

Research Article

Short- and Long-Term Prognosis of Intravascular Ultrasound-Versus Angiography-Guided Percutaneous Coronary Intervention: A Meta-Analysis Involving 24,783 Patients

Qun Zhang,^{1,2,3,4} Bailu Wang,⁵ Yu Han,^{1,2,3,4} Shukun Sun,^{1,2,3,4} Ruijuan Lv^(D),^{1,2,3,4} and Shujian Wei ^{1,2,3,4}

¹Department of Emergency and Chest Pain Center, Qilu Hospital, Cheeloo College of Medicine, Shandong University, Jinan, Shandong 250012, China

²Clinical Research Center for Emergency and Critical Care Medicine of Shandong Province,

Institute of Emergency and Critical Care Medicine of Shandong University, Qilu Hospital, Cheeloo College of Medicine, Shandong University, Jinan, Shandong 250012, China

³Key Laboratory of Emergency and Critical Care Medicine of Shandong Province,

Key Laboratory of Cardiopulmonary-Cerebral Resuscitation Research of Shandong Province, Qilu Hospital,

Cheeloo College of Medicine, Shandong University, Jinan, Shandong 250012, China

⁴The Key Laboratory of Cardiovascular Remodeling and Function Research, Chinese Ministry of Education,

Chinese Ministry of Health and Chinese Academy of Medical Sciences,

The State and Shandong Province Joint Key Laboratory of Translational Cardiovascular Medicine, Qilu Hospital,

Cheeloo College of Medicine, Shandong University, Jinan, Shandong 250012, China

⁵Clinical Trial Center, Qilu Hospital, Cheeloo College of Medicine, Shandong University, Jinan, Shandong,250012, China

Correspondence should be addressed to Ruijuan Lv; ruijuanlv@126.com and Shujian Wei; weishujian@sdu.edu.cn

Received 11 May 2021; Revised 15 September 2021; Accepted 21 September 2021; Published 15 October 2021

Academic Editor: Joseph Dens

Copyright © 2021 Qun Zhang et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Background. Intravascular ultrasound (IVUS) guided percutaneous coronary intervention (PCI) has potential benefits. This metaanalysis aimed to explore whether IVUS-guided PCI had better short- and long-term prognoses than angiography-guided PCI. Methods. We retrieved studies from PubMed, Embase, and Cochrane Library. Clinical trials including retrospective and randomized controlled trials (RCTs) that compared IVUS-guided PCI with angiography-guided PCI were included. The patients were followed up after operation at 30 days, 1 year, 2 years, and 3 years. The clinical outcomes were target lesion revascularization (TLR), target vessel revascularization (TVR), and MACEs, including stent thrombosis (ST), myocardial infarction (MI), cardiac death, and all-cause death. The study population included patients with MI, coronary bifurcation lesions, short or long lesions, and unprotected left main coronary artery stenosis (ULMCA). The quality of retrospective trials was evaluated using the Newcastle-Ottawa Scale, and the quality of randomized controlled trials was evaluated using the Jadad score. A total of 20 clinical trials met the criteria. Three trials were randomized controlled trials, while 17 were retrospective trials. Results. A total of 24,783 patients were included. In observational trials, the OR of MACEs was 0.49 (95% CI: 0.38-0.62) in 30 days, 0.65 (95% CI: 0.58-0.73) in one year, 0.51 (95% CI: 0.36-0.71) in two years, and 0.45 (95% CI: 0.31-0.65) in three years. In patients with long coronary lesions, the OR of MACEs in 1 year was 0.64 (95% CI: 0.28–1.50). In patients with left main artery disease, the OR of MACEs in 3 years was 0.42 (95% CI: 0.26–0.67). Compared with angiography-guided PCI, IVUS-guided PCI was associated with a lower incidence of MACEs during the same following period. Conclusion. Compared with angiography-guided PCI, IVUS-guided PCI has better performance in reducing the occurrence of MACEs.

1. Introduction

Coronary artery disease (CAD) due to blockage or stenosis of the coronary arteries is a major cause of morbidity and mortality worldwide [1]. Coronary revascularization, including percutaneous coronary intervention (PCI) and coronary artery bypass graft (CABG), is the most effective treatment for CAD. PCI has been frequently performed because of its convenience and reduced risk of trauma [2]. However, PCI-related complications, including in-stent restenosis and stent thrombosis, limit its advantages. Thus, improving the procedural technologies of PCI is critical to the clinical outcomes of patients with CAD [3]. The clinical application of IVUS provides more accurate details of coronary lesions by comprehensively evaluating the structure of the coronary arteries [4, 5]. Since IVUS shows the whole coronary vessel wall and lumen, it facilitates the understanding of the pathophysiological process involved in coronary atherosclerosis [6].

The clinical benefits of IVUS-guided PCI were verified by several randomized controlled trials (RCTs). However, in clinical practice, the use of IVUS technology to guide PCI remains low, which may be related to the lack of clinical evidence. This study aimed to provide more detailed clinical evidence for IVUS to optimize PCI. In this meta-analysis, the clinical outcomes of major cardiovascular adverse events (MACEs) were compared between the IVUS-guided PCI group and the angiography-guided PCI group. We investigated the short- and long-term prognoses of IVUS-guided PCI in different populations by merging their follow-up time.

2. Materials and Methods

2.1. Retrieval Strategy. The relevant literature was retrieved by searching Embase, PubMed, Cochrane Controlled Trial Registry, and other online electronic databases. The search terms were as follows: "intravascular ultrasound," "angiography," and "percutaneous coronary intervention." The purpose of our study was to compare the short- and longterm prognoses of the IVUS and angiography-guided PCI in CAD patients. Retrieved trials were further screened to identify studies that meet the criteria.

2.2. Inclusion and Exclusion Criteria. The inclusion criteria were as follows: (1) patients treated with IVUS-guided PCI as the experimental group; (2) patients treated with angiography-guided PCI as the control group; (3) randomized controlled trials or retrospective studies; and (4) no limit for the relevant population, including complex coronary artery disease, and left main artery disease.

2.3. Data Extraction, Quality Assessment, and Study Outcomes. Two researchers extracted data from articles that met the criteria. They subsequently summarized the basic characteristics of these articles, which included the name of the investigator, the date the article was published, study population, follow-up time, study design, and quality assessment score. The following data were then extracted: investigator's name, time of publication, and clinical outcomes. The primary outcomes were MACEs, including stent thrombosis, cardiac death, myocardial infarction, and allcause death. The secondary outcomes were TLR and TVR. We analyzed the occurrence of clinical events in different followup times. Quality assessment was performed for studies that met the criteria. Two tools, the Jadad score and the Newcastle–Ottawa Scale (NOS), were used for quality assessment.

2.4. Statistical Analyses. All of the data were binary variables. Statistical analyses were performed using odds ratio (OR), risk ratio (RR), and 95% confidence interval (CI) to assess the risk of different surgical approaches. Heterogeneity was evaluated using the Q test and the I^2 test. P < 0.1 or $I^2 > 50\%$ corresponded to a greater heterogeneity. Data were analyzed using a random-effects model. The stability of the included studies was assessed by sensitivity analysis. Sensitivity analysis was performed by deleting one study and then repeating the meta-analysis. If $I^2 > 50\%$, we performed sensitivity and subgroup analyses. The full text of the trials that caused the heterogeneity of the analysis results and the explanation on whether to delete the article in the discussion section may be read. The Egger test and the funnel plots were used to assess potential bias. All operations were performed using Review Manager 5.3 software.

3. Results

3.1. Included Studies. We searched related electronic databases, in which a total of 4,072 articles were retrieved. The full text, title, and abstract of the articles were read. Duplicate documents were deleted. In total, 29 articles were retained. The specific details of the 29 articles were discussed by all of the researchers. Among them, nine articles did not meet the inclusion criteria, seven articles were meta-analyses, and the follow-up time of the two other articles could not be classified. The flowchart of literature retrieval is shown in Figure 1.

