inconsistent information by verifying the information source. The study lead reviewed all extracted information for

any abnormal information before evidence synthesis.

2.5 Data items

The full publication of the included studies was reviewed to collect the following information: (1) study characteristics such as country setting, study design, and patient inclusion and exclusion criteria; (2) study arm information including the arm definition, sample size, and patient baseline characteristics (demographics, AF-related clinical characteristics, and comorbidities); (3) ablation catheter type; (4) outcome measures that included procedural characteristics (procedure time, ablation time, fluoroscopy time, irrigation fluid volume), clinical outcomes (acute procedural success of pulmonary vein isolation (PVI), one-year post-ablation cardiac arrhythmia recurrence, ablation-related complications); and other relevant outcomes (eschar, use of diuretics, and use of urinary catheter). Most of the included studies didn't provide adequate information for the definitions of outcome measures except catheter irrigation fluid volume, fluoroscopy time, and acute procedural success of PVI.

2.6 Study risk of bias assessment

This SLR used Newcastle-Ottawa Scale (NOS) [7] to assess the study quality of the included studies. Based on the recommendation from previous research [8], this SLR classified included studies as good quality (NOS 8-9), fair quality (NOS 5-7), and poor quality (NOS 0-4). This SLR included one randomized clinical trial, which was published as a conference abstract and didn't provide adequate information for the quality assessment using the Jadad score [9]. Two reviewers used NOS to assess the fully published studies independently. Any disagreement on assessment was discussed with the study lead to reach a consensus.

2.7 Effect measures

This SLR extracted any reported effect measures from the included studies. The extracted effect measures were standardized according to their original definitions in the included studies and the selected effect measures for evidence synthesis included procedural characteristics and clinical outcomes. This SLR used weighted mean difference (WMD) to present the pooled procedural characteristics for the comparisons of procedure time, ablation time, fluoroscopy time, and catheter irrigation fluid volume. The pooled clinical outcomes for the comparisons of acute procedural success of PVI, one-year post-ablation arrhythmia recurrence, and RFCA-related overall complications were presented with a rate ratio (RR).

2.8 Synthesis methods

The extracted data were standardized and categorized by AF types (paroxysmal AF, persistent AF, and unspecified AF); control catheter types (ST, SF, CELSIUS® catheter, DiamondTemp™, and NAVISTAR®); patient characteristics [age, gender distribution, AF type distribution, disease duration after the diagnosis of AF, left ventricular ejection fraction (LVEF), left atrium diameter, CHA_2DS_2 VASc, and comorbidities]; and effect measures for RFCA procedural characteristics and clinical outcomes. The reported outcomes from the included studies comparing STSF vs. the same control catheter were first pooled for evidence synthesis using a pairwise

meta-analysis method, which used a random-effect model to consider the variance between the included studies and within each included study. Heterogeneity in the conducted meta-analysis was assessed using the I^2 method. The included studies were stratified by AF type for subgroup analysis if the heterogeneity in the pooled outcomes was significant. Further exploration of potential heterogeneity sources was conducted by excluding the studies reporting different patient characteristics if significant heterogeneity was still detected in the pooled outcomes from the subgroup analysis. The leave-one-out sensitivity analysis was conducted to determine the robustness of the overall pooled outcomes for the meta-analysis including 3 or more eligible results. The Egger's test was also performed to assess publication bias for overall pooled outcomes from 10 or more eligible results. This SLR used the statistical software R to conduct the described analyses. Original results from included studies were reported when the meta-analysis was not feasible.

3. Results

3.1 Study selection

This study initially identified 373 unique references from the search of the included English and Chinese bibliographic databases. One-hundred-eighty-two were excluded due to irrelevance following the review of the titles and abstracts of the initial batch of papers. Following the study eligibility assessment of the full publications of the remaining 191 papers, 25 met the inclusion criteria. The search of conference proceedings and review articles identified two additional eligible studies. Thus, a total of 27 studies are included in our SLR. The flowchart of the study identification process is illustrated in Figure 1.

3.2 Characteristics and qualities of included studies

The included 27 studies assessed the procedural characteristics and clinical outcomes associated with STSF relative to ST (in 19 studies), SF (in 4 studies), and other four non-STSF/SF catheters (1 study for each non-STSF/SF catheter), respectively. This SLR only included one randomized clinical trial and the rest of the included studies were observational studies, including 13 retrospective studies and 13 prospective studies. This SLR included 4 studies published in Chinese. The studies published in English included 3 studies from the United States, 13 studies from Europe, and 7 studies from other regions. Among the included studies, 17 studies were fully published and 10 studies were published in conference proceedings. Even though all these studies included patients who underwent RFCA for AF, 7 studies solely included patients with paroxysmal AF, 1 study only included patients with persistent AF, and 19 studies included patients with either paroxysmal or persistent AF. According to the reported patient baseline characteristics in these included studies, the study patients were characterized with relatively old age (mean age range: 58.0-67.5 years), high CHA_2DS_2 VASc score (mean range: 1.3-2.7), and prevalent cardiovascular comorbidities, which included hypertension (30.4%-98.0%), coronary heart disease (8.3%-29.2%), and heart failure (17.8%-41.7%). Of the 17 studies assessed for study quality, 7 studies had good quality and 10 studies had fair quality. The study characteristics and main extracted information from these included 27 studies are summarized in Supplementary Table 2.

3.3 Synthesized evidence from the included studies comparing the STSF catheter with the ST catheter

Of the included 19 studies comparing STSF with ST, 13 studies [10-22] included patients with unspecified AF (persistent or paroxysmal AF) and 6 studies [23-28] included patients with paroxysmal AF. The synthesized outcomes included procedural characteristics (procedure time, ablation time, fluoroscopy time, and irrigation fluid volume), primary clinical outcomes (acute procedural success of PVI, one-year post-ablation arrhythmia recurrence, and overall complications), and other ablation-related clinical outcomes that included foley catheter use, diuretics use, and eschar development.

3.3.1 Procedural characteristics - Procedure time

Overall, nine included studies with 10 eligible results [10-15, 23-25] report RFCA procedure time (876 operated with STSF and 762 operated with ST). The overall pooled outcomes from nine included studies showed that STSF was associated with significantly shorter procedure time than ST (WMD: -17.4 minutes, 95% CI: -25.3 to -9.4 minutes, $p<0.01$); however, this pooled outcome has considerable heterogeneity [$I^2 = 76\%$, $p<0.01$]. The pooled outcomes from the stratified studies by AF types identified significantly shorter procedure time associated with the STSF catheter from the studies with unspecified AF patients (WMD: -18.7 minutes, 95% CI: -27.6 to -9.7 minutes, $p<0.001$) but not from the studies with paroxysmal AF patients (WMD: -14.7 minutes, 95% CI: -32.3 to 2.9 minutes, $p=0.101$). Because the heterogeneity of the pooled evidence from the 6 studies with unspecified AF patients was still significant, we reviewed these six studies to further explore the potential heterogeneity sources.

We found that 2 studies [10, 11] and a subgroup within one study [12] included patients who were likely to be different from those in other studies in AF duration, left atrial diameter/volume, the proportion of patients with paroxysmal AF, and proportion of patients with cardiomyopathy. After excluding the results from these four studies in the meta-analysis, the shorter procedure time of the STSF catheter remained statistically significant (WMD: -25.9 minutes, 95% CI: -33.0 to -18.8 minutes, $p<0.001$) with non-significant heterogeneity ($I^2=21\%$, $p=0.29$), suggesting that these characteristics are potential heterogeneity sources.

The leave-one-out sensitivity analysis indicated that the point estimation of the overall pooled difference in procedure time between the STSF catheter and the ST catheter had a relatively narrow range (from -15.2 minutes to -19.9 minutes). In addition, Egger's test did not detect significant publication bias for the reported difference in procedure time between the STSF catheter and the ST catheter from the included 9 studies ($p=0.768$). The pooled difference in the procedure time between the STSF catheter and the ST catheter is illustrated in Figure 2. The other reported outcomes are listed in Supplementary Figure 1 and Supplementary Figure 2~~Files~~.

3.3.2 Procedural characteristics - Ablation time

Twelve included studies [10-17, 23-26] with 13 eligible results reported the ablation time associated with using STSF and ST to conduct RFCA in 1,870 patients with AF (992 operated with STSF and 878 with ST). The pooled differences in the ablation time of the two catheters favored the STSF catheter (WMD: -6.6 minutes, 95% CI: -12.5 to -0.6 minutes, $p=0.031$) with significant heterogeneity ($I^2=98\%$, $p<0.01$). To control the potential

heterogeneity associated with AF type, this SLR performed a subgroup meta-analysis for this outcome by including the stratified studies by the AF types of study patients (paroxysmal AF vs. unspecified AF). The pooled difference in ablation time between the two catheters remained significant in the meta-analysis of the studies with unspecified AF patients (WMD: -8.6 minutes, 95% CI: -16.9 to -0.4 minutes, p=0.039) but was not for the studies with paroxysmal AF patients (WMD: -1.1 minutes, 95% CI: -4.8 to 2.6 minutes, p=0.555). However, heterogeneity in the subgroup meta-analysis of the studies with unspecified AF patients was still significant (I^2=98%, p<0.01) and brought our attention to further explore the potential heterogeneity sources in these studies. By reviewing the reported patient baseline characteristics from these included studies, we found 4 studies [10-12, 16] with obviously different patient characteristics (AF duration, left atrial diameter/volume, the proportion of paroxysmal AF, proportion of patients with myopathy, Ablation Index value, baseline CHA_2DS_2 VASc score, saline flow rate) from the other studies. After excluding these four studies from the subgroup meta-analysis, the pooled difference in ablation time still favored the STSF catheter with statistical significance (WMD: -22.5 minutes, 95% CI: -24.3 to -20.6 minutes, p<0.001) and low-level of heterogeneity (I^2=0%, p=0.69), suggesting that these characteristics are potential heterogeneity sources.

The overall pooled difference in ablation time between the two catheters from the leave-one-out sensitivity analysis ranged from -7.5 minutes to -5.1 minutes. No significant publication bias was detected from the included 12 studies comparing the two catheters for ablation time during RFCA (Egger's test: p=0.450). The pooled difference in the ablation time between the STSF catheter and the ST catheter is illustrated in Figure 3. The other reported outcomes are listed in Supplementary Figure 3 and Supplementary Figure 4~~Supplementary Files~~.

3.3.3 Procedural characteristics - Irrigation fluid volume

Six included studies [10-12, 23-25] with 1229 AF patients (629 operated with STSF and 600 with ST) reported catheter irrigation fluid volume during RFCA. The meta-analysis of the reported irrigation fluid volume associated with the two catheters from the 6 studies indicated a significantly lower irrigation volume for using STSF to conduct RFCA (WMD: -492.7 mL, 95% CI -646.1 to -339.3 mL, p<0.001). However, this pooled outcome was associated with significant heterogeneity (I^2=94%, p<0.01). These six included studies were stratified by patient AF type (paroxysmal AF vs. unspecified AF) to conduct a meta-analysis for the control of potential heterogeneity associated with AF types. The pairwise meta-analysis of the three studies with paroxysmal AF patients [23-25] confirmed the significant reduction of catheter irrigation fluid volume (WMD: -538.6 mL, 95% CI: -621.2 to -456.1 mL, p<0.001) with moderate but non-significant heterogeneity (I^2=38%, p=0.20) for RFCA conducted by STSF catheter. However, significant heterogeneity (I^2=94%, p<0.01) was found for the pooled difference in catheter irrigation fluid volume (WMD: -461.4 mL, 95% CI: -739.2 to -183.6 mL, p=0.001) between the two catheters from the left three studies with unspecified AF patients [10-12]. No further exploration of heterogeneity resources for this pooled outcome due to a limited number of studies reporting this outcome measure. The overall pooled difference in catheter irrigation fluid volume between the two catheters from the leave-one-out sensitivity analysis ranged from -532.1 mL to -427.3 mL.

The pooled difference in the catheter irrigation fluid volume between the STSF catheter and the ST catheter is

illustrated in Figure 4. The other reported outcomes are listed in Supplementary Figure 5~~iles~~.

3.3.4 Procedural characteristics - Fluoroscopy time

Eight included studies [10-13, 23, 25-27] compared fluoroscopy time between STSF catheter and ST catheter used to conduct RFCA (four studies [10-13] with unspecified AF patients and four studies [23, 25-27] with paroxysmal AF). The overall pooled difference in fluoroscopy time during RFCA between the two catheters showed that the STSF catheter was associated with significantly shorter fluoroscopy time than the ST catheter (WMD: -1.6 minutes, 95% CI: -2.8 to -0.3 minutes, p=0.014); however, this pooled outcome was associated with significant heterogeneity (I^2=77%, p<0.014). The included studies were further stratified by the patient AF types (paroxysmal AF vs. unspecified AF) to conduct subgroup meta-analysis to explore potential heterogeneity associated with AF types. The subgroup meta-analysis including studies with paroxysmal AF patients confirmed the significantly shorter fluoroscopy time during RFCA conducted by STSF catheter (WMD: -1.4 minutes, 95% CI: -2.2 to -0.6 minutes, p<0.001) with a low level of heterogeneity (I^2=8%, p=0.35) [23, 25-27]. However, the pooled difference in fluoroscopy time between the two catheters from the subgroup meta-analysis of 5 eligible results from the four studies with unspecified AF patients [10-13] didn't reach statistical significance and also had substantial heterogeneity. No further exploration of heterogeneity sources for this subgroup meta-analysis due to a limited number of included studies reporting this outcome. The overall pooled difference in fluoroscopy time between the two catheters from all included studies in the leave-one-out sensitivity analysis ranged from -1.9 minutes to -1.4 minutes.

The results of the meta-analysis of the included 8 studies reporting fluoroscopy time associated with STSF catheter and ST catheter are illustrated in Figure 5. The other reported outcomes are listed in Supplementary Figure 6~~les~~.

3.3.5 Primary clinical outcomes

Thirteen studies [10-17, 22-24, 26, 28] reported primary clinical outcomes, including the acute procedural success of PVI, one-year post-ablation cardiac arrhythmia recurrence, and overall complications related to RFCA. The overall pooled RR for acute procedure success [10, 12, 14-17, 26, 28], one-year post-ablation cardiac arrhythmia recurrence [10, 13, 17, 22, 28], and overall complications [11, 14, 16, 17, 23, 24, 26, 28] from these studies were 0.995 (95% CI: 0.976 to 1.014, p=0.592), 0.727 (95% CI: 0.355 to 1.490, p=0.384), and 0.766 (95% CI: 0.299 to 1.959, p=0.578), respectively, without reaching statistical significance. Among these three pooled outcomes, only the pooled RR for one-year post-ablation arrhythmia recurrence between the two catheters was associated with significant heterogeneity (I^2 = 68%, p<0.01). Subgroup meta-analysis including stratified studies by patient AF types (paroxysmal AF vs. unspecified AF) was unable to homogenize the pooled RR for one-year post-ablation cardiac arrhythmia recurrence between the two catheters. The leave-one-out sensitivity analyses for the three pooled outcomes observed a narrow range for pooled RR for the acute procedural success of PVI (0.993 to 0.999) but wide ranges for one-year post-ablation cardiac arrhythmia recurrence (0.555 to 0.929) and overall complications (0.600 to 0.927). All reported outcomes are illustrated in Supplementary Figure 7-10.

3.3.6 Other ablation-related clinical outcomes

Three included studies reported other ablation-related clinical outcomes. Two studies [23, 24] (502 paroxysmal AF patients) reported significantly lower utilizations of the foley catheter [RR: 0.506, 95% CI 0.393 to 0.651, $p<0.001$] without heterogeneity ($I^2=0\%$, p=0.68). One study [25] with 47 paroxysmal AF patients reported STSF catheter was associated with a significantly lower risk of diuretics use (RR: 0.050, 95% CI: 0.003 to 0.819, $p=0.036$). In addition, one study [27] with 68 paroxysmal AF patients reported that STSF catheter was associated with a reduced risk of eschar formation during ablation without reaching statistical significance (RR: 0.143, 95% CI 0.008 to 2.663, $p=0.192$). The pooled outcomes are illustrated in Supplementary Figure 11~~iles~~.

