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ORIGINAL ARTICLE

Far-infrared therapy on arteriovenous fistula among hemodialysis patients: A systematic review and meta-analysis

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Abstract

Background: Far-infrared (FIR) is one of the alternative therapies used to improve the performance of arteriovenous fistula (AVF) in hemodialysis patients. This review was done to pool the mean difference of vascular access flow and AVF diameter between the FIR and the control group. It also pooled the risk ratio of 1-year unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction between groups.

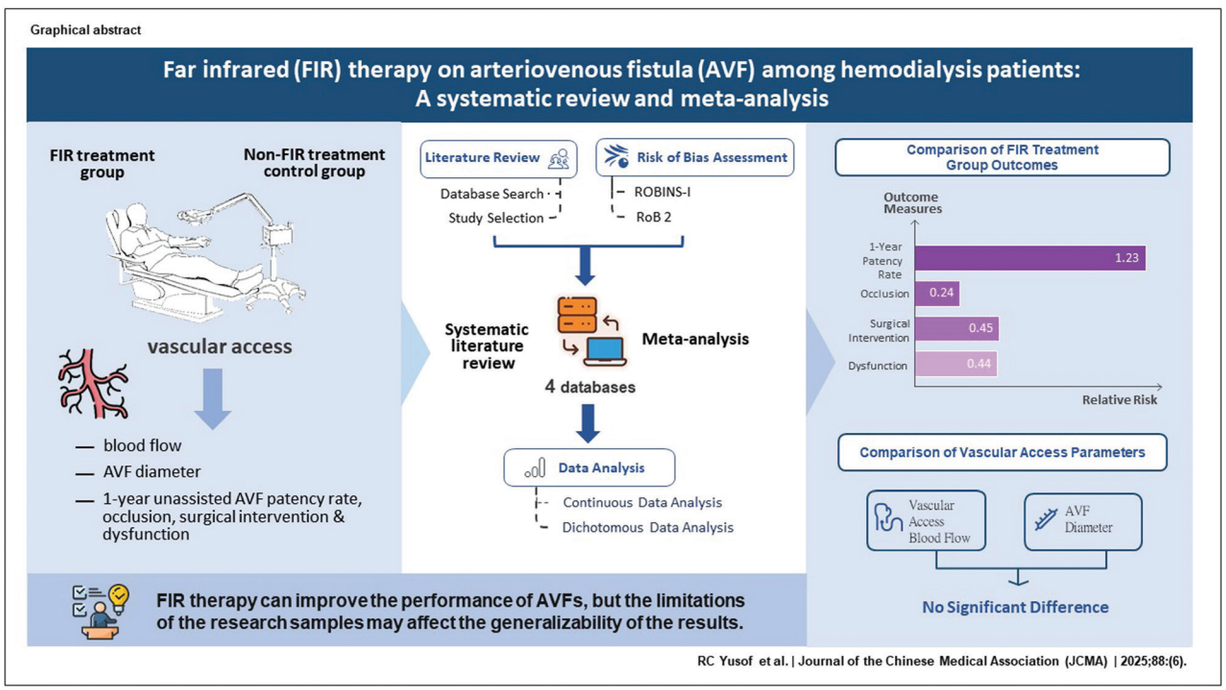
Methods: The studies were reviewed using a systematic review, meta-analysis, and a search of four databases. The risk of bias in non-randomized studies of interventions (ROBINS-I) and the Revised Cochrane risk-of-bias instrument for randomized trials (RoB-2) were used to assess the data quality. The meta-analysis was performed using the random-effects model by inverse variance to measure the mean difference for continuous data and the Mantel-Haenszel method for dichotomous data.

Results: FIR therapy group had a significant difference in risk ratio in 1-year unassisted AVF patency (risk ratio: 1.23 [95% CI, 1.12-1.36]), AVF occlusion (risk ratio: 0.24 [95% CI, 0.08-0.68]), surgical intervention (risk ratio: 0.45 [95% CI, 0.23-0.86]), and AVF malfunction (risk ratio: 0.44 [95% CI, 0.30-0.62]) compared with the control group. However, for vascular access flow and AVF diameter, there was no difference between the groups (mean difference: 68.38 [95% CI, –3.84 to 140.61] and –0.07 [95% CI, –0.31 to 0.17], respectively).

Conclusion: The findings showed that the FIR therapy improved AVF performance. However, the limited number of studies primarily from Taiwanese may act differently from others.

Keywords: Arteriovenous fistula; Far-infrared therapy; Hemodialysis; Meta-analysis; Systematic review

Graphical abstract



Lay Summary: Far-infrared therapy improved blood flow through access points and significantly enhanced how long these access points remained functional without requiring intervention. It reduced the risk of access point malfunction by 56%, decreased complete blockage by 76%, and lowered the need for surgical procedures by 55% for kidney dialysis patients. It appears to be a valuable approach for maintaining healthier dialysis access points, potentially leading to fewer complications and better patient outcomes.

