Journal of the Saudi Heart Association

Volume 36 | Issue 2 Article 8

2024

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Recommended Citation

Omer, Ibrahim; Bukhari, Mohammed; Alsharif, Mohammad; Alsamadani, Abdulrahman; Alahmadi, Dinah; Alsudais, Ali Saleh; Abdulkareem, Abdullah; and Alamir, Hashem Alhashmi (2024) "Ultrasound-Guided vs. Standard Coronary Access in Coronary Angiography: A Systematic Review and Meta-Analysis," *Journal of the Saudi Heart Association*: Vol. 36 : Iss. 2 , Article 8.
Available at: https://doi.org/10.37616/2212-5043.1383

REVIEW ARTICLE

Ultrasound-guided vs. Standard Coronary Access in Coronary Angiography: A Systematic Review and Meta-analysis

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Abstract

Objectives: **Coronary angiography is a procedure performed during cardiac catheterization to define the coronary anatomy and determine the extent of coronary artery disease (CAD). The use of a cheap, relatively available tool like an ultrasound machine to assist in vascular access might reduce the risks associated with blind access. This study aimed to explore the efficacy and associated complications of ultrasound-guided coronary artery catheterization.**

Methods: **This systematic review of randomized controlled trials (RCTs) was conducted according to the Preferred Reporting Item for Systematic Reviews and Meta-Analysis (PRISMA) and was registered in PROSPERO (CRD42022365518). A systematic search was performed for all published studies without language or country restrictions and all study variables were extracted into prefilled sheets by two independent reviewers.**

Results: **This meta-analysis identified 10 RCTs. The results confirmed statistically significantly reductions of total complications (RR = 0.53, 95% CI 0.39−0.72, P < .001), and hematoma >5 cm formation (RR = 0.43, 95% CI 0.25−0.75, P = 0.003) in patients who underwent ultrasound-guided coronary artery catheterization.**

Conclusion: **Ultrasound with catheterization, as opposed to landmark-based catheterization, significantly improved the peri-catheterization operative outcomes, providing evidence for further research to be conducted and consideration for its implementation within the medical setting.**

Keywords: Cardiac catheterization, Ultrasound, Coronary angiography

1. Introduction

Coronary angiography is a procedure that can be performed during cardiac catheterization to define the coronary anatomy and determine the extent of coronary artery stenosis in cases of coronary artery disease (CAD). Cardiac catheterization is a versatile procedure, as it can be used in a number of conditions both as a diagnostic and therapeutic tool. Some of its indications include the evaluation of cardiac hemodynamics, left ventricular function, and heart failure; it can also evaluate and have a role in the treatment of CAD, valvular heart disease and cardiac arrhythmias. Coronary angiography involves using anatomical landmarks or ultrasonography to insert a vascular sheath for arterial cannulation through the radial artery, femoral artery, or the brachial artery to insert coronary catheters that enter the left and right coronary ostia with x-ray fluoroscopy guiding the catheter, followed by injection of a radiopaque contrast agent that creates a "luminogram" seen on radiographic videos [1−3]. The prevalence of cardiac catheterization-related complications is less than 2%, and they include allergic reactions to anesthetic or

Received 13 March 2024; revised 5 June 2024; accepted 7 June 2024.
Available online 10 July 2024

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https://doi.org/10.37616/2212-5043.1383

contrast agents, heparin-induced thrombocytopenia (incidence <1%), contrast-induced nephropathy (incidence 3–16.5%), cholesterol embolism (incidence <2%), vascular injury (pseudoaneurysm, hematoma, arteriovenous fistula, etc.), myocardial infarction (mostly in patients with periprocedural symptoms or ischemia on ECG), cerebrovascular complications (most debilitating complication), conduction abnormalities (bradyarrhythmia or tachyarrhythmia), dissection and perforation, hypotension, hypoglycemia, and respiratory insufficiency. Other complications include those caused by radiation exposure [3,4]. Although modern day cardiac catheterization is a relatively safe procedure of great diagnostic and therapeutic value, there are still risks associated with it, some of which depend on the skill and judgement of the operator [4]. Melvinp and Martnip stated that the complication rates at that time were "unacceptably high" and that the competence of the operator was attributed to have a major role [5]. Therefore, the use of a cheap, relatively common tool like an ultrasound machine to assist in vascular access might reduce the risks associated with blind access using anatomical landmarks that might be difficult for inexperienced physicians.