3.4 Synthesized evidence from the studies comparing the STSF catheter with the SF catheter

This SLR identified 4 studies [29-32] comparing STSF with SF for procedural characteristics and clinical outcomes in AF patients. One study [29] with a small sample size (26 using STSF catheter and 26 using SF catheter) reported significantly longer RFCA procedure time (mean difference: 20.0 minutes, 95% CI: 2.9 to 37.1 minutes, $p=0.022$) and fluoroscopy time (mean difference: 4.0 minutes, 95% CI: 1.1 to 6.9 minutes, $p=0.007$) in the STSF group. The meta-analysis including 2 studies [29, 30] with 252 patients did not identify significant differences in both acute procedure success of PVI and ablation-related complications between the two catheters. One study [31] with 395 patients with paroxysmal AF (298 using STSF and 97 using SF) reported significantly shorter ablation time (mean difference: -5.7 minutes, 95% CI: -8.4 to -3.1 minutes, $p<0.001$). The pooled RR for one-year post-ablation arrhythmia recurrence between the two catheters from the two studies [31, 32] favored the STSF catheter with statistical significance (RR: 0.503, 95% CI: 0.379 to 0.667, $p<0.001$, heterogeneity test: $I^2=0\%$, $p=0.98$) when compared to SF catheter. The reported RFCA-related outcomes from the four studies are summarized in Table 1. The pooled outcomes are illustrated in Supplementary Figure 12-15.

Table 1. Summary of the pooled differences in RFCA-related outcomes between STSF catheter and SF catheter in AF patients.

AF type	Outcome type	Outcome	Number of studies	Sample size	Outcome measure	Pooled outcomes			
						Point estimation	95%CI lower	95%CI upper	P value
Unspecified AF	Procedural characteristics	Procedure time (minutes) [29]	1	STSF: 26; SF: 26	WMD	20.0	2.9	37.1	***0.022***
		Fluoroscopy time (minutes) [29]	1	STSF: 26; SF: 26	WMD	4.0	1.1	6.9	***0.007***
	Clinical outcomes	Acute procedural success of PVI (%) [29]	1	STSF: 26; SF: 26	RR	1.000	0.928	1.078	1.000
		Any complications [29, 30]	2	STSF: 126; SF: 126	RR	0.745	0.052	10.574	0.828
Paroxysmal AF	Procedural characteristics	Ablation time (minutes) [31]	1	STSF: 298; SF: 97	WMD	-8.7	-8.4	-3.1	***<0.001***
		Radiofrequency energy use (J) [31]	1	STSF: 298; SF: 97	WMD	-3,432.5	-9,629.5	-1,235.5	***0.011***
	Clinical outcomes	Acute procedural success of PVI (%) [31]	1	STSF: 298; SF: 97	RR	1.000	0.985	1.015	1.000
		One-year post-ablation arrhythmia recurrence rate (%) [31]	1	STSF: 298; SF: 97	RR	0.504	0.368	0.689	***<0.001***
Persistent AF	Clinical outcomes	One-year post-ablation arrhythmia recurrence rate (%) [32]	1	STSF: 74; SF: 74	RR	0.500	0.262	0.956	***0.036***
		Any complications [32]	1	STSF: 74; SF: 74	RR	2.000	0.378	10.587	0.415

STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; WMD: Weighted mean difference; RR: Rate ratio; CI: Confidence interval.

3.5 Reported outcomes between STSF catheter and non-ST/SF catheter

This SLR identified 4 studies comparing STSF with four non-ST/SF catheters which were the CELSIUS® catheter [33], DiamondTemp™ catheter [34], DirectSense catheter guided by Rhythmia™ System [35], and NAVISTAR® catheter [36]. The 4 studies reported that the STSF catheter was associated with significantly shorter RFCA procedure time than the DiamondTemp™ catheter(mean difference: -20.6 minutes, 95% CI: -32.5 to -8.7 minutes, p<0.001) and NAVISTAR® catheter (mean difference: -30.0, 95% CI: -39.9 to -20.1 minutes, p<0.001); significantly shorter ablation time than NAVISTAR® catheter (mean difference: -15.0 minutes, 95% CI: -20.5 to -9.5 minutes, p<0.001); and significantly shorter fluoroscopy time than DirectSense catheter guided by Rhythmia™ System (mean difference: -7.0 minutes, 95% CI: -10.9 to -3.1 minutes, p<0.001) and NAVISTAR® catheter (mean difference: -2.0 minutes, 95% CI: -2.8 to -1.2 minutes, p<0.001). However, one study with 116 patients with persistent or paroxysmal AF [34] reported that the STSF catheter was associated with a significantly longer ablation time than the DiamondTemp™ catheter (mean difference: 4.1 minutes, 95% CI: 2.0 to 6.2 minutes, p<0.001). None of these 4 studies reported any significant differences in the rates of ablation-related overall complications between the STSF catheter and the four non-ST/SF catheters.

4. Discussion

Compared to a similar SLR published in 2020 [5], our SLR was designed with an expansive search period and search scope which has resulted in the inclusion of a larger pool of studies and much more robust evidence to demonstrate the values of STSF catheter for RFCA in AF patients. For example, our SLR captured and studied significantly more studies than the aforementioned SLR (27 studies vs. 4 studies). Additionally, not only did our SLR include studies comparing STSF with ST but also with SF and other ablation catheters in AF patients; in contrast, the other SLR only included studies comparing STSF with ST. Furthermore, our SLR synthesized evidence for more outcomes than the previous SLR and conducted additional heterogeneity analysis and publication bias assessment to make the pooled findings more robust. Therefore, our SLR should be more informative regarding the clinical values of STSF for RFCA in AF patients.

According to the studies reviewed in this SLR, the STSF catheter was mainly studied in comparison with the ST catheter in AF patients. As the STSF catheter evolved from the ST catheter by upgrading the irrigation system to improve procedural characteristics, the STSF catheter contains all the features of the ST catheter such as the contact force technology and advanced irrigation system that provides uniform cooling at half the flow rate of ST catheter and facilitates the process of fluid management [4]. The pooled evidence for the outcomes that were compared between the two catheters in our SLR aligned with the expected impact of the advanced irrigation system of STSF. For example, the pooled evidence showed that the STSF catheter significantly save RFCA procedure time (17.4 minutes, p<0.001), ablation time (6.6 minutes, p=0.031), and fluoroscopy time (1.6 minutes, p=0.016) with significantly reduced catheter irrigation fluid volume (492.7 mL, p<0.001) relative to ST catheter. These benefits could potentially improve the performance efficiency of RFCA and enhance the capacity of conducting RFCA in hospital settings. The substantial reduction in the irrigation volume of STSF could substantially limit the cardiac burden due to catheter irrigation infusion and make ablation treatment safer to treat AF with heart failure. Even though the pooled outcome for reduced fluoroscopy time was statistically significant, the estimated reduction of fluoroscopy time by STSF in this review was unlikely to be substantial and this finding should be interpreted with caution. As a new technology, STSF could be often used with more fluoroscopy to confirm the position of catheter during the learning process. With more use of STSF in real-world settings, the benefits of STSF in reducing occupational health hazards during RFCA could be better demonstrated in future studies.

The pooled evidence also indicates that primary clinical outcomes, including acute procedure success of PVI,

one-year post-ablation arrhythmia recurrence, and overall complications, are comparable for the STSF catheter and ST catheter. A possible explanation is that both catheters use the same contact force technology, which is the primary driver of the ablation effects [37]. However, the advanced irrigation system of the STSF could bring more clinical benefits to AF patients with heart failure. According to the reported patient characteristics from the included studies, AF patients are characterized by old age (mean age range: 58.0-67.5 years old) and a high prevalence of heart failure (17.8% to 41.7%). The fluid infusion through the catheter during RFCA could stress the heart and deteriorate the cardiac function in patients with heart failure. Even though RFCA has been proven to improve cardiac function (indicated by LVEF [38]), previous studies observed a high rate of developing acute heart failure (4.9% to 26.1%) after open-irrigated catheter ablation [39-41]; the development of acute heart failure after ablation in these studies was likely due to excessive infusion fluid during ablation procedure as patients with developed acute heart failure after ablation was associated with significantly higher net fluid infusion volume during ablation than those without developing acute heart failure. Thus, the substantial reduction of the catheter irrigation infusion volume of the STSF catheter could lower the burden of RFCA on the cardiac load and potentially reduce the risk of acute heart failure after RFCA [42]. In addition, the shortened ablation time through STSF could make RFCA more tolerable for AF patients with heart failure who are prone to developing respiratory distress with the flat position required by the ablation procedure [43]. Since AF patients are often complicated with heart failure due to old age and other cardiovascular conditions, future research should be encouraged to confirm the cardiac function-related benefits of STSF and generate robust evidence to inform clinical practices and guidelines regarding the appropriate applications of STSF catheter ablation for AF. Another potential clinical benefit of the improved irrigation system of STSF is the reduction of the risk of eschar due to the amplified cooling effects. Eschar occurs more often with unipolar radiofrequency ablation that generates excessive local temperature leading to the formation of eschar on the tissue surface; carbonization; and thromboembolic complications; and even damage to the esophagus and atrium, which induces serious complications such as atrial esophageal fistula, atrial rupture, and pulmonary vein stenosis [44]. Because the STSF catheter has a more advanced irrigation system than the ST catheter, it is expected that the STSF catheter could be associated with a lower risk of eschar formation than the ST catheter. However, this SLT didn't identify robust evidence to support this clinical benefit of STSF as only one study with a small sample size reported a non-significant trend for the reduced risk of eschar for STSF catheter [27].

This SLR also identified 4 eligible studies comparing the STSF catheter with SF catheter and other 4 studies comparing the STSF catheter with non-ST/SF catheters. The pooled evidence from two eligible studies identified significantly reduced one-year post-ablation arrhythmia recurrence for STSF catheter relative to SF catheter. Because these SF catheters were equipped with a similar irrigation technology as the STSF catheter but without contact force technology, which mainly drives the ablation outcomes [37]. The reported outcomes from the four studies comparing the STSF catheter with contemporary non-ST/SF catheters suggested that the STSF catheter could be better than the non-ST/SF catheter regarding the procedure characteristics, which included procedural time, ablation time, and fluoroscopy time. However, these findings are not robust due to a limited number of studies (only one study comparing STSF with each non-ST/SF catheter) and the small sample size in each included study.

The generated evidence from this SLR should be interpreted with caution as most of the included studies were observational studies (26 observational studies and one randomized clinical trial) and the reported outcomes from the included studies were not pooled separately by study design. Thus, the pooled evidence in our review is likely to have the common limitations of observational studies that include bias, measurement bias, and unknown confounders. These limitations could introduce heterogeneity in the pooled evidence in our review. Additionally, the included studies with small sample size could further introduce heterogeneity. That might explain why most of the overall pooled outcomes in this SLR had significant heterogeneity. This SLR did recognize that AF type could an important heterogeneity source as the persistent AF usually requires additional substrate ablation beyond PVI than paroxysmal AF. Thus, this SLR stratified the included studies by patient AF types to control heterogeneity in the pooled outcomes. This strategy seems to work well in reducing heterogeneity in the pooled outcomes from the studies only including paroxysmal AF patients. Due to insufficient studies, this SLR only tried to explore

heterogeneity resources for procedure time and ablation time by further excluding studies with obviously different patient characteristics rather than conducting meta-regression analyses. The lack of definitions for some outcome measures in the included studies could introduce measurement bias and further increase the heterogeneity in the pooled evidence. In addition, this SLR doesn't have enough studies to explore the heterogeneity sources in other pooled outcomes. For the same reason, this SLR only assessed the publication bias for RFCA procedure time and ablation time. Given the fact that most of the included studies compared the STSF catheter with the ST catheter, the pooled evidence regarding the comparisons between STSF with non-ST catheters was not robust enough. Thus, this SLR didn't grade the pooled evidence because of the limitations discussed above. Future research with adequate quality is still needed to confirm the generated evidence from this SLR and further explore the potential clinical benefits of using the STSF catheter to conduct RFCA for AF (such as preventing eschar and acute heart failure).

In summary, this SLR demonstrated that STSF is superior to ST catheter by reducing procedure time, ablation time, fluoroscopy time, and irrigation fluid volume. Because both catheters use contact force technology which is a key factor in determining ablation outcomes, it is not a surprise to see highly comparable acute procedure success of PVI and one-year post-ablation arrhythmia recurrence between STSF catheter and ST catheter from the pooled evidence. Due to the lack of sufficient and robust evidence to support other clinical benefits of the STSF catheter relative to other catheters, such as preventing eschar and acute heart failure, more future studies with appropriate study designs and sufficient sample size are needed in this field.

5. Figures

Figure 1. Literature search flowchart for identifying eligible studies (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; AF: Atrial fibrillation).

Figure 2. Forest plot for the paired meta-analysis of the included studies for the difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 3. Forest plot for the paired meta-analysis of the included studies for the difference in ablation time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 4. Forest plot for the paired meta-analysis of the included studies for the difference in catheter irrigation fluid volume (mL) between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

Figure 5. Forest plot for the paired meta-analysis of the included studies for the difference in fluoroscopy time between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval)

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Patients and or the public were not involved in this study.

Conflict of Interest

Liang Tan and Wendong Chen are employed by contract research organizations that receive industry funds to conduct health economics and outcomes research. Other 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.

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Availability of Data and Materials

Data sharing is not applicable to this article, as no datasets were generated or analyzed during the current study.

Contributions Statement

Jianyong Li, Guifang Zhou, Yuegang Wang, and Xiaobo Huang formulated the research idea. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Yuegang Wang, Xiaobo Huang, Liang Tan, and Wendong Chen developed the study protocol. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Hairuo Lin, Shaopeng Lin, and Liang Tan conducted the literature search, study quality assessment, data extraction, and evidence synthesis. Jianyong Li, Guifang Zhou, Xinzhong Li, Senlin Huang, Xiaobo Huang, Yuegang Wang, and Wendong Chen drafted the manuscript based on the study findings. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

Not applicable.

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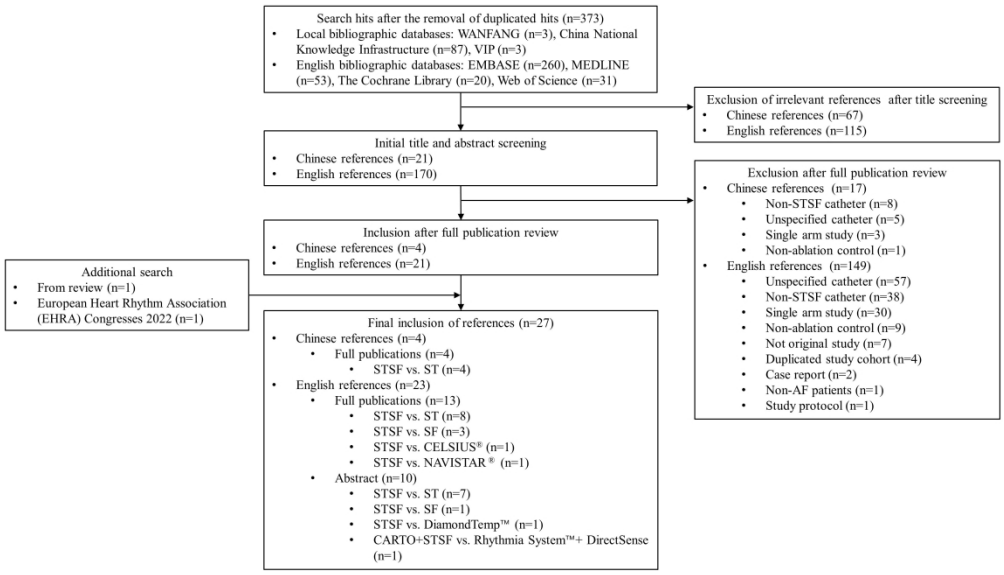

Figure 1. Literature search flowchart for identifying eligible studies (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; AF: Atrial fibrillation).