1. INTRODUCTION

Many innovations were created for hemodialysis assessment. Arteriovenous fistula (AVF) is a preferred option for vascular assessment in hemodialysis patients.[1] The other options are arteriovenous graft and central vein catheter.[2] The AVF has a longer patency, fewer complications, and lower death rates.[3,4] However, because of early thrombosis and maturation failure, the AVF is more susceptible to primary failure and worsens since the proportion of frail old patients is rising, which could further reduce AVF performance, given the shifting patient demographics.[5] Patient-related factors, including failure in AVF maturation, contribute to some of the disparity in mortality.[4]

AVF maturation is necessary for repeated cannulation and adapting the cannula implanted. It can be measured by factors such as vascular access flow through the AVF, the diameter of the arterial and venous limbs of the AVF, and its wall thickness.[6] Far-infrared (FIR) therapy is one of the procedures for AVF maturation and has mainly been researched in Taiwanese patients. The review described the FIR waves as undetectable electromagnetic waves that can enhance endothelial function and cutaneous vascular access flow. It is administered to the location of arteriovenous anastomosis of an AVF using an FIR wave emitter with wavelengths between 5 and 25 mm from a height of 20 cm above the AVF for 40 minutes, for a few weeks to 12 months during hemodialysis.[7] There are a variety of probable mechanisms of action, such as heat effects, activation of the L-arginine nitric oxide pathway, suppression of inflammation, a reduction in oxidative injury, and a reduction in neointimal hyperplasia.[2]

According to a meta-analysis, FIR therapy can dramatically improve the diameter and primary patency of AVFs as well as their maturity and function. It can also lower the likelihood that an AVF would occlude and the discomfort associated with needling.[8] Another meta-analysis concurred that FIR therapy might positively affect the complex process of AVF maturation by raising both primary and secondary patency rates and necessitating fewer interventions to restore a dysfunctional AVF.[9] However, both meta-analysis studies were done in the Taiwanese population.

Therefore, this review aimed to pool the mean difference (MD) of vascular access flow and AVF diameter between the FIR therapy and control groups and the risk ratio of 1-year unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction compared between the FIR therapy and control group among hemodialysis patients in multi-population.

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2. METHODS

2.1. Study design

A systematic review and meta-analysis of studies were performed to assess the MDs in vascular access flow and AVF diameter between the FIR therapy and the control groups, as well as the risk ratio of patients with 1-year unassisted AVF patency, secondary (assisted) AVF patency, AVF occlusion, surgical intervention, and AVF malfunction between the FIR therapy group and the control group in hemodialysis patients. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines were followed.[10] This review was registered in the PROSPERO database (CRD42023394039). To make sure that the measurement of interest outcomes is consistent with the study objectives and that the review is appropriate if it has not gone beyond data extraction, search results were formally evaluated against eligibility criteria before being submitted to PROSPERO. This step also included doing preliminary searches and piloting the research selection procedure. After registration, data extraction for this review officially began.

2.2. Search strategies

A comprehensive search was conducted in the PubMed, EBSCOhost, Cochrane Library, and Scopus databases. The keywords far infrared, AVF, hemodialysis, and trial were used in the search. The Medical Subject Headings (MeSH) and text words were combined. The search keywords were adaptable to many electronic databases. All published studies were obtained to determine their suitability for inclusion in this analysis. The searches were limited to full-text articles in English. Reference lists of included citations were cross-checked to locate other potentially acceptable research.

2.2.1. Eligibility criteria

Study designs such as case reports, conference papers, proceedings, articles available only in abstract form, editorial reviews, letters of communication, commentaries, systematic reviews, and qualitative studies were excluded from this review. Only randomized control, clinical, and case–control trials were selected to be included in this review. This search was also limited to published studies in English.

2.2.2. Study selection and screening

All records found using our search approach were saved to the EndNote program. Articles that were duplicated were removed. The titles and abstracts of the identified papers will be checked by two independent reviewers (RCY and MNN). All the texts of the qualifying research were obtained and thoroughly studied to determine their appropriateness. If there was a disagreement between the two reviewers, a consensus meeting was held, and a third reviewer (MYA) was consulted. The PRISMA flowchart depicted the search strategy, including the included and excluded studies and the reasons for exclusion.

2.2.3. Definition of outcome interest

The main study outcomes were the MDs in vascular access flow and AVF diameter between the FIR therapy group and the control group. The risk ratio between the FIR therapy and control groups was also measured to compare the outcomes of 1-year unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction.