Abbreviations

CAD	coronary artery disease
ECG	electrocardiography
PRISMA	Preferred Reporting of Systematic Reviews and Meta-Analyses
ACUITY	the acute catheterization and urgent intervention triage strategy
MACE	major adverse cardiovascular events
ROB2	Cochrane risk of bias assessment tool for randomized trials
NK	natural killer cell(s)
CTL	cytotoxic T lymphocyte(s)
RR	risk ratio
CI	confidence interval

2. Methods

2.1. Registration

The protocol of this systematic review and meta-analysis was registered in the PROSPERO online database (identifier no. CRD42022365518). The study was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guideline.

2.2. Data sources and searches

An extensive literature search identified studies without country or language restrictions. The search was carried out in the four electronic databases and registries, including PubMed, ClinicalTrials.gov, Directory of Open Access Journals, and Web of Science. Furthermore, references to relevant studies were searched for further studies. The predefined keywords used in this study included (I) Ultrasound; (II) US; (III) Femoral; (IV) Catheterization; (V) Cath; (VI) I OR II; (VII) II AND III AND IV; (VIII) IV OR V.

2.3. Eligibility criteria

Two reviewers blindly screened all 423 articles in duplicate based on titles and abstracts for eligibility criteria. This systematic review included randomized controlled trials of patients undergoing ultrasound-guided coronary angiogram versus standard coronary angiogram. All studies with different study designs (i.e cohort) were excluded.

2.4. Data extraction and risk of bias

Two independent reviewers extracted data regarding patients' demographics as well as adverse effects following IVUS or standard angioplasty into pre-built tables. The Acute Catheterization and Urgent Intervention Triage Strategy (ACUITY), mechanical complications, and major adverse cardiovascular events (MACE) were among the variables which were included. A third independent reviewer was approached in the case of a disagreement between the reviewers.

The studies included in the meta-analysis were assessed using the Improved Cochrane Risk of Bias Assessment Tool for Randomized Trials (ROB2) [6] by two independent reviewers. The ROB2 tool incorporates five domains such as randomization, deviation from the intended intervention, and missing outcome data to determine the quality of a study.

2.5. Statistical analysis

Statistical analysis was carried out using the Comprehensive Meta-analysis Version 3 (Biostat, Inc. Eaglewood, New Jersey, USA). A confidence interval of 95% and a P value < 0.05 were considered significant. The fixed-effects model was also incorporated to estimate the relative risks.

3. Results

3.1. Study selection

A thorough systematic literature search was conducted in 3 databases and 1 registry. After removing

2 duplicate records before screening, the search yielded a total of 423 potentially pertinent studies. Two independent reviewers screened the titles and abstracts of all the identified studies according to our eligibility criteria. Only 20 studies met our inclusion criteria. Disagreements between authors after the screening phase were resolved by a third author. An overall number of 10 studies were considered eligible for inclusion in this review [7–16] (Fig. 1).

3.2. Study characteristics

In this systematic review, all included studies were randomized controlled trials (RCTs). Included trials were conducted in Europe, North America, China, and Australia in the period between 2004 and 2021. A total of 3983 patients were assessed in all 10 trials. While nine of the studies were RCTs, one study was a post hoc analysis of RCTs (see Table 1, supplementary). All patients in the included trials underwent either ultrasound-guided or standard approach to coronary angiography with one study [9] subdividing the ultrasound guided group to either trans-femoral or trans-radial approaches. Variables such as procedural success, first pass success, total complications, and hematoma of size >5 cm were used to determine if ultrasound guided approach is superior to the standard approach. Tables 1–5 (supplementary) show the patients' demographic data and parameters assessed in each RCT.