327x185mm (300 x 300 DPI)

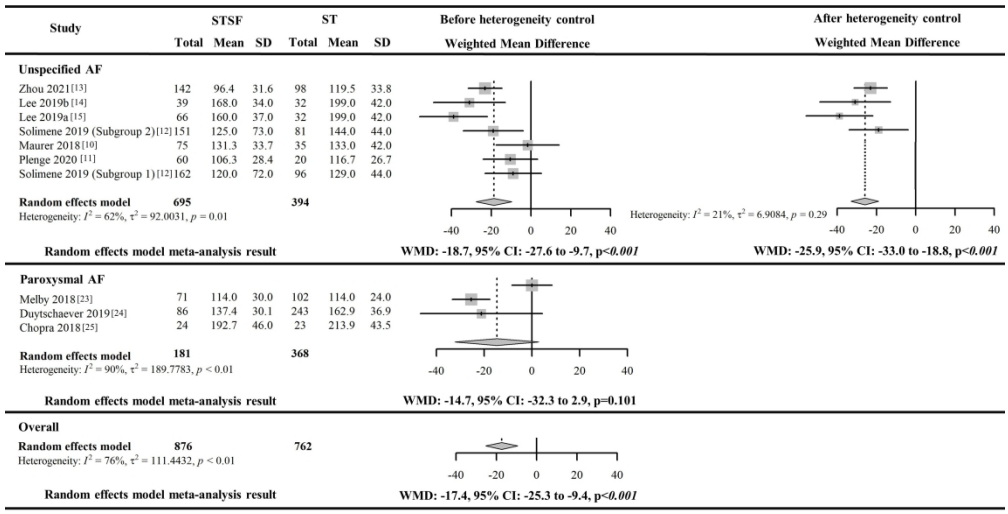

Figure 2. Forest plot for the paired meta-analysis of the included studies for the difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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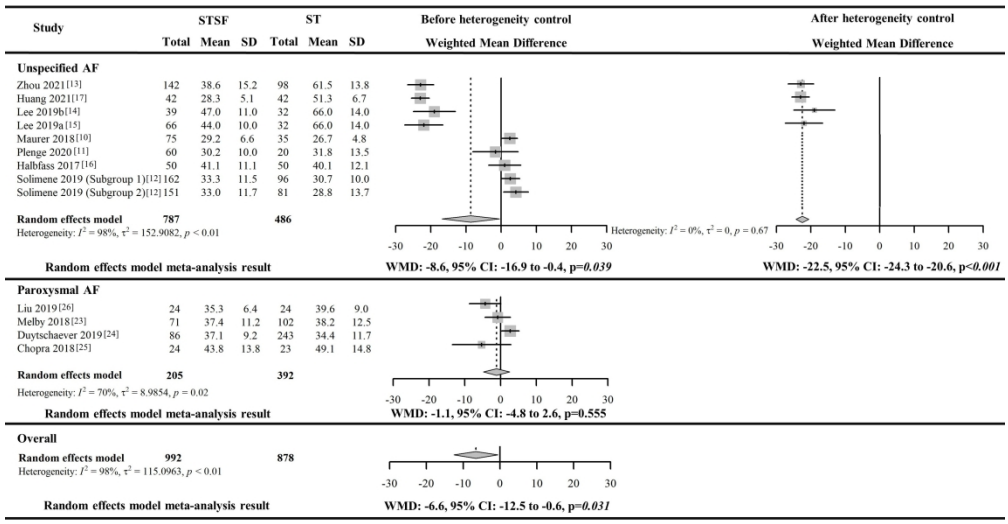

Figure 3. Forest plot for the paired meta-analysis of the included studies for the difference in ablation time (minutes) between STSF catheter and ST catheter (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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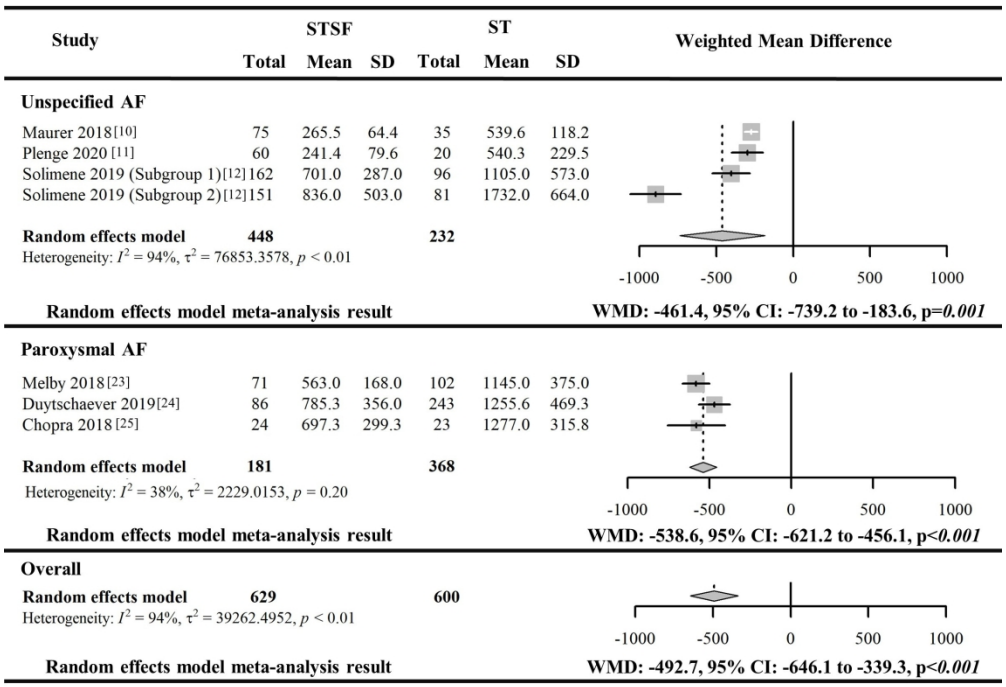

Figure 4. Forest plot for the paired meta-analysis of the included studies for the difference in catheter irrigation fluid volume (mL) between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval).

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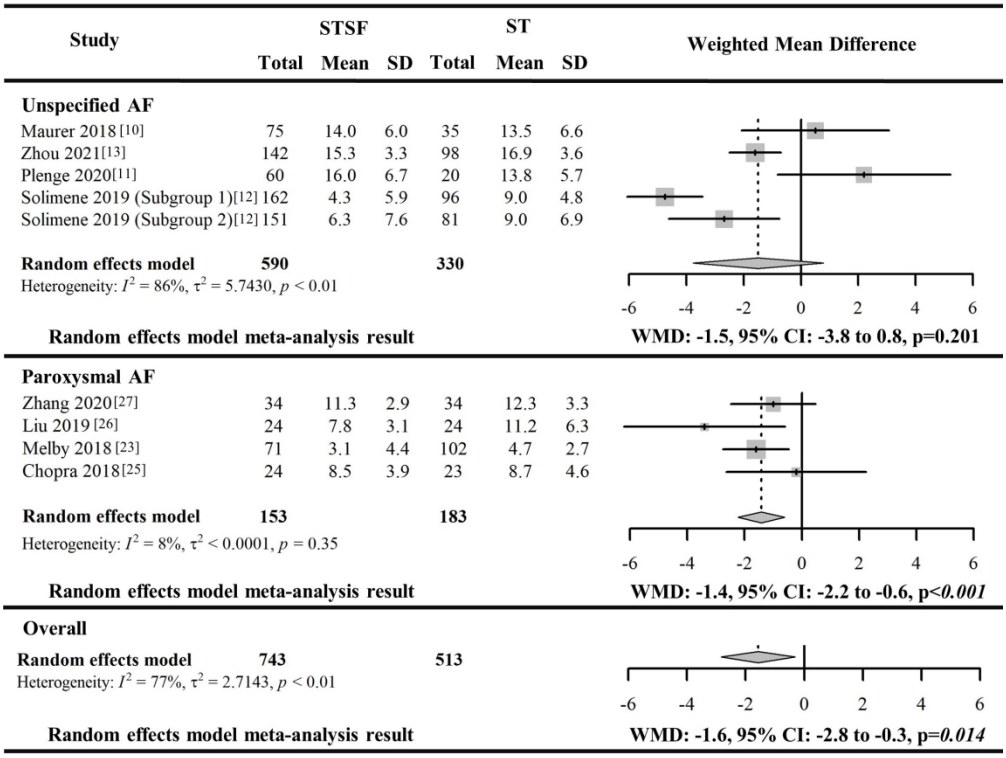
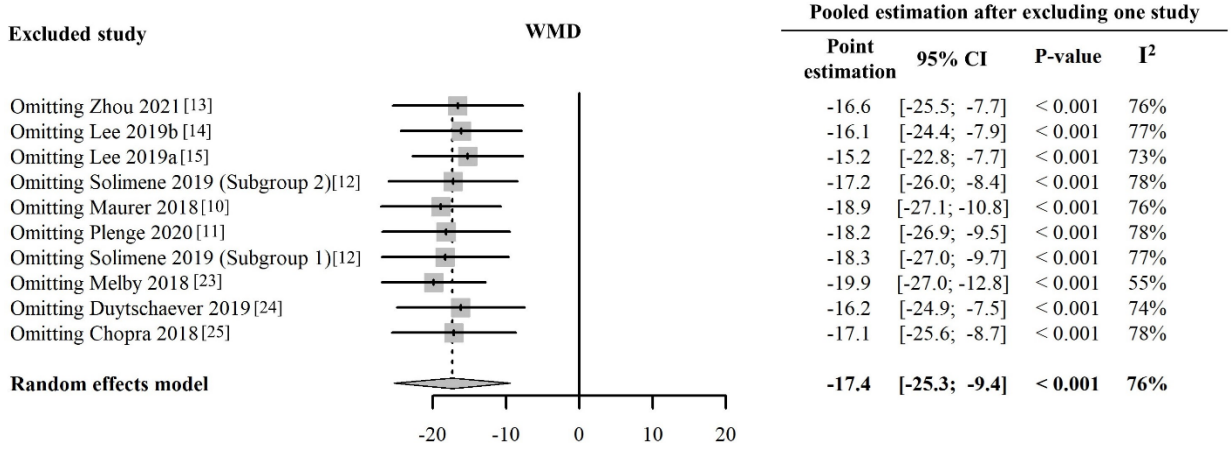


Figure 5. Forest plot for the paired meta-analysis of the included studies for the difference in fluoroscopy time between STSF catheter and ST catheter for RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; SD: Standard deviation; WMD: Weighted mean difference; CI: Confidence interval)

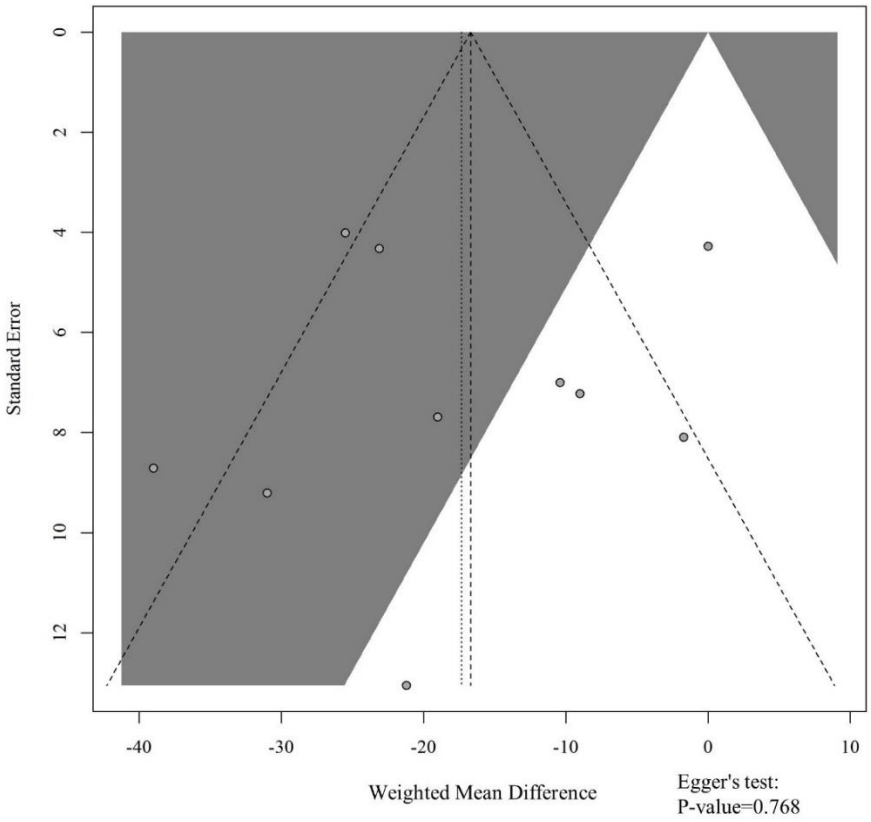
192x147mm (300 x 300 DPI)

Supplementary Figures

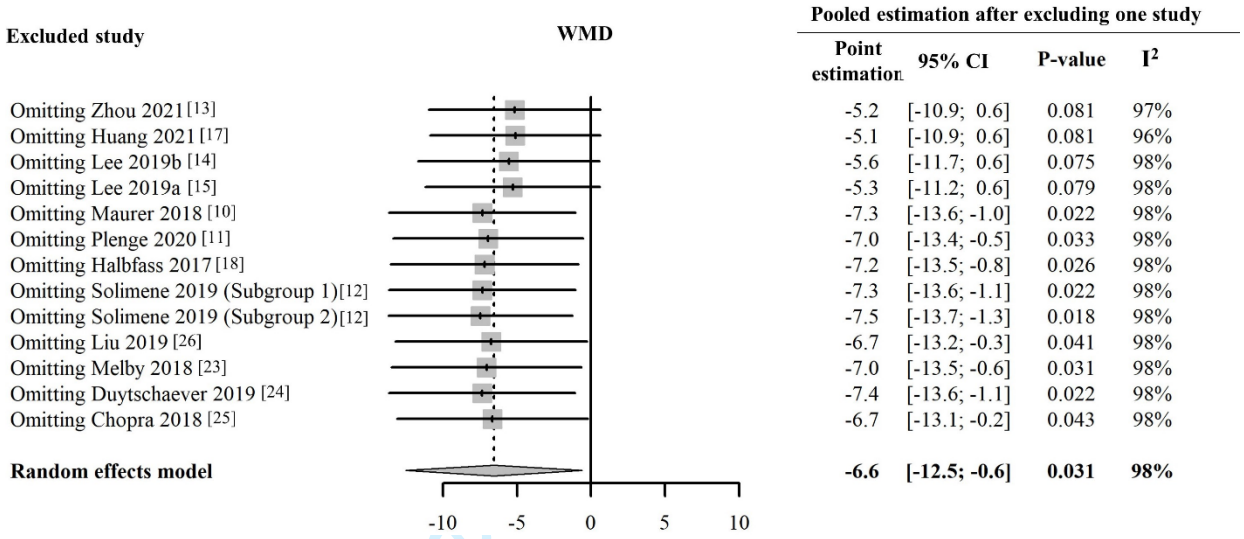
Supplementary Figure 1. Forest plot of the leave-one-out sensitivity analysis for pooled difference in RFCA procedure time (minutes) between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



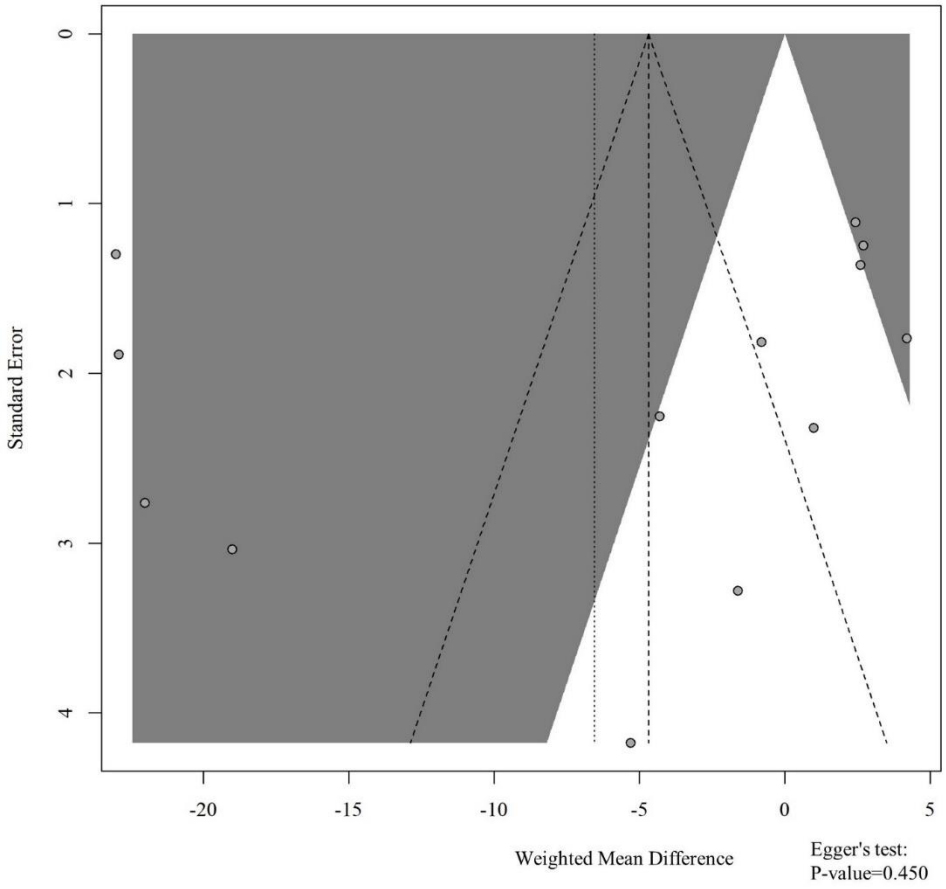
Supplementary Figure 2. Illustrated publication bias analysis for the included studies comparing STSF catheter with ST catheter for RFCA procedure time (minutes).