2.2.4. Quality assessment and bias

The data quality was assessed using the Revised Cochrane risk-of-bias instrument for randomized trials (RoB-2) and the risk of bias in non-randomized studies–of interventions (ROBINS-I) assessment tool. Two authors independently assessed the bias.

2.3. Data extraction process

Population, Intervention, Comparison, and Outcomes (PICO) guidelines were used to extract the data into Microsoft Excel. This included the first author, the year of publication, the study location, the study design, the study population, the sample size, the setting, the vascular access flow (Qa), the AVF diameter, the 1-year unassisted AVF patency, the AVF occlusion, surgical intervention, and the AVF malfunction.

2.4. Statistical analysis

Measurement of outcomes at baseline and the end of the study (within a group), as well as between the FIR therapy and the control groups (between groups), were collected from the studies and documented in Excel format. The mean and pooled SD were used for within-group comparison to determine the MD. Meanwhile, MDs and SDs of within-group outcomes from each group were used to determine the MD of the between-group comparison. These measurements included the following outcomes:

a. Vascular access flow
b. AVF diameter

Meanwhile, the risk ratio between the FIR therapy and control groups was calculated using the Mantel-Haenszel method by a random effect model. The estimated pooled risk ratio with a 95% CI was presented. This measurement included the following outcomes:

a. 1-year unassisted AVF patency
b. AVF malfunction
c. AVF occlusion
d. Surgical intervention

The analyses were carried out using the Review Manager software version 5.4. (Nordic Cochrane Centre). The MD outcomes were pooled using a generic inverse variance with a random-effects model, and the risk ratio was measured using Mantel-Haenszel with a random-effects model. The I^2 statistic was employed to assess heterogeneity, and the following guidelines were followed: 0% to 40% may not be significant; 30% to 60% may indicate moderate heterogeneity; 50% to 90% may represent significant heterogeneity; and 75% to 100% would consider considerable heterogeneity.[11] The publication bias was not assessed since this review only involved seven studies, and it was unreliable to test. Generally, testing for funnel plot asymmetry should not be performed in meta-analyses with less than 10 studies because the test power is typically insufficient to distinguish between chance and actual asymmetry.[12]

3. RESULTS

3.1. Study selection

Search strategies cumulated a total of 211 published studies from the four databases. After removing the duplicate studies and screening, 124 were assessed for eligibility. Studies of 117 were excluded from the review, and only seven studies were selected to be included in the study. However, one study[13] was

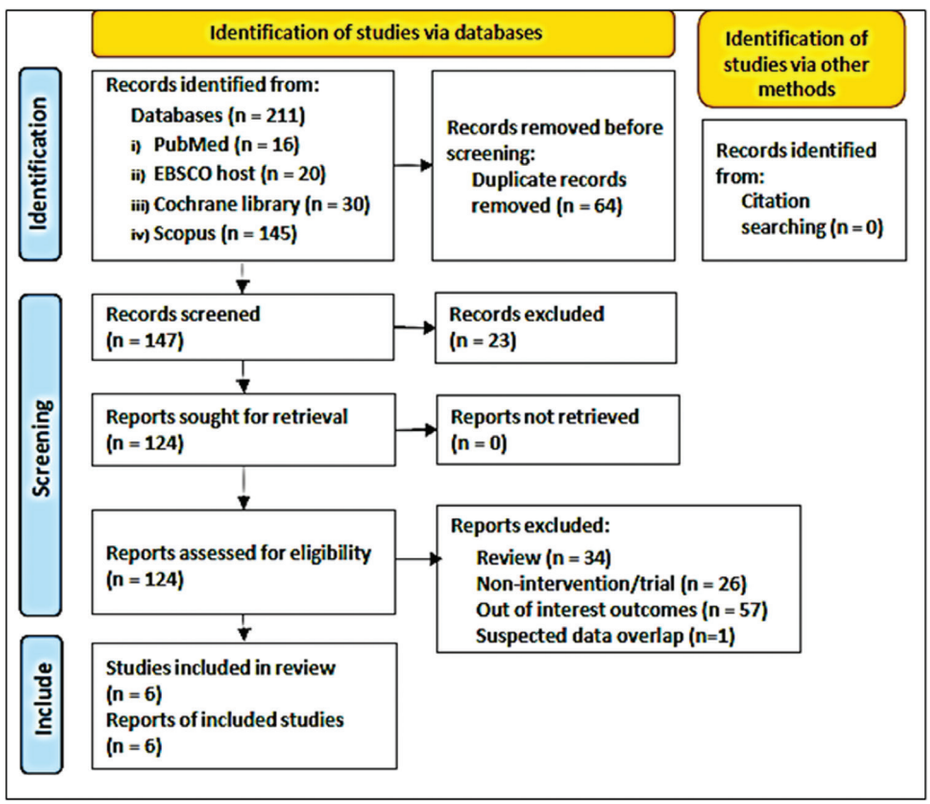

Fig. 1 A PRISMA flowchart of the review. PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

removed due to suspected data overlaps, and only six studies were reported in this review (Supplementary Table S1, https://links.lww.com/JCMA/A327). A PRISMA flowchart summarized the study selection in detail, as shown in Fig.1.