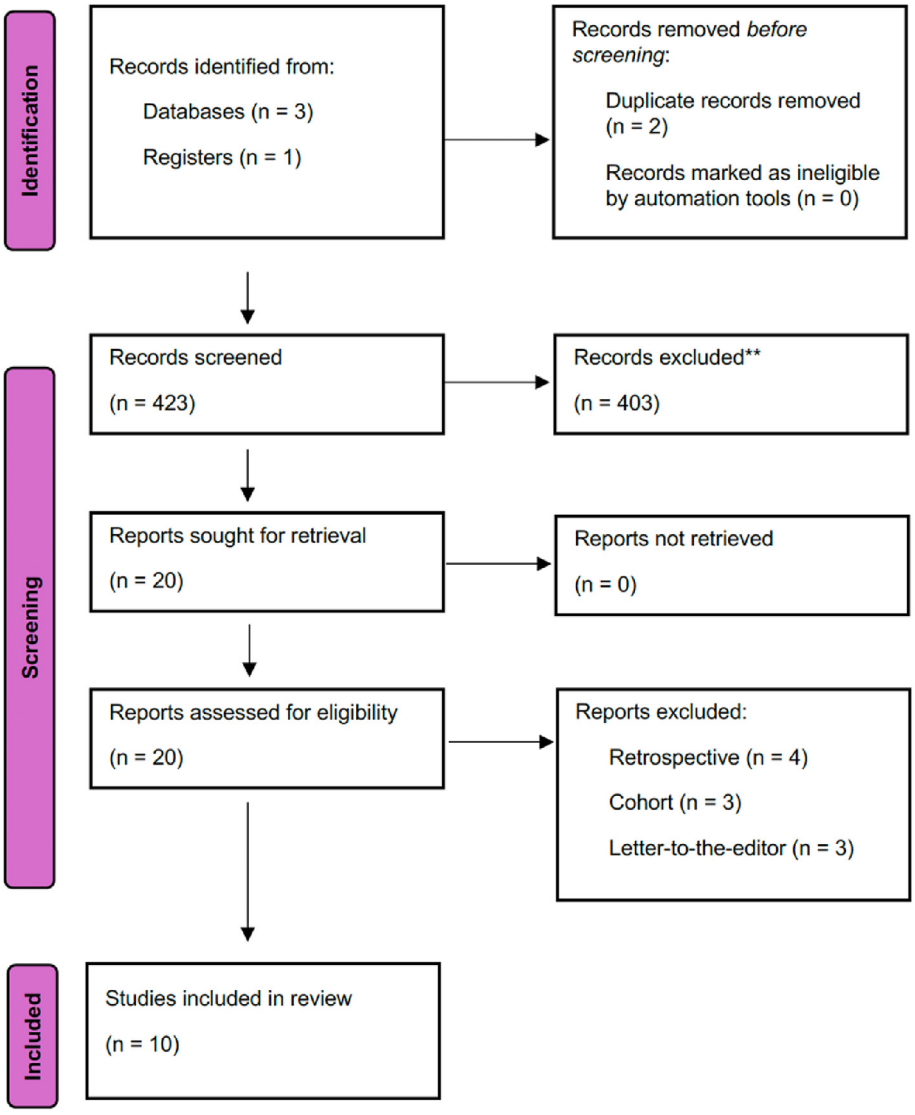

Fig. 1. PRISMA flowchart.

Table 1. Participants' characteristics.