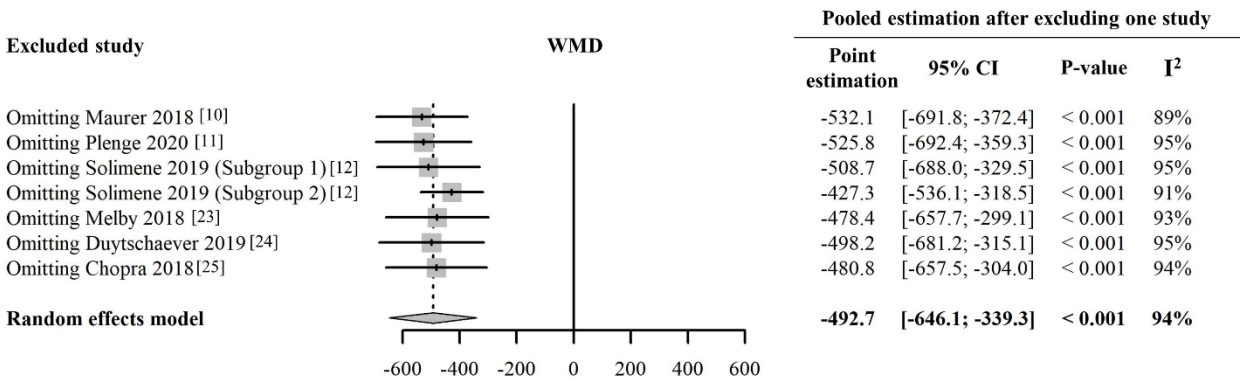
Supplementary Figure 3. Forest plot of the leave-one-out sensitivity analysis for pooled difference in ablation time (minutes) between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



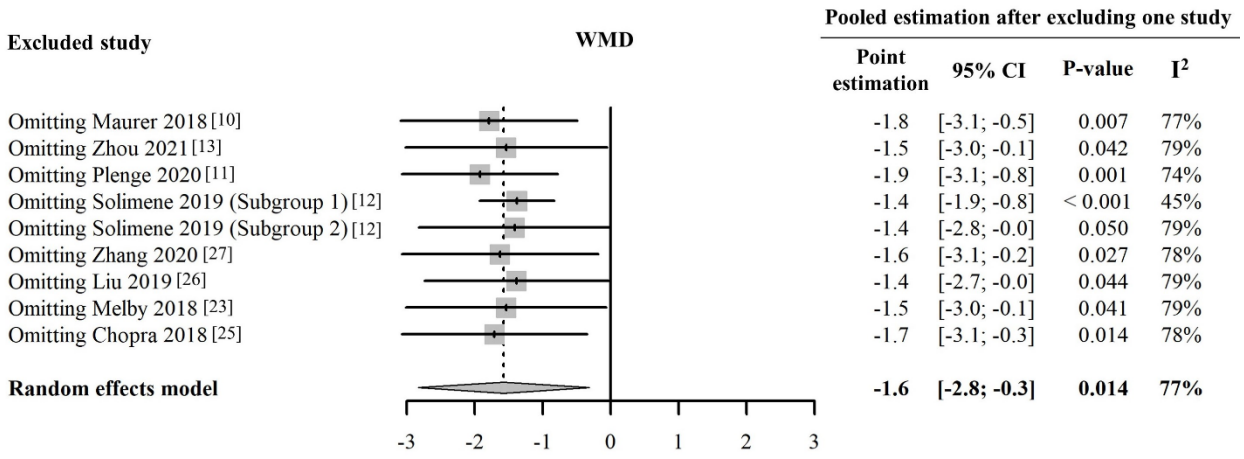
Supplementary Figure 4. Illustrated publication bias analysis for the included studies comparing STSF catheter with ST catheter for ablation time (minutes).



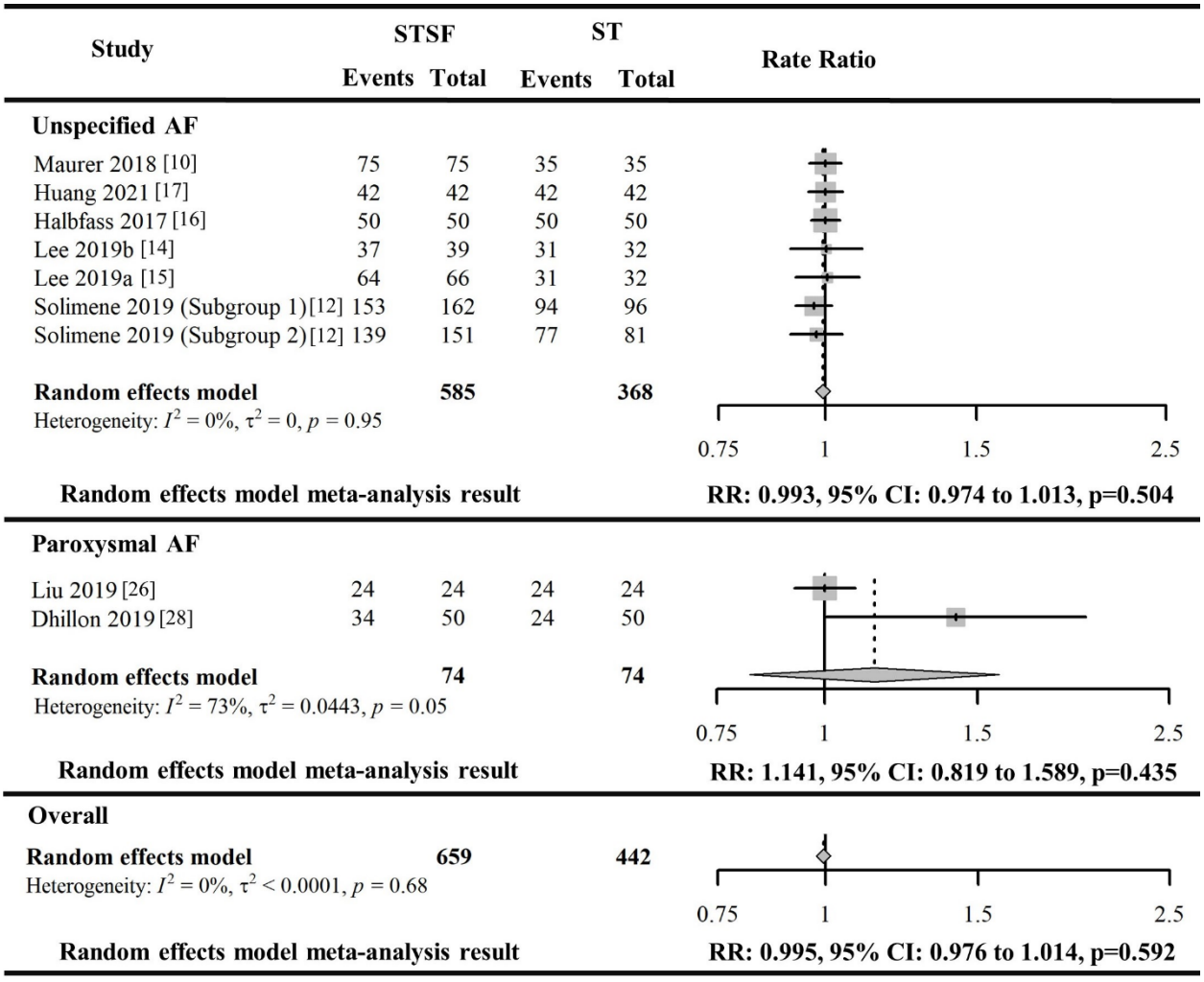
Supplementary Figure 5. Forest plot of the leave-one-out sensitivity analysis for pooled difference in irrigation fluid volume (mL) during RFCA between STSF catheter and ST catheter (WMD: Weighted mean difference; CI: Confidence interval).



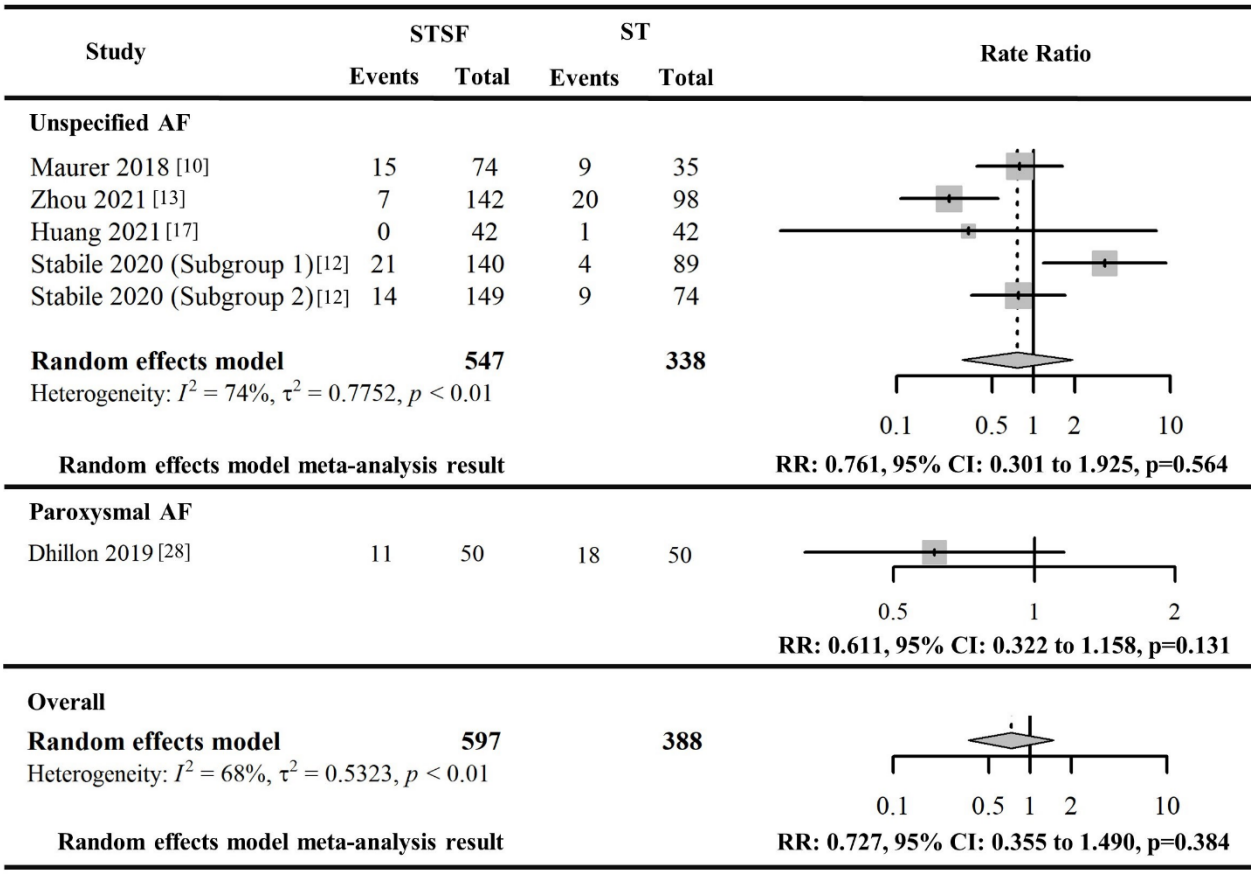
Supplementary Figure 6. Forest plot of the sensitivity analysis for pooled difference in fluoroscopy time (minutes) during RFCA between STSF and ST (WMD: Weighted mean difference; CI: Confidence interval).



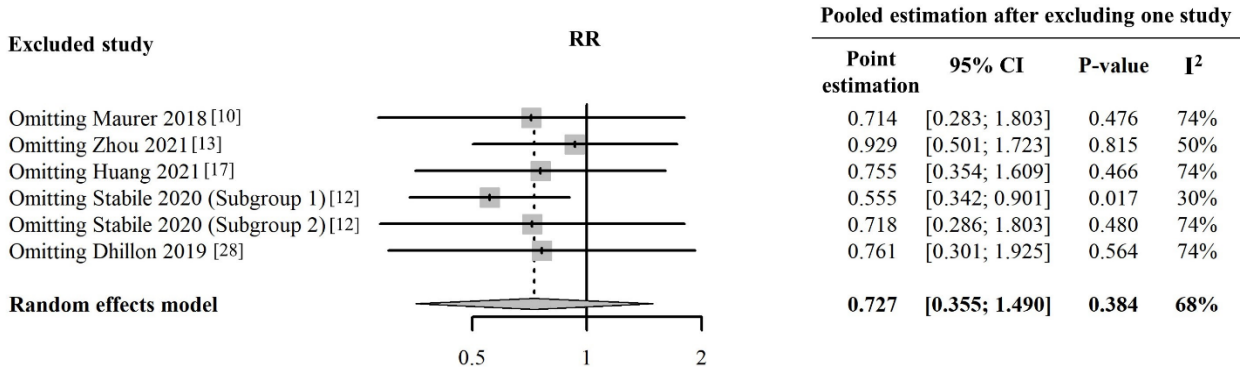
Supplementary Figure 7. Forest plot for the paired meta-analysis of the included studies comparing STSF vs. ST for acute procedural success of PVI (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