3.2. Study characteristics

The six studies selected for this review were designed as trial studies involving 738 participants. Five studies[6,7,14–16] were randomized control trials, and the other one[17] was non-randomized control trial. The studies were primarily done in Taiwan (n = 4),[14–16,18] and one study each from India[6] and Korea.[17] All the studies used a WS TY101 FIR emitter as an FIR therapy lamp except for study[6] that used a TDP FIR lamp (model: KS 9800) for the therapy. The intervention therapy was done in 40 minutes per session, three times weekly for all the studies except for study,[6] which was done twice weekly for 40 minutes per session.

3.3. Risk of bias assessment

The risk of bias was assessed by RoB-2 (Supplementary Table S2, https://links.lww.com/JCMA/A328) for five studies[6,14–16,18] and ROBIN-I (Supplementary Table S3, https://links.lww.com/JCMA/A329) for nonrandomized study.[17] All studies had a low risk of bias.

3.4. Results of individual study

3.4.1. Mean differences

MDs were measured for the two continuous outcomes: vascular access flow and AVF diameter. Table 1 summarizes the results of the MDs for the outcomes.

3.4.1.1. Vascular access flow Five studies reported the effect of FIR on vascular access flow. Three comparisons were made for this outcome: within-group comparisons involving the MDs between the study end and baseline for the FIR therapy and control groups and between-group comparisons involving the MDs between the FIR therapy and control groups (Fig.2).

Within FIR therapy group comparison: MDs between the study end and baseline ranged between 131.80 and 300.40 mL/min, with the pooled MD being 202.68 mL/min (95% CI, 140.31-265.06) (Fig. 2A). This showed that the vascular assessment flow for the FIR therapy group increased at the study end

Table 1

Mean differences for the vascular assess flow and the AVF diameter

Outcome	Studies	n	MD (95% CI)	I^2 (%)	*p*
Vascular assess flow					
Within FIR therapy group	5	305	202.68 (140.31-265.06)	11	0.350
Within control group	5	314	106.68 (13.07-200.29)	71	0.009
Between-groups	5	619	68.38 (–3.84 to 140.61)	0	0.950
AVF diameter					
Within FIR therapy group	2	118	1.74 (–1.31 to 4.79)	99	<0.001
Within control group	2	111	1.85 (–1.31 to 5.00)	100	<0.001
Between-groups	2	229	–0.07 (–0.31 to 0.17)	0	0.730

AVF = arteriovenous fistula; FIR = far-infrared; MD = mean difference.