A total of 20 clinical trials met the criteria [7-26]. Of the 20 trials, three were randomized controlled trials, while the other 17 were retrospective trials. Patients who were treated with IVUS-guided PCI belonged to the experimental group, while those who were treated with angiography-guided PCI belonged to the control group. The types of stents included drug-eluting stents and nondrug-eluting stents. The followup time of the six studies was 30 days; the follow-up time of 13 studies was one year; the follow-up time of five studies was 2 years; and the follow-up time of six studies was 3 years. The clinical endpoints in this trial were TLR, TVR, and MACEs, including ST, MI, cardiac death, and all-cause death. The populations of two studies involved patients with colonial bifurcation lesions; the population of one study was patients with complex lesions; the populations of two studies were patients with long coronary lesions; and the populations of six studies were patients with left main lesions. The basic characteristics of the articles that are included in the meta-analysis are summarized in Table 1.



FIGURE 1: The flowchart of literature retrieval.

| TABLE 1 | : The | characteristics | of | included | studies. |
|---------|-------|-----------------|----|----------|----------|
|---------|-------|-----------------|----|----------|----------|

| Study | Year | No. of participants | Study design | Population | Follow-up time | Quality assessment |
|-----------------------------------|------|---------------------|---------------|------------|---------------------------|--------------------|
| Hong et al. [7] | 2014 | 206/328 | Observational | (1) | 3 months, 1 year, 2 years | 8 |
| Kim et al. [8] | 2011 | 487/487 | Observational | (2) | 3 years | 8 |
| Chieffo et al. [9] | 2013 | 142/142 | RCT | (3) | 30 days, 2 years | 7 |
| Yoon et al. [10] | 2013 | 662/912 | Observational | (4) | 1 year | 8 |
| Park et al. [11] | 2012 | 619/802 | Observational | (5) | 1 year | 8 |
| Claessen et al. [12] | 2011 | 631/873 | Observational | (1) | 30 days, 1 year, 2 years | 9 |
| Kim et al. [14] | 2011 | 269/274 | Observational | (6) | 1 year | 9 |
| de la Torre Hernandez et al. [13] | 2014 | 505/505 | Observational | (7) | 3 years | 8 |
| Ahn et al. [15] | 2013 | 49/36 | Observational | (8) | 2 years | 7 |
| Chen et al. [16] | 2012 | 324/304 | Observational | (9) | 1 year | 8 |
| Park et al. [21] | 2009 | 756/219 | Observational | (10) | 3 years | 9 |
| Kim et al. [39] | 2015 | 201/201 | RCT | (11) | 1 year | 7 |
| Witzenbichler et al. [40] | 2013 | 3349/5234 | Observational | (1) | 1 year | 9 |
| Youn et al. [26] | 2011 | 125/216 | Observational | (12) | 30 days, 1 year, 3 years | 8 |
| Roy et al. [22] | 2008 | 884/884 | Observational | (1) | 30 days, 1 year | 9 |
| Gao et al. [17] | 2014 | 291/291 | Observational | (7) | 1 year | 9 |
| Hong et al. [18] | 2014 | 700/700 | Observational | (6) | 1 year | 9 |
| Kim et al. [20] | 2017 | 122/74 | Observational | (10) | 30 days, 3 years | 9 |
| Tan et al. [23] | 2015 | 40/40 | RCT | (10) | 2 years | 6 |
| Tian et al. [24] | 2017 | 713/1186 | Observational | (10) | 30 days, 1 year, 3 years | 9 |

RCT: randomized controlled trial; (1) patients were treated by DES; (2) patients with bifurcation lesions; (3) patients with coronary complex lesions; (4) patients with coronary short-length lesions; (5) patients were treated by PCI; (6) patients with coronary long lesions; (7) patients with coronary left main lesions; (8) patients with diffuse coronary artery disease; (9) patients with coronary bifurcation lesions; (10) patients with unprotected left main coronary artery lesions; (11) patients with chronic total occlusion; (12) patients with myocardial infarction.

3.2. Primary Outcomes. In observational trials, after a 30-day follow-up period, it was found that IVUS-guided PCI was associated with a lower incidence of ST (OR: 0.46, 95% CI: 0.23–0.96, P = 0.04, $I^2 = 0\%$), MI (OR: 0.57, 95% CI: 0.41–0.81, P = 0.001, $I^2 = 0\%$), cardiac death (OR: 0.37, 95% CI: 0.20–0.70, P = 0.002, $I^2 = 0\%$), all-cause death (OR: 0.48, 95% CI: 0.30–0.79; P = 0.003, $I^2 = 0\%$), and MACEs (OR: 0.49, 95% CI: 0.38–0.62; P < 0.001, $I^2 = 55\%$) (Figure 2). After a 1-year follow-up period, the IVUS-guided PCI was associated with a lower incidence of ST (OR: 0.47, 95% CI: 0.33–0.67, P < 0.001, $I^2 = 4\%$), MI (OR: 0.68, 95% CI: 0.57–0.80, P < 0.001, $I^2 = 14\%$), cardiac death (OR: 0.62, 95% CI: 0.47–0.82, P < 0.001, $I^2 = 0\%$), all-cause death (OR: 0.79,

95% CI: 0.63–0.98, P = 0.03, $I^2 = 0\%$), and MACEs (OR: 0.65, 95% CI: 0.58–0.73, P < 0.001, $I^2 = 48\%$) (Figure 3). At the 2-year follow-up, the IVUS-guided PCI was associated with a lower incidence of ST (OR: 0.28, 95% CI: 0.10–0.80, P = 0.02, $I^2 = 0\%$), MI (OR: 0.57, 95% CI: 0.37–0.87, P = 0.010, $I^2 = 72\%$), and MACEs (OR: 0.51, 95% CI: 0.36–0.71; P < 0.001, $I^2 = 0\%$) (Figure 4). At the 3-year follow-up, the IVUS-guided PCI was associated with a lower incidence of MI (OR: 0.64, 95% CI: 0.49–0.83, P = 0.0009, $I^2 = 5\%$), cardiac death (OR: 0.41, 95% CI: 0.24–0.69, P = 0.0009, $I^2 = 55\%$), all-cause death (OR: 0.54, 95% CI: 0.36–0.81, P = 0.003, $I^2 = 53\%$), and MACEs (OR: 0.45, 95% CI: 0.31–0.65, P < 0.001, $I^2 = 74\%$) (Figure 5). In the