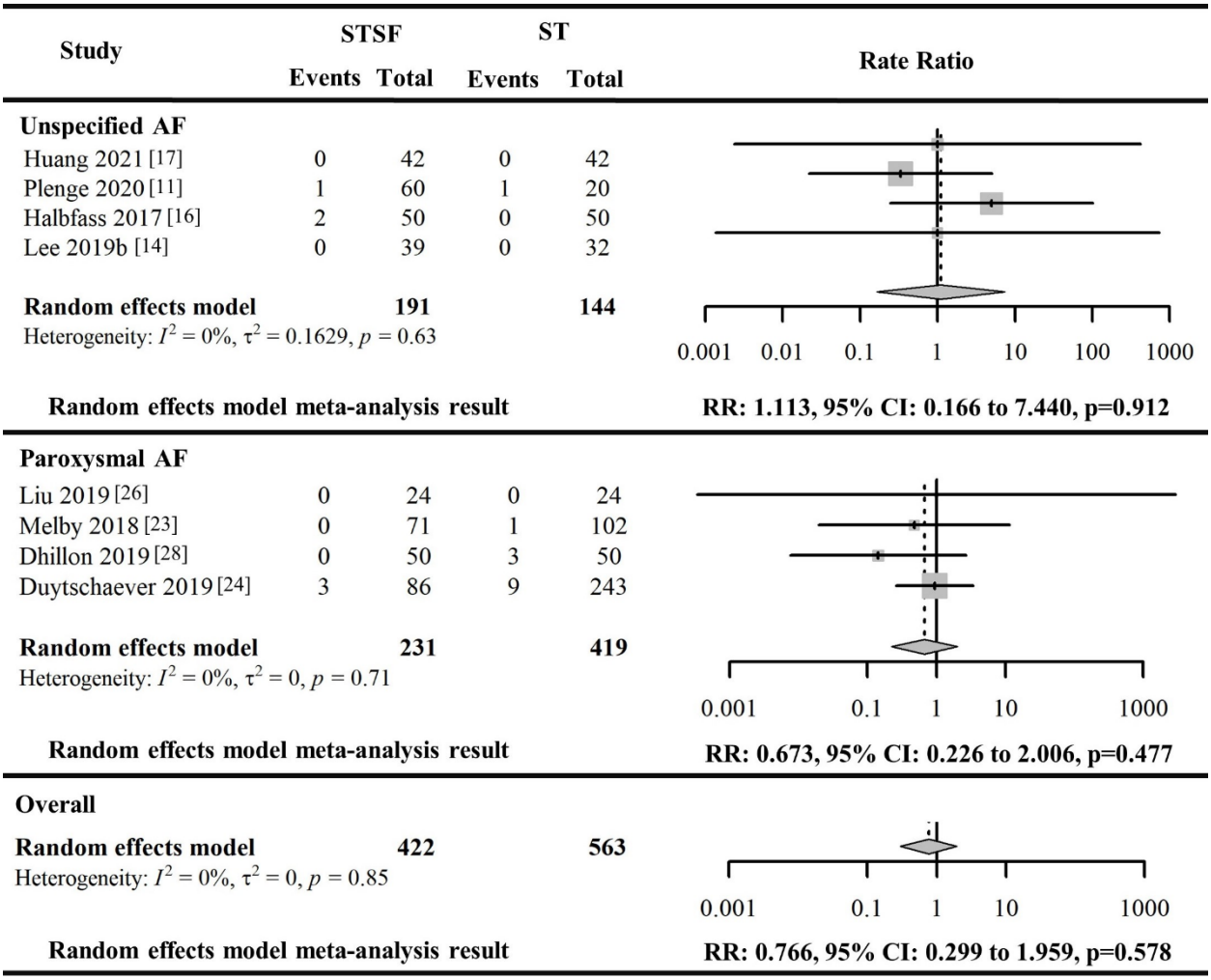
Supplementary Figure 8. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for one-year post-ablation cardiac arrhythmia recurrence (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



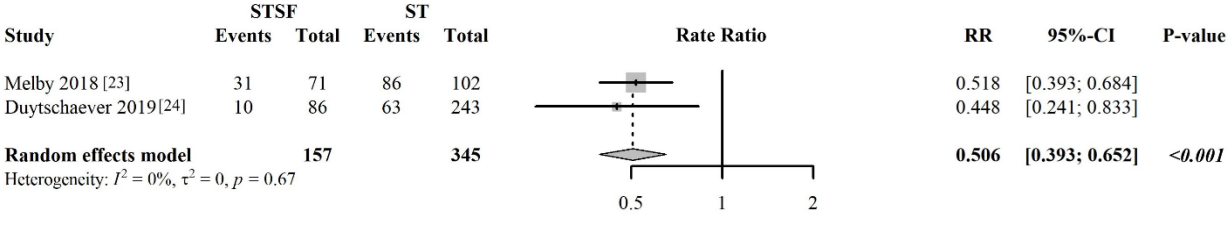
Supplementary Figure 9. Forest plot of the leave-one-out sensitivity analysis for pooled RR for one-year post-ablation cardiac arrhythmia recurrence between STSF catheter and ST catheter (RR: Rate ratio; CI: Confidence interval).



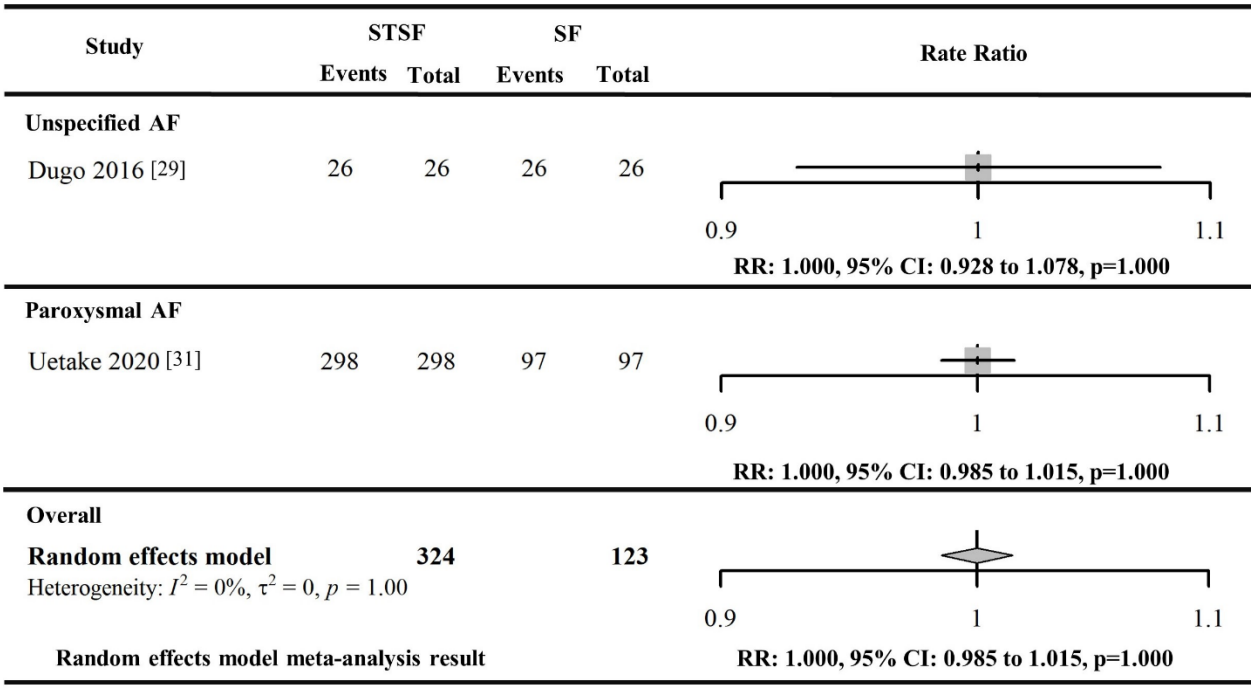
Supplementary Figure 10. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for the risk of overall complications related to RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



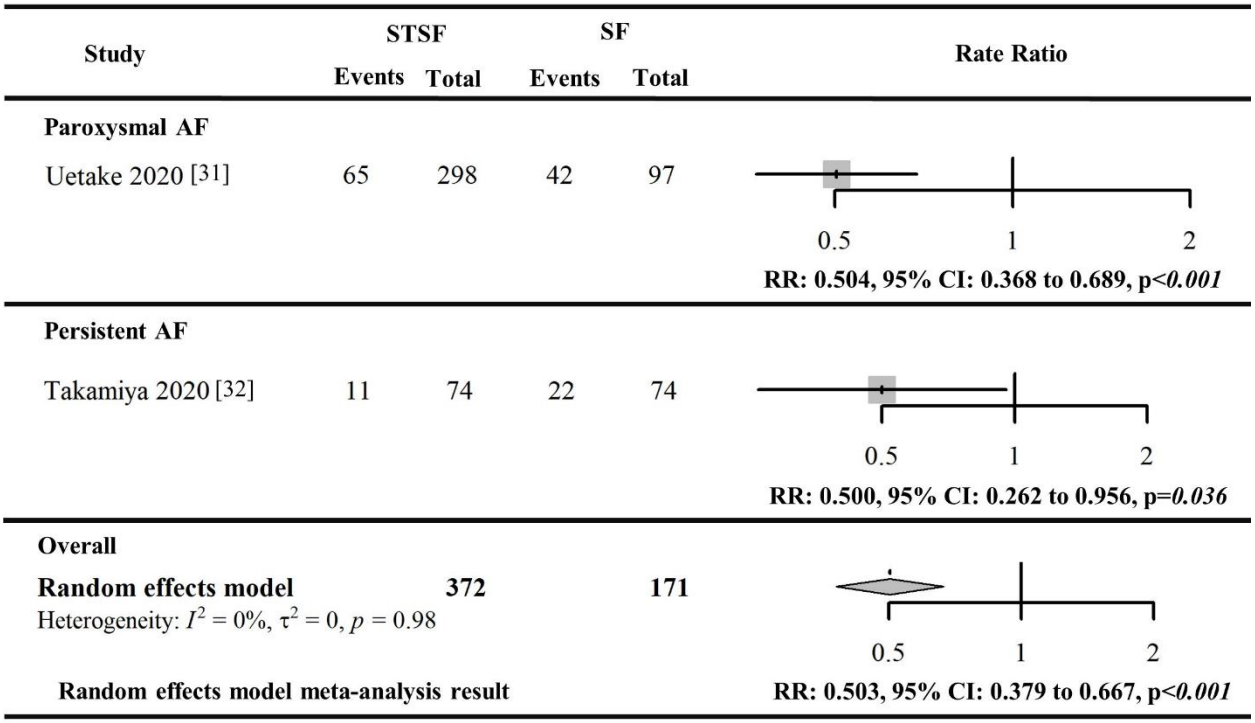
Supplementary Figure 11. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with ST catheter for foley catheter use (STSF: SMARTTOUCH® SURROUNDFLOW; ST: THERMOCOOL SMARTTOUCH®; RR: Rate ratio; CI: Confidence interval).



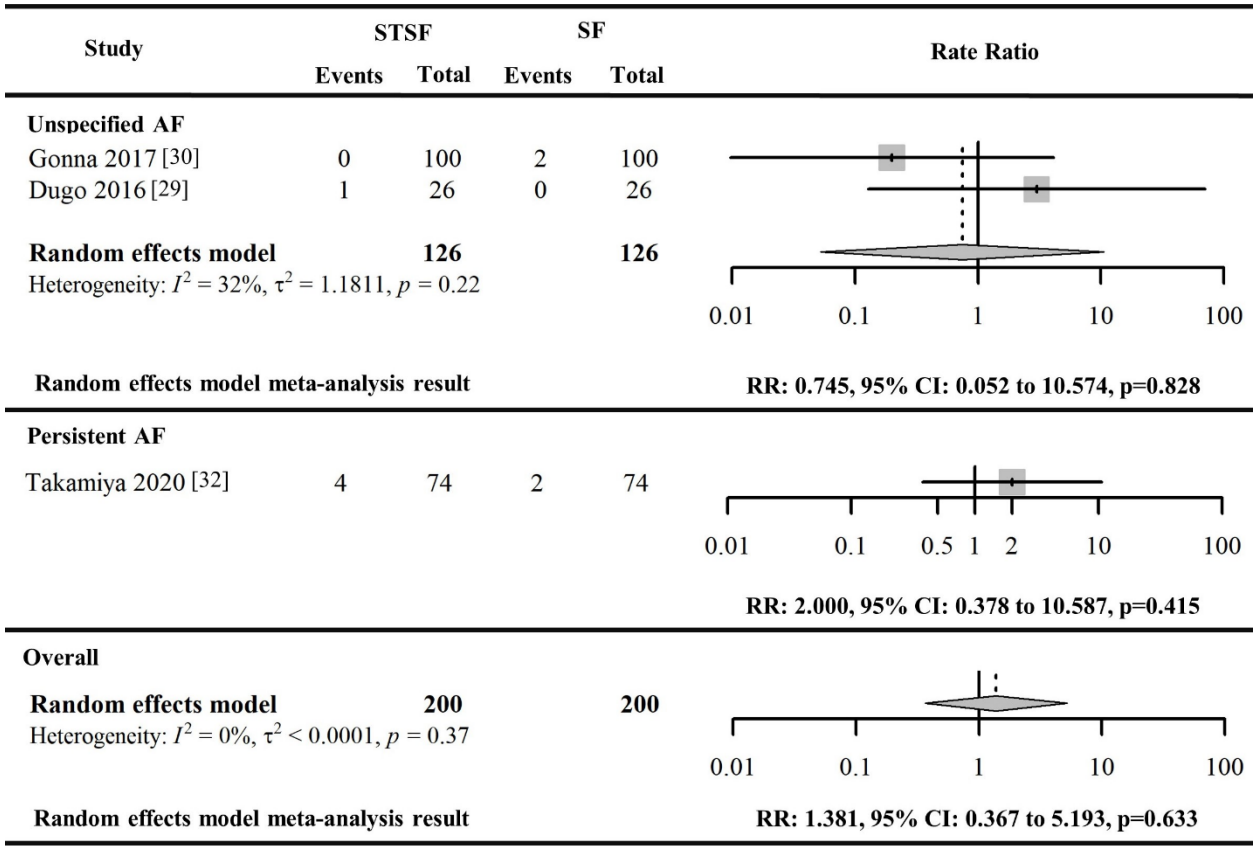
Supplementary Figure 12. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for acute procedure success of PVI (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



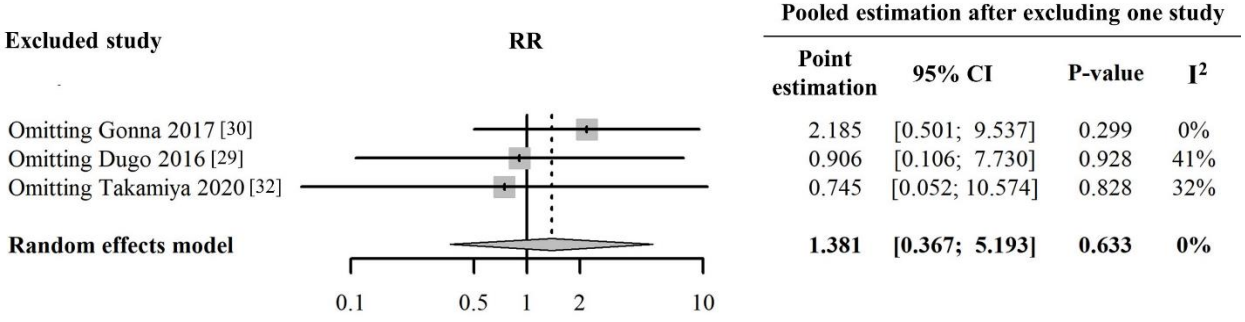
Supplementary Figure 13. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for one-year post-ablation arrhythmia recurrence (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



Supplementary Figure 14. Forest plot for the paired meta-analysis of the included studies comparing STSF catheter with SF catheter for the risk of overall complications related to RFCA (STSF: SMARTTOUCH® SURROUNDFLOW; SF: SURROUNDFLOW; AF: Atrial fibrillation; RR: Rate ratio; CI: Confidence interval).



Supplementary Figure 15. Forest plot of the leave-one-out sensitivity analysis for pooled RR for the risk of overall complications related to RFCA between STSF catheter and SF catheter (RR: Rate ratio; CI: Confidence interval).



Supplementary Table

Supplementary Table 1. Search strategies for all databases of systematic literature retrieval.