Study/ First author	Patients (n)	Age (years)	Male	BMI (kg/m^2)	Hypertension	Hyperlipidemia	DM	Smoker	Prior MI	Prior PCI
	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio	IVUS/Angio
[7]	67/69	44.5(27-60-)/51 (34–62)	56/46	24.7 (22.6–28.0)/24.7 (22.7–27.3)	NA	NA	NA	NA	NA	NA
[8]	688/700	63.38/63.60	488/518	28.85/28.51	444/467	434/425	226/246	421/436	101/115	141/140
[9]	228/85	63.41/65.20	All are women	30.41/30.12	195/73	194/69	98/36	69/21	63/19	101/38
[10]	64/65	65 (58–72)/67 (59–72)	48/47	27.5 (24.8–31.2)/27.2 (24.4–30.9)	51/52	57/55	19/22	13/25	NA	36/39
[11]	501/503	63.5/64.2	371/366	30.1/29.4	426/427	405/387	203/182	226/184	NA	NA
[12]										
[13]	38/42	56.4/53.7	23/28	NA	15/10	10/10	8/5	19/25	NA	NA
[14]	108/100	59.0/59.5	70/66	26.2/26.6	NA	NA	NA	NA	NA	48/34 (only previous ipsilateral puncture)
[15]	56/54	60/60	32/36	NA	NA	NA	NA	NA	NA	NA
[16]	53/47	68/66	38/31	25.7/25.3	NA	NA	NA	NA	NA	NA

IVUS: intravascular ultrasound; Angio: angiography (standard); DM: diabetes mellitus; MI: myocardial infarction; PCI: percutaneous coronary intervention; NA: not applicable.

3.3. Heterogeneity and bias

Some of the studies in this review had some concerns of bias due to biases in selected results and/or data outcome measurements [Figs. 2 and 3]. However, none of the included studies had high levels of bias arising from any of the subdomains of ROB2 criteria.

3.4. Procedural failure

Our meta-analysis of procedural success included a total of 344 patients [7,14]. Among included individuals, a significant difference was observed (Risk Ratio [RR] = 0.16, 95% Confidence Interval [CI] = 0.05–0.47, P = <.001, I^2 = 0%). Procedural failure was significant higher in the control group in contrast to the ultrasound-guided group. Only two of the total 10 studies were included as the rest did not report procedural success, which in turn may have contributed to the significant heterogeneity among included RCTs [see Fig. 4].

3.5. First-pass failure

A sum of 2600 individuals were included in our meta-analysis for first-pass success. Significant differences were observed among the 3 included studies (Risk Ratio [RR] = 0.49, 95% Confidence Interval [CI] = 0.44–0.55, P < .001, I^2 = 94%), favoring ultrasound guidance [8,11,14]. The control group reflected significant first-pass failure compared to the ultrasound-guided approach despite high heterogeneity [see Fig. 5].

3.6. Total complications

A total of 2082 participants were included in our meta-analysis for total complications [7,9–11,13–16]. Significant differences were observed among the included population (Risk Ratio [RR] = 0.53, 95% Confidence Interval [CI] = 0.39–0.72, P = 0.0001, I^2 = 0%), favoring ultrasound guidance. No significant heterogeneity was observed [see Fig. 6].

3.7. Hematoma >5 cm

A total of 2528 participants were included in our meta-analysis for hematoma formation (size > 5 cm) [7,8,11]. Significant differences were observed among the included population (Risk Ratio [RR] = 0.43, 95% Confidence Interval [CI] = 0.25–0.75, P = 0.003, I^2 = 0%). Hematoma size of more than 5 cm significantly favored the

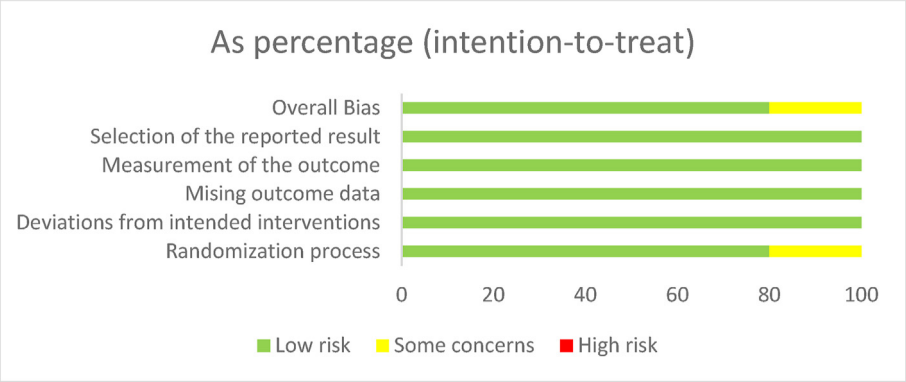

Fig. 2. Weighted-bar plot of the risk of bias.