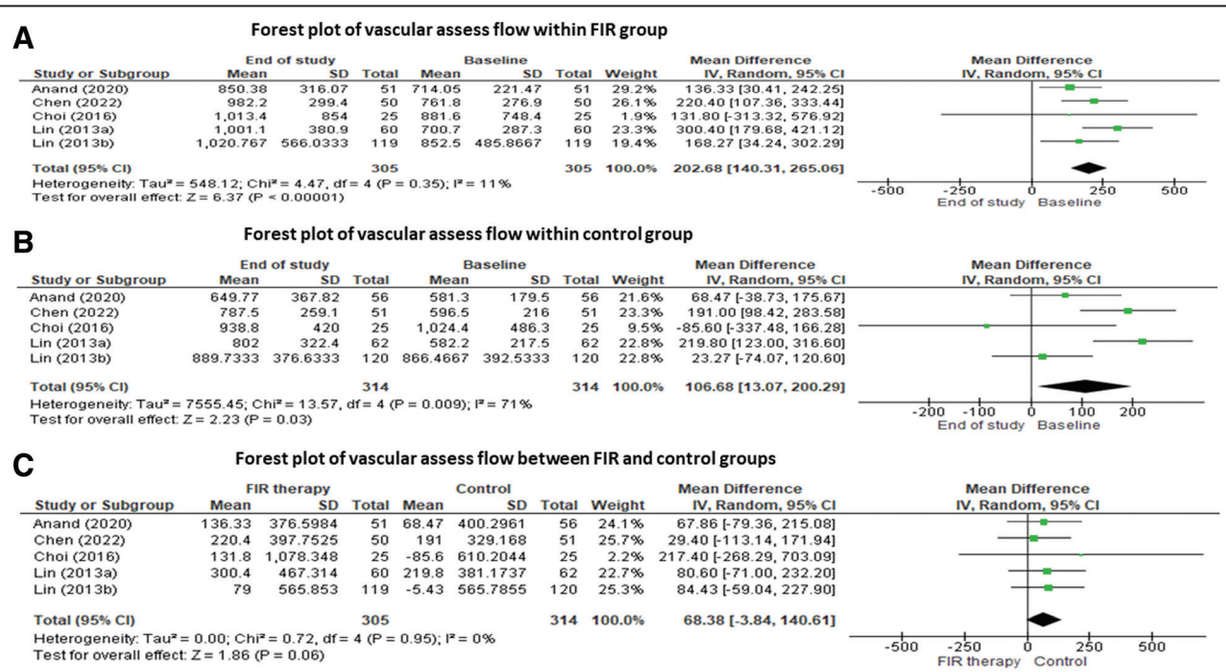

Fig. 2 Forest plots of the vascular assessment flow; (A) forest plots of the vascular assessment flow within FIR group; (B) forest plots of the vascular assessment flow within control group; (C) forest plots of the vascular assessment flow between FIR and control group. FIR = far-infrared.

compared to the baseline. The I^2 statistic was 11% (p = 0.35), indicating insignificant heterogeneity.

Within control group comparison: MDs between the study end and baseline ranged between −85.60 and 219.80 mL/min. The pooled MD for this group was 106.68 mL/min (95% CI, 13.07-200.29) (Fig. 2B). The vascular assessment flow was slightly increased in some studies and decreased in two. The I^2 statistic was 71% (p < 0.009), representing significant heterogeneity.

Between FIR therapy and control groups comparison: MDs between the FIR therapy and control group ranged between 29.40 and 217.40 mL/min. The pooled MD of vascular access flow between FIR therapy and control groups for the six studies was 68.38 mL/min (95% CI, −3.84 to 140.61) (Fig. 2C) with an I^2 statistic of 0% (p = 0.95), indicating insignificant heterogeneity. The FIR therapy group increased the vascular assessment flow compared to the control group.

3.4.1.2. AVF diameter Only two studies reported the AVF diameter as an outcome. Comparisons were made within the groups and between the FIR therapy and control groups (Fig. 3).

Within FIR therapy group comparison: The FIR therapy group showed an insignificant increase in the diameter of AVF at the study end compared to the baseline, with a pooled MD of 1.74 mm (95% CI, −1.31 to 4.79) (Fig. 3A). The I^2 statistic was 99% (p < 0.001), indicating considerable heterogeneity.

Within control group comparison: In the control group, the diameter of AVF increased insignificantly at the study end compared to the baseline, with a pooled MD of 1.85 mm (95% CI, −1.31 to 5.00) (Fig. 3B). The I^2 statistic was 100% (p < 0.001), indicating considerable heterogeneity. The subgroup analysis was not done due to the small number of included studies.

Between FIR therapy and control groups comparison: There was no difference in AVF diameter between the FIR therapy and control groups, with a pooled MD of −0.07 mm (95% CI, −0.31 to 0.17) (Fig. 3C). The I^2 statistic was 0% (p < 0.73), indicating insignificant heterogeneity.