Embase retrieval via Ovid, run on July 31, 2022		
#	**Searches**	**Results**
1	exp atrial fibrillation/	100,822
2	atrial fibrillation.ti,ab,kw.	149,900
3	1 or 2	175,990
4	(Smart Touch or Smarttouch or ST).af.	2,039,661
5	(Surround Flow or Surroundflow or SF).af.	147,154
6	4 and 5	9,825
7	STSF.af.	81
8	6 or 7	9,875
9	3 and 8	336
10	limit 9 to yr="2016 -current"	263
11	limit 10 to english language	260
Medline retrieval via Ovid, run on July 31, 2022		
#	**Searches**	**Results**
1	exp atrial fibrillation/	65,749
2	atrial fibrillation.ti,ab,kw.	83,864
3	1 or 2	96,391
4	(Smart Touch or Smarttouch or ST).af.	1,566,840
5	(Surround Flow or Surroundflow or SF).af.	58,697
6	4 and 5	4,937
7	STSF.af.	29
8	6 or 7	4,953
9	3 and 8	75
10	limit 9 to yr="2016 -current"	53
11	limit 10 to english language	53

The Cochrane library retrieval via Ovid, run on July 31, 2022		
#	**Searches**	**Results**
1	exp atrial fibrillation/	5,190
2	atrial fibrillation.ti,ab,kw.	14,561
3	1 or 2	14,959
4	(Smart Touch or Smarttouch or ST).af.	66,732
5	(Surround Flow or Surroundflow or SF).af.	26,824
6	4 and 5	2,022
7	STSF.af.	9
8	6 or 7	2,027
9	3 and 8	38
10	limit 9 to yr="2016 -current"	21
11	limit 10 to english language	20
Web of Science Core Collection, run on July 31, 2022		
#	**Searches**	**Results**
1	TS=atrial fibrillation	109,124
2	TS=(Smart Touch or Smarttouch or ST)	179,345
3	TS=(Surround Flow or Surroundflow or SF)	102,686
4	#2 AND #3	973
5	TS=STSF	56
6	#4 OR #5	1,018
7	#1 AND #6	34
8	PY="2016-2022"	21,184,249
9	#7 AND #8	31
WANFANG, run on July 31, 2022		
#	**Searches**	**Results**
1	主题:("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤")	15,732
2	全部:("Smart Touch" or "Smarttouch" or "ST")	32,844

3	全部:("Surround Flow" or "Surroundflow" or "SF")	28,101
4	2 AND 3	125
5	全部:("STSF")	3
6	4 OR 5	127
7	1 AND 6	3
CNKI, run on July 31, 2022		
#	**Searches**	**Results**
1	TKA=('房颤' + '心房颤动' + '心房纤维颤动' + '心房纤颤')	13,497
2	FT=('Smart Touch' + 'Smarttouch' + 'ST')	426,266
3	FT=('Surround Flow' + 'Surroundflow' + 'SF')	155,221
4	2 AND 3	18,007
5	FT=('STSF')	71
6	4 OR 5	18,070
7	1 AND 6	87
VIP, run on July 31, 2022		
#	**Searches**	**Results**
1	M=("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤") OR R=("房颤" or "心房颤动" or "心房纤维颤动" or "心房纤颤")	13,437
2	U=("Smart Touch" or "Smarttouch" or "ST") OR R=("Smart Touch" or "Smarttouch" or "ST")	43,133
3	U=("Surround Flow" or "Surroundflow" or "SF") OR R=("Surround Flow" or "Surroundflow" or "SF")	52,374
4	2 AND 3	288
5	U=("STSF") OR R=("STSF")	4
6	4 OR 5	291
7	1 AND 6	3
US Clinical Trials Registry, run on July 31, 2022		

1	(atrial fibrillation) AND (STSF or Smart Touch Surround Flow)	7
EU Clinical Trials Registry, run on July 31, 2022		
1	STSF or Smart Touch Surround Flow	0
International Clinical Trials Registry Platform, run on July 31, 2022		
1	STSF or Smart Touch Surround Flow	7

Supplementary Table 2. Study characteristics and main extracted information from the included studies.

Reference ID	Region	Publication type	Publication language	Study design	Patient inclusion and exclusion criteria	Catheter comparison and sample size	Patient characteristics	Main outcomes
Halbfass 2017 [16]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Patients with symptomatic, drug-refractory paroxysmal or persistent atrial fibrillation (AF) who underwent left atrial radiofrequency (RF) catheter ablation and post-procedural esophagogastroduodenoscopy (EGD) Exclusion criteria: Unspecified.	STSF (n=50) vs. ST (n=50)	Demographics • Mean age: STSF vs. ST (64.0±10.7 vs. 63.3±9.5 years, p=0.39); • Male: STSF vs. ST (58% vs. 58%, p=1.00); • BMI: STSF vs. ST (29.0±4.9 vs. 29.7±6.1 kg/m^2, p=0.50); Clinical characteristics • Paroxysmal AF: STSF vs. ST (44% vs. 38%, p=0.66); • Left ventricular ejection fraction: STSF vs. ST (55.6±11.0 vs. 56.5±9.8%, p=0.69); • CHA_2DS_2 VASc score: STSF vs. ST (2.3±1.5 vs. 2.2±1.4, p=0.20); Comorbidities • Hypertension: STSF vs. ST (90% vs. 98%, p=0.20); • Coronary artery disease: STSF vs. ST (26% vs. 30%, p=0.82); • Diabetes: STSF vs. ST (14% vs. 20%, p=0.60); • Stroke/transient ischemic attack: STSF vs. ST (10% vs. 8%, p=1.00).	Procedural characteristics • Ablation time: STSF vs. ST (41.1±11.1 vs. 40.1±12.1 minutes, p=0.66); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%); • Any complications: STSF vs. ST (4% vs. 0%, p=0.49); • Cardiac tamponade: STSF vs. ST (2% vs. 0%); • Bleeding: STSF vs. ST (2% vs. 0%).
Horiuchi 2017 [18]	Japan	Abstract	English	Randomized controlled study	Inclusion criteria: Atrial fibrillation patients undergoing circumferential pulmonary vein isolation. Exclusion criteria: Unspecified.	STSF (n=20) vs. ST (n=20)	Pooled information of two groups Demographics • Mean age: 60±11 years; Clinical characteristics • Paroxysmal AF: 47.5%.	Procedural characteristics • Median radiofrequency time from superior to anterior sites: STSF vs. ST (9 vs. 22 seconds, p<0.01); • Median radiofrequency time at inferior and posterior sites: STSF vs. ST (9 vs. 8 seconds, p=NS); • There was no difference between the two groups in the

								mean contact force at each of 6 sites (anterior, anterosuperior, anteroinferior, inferior, posteroinferior, and posterosuperior site); • Total number of residual conduction gaps: STSF vs. ST (1.0±1.1 vs. 0.9±1.1, *p*=NS).
Ullah 2017 [19]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Patients undergoing their first catheter ablation procedure for atrial fibrillation (AF) Exclusion criteria: Unspecified.	STSF (n=10) vs. ST (n=30)	Demographics • Mean age: STSF vs. ST (65.8±5.3 vs. 61±8.2 yrs, *p*=0.65); • Male: STSF vs. ST (70% vs. 70%, *p*=1); Clinical characteristics: • Paroxysmal AF: STSF vs. ST (50 % vs. 50%, *p*=1); • Duration of persistent AF: STSF vs. ST (11±3 vs. 10±3 months, *p*=0.13); • Left atrial diameter: STSF vs. ST (4.1±0.8 vs. 4.4±0.5 cm, *p*=0.17); • CHA_2DS_2 VASc score: STSF vs. ST (1.5±0.8 vs. 1.4±1.0, *p*=0.61).	Procedural characteristics • Median catheter tip temperature at the start of energy delivery: STSF vs. ST (28 vs. 36 °C, *p*<0.005); • Median impedance at start of energy delivery: STSF vs. ST (154 vs. 181 Ω, *p*<0.005); • Median minimum catheter tip temperature during RF delivery: STSF vs. ST (25 vs. 35 °C, *p*<0.005); • Median time to reach minimum catheter tip temperature: STSF vs. ST (8.4 vs. 1.2 seconds, *p*<0.005); • Median maximum catheter tip temperature during RF delivery: STSF vs. ST (29 vs. 41 °C, *p*<0.005); • Median time to reach maximum catheter tip temperature: STSF vs. ST (0 vs. 14.9 seconds, *p*<0.005); • Median time to reach maximum ablation power: STSF vs. ST (0.6 vs. 8.1 seconds, *p*<0.005).
Chopra 2018 [25]	United States	Full text	English	Retrospective study	Inclusion criteria: Patients aged between 18 and 81 years who had undergone a radiofrequency ablation procedure for the indication of paroxysmal AF at OhioHealth Riverside	STSF (n=24) vs. ST (n=23)	Pooled information of two groups Clinical characteristics: • Left atrial diameter: 44.2±7.5 mm; • Left ventricular ejection fraction: 57.8%±7%; • CHADS VASc Score: 2.4±1.4.	Procedural characteristics • Procedure time: STSF vs. ST (192.7±46.6 vs. 213.9±43.5 minutes, *p*=0.11); • Ablation time: STSF vs. ST (43.8±13.8 vs. 49.1±14.8 minutes, *p*=0.18);

					Methodist Hospital, Columbus, Ohio, USA, from May 1, 2017, to June 1, 2018. Exclusion criteria: Unspecified.			• Fluoroscopy time: STSF vs. ST (511.8±231.8 vs. 523.6±277.4 seconds, p=0.39); • Total fluid: STSF vs. ST (2,288.8±725.8 vs. 3,105±803 mL, p<0.001); • Fluid via ablation catheter: STSF vs. ST (697.3±299.3 vs. 1277±315.8 mL, p<0.001); • Fluid from sources other than ablation catheter: STSF vs. ST (1591±583.6 vs. 1828±689 mL, p=0.21); • Post-RFA Furosemide use (0% vs. 39%; p=0.0006).
Maurer 2018 [10]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Patients with symptomatic, drug-refractory paroxysmal, or short-term persistent AF (< 3 months in duration). Exclusion criteria: 1. Prior pulmonary vein isolation or left atrial surgery; 2. A left atrial (LA) diameter > 60 mm; 3. Severe valvular heart disease or contraindications to post-interventional oral anticoagulation.	STSF (n=75) vs. ST (n=35)	Demographics • Mean age: STSF vs. ST (65.4±11.5 vs. 66.6±9.1 years); • Male: STSF vs. ST (66.7% vs. 68.6%); • BMI: STSF vs. ST (28.5±6 vs. 26.3±4.3 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (52% vs. 43%); • Left atrial diameter: STSF vs. ST (45.2±6.6 vs. 44.2±6 mm); • Median CHA_2DS_2 VASc Score: STSF vs. ST (2 vs. 2); • Median CHADS Score: STSF vs. ST (1 vs. 1); Comorbidities • Coronary artery disease: STSF vs. ST (29.3% vs. 22.8%); • Congestive heart failure: STSF vs. ST (17.3% vs. 3%); • Arterial hypertension: STSF vs. ST (61.3% vs. 71.4%); • Diabetes mellitus: STSF vs. ST (9.3% vs. 11.4%); • Stroke/transient ischaemic attack: STSF vs. ST (4% vs. 14.3%).	Procedural characteristics • Procedure time: STSF vs. ST (131.3±33.7 vs. 133.0±42 minutes, p=0.995); • Ablation time: STSF vs. ST (1751±394.0 vs. 1604.6±287.8 seconds, p=0.201); • Fluoroscopy time: STSF vs. ST (14±6 vs. 13.5±6.6 minutes, p=0.559); • Total fluid: STSF vs. ST (265.5±64.4 vs. 539.6±118.2 mL, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%); • 12-month arrhythmia recurrence rate: STSF vs. ST (20.3% vs. 25.7%); • Audible steam pop: STSF vs. ST (0% vs. 0%).

Melby 2018 [23]	Unspecified	Abstract	English	Retrospective study	Inclusion criteria: Paroxysmal AF patients undergoing first-time ablation, guided by CARTO VISITAG™ Module. Exclusion criteria: Unspecified.	STSF (n=71) vs. ST (n=102)	Demographics • Mean age: STSF vs. ST (60±10 vs. 61±9 years, p=0.79); Clinical characteristics • Left ventricular ejection fraction: STSF vs. ST (60.2±7.6 vs. 59.5±7.9%, p=0.5); • CHADS VASc score: STSF vs. ST (1.62±1.4 vs. 1.4±1.24, p=0.56); Comorbidities • Congestive heart failure: STSF vs. ST (0% vs. 4%).	Procedural characteristics • Procedure time: STSF vs. ST (1.9±0.5 vs. 1.9±0.4 hours, p=0.77); • Ablation time: STSF vs. ST (37.4±11.2 vs. 38.2±12.5 minutes, p=0.74); • Fluoroscopy time: STSF vs. ST (3.1±4.4 vs. 4.7±2.7 minutes, p<0.001); • Fluoroscopy dose: STSF vs. ST (12.4±16.7 vs. 27.3±18.6 mGy, p<0.001); • Total fluid: STSF vs. ST (1505±440 vs. 2353±605 mL, p<0.001); • Fluid via ablation catheter: STSF vs. ST (563±168 vs. 1145±375 mL, p<0.001); • Foley catheter usage (%): STSF vs. ST (43.7% vs. 84.3%, p<0.001); Clinical outcomes • Any complications: STSF vs. ST (0% vs. 1%); • Cerebrovascular accident: STSF vs. ST (0% vs. 1%).
Dhillon 2019 [28]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Consecutive patients with paroxysmal atrial fibrillation underwent pulmonary vein isolation guided by ablation index (AI) between January 2017 and October 2017. Exclusion criteria: Unspecified.	STSF (n=50) vs. ST (n=50)	Demographics • Mean age: STSF vs. ST (60.1±11.8 vs. 59.9±10.8 years, p=0.915); • Male: STSF vs. ST (70% vs. 48%, p=0.042); Clinical characteristics • Median duration of AF: STSF vs. ST (24 vs. 42 months, p=0.057); • Left atrial diameter: STSF vs. ST (37.6±5 vs. 38.7±4.3mm, p=0.145); • CHA_2DS_2 VASc Score: STSF vs. ST (1.3±1.2 vs. 1.4±1.6, p=0.184);	Procedural characteristics • Mean procedure time: STSF vs. ST (156 vs. 199 minutes, p<0.001); • Mean ablation time: STSF vs. ST (27.2 vs. 43.2 minutes, p<0.001); • Mean left wide antral circumferential ablation Time: STSF vs. ST (29.5 vs. 38.5 minutes, p<0.001); • Mean right wide antral circumferential ablation Time: STSF vs. ST (32 vs. 38.5 minutes, p=0.001);

							Comorbidities • Hypertension: STSF vs. ST (38% vs. 34%, p=0.85); • Diabetes Mellitus: STSF vs. ST (12% vs. 6%, p=0.485); • Ischemic Heart Disease: STSF vs. ST (4% vs. 2%, p=0.291).	• Mean fluoroscopy time: STSF vs. ST (7.7 vs. 8.5 minutes, p=0.079); Clinical outcomes • Acute procedure success rate: STSF vs. ST (68% vs. 48%, p=0.068); • 12-month AF/AT recurrence rate: STSF vs. ST (6% vs. 34%); • Any complications: STSF vs. ST (0% vs. 6%); • Pericarditis: STSF vs. ST (0% vs. 4%); • Femoral venous hematoma: STSF vs. ST (0% vs. 2%).
Duytschaever 2019 [24]	Europe	Abstract	English	Prospective cohort study	Inclusion criteria: Patients underwent point-by-point paroxysmal atrial fibrillation ablations across 17 European centers in the VISTAX study. Exclusion criteria: Unspecified.	STSF (n=86) vs. ST (n=243)	Not reported	Procedural characteristics • Procedure time: STSF vs. ST (137.4±30.1 vs. 162.9±36.9 minutes); • Ablation time: STSF vs. ST (37.1±9.23 vs. 34.4±11.73 minutes); • Fluid via ablation catheter: STSF vs. ST (785.3±356.0 vs. 1,255.6±469.3 mL); • Foley catheter usage (%): STSF vs. ST (11.6% vs 25.9%); Clinical outcomes • Any complications: STSF vs. ST (3.5% vs. 3.7%).
Goldstein 2019a [20]	United States	Abstract	English	Retrospective study	Inclusion criteria: Patients with a primary diagnosis of AF (≥18 years) who underwent radiofrequency ablation between 09/01/2016–03/31/2018, identified from the Premier Healthcare database.	STSF (n=1,445) vs. ST (n=1,766)	Demographics • Age group ≥70: STSF vs. ST (35.09% vs. 30.18%, p=0.0031); Clinical characteristics • Paroxysmal AF: STSF vs. ST (63.32% vs. 67.21%, p=0.0210); • $CHADS_2VASc$ score ≥3: STSF vs. ST (43.39% vs. 35.18%, p<0.001);	Not reported