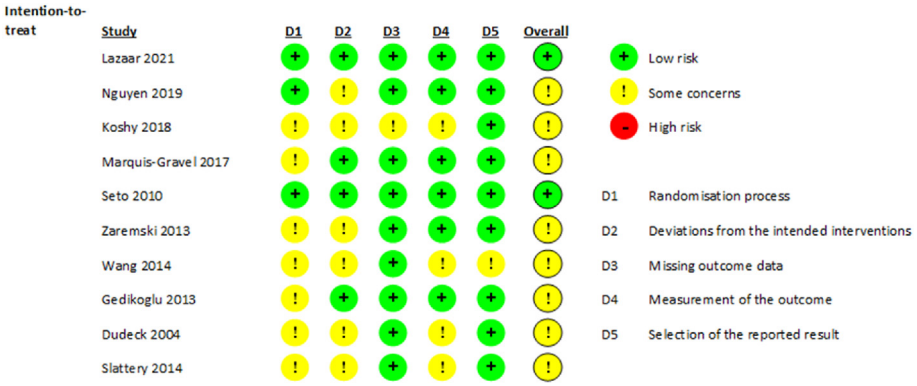

Fig. 3. Traffic–light plot of the risk of bias.

Fig. 4. Procedural failure.

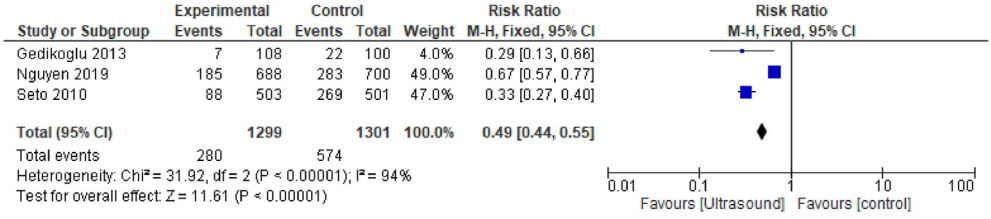

Fig. 5. First-pass failure.

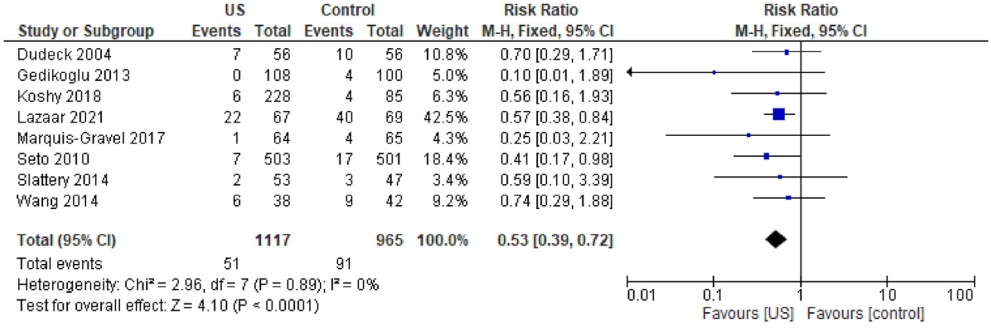

Fig. 6. Total complications.

