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**META-ANALYSIS**

- 126** Who benefits from percutaneous closure of patent foramen ovale *vs* medical therapy for stroke prevention?  
In-depth and updated meta-analysis of randomized trials  
*Dahal K, Yousuf A, Watt H, Liang B, Sharma S, Rijal J, Katikaneni P, Modi K, Tandon N, Azrin M, Lee J*

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## Who benefits from percutaneous closure of patent foramen ovale vs medical therapy for stroke prevention? In-depth and updated meta-analysis of randomized trials

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### Abstract

#### BACKGROUND

A few randomized clinical trials (RCT) and their meta-analyses have found patent foramen ovale closure (PFOC) to be beneficial in prevention of stroke compared to medical therapy. Whether the benefit is extended across all groups of patients remains unclear.

#### AIM

To evaluate the efficacy and safety of PFOC *vs* medical therapy in different groups of patients presenting with stroke, we performed this meta-analysis of RCTs.

#### METHODS

Electronic search of PubMed, EMBASE, Cochrane Central, CINAHL and ProQuest Central and manual search were performed from inception through September 2018 for RCTs. Ischemic stroke (IS), transient ischemic attack (TIA), a composite of IS, TIA and systemic embolism (SE), mortality, major bleeding,

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atrial fibrillation (AF) and procedural complications were the major outcomes. Random-effects model was used to perform analyses.

## RESULTS

Meta-analysis of 6 RCTs including 3560 patients showed that the PFOC, compared to medical therapy reduced the risk of IS [odds ratio: 0.34; 95% confidence interval: 0.15-0.78;  $P = 0.01$ ] and the composite of IS, TIA and SE [0.55 (0.32-0.93);  $P = 0.02$ ] and increased the AF risk [4.79 (2.35-9.77);  $P < 0.0001$ ]. No statistical difference was observed in the risk of TIA [0.86 (0.54-1.38);  $P = 0.54$ ], mortality [0.74 (0.28-1.93);  $P = 0.53$ ] and major bleeding [0.81 (0.42-1.56);  $P = 0.53$ ] between two strategies. Subgroup analyses showed that compared to medical therapy, PFOC reduced the risk of stroke in persons who were males,  $\leq 45$  years of age and had large shunt or atrial septal aneurysm.

## CONCLUSION

In certain groups of patients presenting with stroke, PFOC is beneficial in preventing future stroke compared to medical therapy.

**Key words:** Patent foramen ovale; Stroke; Antiplatelet therapy; Anticoagulation; Meta-analysis

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**Core tip:** Closure of patent foramen ovale closure (PFOC) is a treatment modality for patients with stroke. To evaluate the efficacy and safety of PFOC vs medical therapy in different groups of patients presenting with stroke, we performed this meta-analysis of randomized trials following standard techniques. It showed that PFOC, compared to medical therapy reduced the risk of ischemic stroke and the composite outcome of stroke, transient ischemic attack (TIA) and systemic thromboembolism but no difference was observed in the risk of TIA, mortality and major bleeding. PFOC increased the risk of atrial fibrillation. Subgroup analyses showed that PFOC reduced the risk of stroke in males.

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## INTRODUCTION

Every year more than 10 million people suffer from stroke in the world, two thirds of which are ischemic in etiology<sup>[1]</sup>. Up to 32% of patients with ischemic stroke (IS) are cryptogenic in origin<sup>[2]</sup> and 43% of cryptogenic stroke patients have patent foramen ovale (PFO)<sup>[3]</sup>. Many people who are living with a PFO are asymptomatic, until they experience the symptoms of a cryptogenic stroke. While the current guidelines recommend medical therapy to prevent future strokes in such patients, percutaneous closure of PFO is an alternative that has been shown to reduce future strokes in several randomized trials and their meta-analyses<sup>[4-8]</sup>.

While previously published randomized clinical trials (RCTs) were inconclusive<sup>[9-11]</sup> to show a benefit, their meta-analyses did show a statistically clear benefit of PFO closure over medical therapy<sup>[12,13]</sup>. Recently three additional trials, and a prolonged follow-up results of a previously published RCT have been published and reported more evidence of a reduction in recurrent stroke after PFO closure<sup>[6-8,14]</sup>. Nevertheless, it is unclear which group of patients benefit from PFO closure compared to medical therapy and how PFO closure compares with anticoagulation therapy. In that regard, to perform an updated meta-analysis on this evolving topic of interest and to evaluate the different patient groups who will benefit from PFO closure compared to medical therapy, we performed a meta-analysis.