					Exclusion criteria: Unspecified.		Comorbidities • Obesity: STSF vs. ST (23.88% vs. 19.42%, p=0.0022); • Diabetes: STSF vs. ST (20.90% vs. 17.27%, p=0.0090); • Atrial flutter: STSF vs. ST (41.38% vs. 32.61%, p<0.0001); • Valvular disease: STSF vs. ST (21.87% vs. 12.31%, p<0.0001); • Cardiomyopathy: STSF vs. ST (12.87% vs. 9.68%, p=0.0042); • Hypertension: STSF vs. ST (69.48% vs. 63.02%, p=0.0001); • Heart failure: STSF vs. ST (20.69% vs. 17.84%, p=0.0407).	
Goldstein 2019b [21]	United States	Abstract	English	Retrospective study	Inclusion criteria: Patients with a primary diagnosis of AF (≥18 years) who underwent index (first occurrence) radiofrequency ablation in an outpatient setting (09/01/2016–03/31/2018), identified from the Premier Healthcare database. Exclusion criteria: Unspecified.	STSF (n=571) vs. ST (n=571)	Not reported	Hospital readmission outcomes • 4-6 months all-cause readmission rate: STSF vs. ST (2.78% vs. 2.78%, p=1.000); • 4-6 months cardiovascular-related inpatient readmission rate: STSF vs. ST (1.23% vs. 1.23%, p=1.000); • 4-6 months AF-related inpatient readmission rate: STSF vs. ST (0.93% vs. 0.62%, p=0.6535).
Lee 2019a [15]	South Korea	Abstract	English	Prospective cohort study	Inclusion criteria: Drug refractory symptomatic AF patients. Exclusion criteria: Unspecified.	STSF (n=66) vs. ST (n=32)	Pooled information of two groups Demographics • Mean age: 61±8 years; Clinical characteristics • Paroxysmal AF: 67%	Procedural characteristics • Procedure time: STSF vs. ST (160±37 vs. 199±42 minutes, p<0.001); • Ablation time: STSF vs. ST (44±10 vs. 66±14 minutes, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (96.3% vs. 95.8%, p=0.613).
Lee 2019b [14]	South Korea	Abstract	English	Retrospective study	Inclusion criteria: Drug refractory symptomatic AF patients.	STSF (n=39) vs. ST (n=32)	Pooled information of two groups Demographics Mean age: 61±10 years;	Procedural characteristics

					Exclusion criteria: Unspecified.		Male: 79%; Clinical characteristics Paroxysmal AF: 79%	• Procedure time: STSF vs. ST (168±34 vs. 199±42 minutes, p=0.001); • Ablation time: STSF vs. ST (47±11 vs. 66±14 minutes, p<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. ST (96.0% vs. 95.8%, p=0.867); • Any complications: STSF vs. ST (0% vs. 0%).
Liu 2019 [26]	China	Full text	Chinese	Retrospective study	Inclusion criteria: Drug-refractory paroxysmal AF patients underwent pulmonary vein isolation. Exclusion criteria: Unspecified.	STSF (n=24) vs. ST (n=24)	Demographics • Mean age: STSF vs. ST (65.0±9.6 vs. 65.2±10.2 years, p=0.95); • Male: STSF vs. ST (37.5% vs. 37.5%, p=1.00); • BMI: STSF vs. ST (22.1±1.7 vs. 21.8±1.4 kg/m^2, p=0.53); Clinical characteristics • Duration of AF: STSF vs. ST (10.4±10.1 vs. 6.1±4.1 months, p=0.08); • Left atrial diameter: STSF vs. ST (34.1±13.9 vs. 39.1±5.4 mm, p=0.09); • Left ventricular ejection fraction: STSF vs. ST (55±6 vs. 53±8%, p=0.23); Comorbidities • Coronary heart disease: STSF vs. ST (8.3% vs. 29.2%, p=0.14); • Heart failure: STSF vs. ST (25.0% vs. 41.7%, p=0.22); • Hypertension: STSF vs. ST (41.7% vs. 50%, p=0.76); • Diabetes: STSF vs. ST (12.5% vs. 29.2%, p=0.16); • Stroke: STSF vs. ST (4.2% vs. 8.3%, p=1.00).	Procedural characteristics • Procedure time: STSF vs. ST (67 vs. 70 minutes, p=0.45); • Ablation time: STSF vs. ST (35.3±6.4 vs. 39.6±9.0 minutes, p=0.07); • Fluoroscopy time: STSF vs. ST (7.8±3.1 vs. 11.2±6.3 minutes, p=0.02); • Total infusion fluid: STSF vs. ST (356 vs. 700 mL, p<0.01); Clinical outcomes • Acute procedure success rate: STSF vs. ST (100% vs. 100%, p=1); • Any complications: STSF vs. ST (0% vs. 0%).

Solimene 2019 [12]	Italy	Full text	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF who underwent their first AF ablation. Exclusion criteria: 1. Age <18; 2. Longstanding persistent AF (AF was the sole rhythm for the last 12 months); 3. AF secondary to a transient or correctable abnormality, including electrolyte imbalance, trauma, recent surgery, infection, toxic ingestion, and endocrinopathy; 4. Intra-atrial thrombus, tumor, or other abnormality precluding catheter insertion; 5. Left ventricular ejection fraction <35%; 6. Women of childbearing potential who are or might be pregnant; 7. Hematological contraindications to ionizing radiation exposure; 8. Presence of complex congenital heart disease; 9. Cardiac surgery within 1 month from enrollment.	STSF (Subgroup with AI 330-450, n=162; Subgroup with AI 380-500, n=151) vs. ST (Subgroup with AI 330-450, n=96; Subgroup with AI 380-500, n=81)	The subgroup with AI 330-450 Demographics • Mean age: STSF vs. ST (60±12 vs. 58±10 years); • Male: STSF vs. ST (68% vs. 71%); • BMI: STSF vs. ST (27.5±4.3 vs. 27.2±3.8 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (79.6% vs. 81.3%); • Left ventricular ejection fraction: STSF vs. ST (58±8 vs. 52±10%); Comorbidities • Hypertension: STSF vs. ST (30.4% vs. 31.3%); • Ischemic heart disease: STSF vs. ST (5.3% vs. 7.7%); • Valvulopathy: STSF vs. ST (1.2% vs. 1%); • Dilated cardiomyopathy: STSF vs. ST (4.9% vs. 4.2%); • Previous transient ischemic attack/Stroke: STSF vs. ST (4.3% vs. 1%); • Diabetes mellitus: STSF vs. ST (11.1% vs. 2.1%); • Chronic renal failure: STSF vs. ST (1.9% vs. 0%); The subgroup with AI 380-500 Demographics • Mean age: STSF vs. ST (59±10 vs. 59±13 years); • Male: STSF vs. ST (72% vs. 77%); • BMI: STSF vs. ST (26.2±4 vs. 28.1±4.8 kg/m^2); Clinical characteristics • Paroxysmal AF: STSF vs. ST (83.4% vs. 75.3%);	The subgroup with AI 330-450 Procedural characteristics • Procedure time: STSF vs. ST (120±72 vs. 129±44 minutes); • Ablation time: STSF vs. ST (33.3±11.5 vs. 30.7±10 minutes); • Fluoroscopy time: STSF vs. ST (257±356 vs. 542±285 seconds); • Total fluid: STSF vs. ST (701±287 vs. 1105±573 mL); Clinical outcomes • Acute procedure success rate: STSF vs. ST (94.5% vs. 97.5%); The subgroup with AI 380-500 Procedural characteristics • Procedure time: STSF vs. ST (125±73 vs. 144±44 minutes); • Ablation time: STSF vs. ST (33±11.7 vs. 28.8±13.7 minutes); • Fluoroscopy time: STSF vs. ST (379±454 vs. 540±416 seconds); • Total fluid: STSF vs. ST (836±503 vs. 1,732±664 mL); Clinical outcomes • Acute procedure success rate: STSF vs. ST (92.2% vs. 94.5%).

							• Left ventricular ejection fraction: STSF vs. ST (60±7 vs. 57±7%); Comorbidities • Hypertension: STSF vs. ST (45.7% vs. 39.5%); • Ischemic heart disease: STSF vs. ST (5.5% vs. 6.8%); • Valvulopathy: STSF vs. ST (2.6% vs. 6.2%); • Dilated cardiomyopathy: STSF vs. ST (0.7% vs. 0%); • Previous transient ischemic attack/Stroke: STSF vs. ST (2.6% vs. 1.2%); • Diabetes mellitus: STSF vs. ST (4% vs. 6.2%); • Chronic renal failure: STSF vs. ST (0.7% vs. 3.7%);	
Plenge 2020 [11]	Germany	Full text	English	Prospective cohort study	Inclusion criteria: Consecutive patients with symptomatic paroxysmal or persistent AF scheduled for pulmonary vein isolation. Exclusion criteria: Age younger than 18 years, reversible causes of AF, prior pulmonary vein isolation, and intracardiac thrombus.	STSF (n=60) vs. ST (n=20)	Demographics • Mean age: STSF vs. ST (63.0±9.1 vs. 65.1±10.7 years, p=0.33); • Male: STSF vs. ST (63.3% vs. 65.0%, p=0.56); • BMI: STSF vs. ST (27.4±5.1 vs. 25.7±4.3 kg/m^2, p=0.24); Clinical characteristics • Duration of AF: STSF vs. ST (79.6±97.2 vs. 88.8±90.7 months, p=0.82); • Left atrial diameter: STSF vs. ST (41.2±7.0 vs. 42.7±6.3 mm, p=0.64); • Left ventricular ejection fraction: STSF vs. ST (61.3±8.4 vs. 62.2±5.3 %, p=0.68); Comorbidities • Hypertension: STSF vs. ST (65% vs. 73.3%, p=0.50); • Hyperlipoproteinemia: STSF vs. ST (33.3% vs. 40%, p=0.42);	Procedural characteristics • Procedure time: STSF vs. ST (106.3±28.4 vs. 116.7±26.7 minutes, p=0.2); • Ablation time: STSF vs. ST (25.9±7.3 vs. 32.1±16 minutes, p=0.045); • RF time for PVI left veins: STSF vs. ST (836.5±296.3 vs. 1,086.6±523.0 seconds, p=0.08); • RF time for PVI right veins: STSF vs. ST (913.5±1,435.8 vs. 1,002.8±544.6 seconds, p=0.8); • Fluoroscopy time: STSF vs. ST (16.0±6.7 vs. 13.8±5.7 minutes, p=0.25) • Fluoroscopy dose: STSF vs. ST (1,854.7±1,247.9 vs. 1,756.7±822.6 µGym2, p=0.77); • Fluid via ablation catheter: STSF vs. ST (241.4±79.6 vs. 540.3±229.5 mL, p<0.01);

							• Cardiovascular disease: STSF vs. ST (20% vs. 10%, p=0.10); • Cardiomyopathy: STSF vs. ST (15% vs. 13.3%, p=0.72); • Diabetes mellitus: STSF vs. ST (15% vs. 13.3%, p=0.72); • Renal failure: STSF vs. ST (11.7% vs. 0%, p=0.02); • Sleep-disordered breathing: STSF vs. ST (8.8% vs. 26.7%, p=0.63).	Clinical outcomes • Any complications: STSF vs. ST (1.7% vs. 5%); • Audible steam pop: STSF vs. ST (1.7% vs. 0%); • Bleeding: STSF vs. ST (0% vs. 5%).
Stabile 2020 [22]	Italy	Full text	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF who underwent their first AF ablation. Exclusion criteria: 1. Age <18; 2. Longstanding persistent AF (AF was the sole rhythm for the last 12 months); 3. AF secondary to a transient or correctable abnormality, including electrolyte imbalance, trauma, recent surgery, infection, toxic ingestion, and endocrinopathy; 4. Intra-atrial thrombus, tumor, or other abnormality precluding catheter insertion; 5. Left ventricular ejection fraction <35%; 6. Women of childbearing potential who are or might be pregnant; 7. Hematological contraindications to	STSF (Subgroup with AI 330-450, n=140; Subgroup with AI 380-500, n=149) vs. ST (Subgroup with AI 330-450, n=89; Subgroup with AI 380-500, n=74)	Duplicate with Stabile 2019.	The subgroup with AI 330-450 Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (14.9% vs. 4.5%); The subgroup with AI 380-500 Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (9.4% vs. 12.2%).

					ionizing radiation exposure; 8. Presence of complex congenital heart disease; 9. Cardiac surgery within 1 month from enrollment.			
Zhang 2020 [27]	China	Full text	Chinese	Retrospective study	Inclusion criteria: 1. Recurrent paroxysmal atrial fibrillation (defined as paroxysmal atrial fibrillation that can be terminated by itself or intervention within 7 days after the attack), which does not respond to antiarrhythmic drugs. 2. Preoperative echocardiography showed left atrial diameter <55mm and left ventricular ejection fraction (LVEF) > 35%. Exclusion criteria: Stroke, heart valve disease, heart failure (cardiac function IV level), atrial thrombus, cardiomyopathy (including hypertrophic cardiomyopathy and dilated cardiomyopathy), acute coronary syndrome, hyperthyroidism, hypothyroidism, coronary heart disease, chronic renal insufficiency (chronic kidney disease stage 4-5)	STSF (n=34) vs. ST (n=34)	Demographics • Mean age: STSF vs. ST (66.63±7.59 vs. 67.53 years, p>0.05); • Male: STSF vs. ST (55.9% vs. 58.8%, p>0.05); Clinical characteristics • Duration of AF: STSF vs. ST (9.6±3.6 vs. 8.7±5.6 months, p>0.05); • Left atrial diameter: STSF vs. ST (36.8±3.7 vs. 34.9±5.3 mm, p>0.05); • Left ventricular ejection fraction: STSF vs. ST (60.1±3.7 vs. 59.3±3.4%, p>0.05).	Procedural characteristics • Right PVI time: STSF vs. ST (23.30±5.53 vs. 28.65±4,95 minutes, p<0.05); • Left PVI time: STSF vs. ST (28.25±9.67 vs. 33.25±5.60 minutes, p<0.05); • Fluoroscopy time: STSF vs. ST (11.30±2.91 vs. 12.30±3.31 minutes, p>0.05); • Total fluid: STSF vs. ST (930.00±319.70 vs. 1,770.00±482.43 mL); Clinical outcomes • Unilateral PVI success rate: STSF vs. ST (88.23% vs. 58.82%, p<0.05); • Cardiac tamponade: STSF vs. ST (2.9% vs. 2.9%); • Eschar: STSF vs. ST (0.0% vs. 8.8%, p<0.05).

Huang 2021 [17]	China	Full text	Chinese	Retrospective study	Inclusion criteria: 1. Aged between 18 and 75 years; 2. ECG examination confirmed AF attack. Exclusion criteria: 1. Patients with cardiac thrombosis; 2. Patients complicated with active hemorrhagic disease, severe organic disease, or advanced chronic wasting disease; 3. Left atrial diameter > 55mm; 4. Patients with valvular heart disease or vascular disease requiring surgical treatment.	STSF (n=42) vs. ST (n=42)	Demographics • Mean age: STSF vs. ST (62.3±8.8 vs. 61.1±10.3 years, p=0.510); • Male: STSF vs. ST (69.0% vs. 64.3%, p=0.643); Clinical characteristics • Paroxysmal AF: STSF vs. ST (45.2% vs. 54.8%, p=0.383); • Left atrial diameter: STSF vs. ST (4.38±0.48 vs. 4.40±0.62 cm, p=0.854); • Left ventricular ejection fraction: STSF vs. ST (59.45±4.72 vs. 57.[illegible]±10.91%, p=0.340); Comorbidities • Hypertension: STSF vs. ST (54.8% vs. 52.4%, p=0.827); • Coronary heart disease: STSF vs. ST (21.4% vs. 21.4%, p=1.000); • Cardiac insufficiency: STSF vs. ST (9.5% vs. 9.5%, p=1.000); • Diabetes: STSF vs. ST (4.8% vs. 11.9%, p=0.206); • Cerebral infarction: STSF vs. ST (7.1% vs. 19.0%, p=0.106).	Procedural characteristics • Ablation time: STSF vs. ST (28.3±5.1 vs. 51.3±6.7 minutes, p<0.001); Clinical outcomes • Circumferential pulmonary vein isolation success rate: STSF vs. ST (100.0% vs. 100.0%, p=1.000); • Complement ablation rate in CPVI: STSF vs. ST (45.2% vs. 85.7%, p=0.087); • 12-month arrhythmia recurrence rate: STSF vs. ST (0% vs. 2.4%, p=0.314); • Any complications: STSF vs. ST (0% vs. 0%).
Zhou 2021 [13]	China	Full text	Chinese	Retrospective study	Inclusion criteria: Patients undergoing first-time percutaneous radiofrequency catheter ablation. Exclusion criteria: Unspecified.	STSF (n=142) vs. ST (n=98)	Demographics • Mean age: STSF vs. ST (63.2±9.2 vs. 63.[illegible]±10.6 years, p=0.950); • Male: STSF vs. ST (59.2% vs. 65.3%, p=0.491); Clinical characteristics • Paroxysmal AF: STSF vs. ST (59.9% vs. 66.3%, p=0.335); • Left atrial diameter: STSF vs. ST (43.4±4.4 vs. 44.4±5.6 mm, p=0.193);	Procedural characteristics • Procedure time: STSF vs. ST (96.4 ±31.6 vs. 119.5±33.8 minutes, p=0.021); • Ablation time: STSF vs. ST (38.6±15.2 vs. 61.5±13.8 minutes, p=0.013); • Fluoroscopy time: STSF vs. ST (15.3±3.3 vs. 16.9±3.6 minutes, p=0.144); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. ST (4.9% vs. 20.4%, p=0.025).