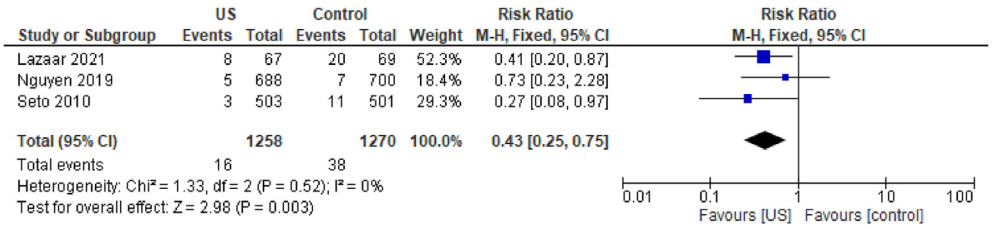

Fig. 7. Hematoma >5 cm.

ultrasound group over the control group [see Fig. 7].

3.8. Immediate and delayed complications

Only one study [7] reported immediate and delayed complications in both arms, with unguided coronary angiography reporting more complications (immediate complications 35, delayed complications 16) than ultrasound-guided angiography (immediate complications 18, delayed complications 7).

4. Discussion

While arterial pulsation provides easier arterial access via landmark palpation, the absence of venous pulse, physiologically, has prompted the use of ultrasound to guide vascular access such that nowadays ultrasound-guided venous catheterization is considered the norm in the healthcare setting [17]. It is of particular note that ultrasound-guided venous access reduced the number of total complications, increased the number of vascular access success rates, and reduced the number of attempts at cannulation [18].

In accordance with studies conducted on venous cannulation, our study presented findings that suggested significantly reduced risk of procedural failure (Risk Ratio [RR] = 0.16, 95% Confidence Interval [CI] = 0.05–0.47, P = <.001, I2 = 0%), first-pass failure (Risk Ratio [RR] = 0.49, 95% Confidence Interval [CI] = 0.44–0.55, P < .001, I2 = 94%), total complications (Risk Ratio [RR] = 0.53, 95% Confidence Interval [CI] = 0.39–0.72, P = 0.0001, I2 = 0%), and hematoma > 5 cm (Risk Ratio [RR] = 0.43, 95% Confidence Interval [CI] = 0.25–0.75, P = 0.003, I2 = 0%); albeit the high heterogeneity, which we attribute to the limited number of RCTs included in this meta-analysis. Nevertheless, it is of note that these favorable outcomes existed despite that the use of ultrasonography remains a highly operator-dependent approach, as evidenced by findings from Seto et al. [11] that had included operators with limited training in ultrasonography. Furthermore, this meta-analysis included studies, such as the one conducted by Gedikoglu et al. [14], that reported favorable outcomes despite the exclusion of patients without a palpable pulse, adding another dimension of strength to this meta-analysis.

Favorable outcomes in this systematic review were not only limited to the before mentioned variables but also included less mean access attempts, immediate complications, delayed complications, ACUITY major bleeding, and MACE complications with the use of ultrasound-guided arterial access (Tables 2–4). However, such outcomes were limited

Table 2. Complications.

Study/First author	ACUITY Major Bleeding		MACE	
	IVUS	Angio	IVUS	Angio
[7]	N/A	N/A	N/A	N/A
[8]	9	10	3	7
[9]	N/A	N/A	N/A	N/A
[10]	N/A	N/A	N/A	N/A
[11]	N/A	N/A	N/A	N/A
[12]	NA	NA	NA	NA
[13]	NA	NA	NA	NA
[14]	NA	NA	NA	NA
[15]	NA	NA	NA	Na
[16]	NA	NA	NA	NA

IVUS: intravascular ultrasound; Angio: angiography (standard); MACE: Major Adverse Cardiac Events; NA: not applicable.

Table 3. Procedural specifics.

Study/First author	Mean Access Attempts		Mean Access Time (s)	
	IVUS	Angio	IVUS	Angio
[7]	2	3	103	121
[8]	1.47	1.90	93.10	111.03
[9]	NA	NA	NA	NA
[10]	NA	NA	NA	NA
[11]	1.3	3	185	213
[12]	NA	NA	NA	NA
[13]	NA	NA	NA	NA
[14]	NA	NA	68.6	94.3
[15]	1.93	2.16	208	197
[16]	NA	NA	466	581

IVUS: intravascular ultrasound; Angio: angiography (standard); NA: not applicable.