| - | | | | | | | |
|-------------------------|-------------------------|----------------------|-----------|-----------------|---------|---------------------|--|
| IV | US-guid | ed PCI | angiogr | aphy-gi | ided PC | I Odds Ratio | Odds Ratio |
| Study or Subgroup | Events | Total | Events | Total | (%) | M-H, Fixed, 95% Cl | I M-H, Fixed, 95% CI |
| | | | | | (70) | | |
| Claessen 2011 | 10 | 631 | 27 | 873 | 23.9 | 0.50 [0.24, 1.05] | |
| Kim 2017 | 3 | 122 | 7 | 74 | 91 | 0.40 [0.04, 3.30] | |
| Roy 2008 | 6 | 884 | 12 | 884 | 12.8 | 0.50 [0.19, 1.33] | |
| Tian 2017 | 28 | 713 | 66 | 1186 | 51.0 | 0.69 [0.44, 1.09] | |
| Youn 2011 | 0 | 125 | 0 | 216 | | Not estimable | |
| Total (95% CI) | | 2681 | | 3561 | 100 | 0.57 [0.41, 0.81] | • |
| Total events | 48 | | 116 | | | | |
| Heterogeneity: Chi | 2 - 2 19 | f = A(0) | P = 0.65 | $1^2 - 00^{-1}$ | 16 | | |
| Test for overall effect | - 2.49, 0 | 11 – 4 (1 19 (P – | 0.001 | ,1 = 0 | 0 | | |
| MI | | 1)(1 = | 0.001) | | | | |
| Voun 2011 | 1 | 125 | 0 | 216 | 1.5 | 5 22 [0 21 120 04] | |
| Tian 2017 | 3 | 713 | 7 | 1186 | 21.5 | 0.71 [0.18 2.76] | |
| Roy 2008 | 4 | 884 | 12 | 884 | 49.0 | 0.33 [0.11, 1.03] | |
| Kim 2017 | 0 | 122 | 0 | 74 | | Not estimable | - |
| Hong 2014 | 0 | 206 | 4 | 328 | 14.2 | 0.17 [0.01, 3.26] | ← |
| Claessen 2011 | 1 | 631 | 4 | 873 | 13.8 | 0.34 [0.04, 3.09] | · · · · · · · · · · · · · · · · · · · |
| Total (95% CI) | | 2681 | | 3561 | 100 | 0.46 [0.23, 0.96] | • |
| Total events | 9 | | 27 | | | | |
| Heterogeneity: Chi | 2 - 3 41 4 | f = A(0) | P = 0.49 | $t^2 = 00$ | 6 | | |
| Test for overall effor | - 5.41, (-t· 7 - 24 | – 4 (1)8(P – 4 |) ()4) | , 1 = 0 | 0 | | |
| ST | | | | | | | |
| Hong 2014 | 0 | 204 | 0 | 370 | | Not estimable | |
| Kim 2017 | 0 | 200 122 | 1 | 528 74 | 92 | 0.20 [0.01 4 97] | |
| Rov 2008 | 6 | 884 | 15 | 884 | 74.1 | 0.40 [0.15, 1.03] | |
| Tian 2017 | 6 | 713 | 4 | 1186 | 14.8 | 2.51 [0.71, 8.92] | |
| Youn 2011 | 2 | 125 | 0 | 216 | 1.8 | 8.77 [0.42, 184.05] | _ |
| Total (95% CI) | | 2050 | | 2688 | 100.0 | 0.84 [0.44, 1.61] | · · · · · · · · · · · · · · · · · · · |
| Total events | 14 | | 20 | | | | |
| | | 16 2 (| | x ² | | | |
| Heterogeneity: Chi | = 8.30, 0 | 11 = 3(1) | P = 0.04) | ; 1 = 64 | £% | | |
| Test for overall effec | et: $Z = 0.5$ | 52 (P = | 0.60) | | | | |
| TLR | | | | | | | |
| Hong 2014 | 0 | 206 | 3 | 328 | 9.9 | 0.23 [0.01, 4.38] | |
| Kim 2017 | 0 | 122 | 1 | 74 | 6.8 | 0.20 [0.01, 4.97] | |
| Koy 2008 Tion 2017 | 10 | 884 712 | 7 | 884 | 61.6 | 0.58 [0.27, 1.28] | |
| Youn 2011 | 2 | 125 | 1 | 216 | 26 | 3 50 [0 31 38 95] | |
| Total (95% CI) | 2 | 2050 | 1 | 2688 | 100.0 | 0.85 [0.49 1.48] | |
| Total events | 20 | 2050 | 20 | 2000 | 100.0 | 0.05 [0.49, 1.40] | |
| iotai evento | 20 | | 27 | 2 | | | |
| Heterogeneity: Chi | = 6.18, 0 | 4f = 4(1) | P = 0.19) | ; $I^2 = 35$ | 5% | | |
| Test for overall effect | t: $Z = 0.5$ | 57 (P = | 0.57) | | | | |
| TVR | | | | | | | |
| Hong 2014 | 2 | 206 | 2 | 328 | 3.1 | 1.60 [0.22, 11.43] | |
| Kim 2017 | 5 | 122 | 10 | 74 | 24.1 | 0.27 [0.09, 0.83] | |
| Roy 2008 | 15 | 884 | 29 | 884 | 57.6 | 0.51 [0.27, 0.96] | |
| 11an 2017 Youn 2011 | 3 | /13 | 10 | 216 | 15.1 | 0.50 [0.14, 1.81] | |
| Total (05% CI) | 0 | 2050 | 0 | 210 | 100.0 | | |
| Total grants | 25 | 2050 | 51 | 2000 | 100.0 | 0.48 [0.50, 0.79] | • |
| iotai events | 23 | | 51 | | | | |
| Heterogeneity: Chi | = 2.45, 0 | df = 3 (1) | P = 0.49) | ; $I^2 = 0$ | 6 | | |
| Test for overall effect | et: $Z = 2.9$ | 92 (P = | 0.003) | | | | |
| All-cause death | | | | | | | |
| Claessen 2011 | 0 | 631 | 3 | 873 | 8.1 | 0.20 [0.01, 3.82] | |
| Hong 2014 | 1 | 206 | 3 | 328 | 6.4 | 0.53 [0.05, 5.11] | |
| Kim 2017 | 3 | 122 | 9 | 74 | 30.3 | 0.18 [0.05, 0.70] | |
| Koy 2008 Tian 2017 | 6 | 884 | 14 | 884 | 38.6 | 0.42 [0.16, 1.11] | |
| $T_{11} = 1 (050) (CT)$ | 3 | 713 | δ | 1186 | 16.6 | 0.62 [0.16, 2.35] | |
| Total grants | 12 | 2550 | 27 | 5545 | 100.0 | 0.37 [0.20, 0.70] | - |
| iotai events | 15 | | 37 | | | | |
| Heterogeneity: Chi | = 2.01, 0 | df = 4 () | P = 0.73) | ; $I^2 = 0$ | 6 | | |
| Test for overall effect | ct: $Z = 3.0$ |)9 (P = | 0.002) | | | | |
| Cardiac death | | | | | | | |
| Claessen 2011 | 11 | 631 | 34 | 873 | 14.7 | 0.44 [0.22, 0.87] | • |
| Hong 2014 | 4 | 206 | 13 | 328 | 5.2 | 0.48 [0.15, 1.49] | + |
| Kim 2017 | 11 | 122 | 26 | 74 | 15.5 | 0.18 [0.08, 0.40] | |
| Koy 2008 | 31 | 884 | 67 | 884 | 34.0 | 0.44 [0.29, 0.69] | |
| 11an 2017 | 54 | /13 | 81 | 1186 | 50.4 | 0.68 [0.45, 1.03] | • |
| roun 2011 | 1 | 124 | 0 | 216 | 0.2 | 5.26 [0.21, 130.09] | |
| 10tal (95% CI) | <i>a</i> = | 2680 | | 3561 | 100.0 | 0.49 [0.38, 0.62] | ◆ |
| 10tal events | 92 | | 221 | | | | |
| Heterogeneity: Chi | $^{2} = 11.00,$ | df = 5 | (P = 0.05 | $(i); I^2 = 5$ | 5% | | |
| Test for overall effect | ct: Z = 5.6 | 54 (P < | 0.00001) | | | | 0.01 0.1 1 10 100 |
| MACEs | | | | | | | IVUS-guided PCI angiography guided PCI |
| | | | | | | | angiography-guided PCI |

FIGURE 2: The forest plots of MACEs, TLR, and TVR in 30 days. MI: myocardial infarction; TLR: target lesion revascularization; TVR: target vessel revascularization; ST: stent thrombosis; MACEs: major adverse cardiovascular events.