## MATERIALS AND METHODS

### Data sources and search strategy

We performed and reported this meta-analysis according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines<sup>[15]</sup>. We searched electronic databases of MEDLINE, EMBASE, Cochrane Central Register of Clinical Trials and CINAHL with no language restriction from inception through September 2018 using the search terms: “patent foramen ovale” OR “PFO” AND “closure” AND “stroke” OR “transient ischemic attack” OR “TIA” with restriction to randomized design. Two investigators (KD and AY) independently performed the database search and agreed on final study selection. In addition, a manual search was performed by reviewing the references of randomized trials and meta-analyses.

### Study inclusion and exclusion criteria

Randomized trials comparing patent foramen ovale closure and medical therapy in adult patients ( $\geq 18$  years) with stroke were selected for meta-analysis. Studies were excluded if they were meeting abstracts, single arm or non-randomized studies and were performed for different disease states.

### Data extraction

Two investigators (BL and AY) extracted data from the selected studies in duplicate using standardized data-extraction form and obtained data on study characteristics (study design, patient selection, inclusion and exclusion criteria, follow-up duration, number of patients, type of PFO device and medical therapy and outcomes), patient characteristics (age, sex, race, co-morbidities including diabetes mellitus, hypertension, hyperlipidemia and body mass index, and medication use), and crude events on mortality, recurrent stroke, transient ischemic attack (TIA), systemic embolism (SE), major bleeding and procedural complications at follow-up.

### Outcomes

Recurrent IS, TIA, SE, a composite of IS, TIA and SE, major bleeding, mortality and procedural complications including atrial fibrillation (AF) risk were the major outcomes.

### Statistical analysis

We calculated odds ratio (OR) with 95% confidence interval (CI) using random-effects model from the individual studies using the total number of events and patients. The quality of studies was assessed with Cochrane Collaboration's Bias Assessment Tools<sup>[16]</sup>. Study heterogeneity was evaluated with Cochran's  $Q$  and  $I^2$  index and significant heterogeneity ( $I^2 > 50\%$ ) was further explored with sensitivity analyses. We planned pre-specified subgroup analyses based on age, gender, presence of atrial septal aneurysm (ASA) and PFO size (as defined the individual papers). We performed statistical analyses with Review Manager (RevMan 5.3, Cochrane Collaboration, Nordic Cochrane Center, Copenhagen, Denmark).

## RESULTS

### Description of included studies

The flow diagram of study selection is shown in **Figure 1**. Electronic search of five databases (PubMed, EMBASE, CENTRAL, CINAHL and ProQuest Central) retrieved a total of 564 publications. After removal of 136 duplicates, we screened 428 citations for eligibility and extracted 33 publications for full text review. Finally, we had a total of seven publications from six randomized trials for qualitative and quantitative analysis. One study resulted in two publications reporting findings at different duration of follow-up.

The individual study characteristics, patient characteristics, and procedural outcomes and complications of the included studies are shown respectively in Tables 1, 2 and 3. There were 3560 total patients (1889 in patent foramen ovale closure (PFOC) arm and 1671 in medical therapy arm). Studies included only patients under 60 years of age. Follow-up duration was between 2 and 5.9 years. The medical therapy arm in two of these trials (REDUCE and CLOSE) consisted of anti-platelet therapy only<sup>[6,8]</sup>, whereas the other four trials (RESPECT, CLOSURE I, PC and DEFENSE PFO) permitted the use of anti-platelet therapy, anticoagulation or both in the medical-therapy group at the discretion of the investigating physicians<sup>[7,9,10,14]</sup>.

### Outcomes

PFO closure, compared to medical therapy reduced the risk of IS (OR: 0.34; 95%CI:

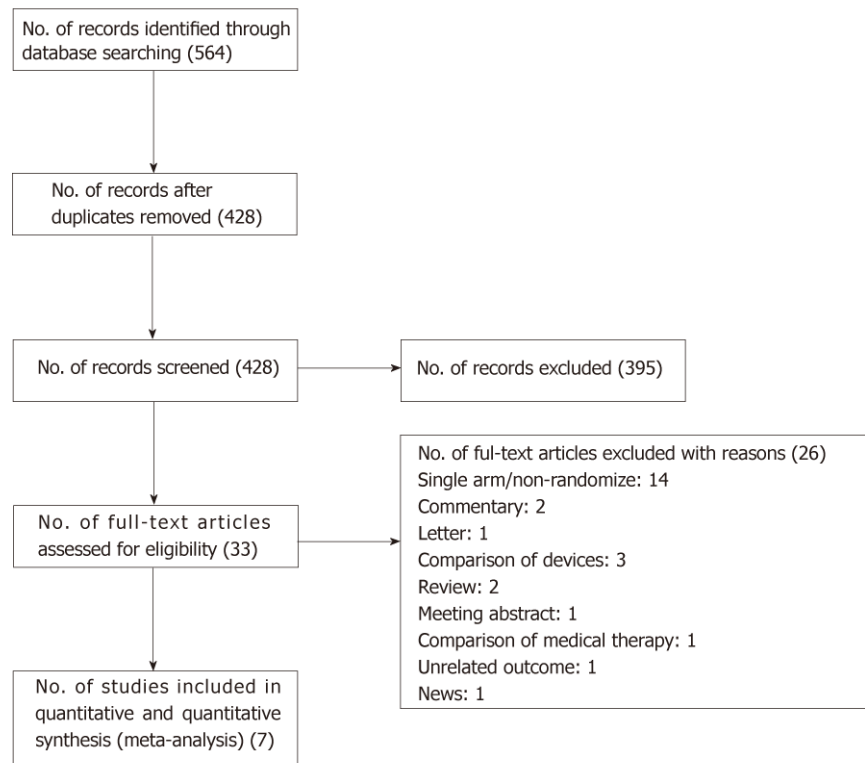


Figure 1 PRISMA flow diagram of the study search.

0.15-0.78,  $P = 0.01$ ;  $I^2 = 54\%$ ) and the composite outcome of IS, TIA and systemic thromboembolism [0.44 (0.22-0.90);  $P = 0.02$ ;  $I^2 = 76\%$ ] (Figure 2). With PFO closure, no difference was observed in the risk of TIA [0.55 (0.32-0.93);  $P = 0.02$ ], mortality [0.74 (0.28-1.93);  $P = 0.53$ ;  $I^2 = 0\%$ ] and major bleeding [0.81 (0.42-1.56);  $P = 0.53$ ;  $I^2 = 19\%$ ] (Figure 3). PFO closure increased the risk of AF [4.79 (2.35-9.77);  $P < 0.0001$ ;  $I^2 = 12\%$ ] compared to medical therapy (Figure 4). The risk of procedural complications was [18.08 (5.58-58.55);  $P < 0.00001$ ;  $I^2 = 0\%$ ].

### Procedural success, complications and risk of AF

Procedural success ranged from 88.3%-99.6%, and PFO closure was successful in 88.6%-100% patients (Table 3). The risk of AF ranged from 1.4%-6.6% across different devices. The risk of AF seemed to numerically lower in patients who received Amplatzer PFO Occluder (1.4%-3.3%) compared to other devices (4.6%-6.6%).

### Sensitivity and subgroup analyses

Several sensitivity analyses were planned a-priori. Since CLOSURE I Trial used Starflex closure device, which the manufacturer has stopped producing, we performed analysis after excluding that study. The overall results did not change. An analysis restricted to the studies with at least 3 years or more follow-up (after exclusion of CLOSURE I and DEFENCE PFO Trials) did not change the overall results.

Several subgroup analyses were planned a-priori. PFO closure, compared to medical therapy resulted in a reduction in the risk of stroke (Figure 5) in patients who were male [0.25; 0.07-0.96;  $P = 0.04$ ;  $I^2 = 61\%$ ],  $\leq 45$  years of age [0.37; 0.17-0.82;  $P = 0.01$ ;  $I^2 = 0\%$ ] and had large shunt [0.22; 0.11-0.47;  $P < 0.0001$ ;  $I^2 = 0\%$ ] or ASA [0.16; 0.05-0.51;  $P = 0.002$ ;  $I^2 = 0\%$ ]. Compared to medical therapy, PFO closure showed a reduction in stroke risk in females [0.50; 0.23-1.08;  $P = 0.08$ ;  $I^2 = 0\%$ ] and patients  $> 45$  years of age [0.32; 0.10-1.06;  $P = 0.06$ ;  $I^2 = 52\%$ ]; however, it did not reach statistical significance. In patients with small shunt, there was no statistical difference in the stroke outcomes [0.88; 0.34-2.27;  $P = 0.8$ ;  $I^2 = 11\%$ ].

### Study quality and publication bias

All the randomized studies showed bias for non-blinding of the participants and the outcomes per Cochrane collaboration's bias tools. Publication bias was not tested due to small number of studies for meaningful assessment of publication bias.