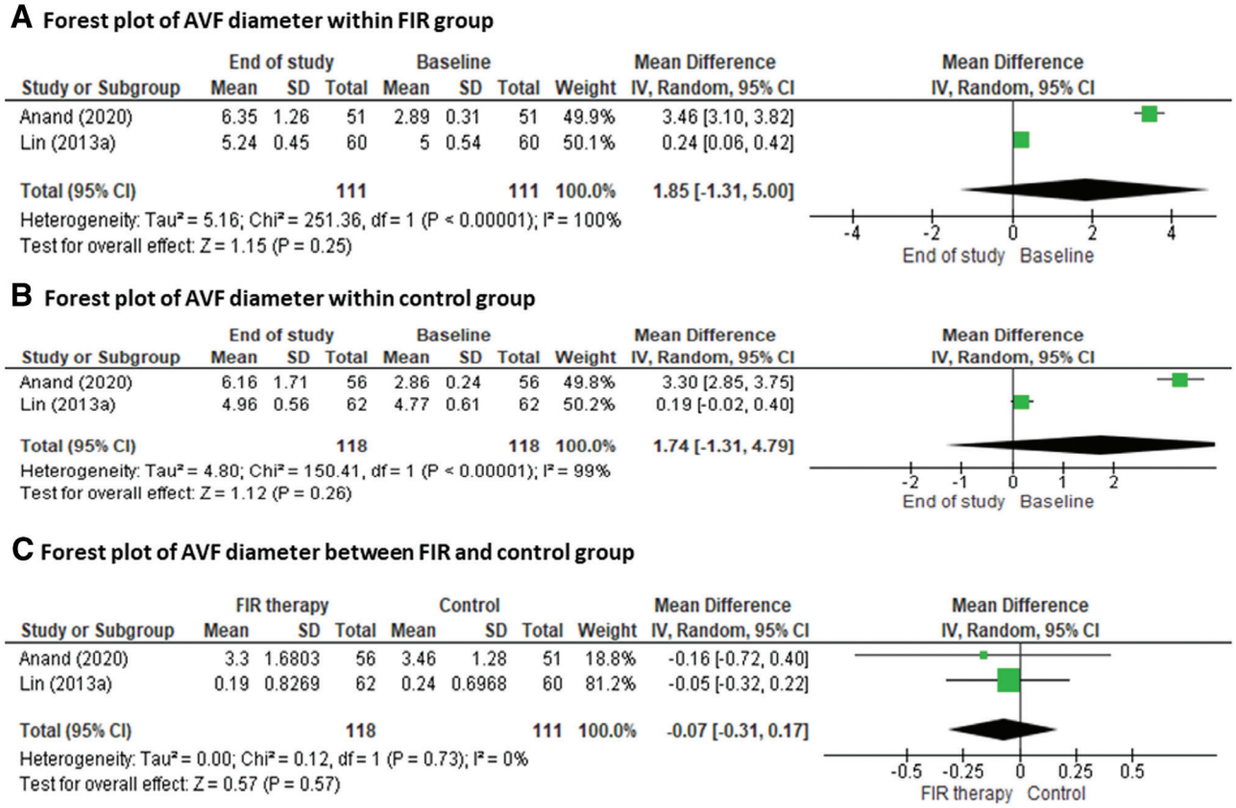

Fig. 3 Forest plots of the AVF diameter; (a) forest plots of the AVF diameter within FIR group; (b) forest plots of the AVF diameter within control group; (c) forest plots of the AVF diameter between FIR and control group. AVF = arteriovenous fistula; FIR = far-infrared.

Table 2

Pooled risk ratio for the 1-y unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction

Outcome	Studies	n	RR (95% CI)	I^2 (%)	p
1-y primary AVF patency rates	5	629	1.23 (1.12-1.36)	0	0.970
AVF malfunction	4	569	0.44 (0.30-0.62)	0	0.990
AVF occlusion	2	223	0.24 (0.08-0.68)	0	0.590
Surgical intervention	2	223	0.45 (0.23-0.86)	0	0.580

AVF = arteriovenous fistula; RR = risk ratio.

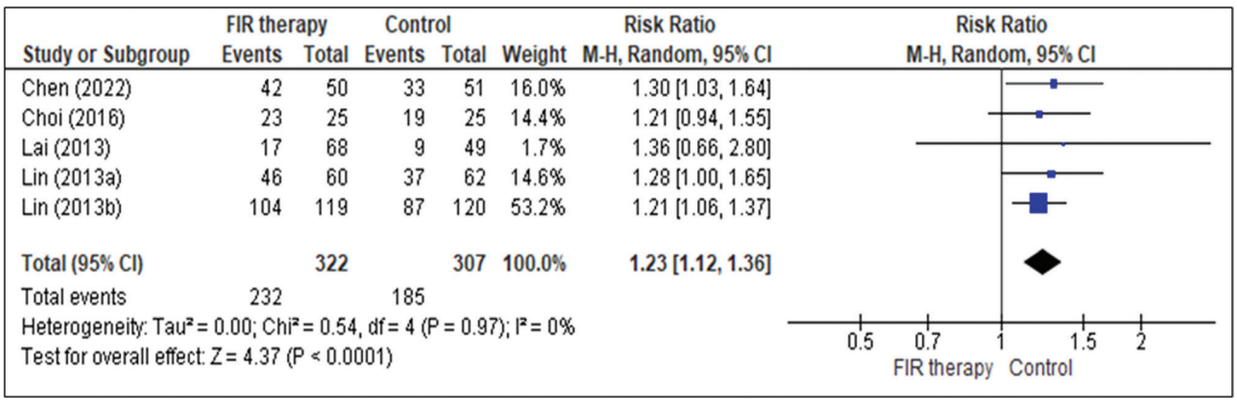

Fig. 4 Forest plot of the 1-y unassisted AVF patency. AVF = arteriovenous fistula; FIR = far-infrared.