| | IVUS-guid | ed PCI | angiog | raphy-gui | ded PCI | Odds Ratio | Odds Ratio |
|---|------------------------------|-------------------------|--------|--------------|------------|---|--|
| Study or Subgroup | Events | Total | Events | Total | Weight (%) | M-H, Fixed, 95% CI | M-H, Fixed, 95% CI |
| | 15 | 22.4 | 07 | 201 | - | 0.50 [0.04 0.04] | |
| Claessen 2011 | 15 | 324 631 | 36 | 304 873 | 7.9 8.8 | 0.50 [0.26, 0.96] | |
| Gao 2014 | 36 | 291 | 44 | 291 | 11.4 | 0.79 [0.49, 1.27] | - |
| Hong 2014 | 2 | 206 | 9 | 328 | 2.0 | 0.35 [0.07, 1.62] | |
| Hong 2014 Kim 2011 | 0 | 269 | 2 | 274 | 0.4 | 0.33 [0.01, 8.18] 0.20 [0.01, 4.23] | |
| Park 2012 | 13 | 619 | 0 | 802 | 1.5 | 2.85 [1.08, 7.53] | · — |
| Roy 2008 | 18 | 884 | 26 | 884 | 7.6 | 0.69 [0.37, 1.26] | |
| Tian 2017 Witzenbichler 2012 | 31 | 713 | 71 | 1186 5224 | 15.1 | 0.71 [0.46, 1.10] | <u></u> |
| Yoon 2013 | 1 | 662 | 3 | 912 | 0.7 | 0.46 [0.05, 4.42] | |
| Yoon 2011 | 2 | 125 | 6 | 216 | 1.3 | 0.57 [0.11, 2.86] | |
| Total (95% CI) | | 8773 | 410 | 12004 | 100.0 | 0.68 [0.57, 0.80] | • |
| iotai events | 211 | , | 419 | | | | |
| Heterogeneity: Chi = 12.84, df = | = 11 (P = 0.3) | (0); I = 149 | % | | | | |
| MI | r < 0.00001) | | | | | | |
| Chen 2012 | 4 | 324 | 21 | 304 | 21.4 | 0.17 [0.06, 0.50] | |
| Claessen 2011 | 2 | 631 | 8 | 873 | 6.7 | 0.34 [0.07, 1.62] | |
| Gao 2014 Hong 2014 | 2 | 291 700 | 2 | 291 700 | 2.0 | 0.14 [0.02, 1.14] | |
| Hong 2014 | 0 | 206 | 5 | 328 | 4.2 | 0.14 [0.01, 2.59] | ← |
| Kim 2011 | 1 | 269 | 1 | 274 | 1.0 | 1.02 [0.06, 16.37] | |
| Park 2012 | 2 | 619 | 5 | 802 | 4.4 | 0.52 [0.10, 2.67] | |
| Witzenbichler 2013 | 18 | 3349 | 53 | 5234 | 41.2 | 0.53 [0.31, 0.90] | |
| Yoon 2013 | 1 | 662 | 2 | 912 | 1.7 | 0.69 [0.06, 7.61] | |
| Yoon 2011 | 2 | 125 | 3 | 216 | 2.2 | 1.15 [0.19, 7.00] | |
| Total (95% CI) Total events | 40 | 7889 | 419 | 11120 | 100.0 | 0.47 [0.33, 0.67] | • |
| 10tal e tents | | | | | | | |
| Heterogeneity: Ch1 = 10.46, df = Test for overall effect: Z = 4.17 (| = 10 (P = 0.4) P < 0.0001 | (0); I = 4% | | | | | |
| ST | 0.0001) | | | | | | |
| Chen 2012 | 28 | 324 | 41 | 304 | 12.7 | 0.61 [0.36, 1.01] | - |
| Gao 2014 Hong 2014 | 8 | 291 206 | 24 | 291 | 7.7 | 0.31 [0.14, 0.71] | - <u> </u> |
| Hong 2014 | 17 | 700 | 33 | 700 | 10.6 | 0.50 [0.28, 0.91] | |
| Park 2012 | 13 | 619 | 18 | 802 | 5.0 | 0.93 [0.45, 1.92] | |
| Roy 2008 | 43 | 884 | 61 | 884 | 19.0 | 0.69 [0.46, 1.03] | * |
| Tian 2017 Witzenbichler 2013 | 15 | 713 | 27 | 5234 | 6.5 | 0.92 [0.49, 0.89] | I. I |
| Yoon 2011 | 8 | 125 | 13 | 216 | 2.9 | 1.07 [0.43, 2.65] | |
| Total (95% CI) | | 7211 | | 9945 | 100.0 | 0.67 [0.56, 0.80] | • |
| Total events | 195 | | 359 | | | | |
| Heterogeneity: Chi = 8.69, df = | 8 (P = 0.37) | ; I = 8% | | | | | |
| Test for overall effect: Z = 4.40 (a | P < 0.0001) | | | | | | |
| Chen 2012 | 33 | 324 | 47 | 304 | 9.1 | 0.62 [0.39, 1.00] | |
| Claessen 2011 | 46 | 631 | 86 | 873 | 13.9 | 0.72 [0.50, 1.05] | - |
| Gao 2014 | 10 | 291 | 29 | 291 | 5.8 | 0.32 [0.15, 0.67] | |
| Hong 2014 Hong 2014 | 15 | 206 | 27 | 328 | 4.0 | 0.88 [0.45, 1.69] | |
| Park 2012 | 12 | 619 | 23 | 802 | 4.1 | 0.66 [0.31, 1.41] | |
| Roy 2008 | 73 | 884 | 77 | 884 | 14.7 | 0.96 [0.51, 1.81] | + |
| Tian 2017 | 29 | 713 | 42 | 1186 | 6.3 | 0.94 [0.68, 1.32] | + |
| Witzenbichler 2013 Voor 2013 | 81 | 3349 | 207 | 5234 | 32.9 | 0.60 [0.46, 0.78] | * |
| Yoon 2011 | 14 | 125 | 23 | 216 | 3.2 | 1.39 [0.66, 2.93] | |
| Total (95% CI) | | 8073 | | 11304 | 100.0 | 0.74 [0.65, 0.85] | • |
| Total events | 342 | | 593 | | | | |
| Heterogeneity: Chi ² = 17.03, df = | = 10 (P = 0.0 | (7); $I^2 = 419$ | % | | | | |
| Test for overall effect: $Z = 4.19$ (a | P < 0.0001) | | | | | | |
| LVK Chen 2012 | 7 | 324 | 12 | 304 | 6.4 | 0.54 [0.21, 1.38] | |
| Hong 2014 | 3 | 206 | 8 | 328 | 3.2 | 0.59 [0.16, 2.25] | |
| Park 2012 | 3 | 269 | 2 | 274 | 1.0 | 1.53 [0.25, 9.25] | |
| Roy 2008 Tian 2017 | 50 | 884 | 62 | 802 884 | 2.7 | 0.79 [0.54, 1.17] | - |
| Witzenbichler 2013 | 9 | 713 | 23 | 1186 | 9.0 | 0.65 [0.30, 1.40] | |
| Yoon 2013 | 58 | 3349 | 103 | 5234 | 41.7 | 0.88 [0.63, 1.21] | + |
| Yoon 2011 Yoon 2011 | 1 | 662 | 7 | 912 | 3.1 | 0.20 [0.02, 1.59] | |
| Total (95% CI) | 1 | 7151 | , | 10140 | 100.0 | 0.79 [0.63, 0.98] | • |
| Total events | 342 | | 593 | | | | · · |
| Heterogeneity: Chi ² = 5.03, df = | 8 (P = 0.75) | $I^{2} = 0\%$ | | | | | |
| Test for overall effect: $Z = 2.17$ (i | P = 0.03) | | | | | | |
| All-cause death Chen 2012 | 3 | 324 | 10 | 304 | 7.8 | 0.27 [0.07 1.01] | |
| Claessen 2011 | 6 | 631 | 7 | 874 | 4.5 | 1.19 [0.40, 3.55] | |
| Gao 2014 | 5 | 291 | 15 | 291 | 11.3 | 0.32 [0.12, 0.90] | |
| Hong 2014 | 2 | 206 | 7 | 328 | 4.1 | 0.45 [0.09, 2.19] | + |
| riong 2014 Kim 2011 | 5 | 700 269 | 5 | 700 274 | 5.8 1.1 | 0.60 [0.14, 2.51] 0.34 [0.01. 8 34] | |
| Park 2012 | 2 | 619 | 3 | 802 | 2.0 | 0.86 [0.14, 5.18] | |
| Roy 2008 | 16 | 884 | 24 | 884 | 18.1 | 0.66 [0.35, 1.25] | |
| Tian 2017 | 7 | 713 | 16 | 1186 | 9.1 | 0.73 [0.30, 1.77] | |
| Voon 2013 | 2/ | 5549 | 4 | 912 | 35.6 | 0.70 [0.44, 1.11] | |
| Total (95% CI) | - | 8648 | - | 11788 | 100.0 | 0.62 [0.47, 0.82] | • |
| Total events | 72 | | 152 | | | | |
| Heterogeneity: Chi ² = 5.58, df = | 10 (P = 0.85 | $i); I^2 = 0\%$ | | | | | |
| Test for overall effect: $Z = 3.36$ (a) | P = 0.0008) | | | | | | |
| Cardica death Chen 2012 | 29 | 324 | 70 | 304 | 93 | 0 33 [0 21 0 52] | - |
| Claessen 2011 | 20 | 631 | 51 | 873 | 5.9 | 0.53 [0.31, 0.89] | |
| Gao 2014 | 42 | 291 | 66 | 291 | 8.0 | 0.58 [0.38, 0.88] | + |
| Hong 2014 | 7 | 206 | 29 | 328 | 3.1 | 0.36 [0.16, 0.84] | |
| Hong 2014 Kim 2011 | 5 | 700 269 | 8 | 700 274 | 1.1 | 0.62 [0.20, 1.91] 0.67 [0.19 2.42] | |
| Park 2012 | 23 | 619 | 20 | 802 | 2.4 | 1.51 [0.82, 2.77] | |
| Roy 2008 | 84 | 884 | 112 | 884 | 14.3 | 0.72 [0.54, 0.98] | + |
| Tian 2017 | 45 | 713 | 98 | 1186 | 9.7 | 0.75 [0.52, 1.08] | - |
| Witzenbichler 2013 Voon 2013 | 184 | 3349 662 | 404 | 5234 912 | 42.1 | 0.70 [0.58, 0.83] | |
| Yoon 2013 | 5 | 125 | 10 | 216 | 1.9 | 0.54 [0.11, 1.02] 0.60 [0.21, 1.71] | |
| Total (95% CI) | - | 8773 | | 12004 | 100.0 | 0.65 [0.58, 0.73] | + |
| Total events | 452 | | 894 | | | | |
| Heterogeneity: Chi ² = 21.29, df = | = 11 (P = 0.0 | (3); $I^2 = 48^{\circ}$ | % | | | | |
| Test for overall effect: $Z = 7.10$ (| P < 0.0001) | | | | | | 0.01 0.1 1 10 100 |
| MACEs | | | | | | | IVUS-guided PCI angiography-guided PCI |
| | | | | | | | |