Table 1 Study characteristics

Study name, year	Country of origin	Study design	Indication of PFOC	Total Patients (PFOC + medical therapy), <i>n</i>	Medical therapy	Type of device	Follow-up, in years (mean)
CLOSE <sup>[6]</sup> , 2017	France and Germany	Multicenter, randomized, open-label, superiority trial	Recent stroke due to PFO with atrial septal aneurysm or substantial right-to-left intra-atrial shunt	663 <sup>1</sup> (238 + 235)	Antiplatelet therapy (aspirin + clopidogrel) <sup>1</sup>	11 different devices	5.4 PFOC, 5.2 AC-AP
CLOSURE I <sup>[11]</sup> , 2012	United States and Canada	Multicenter, randomized, open-label trial	Stroke or TIA within 6 mo	909 (447 + 462)	Warfarin, aspirin or both	STARFlex device	2
PC Trial <sup>[9]</sup> , 2013	Europe, Canada, Brazil, and Australia	Multicenter, randomized, superiority trial	Stroke, TIA or systemic thromboembolism	414 (204 + 210)	Aspirin + ticlopidine/clopidogrel	Amplatzer PFO occluder	4.1 PFOC, 4.0 AC/AP
REDUCE <sup>[8]</sup> , 2017	Europe and United States	Multinational, prospective, randomized, controlled, open-label trial	Stroke within 180 d	664 (441 + 223)	Aspirin, aspirin + dipyridamole, or clopidogrel	Helex or Cardioform Septal Occluder	3.2
RESPECT <sup>[7]</sup> , 2017	United States and Canada	Multicenter, randomized, open-label, controlled clinical trial	Stroke within 270 d	980 (499 + 481)	Aspirin + clopidogrel	Amplatzer PFO occluder	5.9
DEFENCE PFO <sup>[14]</sup> , 2018	South Korea	Multicenter, randomized, open-label, superiority	Ischemic stroke in past 6 mos	120 (60 + 60)	Aspirin, aspirin + clopidogrel, aspirin + cilostazol, or warfarin	Amplatzer PFO occluder	2.8

<sup>1</sup>There were patients who received anticoagulation alone but the comparator for that arm was antiplatelet therapy not PFOC. AC: Anticoagulation; AP: Anti-platelet; PFOC: Patent foramen ovale closure.