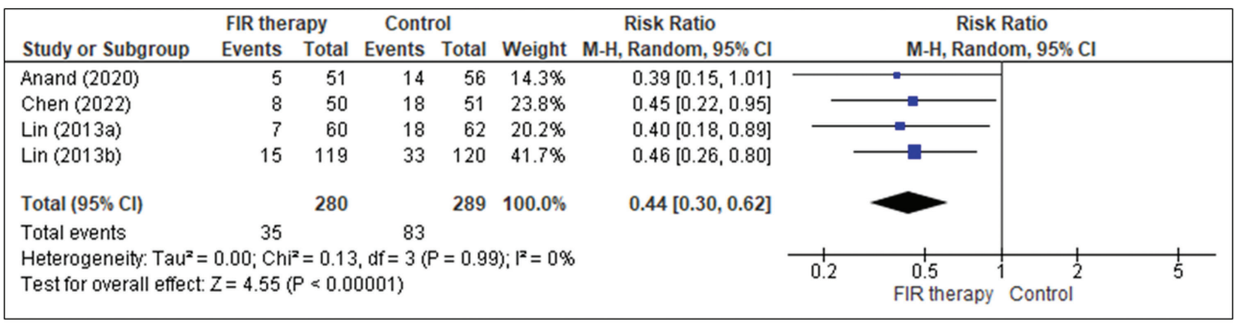

Fig. 5 Forest plot of the AVF malfunction. AVF = arteriovenous fistula; FIR = far-infrared.

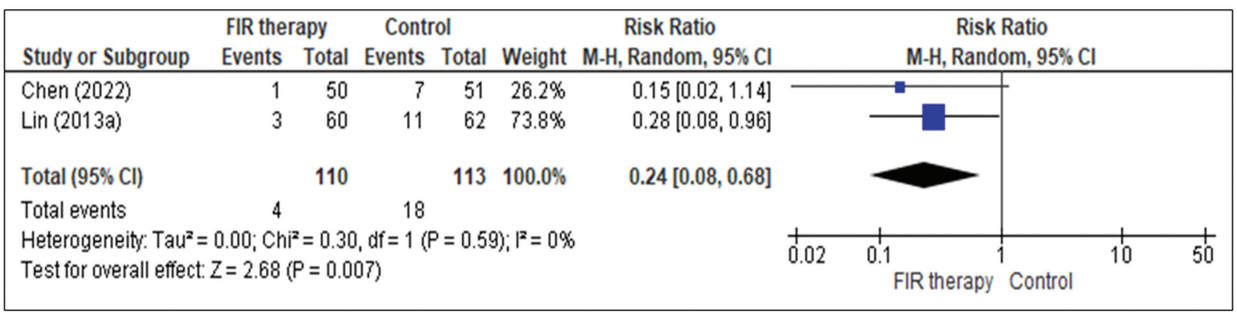

Fig. 6 Forest plot of the AVF occlusion. AVF = arteriovenous fistula; FIR = far-infrared.

3.4.2. Risk ratio

The risk ratio was measured for 1-year unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction outcomes. Table 2 summarizes the pooled risk ratio for the outcomes.

3.4.2.1. 1-Year unassisted AVF patency The pooled risk ratio of 1.23 (95% CI, 1.12-1.36) (Fig. 4) indicated that the FIR therapy group had better 1-year unassisted AVF patency rates than the control group. The range of risk ratios was between 1.21 and 1.36, with I^2 statistics of 0% (p = 0.97) showing insignificant heterogeneity.

3.4.2.2. AVF malfunction Five studies reported AVF malfunction as an outcome. The FIR therapy had a protective risk of AVF malfunction compared with the control group (pooled risk ratio: 0.44 [95% CI, 0.30-0.62]) (Fig. 5). The I^2 was 0% (p = 0.99), indicating insignificant heterogeneity.

3.4.2.3. AVF occlusion The FIR therapy group had a protective risk of AVF occlusion compared to the control group by a pooled risk ratio of 0.24 (95% CI, 0.08-0.68) (Fig. 6) from two studies. The heterogeneity was insignificant (I^2 statistic = 0%, p = 0.59).

3.4.2.4. Surgical intervention The FIR therapy group showed a decreased risk of surgical intervention compared to the control group by a pooled risk ratio of 0.45 (95% CI, 0.23-0.86) (Fig. 7) in three studies. The heterogeneity was insignificant (I^2 statistic = 0%, p = 0.58).

4. DISCUSSION

This review pooled the MD in vascular access flow and AVF diameter between the FIR therapy and the control groups. The FIR therapy increased the vascular access flow but not the AVF diameter. This review also determined the positive results

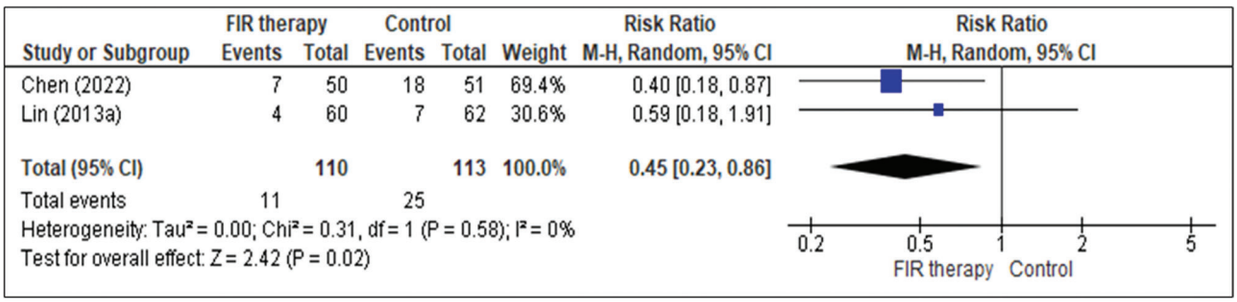

Fig. 7 Forest plot of the surgical intervention. FIR = far-infrared.