FIGURE 3: The forest plots of MACEs, TLR, and TVR in 1 year. MACEs: major adverse cardiovascular events.

| 3110 01 310000000 | Events | Total | angio Events | graphy-g Total | uided PCI Weight (%) | Odds Ratio M-H. Fixed 95% CI | Odds Ratio M-H. Fixed 95% CI |
|---|--|--|--|--|---|--|---------------------------------|
| Ab-2012 | Events | 40 | 11 | 26 | 11.1 | 0.26 [0.00, 0.02] | 191-11, 1 IACU, 7370 CI |
| Allil2013 Classer2011 | 5 | 49 621 | 11 | 36 872 | 11.1 | 0.26 [0.08, 0.83] | |
| Giaessel12011 Hong2014 | 24 | 206 | 70 51 | 378 | 34.9 34.0 | 0.45 [0.26, 0.75] | |
| 11011g2014 | 23 | 200 | 51 | 320 | 54.0 | 0.08 [0.40, 1.10] | |
| Total (95% CI) | | 886 | | 1237 | 100.0 | 0.51 [0.36, 0.71] | |
| Total events | 52 | | 132 | | | | • |
| Heterogeneity: $chi^2 =$ | 2.72. $df = 2$ (| P = 0.26 | $I^2 = 26\%$ | 5 | | | |
| Test for overall effect: | Z = 3.92 (P < 2) | (0.0001) | ,1 207 | , , | | | |
| | (| , | | | | | |
| MACEs | | | | | | | |
| Ab= 2012 | 1 | 40 | - | 26 | 0.4 | 0.12[0.01.1.16] | |
| Classes 2011 | 12 | 49 | 5 | 30 | 9.4 | | |
| Uaessen2011 | 15 | 206 | 45 | 220 | 01.5 | 1.00 [0.57, 2.07] | - - - |
| H011g2014 | 17 | 206 | 25 | 528 | 29.5 | 1.09 [0.57, 2.07] | |
| Total (95% CI) | | 886 | | 1237 | 100.0 | 0.57 [0.37, 0.87] | • |
| Total events | 31 | | 75 | | | | • |
| Heterogeneity: $chi^2 =$ | 7.15, df = 2.0 | P = 0.03) | ; $I^2 = 72\%$ | , D | | | |
| Test for overall effect: | Z = 2.59 (P = | = 0.010) | , | - | | | |
| MI | | | | | | | |
| | | | | | | | |
| Ahn2013 | 1 | 49 | 4 | 36 | 26.6 | 0.17 [0.02, 1.56] — | |
| Claessen2011 | 3 | 631 | 8 | 873 | 39.4 | 0.52 [0.14, 1.95] | |
| Hong2014 | 0 | 206 | 7 | 328 | 34.0 | 0.10 [0.01, 1.83] | |
| H . 1 (0.50) (01) | | 0.0.4 | | | 100.0 | | |
| Total (95% CI) | | 886 | | 1237 | 100.0 | 0.28 [0.10, 1.80] | |
| Total events | 4 | | 19 | | | | |
| Heterogeneity: chi ² = | 1.47, $df = 2$ (| P = 0.48) | ; $I^2 = 0\%$ | | | | |
| Test for smanall offerst. | | | | | | | |
| rest for overall effect: | Z = 2.39 (P = | = 0.02) | | | | | |
| ST | Z = 2.39 (P = | = 0.02) | | | | | |
| ST | Z = 2.39 (P = | = 0.02) | 10 | 26 | 22.5 | | |
| ST Ahn2013 | Z = 2.39 (P = | 49 | 10 | 36 | 33.7 | 0.03 [0.00, 0.45] | |
| ST Ahn2013 Hong2014 | Z = 2.39 (P = 0 21 | 49 206 | 10 34 | 36 328 | 33.7 66.3 | 0.03 [0.00, 0.45] ← 0.98 [0.55, 1.74] | ⊢ _ |
| Ahn2013 Hong2014 | Z = 2.39 (P = 0 21 | 49 206 255 | 10 34 | 36 328 364 | 33.7 66.3 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] | |
| Ahn2013 Hong2014 Total (95% CI) | Z = 2.39 (P = 0 21 | 49 206 255 | 10 34 | 36 328 364 | 33.7 66.3 100.0 | 0.03 [0.00, 0.45] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² – | Z = 2.39 (P = 0) 0 21 6 75 df = 1 (| 49 206 255 P = 0.000 | $10 \\ 34 \\ 44 \\ 0): I^2 - 85$ | 36 328 364 | 33.7 66.3 100.0 | 0.03 [0.00, 0.45] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 0)) | $ \begin{array}{r} 49 \\ 206 \\ 255 \\ P = 0.009 \\ = 0.12) \end{array} $ | 10 34 (1) ; $I^2 = 85$ | 36 328 364 % | 33.7 66.3 100.0 | 0.03 [0.00, 0.45] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: | Z = 2.39 (P = 0 21 6.75, df = 1 (Z = 1.55 (P = | $ \begin{array}{r} 49 \\ 206 \\ 255 \\ P = 0.009 \\ = 0.12 \end{array} $ | 10 34 9); $I^2 = 85^{\circ}$ | 36 328 364 % | 33.7 66.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR | Z = 2.39 (P = 0 21 6.75, df = 1 (Z = 1.55 (P = | $ \begin{array}{r} 49 \\ 206 \\ 255 \\ P = 0.009 \\ = 0.12) \end{array} $ | 10 34 $(44); I^2 = 850$ | 36 328 364 % | 33.7 66.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 | Z = 2.39 (P = 0 21 6.75, df = 1 (Z = 1.55 (P = 70 | 49 206 255 P = 0.005 = 0.12) 631 | 10 34 44 112 | 36 328 364 % | 33.7 66.3 100.0 90.1 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] | • |
| ST Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 | $ \begin{array}{r} 49 \\ 206 \\ 255 \\ P = 0.005 \\ = 0.12) \\ 631 \\ 206 \\ \end{array} $ | 10 34 44 12 12 | 36 328 364 % 873 328 | 33.7 66.3 100.0 90.1 9.9 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] | • |
| ST Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 | Z = 2.39 (P = 0) 0 21 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 70 2 | 49 206 255 (P = 0.005 = 0.12) 631 206 | $ \begin{array}{c} 10 \\ 34 \\ 44 \\ 0); I^2 = 85^{\circ} \\ 112 \\ 12 \end{array} $ | 36 328 364 % 873 328 | 33.7 66.3 100.0 90.1 9.9 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] | • |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) | Z = 2.39 (P = 0 21 6.75, df = 1 (Z = 1.55 (P = 70 2 | 49 206 255 = 0.005 = 0.12) 631 206 837 | $10 \\ 34 \\ 44 \\ 0); I^2 = 85^{\circ}$ $112 \\ 12$ | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | • |
| Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 72 | $ \begin{array}{r} 49 \\ 206 \\ 255 \\ P = 0.005 \\ = 0.12) \\ \hline 631 \\ 206 \\ 837 \\ \end{array} $ | $10 \\ 34 \\ 44 \\ 0); I^2 = 85^{\circ}$ $112 \\ 12 \\ 124$ | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | • |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (| | 10 34 44 12 | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | • |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 0)) 70 2 2.31, df = 1 (Z = 1.50 (P = 0)) | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.009\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 9); I^2 = 85^{\circ}$ $112 \\ 12 \\ 12 \\ 124 \\ ; I^2 = 57\%$ | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TVR | Z = 2.39 (P = 0) $Q = 0$ $Q = 0$ $Q = 0$ $Q = 0$ $Z = 1.55 (P = 0)$ $Z = 1.55 (P = 0)$ $Z = 1.50 (P = 0)$ $Z = 1.50 (P = 0)$ $Z = 0$ | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | 10 34 44 $(12^{2} = 85^{2})$ 112 12 $(12^{2} = 57\%)$ | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | |