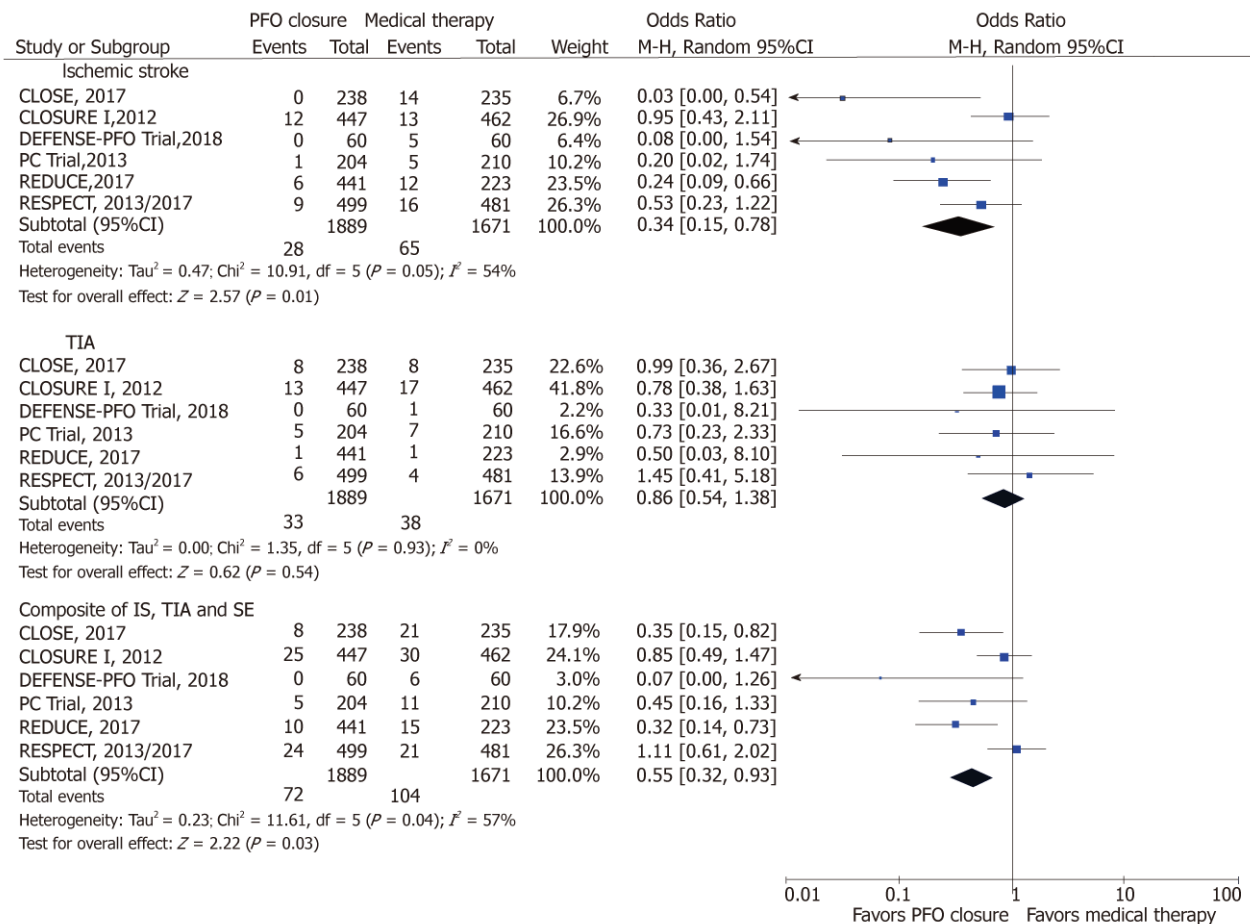
## DISCUSSION

The major findings of our meta-analysis were the reduced risk of recurrent IS and the composite outcome of stroke, TIA, and systemic thromboembolism with PFO closure compared with the medical therapy in patients who presented with stroke. Interestingly, subgroup analyses showed such benefits in persons who were males, ≤ 45 years of age and had large shunt or ASA. In females and persons > 45 years of age, there was a strong trend towards reduction in stroke risk, but it did not reach statistical significance.

Despite all three former PFO trials showing a lack of benefit from PFO closure in reducing the risk of recurrent stroke, meta-analyses and pooled analysis of individual participant data from these three trials showed a significant risk reduction of recurrent IS with PFO closure compared with medical therapy<sup>[12,17]</sup>. The reported risk of recurrent stroke in these studies was small and less than anticipated, which indicated the need for a larger sample and longer follow-ups to increase the possibility of detecting a significant difference in reducing the risk of recurrent stroke. Three recently published trials and a long-term follow-up of a previously published trial demonstrated that among patients with PFO and cryptogenic IS, PFO closure combined with medical therapy was associated with significantly lower risk of recurrent stroke compared with medical therapy alone. Subsequently, a few meta-analyses have been published comparing PFOC with medical therapy, that have consistently shown a reduction in stroke with PFOC<sup>[4,5]</sup>. Our meta-analysis adds substantially by performing subgroup analyses in an attempt to define which groups of patients clearly benefit from PFO closure. In addition, we performed an in-depth analysis on the increased risk of AF and the role of anticoagulation as medical therapy. It is interesting to note that our meta-analysis clearly showed benefit in males who are 45 years of age or younger with large shunt or ASA. These are the patient groups who are at increased risk of stroke. In females and patients > 45 years of age, it did not show statistical significance, which could largely be an issue of sample size.

Medical therapy arm across the studies were not the same, which made it hard to





**Figure 2 Forest plot for stroke, transient ischemic attack and composite of ischemic stroke, transient ischemic attack and systemic embolism.** PFO: Patent foramen ovale.

make a definite statement regarding a medical therapy regimen when compared to PFOC. In the RESPECT trial, anti-platelet agents constituted 74.8% of the medical therapy arm but in the CLOSURE and PC trials, the percentage of patients prescribed antiplatelet *vs* oral anticoagulation was not reported. The subgroup analyses comparing PFO closure *vs* oral anticoagulation in the RESPECT trial did not show advantage in reduction of stroke, whereas similar analysis in CLOSURE Trial did not show advantage of PFOC *vs* medical therapy in reduction of primary end-point, which was a composite of death, stroke, TIA or SE. No such outcomes were reported in the PC trial. In the CLOSE trial, the only trial to compare the anti-platelet agents to oral anticoagulants, the patients in the anti-platelet arm could receive aspirin or aspirin with clopidogrel or with extended release dipyridamole and patients in the oral anticoagulants arm could take either vitamin K antagonists (93%) or direct oral anticoagulants (7%). There were numerically fewer recurrent strokes in the anticoagulation group compared to the antiplatelet group in the intention-to-treat cohort; however, the trial was not powered to detect a difference in such a comparison. Therefore, there is a need for randomized trials with large study population powered to compare the PFO closure to anticoagulation therapy, and anticoagulation to anti-platelet therapy to address the efficacy and safety of anticoagulation therapy compared to antiplatelet therapy and PFO closure.