from the pooled risk ratio for 1-year unassisted AVF patency, AVF occlusion, surgical intervention, and AVF malfunction. However, only seven studies were included to pool the findings from Taiwanese (five studies), Korean (one study), and South Indian (one study) populations.

A previous meta-analysis[8] involving 10 trials found an increased vascular access flow by an MD of 81.69 mL/min (95% CI, 46.17-117.21) between FIR therapy and control groups. It was higher than the current review (68.38 mL/min [95% CI, –3.84 to 140.61]; five studies). Meanwhile, a study conducted in Sweden[19] discovered that a single exposure to FIR dramatically improves vascular access flow velocity in the AVF region. A 3-month trial[20] recommended additional research with a larger population and a longer duration of FIR exposure to evaluate the effect of FIR on vascular access flow. It was reported that FIR increased the vascular access flow 3 months after the baseline, but the difference was not statistically significant.

For AVF diameter in this review involving two studies, there was an insignificant increase in the diameter for both groups. A previous review[8] found that the MD in AVF diameter level between FIR therapy and control groups was 0.36 mm (95% CI, 0.22-0.51). It involved five studies, three of which were not published in English. Meanwhile, according to a Swedish study,[19] one episode of 40 minutes of exposure to FIR improved AVF venous diameter. According to a systematic review, a minimal venous diameter between 2.5 and 4 mm was needed to predict AVF maturation confidently.[21]

Meanwhile, the pooled risk ratio of the 1-year unassisted AVF patency in this review was similar to previous studies.[8,9] The FIR therapy had a protective rate of the 1-year unassisted AVF patency compared with the control group. The 1-year unassisted AVF patency in two meta-analysis studies[5,22] was more than 60%. There was variation in the patency rate across the included studies. The study from the Netherlands[23] suggested that the variation in patency rate was impacted by regional standards practices and expertise in maintaining AVF patency.

Based on an evidence-based medicine review,[24] the AVF malfunction was reduced significantly by the FIR therapy, similar to this review. AVF malfunction was defined as the requirement for any interventional treatment (surgery or angioplasty) to rectify an occlusive or malfunctioning AVF that could not sustain an extracorporeal blood flow of >200 mL/min during hemodialysis. The FIR therapy had a protective risk from AVF malfunction. AVF malfunction is one of the leading causes of morbidity and hospitalization in patients receiving hemodialysis.[16] It is impacted by insufficient vascular access due to thrombosis, recognized as a major factor of AVF primary failure and long-term vascular damage.[25]

In addition, therapy with FIR could also decrease AVF occlusion rates (pooled risk ratio: 0.20 [95% CI, 0.08-0.46]) by a meta-analysis study.[8] The finding was similar to this review (pooled risk ratio: 0.24 [95% CI, 0.08-0.68]). As soon as the AVF occlusion occurs, rescue therapy must be administered promptly and correctly to guarantee the continued use of AVF.[26]

Surgical intervention, one of the assistance intervention procedures besides angioplasty and thrombectomy, has been used to expedite fistula maturation and boost the number of functional AVFs when AVF maturation fails.[27] In this review, FIR therapy lowered the risk of surgical intervention, and the pooled risk ratio between FIR therapy and the control group was 0.45 (95% CI, 0.23-0.86). Similar results were reported in a previous review.[9] The difference between these two reviews was the number of studies involved in pooling the risk ratio.

There were limited studies worldwide on FIR therapy on AVF among hemodialysis patients. Since the data were mostly from the Taiwanese population, this meta-analysis may be introduced to the selection bias. There was an intervention trial on the Danish population,[28] but it was not included in this meta-analysis since the outcomes differed. The study's validity entirely depended on the reporting studies since the data were derived from the studies. Overlapping data might have happened if studies[16,18] came from the same trial.

In conclusion, this review's findings showed that the FIR therapy improved vascular access flow and AVF diameter. It also increased the 1-year unassisted AVF patency rate and had a protective risk toward AVF malfunction, AVF occlusion, and surgical intervention compared to the control group. FIR therapy improved the performance of AVF for vascular access in hemodialysis patients. However, available data did not represent the variety of populations worldwide. More trials should be conducted to collect more evidence of FIR therapy on AVF in different populations with longer duration of trials.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://links.lww.com/JCMA/A327.

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