| Ahn2013 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 <i>Total (95% CI)</i> Total events Heterogeneity: chi ² = Test for overall effect: TVR | Z = 2.39 (P = 0) $Q = 0$ $Z = 1.55 (P = 0)$ $Q = 0$ $Z = 0$ | $ \begin{array}{c} 49\\206\\255\\P=0.005\\=0.12\end{array}\\ \begin{array}{c} 631\\206\\837\\P=0.13\\\end{array} \end{array} $ | 10 34 44 $P_{12}^{12} = 85^{12}$ 112 12 124 ; $I^{2} = 57\%$ | 36 328 364 % 873 328 1201 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TVR Ahn2013 | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (Z = 1.50 (P = 3) 3 | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.009\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 9); I^{2} = 85^{\circ}$ $112 \\ 12 \\ 12 \\ 124 \\ ; I^{2} = 57\% \\ 2$ | 36 328 364 % 873 328 1201 5 | 33.7 66.3 100.0 90.1 9.9 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] | |
| Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TVR Ahn2013 Claessen2011 | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (Z = 1.50 (P = 3) 8 | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 12^{2} = 85^{2}$ $112 \\ 12 \\ 12 \\ 12^{2} = 57\% \\ 2 \\ 17$ | 36 328 364 % 873 328 1201 5 36 873 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] | |
| Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TVR Ahn2013 Claessen2011 Hong2014 | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (Z = 1.50 (P = 3) 3 8 2 | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.009\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 1$ | 36 328 364 % 873 328 1201 5 36 873 328 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] | |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TLR Claessen2011 Hong2014 Total events Heterogeneity: $chi^2 =$ Test for overall effect: TVR Ahn2013 Claessen2011 Hong2014 Truch (05% CI) | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 .31, df = 1 (Z = 1.50 (P = 3) 8 2 | $ \begin{array}{c} 49\\206\\255\\P=0.009\\=0.12\end{array}\\631\\206\\837\\P=0.13\\\\=0.13\end{array}\\49\\631\\206\\026\end{array} $ | $10 \\ 34 \\ 44 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 1$ | 36 328 364 % 873 328 1201 5 36 873 328 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] 0.63 [0.22, 1.51] | |
| Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TVR Ahn2013 Claessen2011 Hong2014 Total (95% CI) | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (Z = 1.50 (P = 3) 3 8 2 10 | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 41 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 1$ | 36 328 364 % 873 328 1201 5 36 873 328 1237 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] 0.62 [0.32, 1.23] | |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ TVR Ahn2013 Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ TVR Ahn2013 Claessen2011 Hong2014 Total (95% CI) Total events Total events Hong2014 | $Z = 2.39 (P = 0)$ Q_{1} Q_{1} Q_{2} $Z = 1.55 (P = 0)$ $Z = 1.55 (P = 0)$ $Z = 1.50 (P = 0)$ $Z = 1.$ | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | 10 34 44 10; $I^2 = 85^{\circ}$ 112 12 124 ; $I^2 = 57\%$ 2 17 8 27 27 27 27 27 27 27 27 27 27 | 36 328 364 % 873 328 1201 5 36 873 328 1237 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] 0.62 [0.32, 1.23] | |
| ST Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Test for overall effect: TVR Ahn2013 Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: $chi^2 =$ Total events Heterogeneity: $chi^2 =$ | Z = 2.39 (P = 0) 0 21 6.75, df = 1 (Z = 1.55 (P = 70) 2 2.31, df = 1 (Z = 1.50 (P = 3) 3 8 2 13 0.72, df = 2 (P = 7) | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | 10 34 10 34 10 12 12 12 12 12 12 12 12 12 12 | 36 328 364 % 873 328 1201 5 36 873 328 1237 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] 0.62 [0.32, 1.23] | |
| Ahn2013 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TLR Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Test for overall effect: TVR Ahn2013 Claessen2011 Hong2014 Total (95% CI) Total events Heterogeneity: chi ² = Total events Heterogeneity: chi ² = Total events Heterogeneity: chi ² = | Z = 2.39 (P = 0) 0 21 $6.75, df = 1 (Z = 1.55 (P = 0))$ 70 2 $2.31, df = 1 (Z = 1.50 (P = 0))$ 3 8 2 13 $0.72, df = 2 (Z = 1.37 (P = 0))$ | $\begin{array}{c} 49\\ 206\\ 255\\ P=0.005\\ =0.12)\\ \end{array}$ | $10 \\ 34 \\ 44 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 12 \\ 1$ | 36 328 364 % 873 328 1201 5 36 873 328 1237 | 33.7 66.3 100.0 90.1 9.9 100.0 9.7 63.0 27.3 100.0 | 0.03 [0.00, 0.45] 0.98 [0.55, 1.74] 0.66 [0.39, 1.12] 0.85 [0.62, 1.17] 0.26 [0.06, 1.17] 0.79 [0.58, 1.07] 1.11 [0.18, 7.00] 0.65 [0.28, 1.51] 0.39 [0.08, 1.87] 0.62 [0.32, 1.23] | |

(a) FIGURE 4: Continued.