There was a significant increase in the risk of AF in the PFO closure group compared to the medical therapy group in our meta-analysis, a finding that was reported in several individual trials (CLOSE, REDUCE, CLOSURE-I) and observational studies that used different devices<sup>[18,19]</sup>. Most of the cases occurred within 30-45 d of the procedure and the majority were transient without recurrence at long-term follow-up (Table 1). This finding suggests that the PFO closure itself could increase the risk for developing AF. However, the significance and clinical relevance of AF associated with PFO closure and the subsequent risk of stroke remains unclear and warrants additional investigations.

### Study limitations

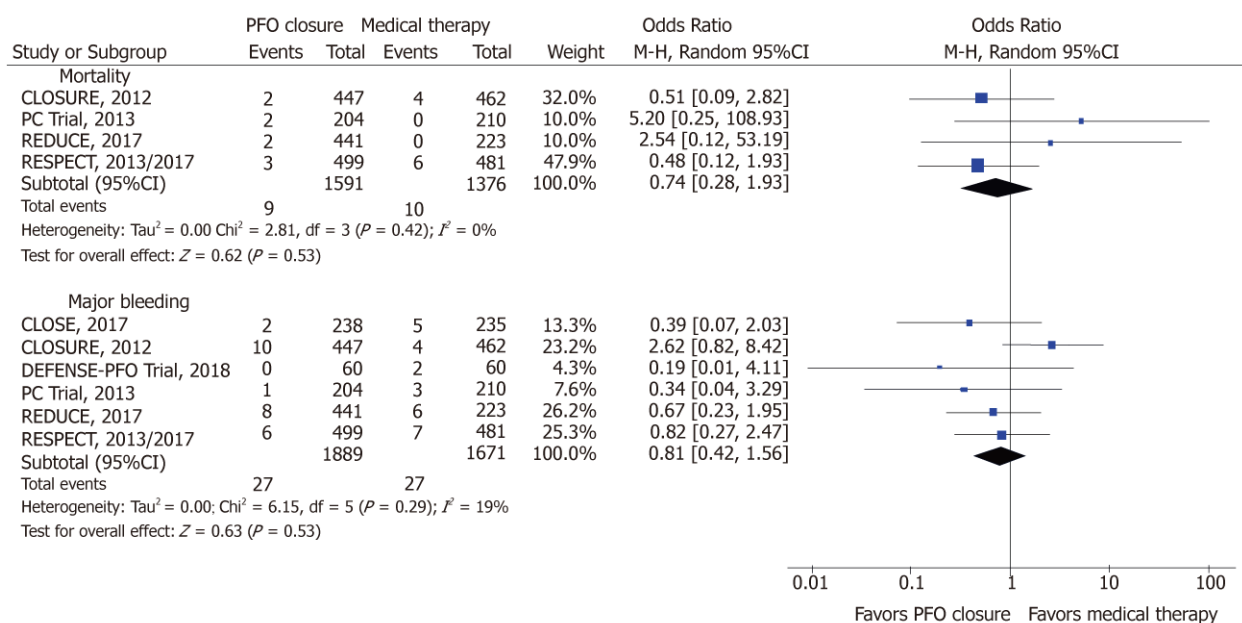


Figure 3 Forest Plot for mortality and major bleeding. PFO: Patent foramen ovale.