							• Left ventricular ejection fraction: STSF vs. ST (61.4±5.7 vs. 61.2±5.1%, p=0.846); • CHA_2DS_2 VASc Score: STSF vs. ST (2.3±1.7 vs. 1.3±1.7, p=0.243).	
Dugo 2016 [29]	Germany	Abstract	English	Retrospective study	Inclusion criteria: Patients with AF underwent ablation between July 2014 and May 2015, with a minimum follow-up of 6 months. Exclusion criteria: Unspecified.	STSF (n=26) vs. SF (n=26)	Demographics • Mean age: STSF vs. SF (66±9 vs. 67±10 years); • Male: STSF vs. SF (54% vs. 50%); Clinical characteristics • Paroxysmal AF: STSF vs. SF (96% vs. 81%); • Left atrial diameter: STSF vs. SF (40±7 vs. 42±6 mm).	Procedural characteristics • Procedure time: STSF vs. SF (98±32 vs. 78±31 minutes, p< 0.05); • Fluoroscopy time: STSF vs. SF (11±7 vs. 7±3 minutes, p< 0.05); Clinical outcomes • Acute procedure success rate: STSF vs. SF (100% vs. 100%); • Any complications: STSF vs. SF (0% vs. 0%); • Cardiac tamponade: STSF vs. SF (0% vs. 0%); • Stroke: STSF vs. SF (0% vs.0%); • Atrial-esophageal fistula: STSF vs. SF (0% vs. 0%); • Vascular access: STSF vs. SF (3.8% vs. 0%);
Gonna 2017 [30]	United Kingdom	Full text	English	Prospective cohort study	Inclusion criteria: Atrial fibrillation patients undergoing ablation, Between May and December 2015. Exclusion criteria: Unspecified.	STSF (n=100) vs. SF (n=100)	Demographics • Mean age: STSF vs. SF (60.5±14.0 vs. 62.4±13.3 years, p=0.38); • Male: STSF vs. SF (73% vs. 71%, p=0.75).	Procedural characteristics • Mean procedure time: STSF vs. SF (225.5 vs. 221.4 minutes, p=0.55); • Mean fluoroscopy time: STSF vs. SF (25.8 vs. 30.0 minutes, p=0.03); Clinical outcomes • Any complications: STSF vs. SF (0% vs. 2%, p=0.16); • Pericardial effusion: STSF vs. SF (0% vs. 1%, p=0.32); • Atrioventricular block: STSF vs. SF (0% vs. 1%, p=0.32).
Takamiya 2020 [32]	Japan	Full text	English	Retrospective study	Inclusion criteria: Patients who underwent	STSF (n=74) vs. SF (n=74)	Demographics	Procedural characteristics

					first catheter ablation for drug-refractory persistent AF. Exclusion criteria: Unspecified.		• Mean age: STSF vs. SF (63±10 vs. 63±12 years, p=0.5[illegible]); • Male: STSF vs. SF (76% vs. 80%, *p*=0.69); • BMI: STSF vs. SF (25±4 vs. 25±4 kg/m^2, *p*=0.[illegible]8); Clinical characteristics • Median duration of persistent AF: STSF vs. SF (5 vs. 6 months, *p*=0.30); • Left atrial diameter: STSF vs. SF (43±6 vs. 43±7, *p*=0.96); • Left ventricular ejection fraction: STSF vs. SF (59±11 vs. 58±14%, *p*=0.57). Comorbidities • Heart failure: STSF vs. SF (18% vs. 20%, *p*=0.83); • Hypertension: STSF vs. SF (61% vs. 54%, *p*=0.5[illegible]); •Diabetes mellitus: STSF vs. SF (20% vs. 19%, *p*=1.0[illegible]).	• Procedure time: STSF vs. SF (180 vs. 200 minutes, *p*=0.150); • Fluoroscopy time: STSF vs. SF (67 vs. 76 minutes, *p*=0.026); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. SF (15% vs. 30%); • Any complications: STSF vs. SF (5% vs. 3%, p=1.0); • Pericardial effusion: STSF vs. SF (1.4% vs. 1.4%); • Esophageal gastroparesis: STSF vs. SF (1.4% vs. 0%); • Phrenic nerve injury: STSF vs. SF (1.4% vs. 0%); • Aspiration pneumonia: STSF vs. SF (1.4% vs. 0%); • Sinus node injury as a result of superior vena cava isolation: STSF vs. SF (0% vs. 1.4%).
Uetake 2020 [31]	Japan	Full text	English	Prospective cohort study	Inclusion criteria: Paroxysmal AF patients who underwent their first radiofrequency catheter ablation procedure. Exclusion criteria: 1. Severe valvular disease; 2. Left ventricular ejection fraction < 35%; 3. Left atrial dimension > 55 mm; 4. Active thyroid disease; 5. Hypertrophic cardiomyopathy; 6. Hemodialysis;	STSF (n=298) vs. SF (n=97)	Demographics • Mean age: STSF vs. SF (65.3±9.9 vs. 63.4±9.[illegible] years, *p*=0.085); • Male: STSF vs. SF (88.8% vs. 79.4%, *p*=0.028); • BMI: STSF vs. SF (24.1±3.5 vs. 24.0±3.1 kg/m^2, p=0.[illegible]85); Clinical characteristics • Duration of AF: STSF vs. SF (32.1±33.5 vs. 2[illegible].9±4[illegible].2 months, *p*=0.023); • Left atrial diameter: STSF vs. SF (41.0±6.0 vs. 40.6±5.9 mm, *p*=0.709); • Left ventricular ejection fraction: STSF vs. SF (65.8±7.7 vs. 65.5±8.4%, *p*=0.8[illegible]);	Procedural characteristics • Ablation time: STSF vs. SF (2,056.8±534.5 vs. 2,401.1±733.4 seconds, *p*<0.001); Clinical outcomes • Acute procedure success rate: STSF vs. SF (100% vs. 100%); • 12-month arrhythmia recurrence rate: STSF vs. SF (21.8% vs. 43.3%, *p*<0.001).

					7. Use of antiarrhythmic drugs during the blanking period.		• CHA_2DS_2 VASc Score: STSF vs. SF (1.94±1.22 vs. 1.51±1.13, p=0.010); Comorbidities • Hypertension: STSF vs. SF (53.4% vs. 52.6%, p=0.493); • Congestive heart failure: STSF vs. SF (4.7% vs. 2.8%, p=0.203); • Diabetes mellitus: STSF vs. SF (10.1% vs. 13.4%, p=0.230); • Previous stroke or transient ischemic attack: STSF vs. SF (3.4% vs. 1.0%, p=0.202); • Vascular disease: STSF vs. SF (5.7% vs. 1.0%, p=0.045).	
Ikeda 2021 [33]	Japan	Full text	English	Retrospective study	Inclusion criteria: 1. Age of > 20 years and provision of informed consent to undergo a second AF ablation at our institute, the performance of the second AF ablation using high-density mapping or the conventional method (CARTO® mapping system; Biosense Webster, Irvine, CA, USA) during that period; 2. ≥ 3 months of follow-up at the outpatient clinic in our institute. Exclusion criteria: 1. Refusal to participate in the study; 2. An inability to undergo follow-up for any reason; 3. The lack of use of a 3D mapping system.	STSF (n=51) vs. CELSIUS® (n=49)	Demographics • Mean age: STSF vs. CELSIUS® (63.5±8.54 vs. 64.2±10.7 years, p=0.98); • Male: STSF vs. CELSIUS® (63% vs. 73%, p=0.2); Clinical characteristics • Paroxysmal AF: STSF vs. CELSIUS® (59% vs. 55%, p=0.5); • Median $CHADS_2$ VASc Score: STSF vs. CELSIUS® (0.8 vs. 0.8, p=0.91); Comorbidities • Sick sinus syndrome: STSF vs. CELSIUS® (14% vs. 16%, p=0.72); • Cerebrovascular disease: STSF vs. CELSIUS® (12% vs. 4%, p=0.16); • Congestive heart failure: STSF vs. CELSIUS® (16% vs. 22%, p=0.39); • Hypertension: STSF vs. CELSIUS® (35% vs. 39%, p=0.78);	Procedural characteristics • Procedure time: STSF vs. CELSIUS® (260.5±82.7 vs. 255.8±45.3 minutes, p=0.82); • Fluoroscopy dose: STSF vs. CELSIUS® (313.2±187.9 vs. 363.4±257.3 mGy, p=0.28); Clinical outcomes • 12-month arrhythmia recurrence rate: STSF vs. CELSIUS® (33% vs. 16%, p=0.017); • Cardiac tamponade: STSF vs. CELSIUS® (0% vs. 0%); • Cerebral infarction: STSF vs. CELSIUS® (0% vs. 0%); • Bleeding: STSF vs. CELSIUS® (13.7% vs. 10.2%); • Congestive heart failure: STSF vs. CELSIUS® (2% vs. 0%, p=0.32); • Pericarditis: STSF vs. CELSIUS® (2% vs. 0%, p=0.32).

							• Diabetes mellitus: STSF vs. CELSIUS® (2% vs. 8%, *p*=0.15); • Chronic kidney disease: STSF vs. CELSIUS® (8% vs. 16%, *p*=0.19).	
Reinsch 2021 [36]	Germany	Full text	English	Retrospective study	Inclusion criteria: Atrial fibrillation patients undergoing ablation at the Alfried Krupp Krankenhaus, Essen, Germany from October 2014 to June 2019. Exclusion criteria: Unspecified.	STSF (n=690) vs. Thermocool NAVISTAR® (n=99)	Demographics • Mean age: STSF vs. Thermocool NAVISTAR® (67.5±10.6 vs. 62.6±9.8 years); • Male: STSF vs. Thermocool NAVISTAR® (58.4% vs. 59.6%); Clinical characteristics • Paroxysmal AF: STSF vs. Thermocool NAVISTAR® (43.5% vs. 48.5%); • Duration of AF: STSF vs. Thermocool NAVISTAR® (50.1±57.5 vs. 55.5±53.4 months); • Left ventricular ejection fraction≥55%: STSF vs. Thermocool NAVISTAR® (77.5% vs. 81.8%); • CHA_2DS_2 VASc Score≥3: STSF vs. Thermocool NAVISTAR® (57.0% vs. 46.9%); Comorbidities • Hypertension: STSF vs. Thermocool NAVISTAR® (69.9% vs. 57.6%).	Procedural characteristics • Procedure time: STSF vs. Thermocool NAVISTAR® (160±48 vs. 190±47 minutes); • Ablation time: STSF vs. Thermocool NAVISTAR® (43±19 vs. 58±27 minutes); • Fluoroscopy time: STSF vs. Thermocool NAVISTAR® (5±3 vs. 7±4 minutes); Clinical outcomes • Cardiac tamponade: STSF vs. Thermocool NAVISTAR® (1.7% vs. 2.9%).
Di 2020 [35]	Italy	Abstract	English	Prospective cohort study	Inclusion criteria: Patients with paroxysmal or persistent AF underwent point-by-point pulmonary vein isolation. Exclusion criteria: Unspecified.	CARTO+STSF (n=59) vs. Rhythmia System™ + DirectSense (n=57)	Pooled information of two groups Clinical characteristics • Paroxysmal AF: 63%	Procedural characteristics • Procedure time: CARTO+STSF vs. Rhythmia System™ + DirectSense (180±56 vs. 180±89 minutes, *p*=0.590); • Fluoroscopy time: CARTO+STSF vs. Rhythmia System™ + DirectSense (13±9 vs. 20±12 minutes, p=0.002); Clinical outcomes

								• Acute procedure success rate: CARTO+STSF vs. Rhythmia System™ + DirectSense (100% vs. 100%); • 9-month arrhythmia recurrence rate: CARTO+STSF vs. Rhythmia System™ + DirectSense(14% vs. 25%, *p*=0.2); • Any complications: CARTO+STSF vs. Rhythmia System™ + DirectSense (0% vs. 0%); • Audible steam pop: CARTO+STSF vs. Rhythmia System™ + DirectSense (0% vs. 0%).
Guckel 2022 [34]	Germany	Abstract	English	Prospective cohort study	Inclusion criteria: Patients undergoing radiofrequency ablation for AF. Exclusion criteria: Unspecified.	STSF (n=69) vs. DiamondTemp ™ (n=33)	Not reported	Procedural characteristics • Procedure time: STSF vs. DiamondTemp™ (78.2±25.6 vs. 98.8±30.1 minutes, *p*=0.002); • Ablation time: STSF vs. DiamondTemp™ (1,035.5±287.2 vs.792.1±311.2 seconds, *p*<0.001); • Fluoroscopy time: STSF vs. DiamondTemp™ (5.5±2.5 vs.4.6±2.1 minutes, p<0.006); • Fluoroscopy dose: STSF vs. DiamondTemp™ (295.8±247.5 vs. 183.8±178.1 yGym2, *p*<0.013); Clinical outcomes • Acute procedure success rate: STSF vs. DiamondTemp™ (100% vs. 100%); • Acute stroke: STSF vs. DiamondTemp™ (0% vs. 3%).

STSF: SMARTTOUCH® SURROUNDFLOW; ST: ST: THERMOCOOL SMARTTOUCH®; SF: SURROUNDFLOW; BMI: Body mass index.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Line 1 to 3
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	See abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Line 59 to 62
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Line 63 to 69
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Line 78 to 85
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Line 89 to 99
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary Table 1
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Line 101 to 108, and Figure 1
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Line 110 to 116, and Figure 1
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Line 121 to 125
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Line 118 to 120
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Line 128 to 133
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Line 135 to 141
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Line 143 to 147
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Not applicable
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Supplementary Table 2
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Line 147 to 150, and Line 156 to 158
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Line 151 to

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
			154
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Line 154 to 155
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Line 155 to 156
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Line 147 to 150
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Line 161 to 166, and Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	
Study characteristics	17	Cite each included study and present its characteristics.	Line 168 to 171, and Supplementary Table 2
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Line 180 to 182, and Supplementary Table 2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Line 292 to 294, Line 297 to 299, Line 302 to 303, and Line 311 to 323
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Line 184 to 189
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Line 192 to 194, Line 214 to 215, Line 238 to 240, Line 257 to 260, Line 276 to 279, Line 288 to 290, Line 300 to 301, and Line 304 to 306
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Line 195 to 205, Line 217

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
			to 230, Line 241 to 249, Line 260 to 268, and Line 280 to 283
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Line 206 to 208, Line 231 to 232, Line 250 to 251, Line 268 to 270, and Line 283 to 286
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Line 208 to 211, and Line 232 to 233
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Figure 2, 3, 4, and 5, and Table 1
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Line 325 to 333
	23b	Discuss any limitations of the evidence included in the review.	Line 388 to 408
	23c	Discuss any limitations of the review processes used.	Line 398 to 400
	23d	Discuss implications of the results for practice, policy, and future research.	Line 367 to 370, and Line 406 to 408
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Not applicable
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Not applicable
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Line 445
Competing interests	26	Declare any competing interests of review authors.	Line 441 to 443
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Upon request

PRISMA 2020 Checklist

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

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