(b)

FIGURE 4: The forest plots of MACEs, TLR, and TVR in 2 years. ST: stent thrombosis; MI: myocardial infarction; TLR: target lesion revascularization; TVR: target vessel revascularization; MACEs: major adverse cardiovascular events.

randomized controlled trials, after a 2-year follow-up period, the incidence of MACEs (RR: 0.68, 95% CI: 0.35–1.34, P = 0.27, $I^2 = 0\%$) was not significantly different between the IVUS-guided PCI and angiography-guided PCI (Figure 4).

In patients with long coronary lesions, after a 1-year follow-up period, the incidence of MACEs (OR: 0.64, 95% CI: 0.28–1.50, P = 0.31, $I^2 = 0\%$), cardiac death (OR: 0.54, 95% CI: 0.15–2.02, P = 0.36, $I^2 = 0\%$), MI (OR: 0.26, 95% CI: 0.03–2.32, P = 0.23, $I^2 = 0\%$), and ST (OR: 1.01, 95% CI: 0.20–5.00, P = 0.99, $I^2 = 0\%$) was not significantly different between the IVUS-guided PCI and angiography-guided PCI (Figure 6).

In patients with left main artery disease, at the 1-year follow-up, the IVUS-guided PCI was associated with a lower incidence of cardiac death (OR: 0.50, 95% CI: 0.26–0.98, P = 0.04, $I^2 = 27\%$). As for MI (OR: 0.75, 95% CI: 0.54–1.03, P = 0.08, $I^2 = 0\%$), ST (OR: 0.48, 95% CI: 0.07–3.47, P = 0.47, $I^2 = 68\%$), and MACEs (OR: 0.72, 95% CI: 0.49–1.08, P = 0.12, $I^2 = 56\%$), there was no significant difference between the IVUS-guided PCI and angiography-guided PCI (Figure 7). At the 3-year follow-up, the IVUS-guided PCI was associated with a lower incidence of all-

cause death (OR: 0.46, 95% CI: 0.30–0.71, P = 0.0004, $I^2 = 58\%$), cardiac death (OR: 0.41, 95% CI: 0.24–0.69, P = 0.0009, $I^2 = 55\%$), MI (OR: 0.68, 95% CI: 0.52–0.88, P = 0.004, $I^2 = 0\%$), and MACEs (OR: 0.42, 95% CI: 0.26–0.67, P = 0.0004, $I^2 = 85\%$) (Figure 8).

3.3. Secondary Outcomes. In the observational trials, after a 30-day follow-up period, the incidence of TLR (OR: 0.84, 95% CI: 0.44–1.61, P = 0.60, $I^2 = 64\%$) and TVR (OR: 0.85, 95% CI: 0.52–1.38, P = 0.50, $I^2 = 19\%$) was not different between the IVUS-guided PCI and angiography-guided PCI (Figure 2). At the 1-year follow-up, the IVUS-guided PCI was associated with a lower incidence of TLR (OR: 0.67, 95% CI: 0.56–0.80, P < 0.001, $I^2 = 8\%$) and TVR (OR: 0.74, 95% CI: 0.65–0.85, P < 0.001, $I^2 = 41\%$) (Figure 3). At the 2-year follow-up, the incidence of TLR (OR: 0.66, 95% CI: 0.39–1.12, P = 0.12, $I^2 = 85\%$) and TVR (OR: 0.79, 95% CI: 0.58–1.07, P = 0.13, $I^2 = 57\%$) was not different between the IVUS-guided PCI and angiography-guided PCI (Figure 4). At the 3-year follow-up, the incidence of TLR (OR: 0.89, 95% CI: 0.58–1.37, P = 0.60, $I^2 = 59\%$) and TVR (OR: 0.95, 95%