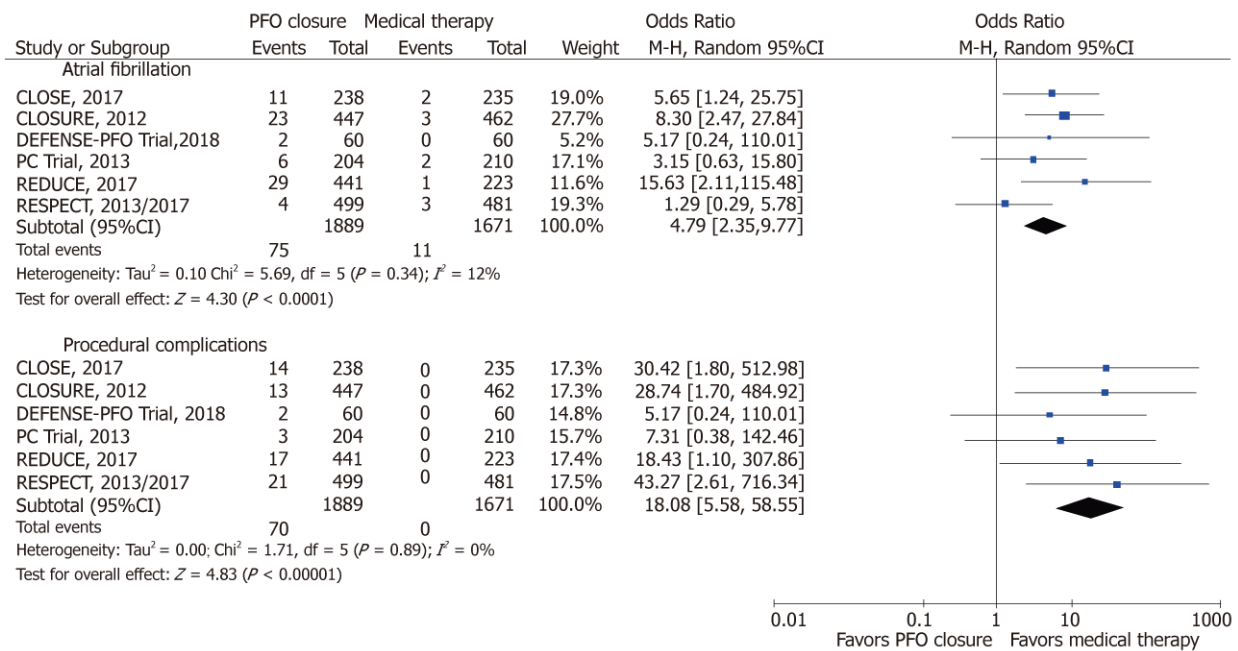
The studies were not blinded, which is always a problem in the procedural trials. The medical therapy arms were heterogenous, which limits our ability to make a definite statement regarding specific medical treatment. The subgroup analyses should be interpreted with caution as not all studies reported those outcomes, which reduced the number of individual patients for analysis. However, this meta-analysis is strengthened by in-depth analysis on the type of patients who may benefit from PFO closure compared to medical therapy.

In conclusion, patients with PFO and cryptogenic stroke benefit from percutaneous closure more so in certain population. Further research is needed to assess how the increased periprocedural AF from PFO closure impacts these patients and how does PFO closure compare with anticoagulation in head-to-head trials.

**Table 3** Procedural success and complications

Study name, year	Total patients PFOC	Type of Device	Success of device implantation	Success of PFO closure	Procedural complications	Atrial fibrillation/flutter in PFOC, n (%)	Timing of Afib/flutter	Recurrence of Afib/flutter at f/u
CLOSE <sup>[6]</sup> , 2017	238	11 different devices	234/235 (99.6)	202/228 (88.6)	14/238 (5.9)	11 (4.6)	10/11 within a month	None
CLOSURE I <sup>[11]</sup> , 2012	447	STARFlex device	362/405 (89.4)	315/366 (86.1)	13/402 (3.2)	23 (5.7)	14/23 within a month	6 persistent
PC Trial <sup>[9]</sup> , 2013	204	Amplatzer PFO occluder	188/196 (95.9)	142/148 (95.9)	3/204 (1.5)	6 (2.9)	Timing not defined	1 persistent
REDUCE <sup>[8]</sup> , 2017	441	Helex or Cardioform Septal Occluder	408/413 (98.8)	408/413 (98.8)	11/441 (2.5)	29 (6.6)	24 within 45 d	Not defined
RESPECT <sup>[7]</sup> , 2017	499	Amplatzer PFO occluder	462/464 (99.1)	NR	25/499 (5.0)	7 (1.4)	Periprocedural period	NR
Defense Trial PFO <sup>[14]</sup> , 2018	60	Amplatzer PFO occluder	53/60 (88.3)	53/53 (100)	2/60 (3.3)	2 (3.3)	1 periprocedural	NR

Afib: Atrial fibrillation; f/u: follow-up; NR: Not reported; PFOC: Patent foramen ovale closure.