Table 4. Studies' endpoints.

Author	Design	Country	Primary endpoint	Follow-up	Sample size		
					Standard	Ultrasound-guided	Total
[7]	RCT	France	Occurrence of one or more mechanical com- plications within 7 days of femoral catheterisation (haematoma, bleeding, a non-functional catheter, and undesired puncture)	7 days	69	67	136
[8]	RCT	Australia	The composite of ACUITY (Acute Catheterization and Urgent Intervention Triage strategY)15 major bleeding, major adverse cardiovascular events (MACE) com- prising death, stroke, myocardial infarction or urgent target lesion revascularisation, and vascular complications at 30 days. The secondary endpoints were access time, number of attempts, venepuncture, difficult accesses and first-pass success. All patients were followed up at one week and one month.	1 week and 1 month	700	688	1388
[9]	POST HOC analysis	USA	Bleeding or vascular complications requiring interven- tion occurring within 72 h of the procedure or by hos- pital discharge, whichever came first. Bleeding was defined according to the BARC definitions,8 and the endpoint of interest for the study included a composite of BARC type 2, 3, or 5 bleeding events. Vascular com- plications were defined as any of the following that required surgical intervention, including thrombin in- jection: arteriovenous fistula, arterial pseudoaneurysm, or arterial occlusion.	30 days	415 TFA: 85 TRA: 330	228	643
[10]	RCT	USA, Canada	A composite of immediate procedural outcomes and access-site outcomes at day one. Immediate procedural outcomes included: access failure, $\geq$1 puncture attempts, transfixing arterial puncture, venipuncture, and catheter insertion outside of the CFA boundaries.	NOT MENTIONED	65	64	129
[11]	RCT	USA	Successful common femoral artery (CFA) cannulation by femoral angiography	30 days	501	503	1004
[12]	RCT	Switzerland	Not stated	Not stated	91	92	183
[13]	RCT	china	Clinical outcomes of PPCI versus the best medical care in the treatment of STEMI patients with HTB, 50–75% residual stenosis or critical lesions after aspiration thrombectomy, and TIMI grade 3 flow.	2–3 weeks, 1, 3, 6, and 12 months postoperatively	42	38	80
[14]	RCT	Turkey	First pass and technical successes, total number of at- tempts, time to sheath insertion, access-related compli- cation, and pain during puncture	N/A	100	108	208
[15]	RCT	Germany	Procedural time and number of attempts for successful puncture	3 days	56	56	112
[16]	RCT	Ireland	Immediate complications and time post administration of anesthetic to vascular sheath insertion	N/A	47	53	100

RCT: Randomized Controlled Trial; NA: not applicable.

by limited study reporting, which hindered the formation of further meta-analyses. Considerable limitations of this study included the limited number of RCTs included, the inclusion of operators with limited in ultrasonography in some RCTs, and the high heterogeneity. We recommend that further RCTs be conducted in order to limit heterogeneity and provide more evidenced recommendation for the use of ultrasonography in conjunction with coronary catheterization.

5. Conclusion

Ultrasound with catheterization, as opposed to landmark-based catheterization, significantly improved the peri-catheterization operative outcomes, providing evidence for further research to be conducted and consideration for its implementation within the medical setting.

Author contributions

Conception and design of Study: IO. Literature review: IO, MB, MA. Acquisition of data: AA, DA, ASA, AA. Analysis and interpretation of data: IO. Research investigation and analysis: IO, MB, MA, AA. Data collection: DA, ASA, AA, HAA. Drafting of manuscript: IO, MB, MA, AA, DA, ASA, AA, HAA. Revising and editing the manuscript critically for important intellectual contents: IO, MB, MA, AA, DA, ASA, AA, HAA. Data preparation and presentation: IO, MB, MA, AA, DA, ASA, AA. Supervision of the research: HAA. Research coordination and management: IO. Funding for the research: IO.

Conflicts of interest

The authors of this study declare no conflict of interest.

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