**Figure 4** Forest plot for atrial fibrillation and procedural complications. PFO: Patent foramen ovale.

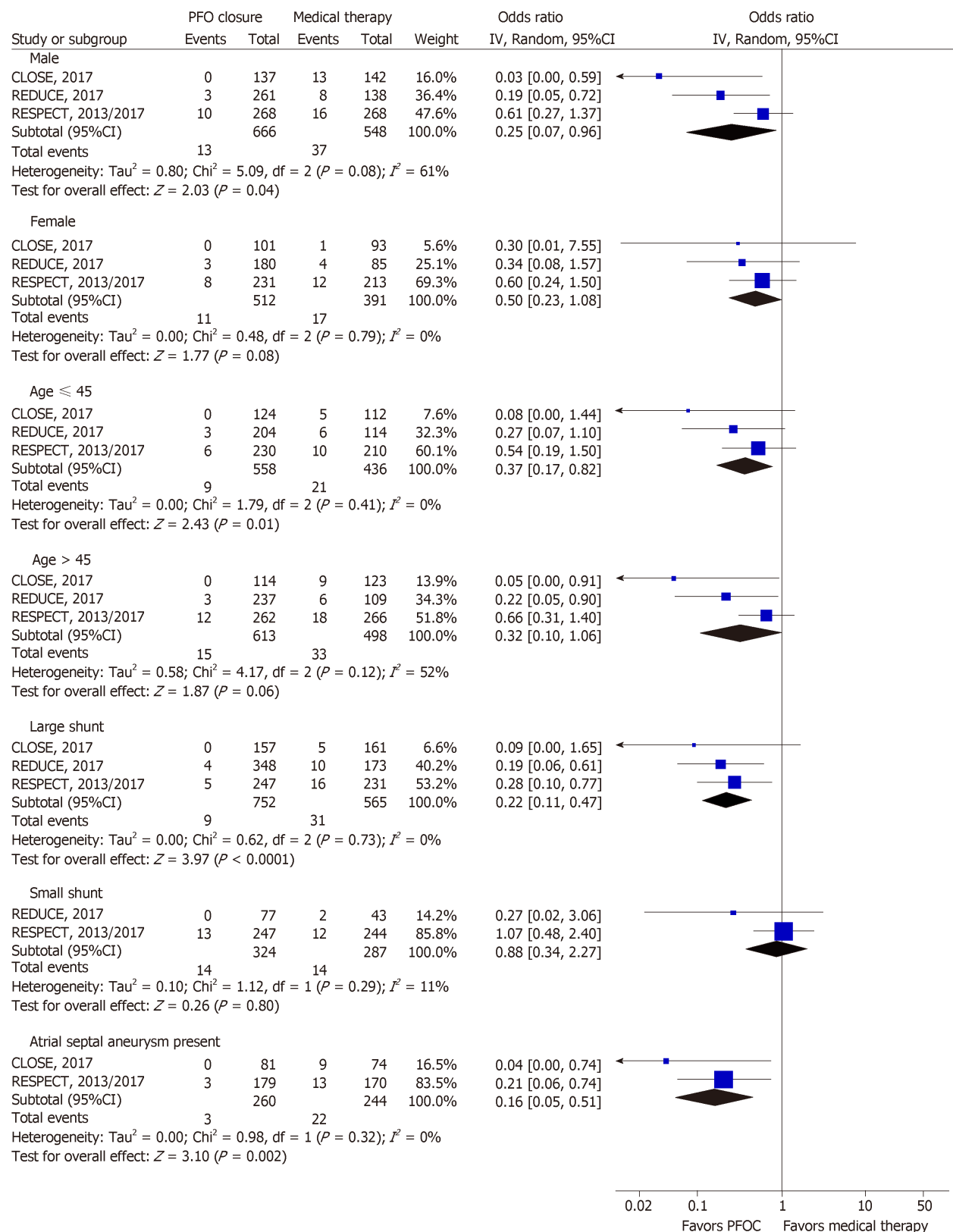


Figure 5 Subgroup analysis of stroke recurrence. PFOC: Patent foramen ovale closure.

## ARTICLE HIGHLIGHTS

## Research background

A few randomized clinical trials (RCT) and their meta-analyses have found patent foramen ovale closure (PFOC) to be beneficial in prevention of stroke compared to medical therapy.

### Research motivation

Whether the benefit is extended across all groups of patients remains unclear.

### Research objectives

To evaluate the efficacy and safety of PFOC *vs* medical therapy in different groups of patients presenting with stroke, we performed this meta-analysis of RCTs.

### Research methods

Following standard technique, a meta-analysis of randomized clinical trials was performed. Random-effects model was used to analyze summary results.

### Research results

PFO closure is beneficial in preventing stroke in patients with stroke and a PFO. In certain population, the benefits are clear.

### Research conclusions

This study showed that PFO closure is beneficial in patients with PFO and stroke. It was beneficial in patients who were male, younger than 45, had atrial septal aneurysm and had a large shunt.

### Research perspectives

Future research should compare anticoagulation *vs* PFO closure and establish whether PFO closure can be useful in all group of patients.

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