| Study or Subgroup | IVUS-gui | ided PCI | angiogr Events | aphy-gui | ded PCI Weight (%) | Odds Ratio | Odds Ratio CL M-H Random 95% CI |
|---|---|----------------------|---------------------|--------------------|-----------------------|-------------------|---|
| Hernandez 2014 | 77 | 505 | 128 | 505 | 20.8 | 0.53 [0.39 0.73] | |
| Kim2010 | 17 | 122 | 36 | 74 | 13.2 | 0.17 [0.09, 0.34] | |
| Kim2011 | 19 | 487 | 35 | 487 | 15.3 | 0.52 [0.30, 0.93] | |
| Park2009 | 113 | 756 | 74 | 219 | 20.2 | 0.34 [0.24, 0.49] | + |
| Tian2017 | 60 | 713 | 133 | 1186 | 20.7 | 0.73[0.53, 1.00] | |
| roun2011 | / | 125 | 20 | 216 | 10.0 | 1.58 [0.24, 1.42] | |
| Total (95% CI) | | 2708 | | 2687 | 100.0 | 0.45 [0.31, 0.65] | • |
| Total events Heterogeneity: $Tau^2 = 0.14$ Test for overall effect: Z = 4 | 293 ; chi ² = 19.4 4.28 (P < 0.4 | 41, df = 5 0001) | 426 (P = 0.002) | ; $I^2 = 74\%$ | 6 | | |
| MACEs | | | | | | | |
| Hernandez 2014 | 23 | 505 | 33 | 505 | 22.2 | 0.68 [0.39, 1.18] | |
| Kim2011 | 3 | 487 | 15 | 487 | 4.5 | 0.20 [0.06, 0.68] | |
| Kim2017 | 4 | 122 | 7 | 74 | 4.4 | 0.32 [0.09, 1.15] | |
| Park2009 Tian2017 | 30 | 713 | 24 | 219 | 25.9 | 0.65 [0.39, 1.08] | |
| Youn2011 | 3/ | 125 | 8 | 216 | 39 | 0.64 [0.17, 2.46] | |
| | 5 | 120 | 0 | 210 | | 0.01 [0.17, 2.10] | |
| Total (95% CI) | 126 | 2708 | 169 | 2687 | 100.0 | 0.64 [0.49, 0.83] | • |
| Heterogeneity: Tau ² - 0.01 | 120 · chi ² = 5.2 | 5 df = 5 (| P = 0.39). f | $^{2} = 5\%$ | | | |
| Test for overall effect: $Z = 3$ | 3.31 (P = 0.2) | 0009) | . – 0.57), 1 | - 570 | | | |
| MI | | | | | | | |
| Kim2011 | 1 | 487 | 3 | 487 | 8.3 | 0.33 [0.03, 3.20] | <u>_</u> |
| Tian2017 | 10 | 713 | 20 | 1186 | 73.0 | 0.83 [0.39, 1.78] | |
| Youn2011 | 3 | 125 | 4 | 216 | 18.7 | 1.30 [0.29, 5.92] | |
| Total (95% CI) | | 1325 | | 1889 | 100.0 | 0.84 [0.43, 1.61] | • |
| Total events Heterogeneity: $Tau^2 = 0.00$ Test for overall effect: Z = 0 | 14 chi ² = 0.92 0.54 (P = 0. | 7, df = 2 (. 59) | 27 P = 0.62); I | $^{2} = 0\%$ | | | |
| ST | | | | | | | |
| Userna dan 2014 | 20 | 505 | 22 | 505 | 24.4 | 1 24 [0 76 2 01] | |
| Hernadez 2014 Kim 2010 | 39 | 122 | 32 | 505 | 24.4 | 1.24 [0.76, 2.01] | +■- |
| Kim2011 | 36 | 487 | 32 | 487 | 24.1 | 1 13 [0.69, 1.86] | |
| Tian2017 | 22 | 713 | 39 | 1186 | 23.0 | 0.94 [0.55, 1.59] | |
| Youn2011 | 10 | 125 | 17 | 216 | 15.6 | 1.02 [0.45, 2.30] | |
| Total (05% CI) | | 1052 | | 2469 | 100.0 | 0 20 [0 52 1 27] | |
| Total events Heterogeneity: $Tau^2 = 0.14$ | 114; chi ² = 9.7 | 1952 1, df = 4 (. | 135 P = 0.05); I | ² = 59% | 100.0 | 0.87 [0.36, 1.37] | Ť |
| Test for overall effect: $Z = 0$ | 0.52 (P = 0. | 60) | | | | | |
| TLR | | | | | | | |
| Kim2010 | 17 | 122 | 18 | 74 | 16.7 | 0.50 [0.24, 1.05] | |
| Park2009 | 86 | 756 | 19 | 219 | 27.0 | 1.35 [0.80, 2.28] | +=- |
| Tian2017 | 43 | 713 | 71 | 1186 | 36.8 | 1.01 [0.68, 1.49] | + |
| Youn2011 | 15 | 125 | 29 | 216 | 19.5 | 0.88 [0.45, 1.71] | |
| Total (95% CI) | | 1716 | | 1695 | 100.0 | 0.95 [0.67, 1.34] | + |
| Total events | 161 | | 137 | | | | |
| Heterogeneity: $Tau^2 = 0.05$ Test for overall effect: $Z = 0$ | ; chi ² = 4.70 0.31 (P = 0. | 0, df = 3 (. 75) | P = 0.19; I | 2 = 36% | | | |
| TVR | | , | | | | | |
| | | | | | 10 - | 0.5410.55.000 | |
| Hernandez 2014 | 37 | 505 | 65 | 505 | 48.7 | 0.54 [0.35, 0.82] | -=- |
| Riii2011 Park2009 | 15 | 480 756 | 29 | 48/ 219 | 17.0 | 0.31 [0.18 0.52] | |
| Tian2017 | 21 | 713 | 46 | 1186 | 31.8 | 0.75 [0.45, 1.27] | _ _ |
| Youn2011 | 1 | 125 | 8 | 216 | 2.0 | 0.21 [0.03, 1.70] | <u>+</u> |
| Total (95% CI) | | 1830 | | 2394 | 100.0 | 0.46 [0.30, 0.71] | • |
| Total events Heterogeneity: $Tau^2 = 0.00$ Test for overall effect: Z = 2 | 74 chi ² = 2.92 2.97 (P = 0. | 2, df = 3 (. 003) | 136 P = 0.40); I | ² = 0% | | | |
| All-cause death | | | | | | | |
| Hernandez 2014 | 17 | 505 | 30 | 505 | 34.2 | 0.55 [0.30, 1.01] | |
| Kim2017 | 4 | 122 | 13 | 74 | 0.0 | 0.16 [0.05, 0.51] | |
| Park2009 | 23 | 756 | 21 | 219 | 34.0 | 0.30 [0.16, 0.55] | |
| Tian2017 | 13 | 713 | 32 | 1186 | 31.7 | 0.67 [0.35, 1.28] | -=+ |
| Total (95% CI) | | 1974 | | 1910 | 100.0 | 0.47 [0.29, 0.77] | • |
| Total events Heterogeneity: $Tau^2 = 0.08$ | 53; chi ² = 3.63 | 3, df = 2 (. | 83 P = 0.16); I | ² = 45% | | | |
| Test for overall effect: $Z = 3$ | 3.01 (P = 0.) | 003) | | | | | |
| Cardica death | | | | | | | IVUS- angiography- guided PCI guided PCI |

FIGURE 5: The forest plots of MACEs, TLR, and TVR in 3 years. MACEs: major adverse cardiovascular events; TVR: target vessel revascularization; TLR: target lesion revascularization.



FIGURE 6: In patients with long coronary lesions, the forest plots of MACEs in 1 year. MACEs: major adverse cardiovascular events; MI: myocardial infarction; ST: stent thrombosis.

CI: 0.67–1.34, P = 0.75, $I^2 = 36\%$) was not significantly different between the IVUS-guided PCI and angiographyguided PCI (Figure 5). In the randomized controlled trials, at the 2-year follow-up, the incidence of TLR (RR: 0.62, 95% CI: 0.35–1.09, P = 0.10, $I^2 = 4\%$) was not significantly different between the IVUS-guided PCI and angiographyguided PCI (Figure 4).

In patients with left main artery disease, at the 1-year follow-up, there were no significant differences between IVUS-guided PCI and angiography-guided PCI in terms of TLR (OR: 0.56, 95% CI: 0.19–1.60, P = 0.28, $I^2 = 76\%$) and TVR (OR: 0.63, 95% CI: 0.18–2.21, P = 0.47, $I^2 = 88\%$) (Figure 7). At the 3-year follow-up, the occurrence of TLR (OR: 0.73, 95% CI: 0.34–1.56, P = 0.41, $I^2 = 78\%$) and TVR (OR: 0.94, 95% CI: 0.59–1.50, P = 0.81, $I^2 = 57\%$) was not significantly different between the IVUS-guided PCI and angiography-guided PCI (Figure 8).

3.4. Bias Analysis. We analyzed the bias of the related results. The funnel plots are shown in Figure 9. For the asymmetric funnel plots, Begg's and Egger's tests were performed. The results showed that there was no significant publication bias (Figure 10).

4. Discussion

A total of 20 clinical trials were included, of which three were randomized controlled and 17 were retrospective. In our analysis, compared with angiography-guided therapy, IVUS-guided therapy had a better long-term prognosis. In the short-term prognosis, IVUS-guided therapy also showed beneficial effects.

IVUS had been used for about 20 years in clinical practice. However, it has not been widely used due to the individual mode of practice, time pressure, and expenses [27]. IVUS can be used to evaluate plaque morphology, coronary artery dissection, and intramural hematoma. In addition, it has certain advantages in evaluating the anatomic severity of coronary artery disease. In the process of stent implantation, the use of IVUS reduces the occurrence of stent underexpansion. Besides, IVUS plays an important role in the evaluation of stent malapposition, tissue protrusion after stent placement, and coronary spasm [28, 29]. Although coronary angiography has always been the gold standard for coronary artery evaluation, it also has some limitations [30, 31]. For example, in patients with left main artery disease, overlap of the vessels may mask the left main artery lesion, which limits the role of angiography in

| | IVUS-gui | ded PCI | angio | graphy-g | uided PCI | Odds Ratio | Odds Ratio |
|--|---|-------------------------------|---------------------------|--------------------------------|----------------|--|---|
| Study or Subgroup | Events | Total | Events | Total | Weight (%) | M-H, Random, 95% | 6 CI M-H, Random, 95% CI |
| Gao2014 Tian2017 | 42 64 | 291 713 | 66 121 | 291 1186 | 43.8 56.2 | 0.58 [0.38, 0.88] 0.87 [0.63, 1.19] | - |
| Total (95% CI) Total events Heterogeneity: $Tau^2 = 0$ Test for overall effect: Z | 106 .05; chi ² = = 1.58 (<i>P</i> = | 1004 2.30, df = = 0.12) | 187 = 1 (P = 0. | 1477 13); I ² = | 100.0 56% | 0.72 [0.49, 1.08] | |
| MACEs | | | | | | | |
| Gao2014 Tian2017 | 36 31 | 291 713 | 44 71 | 291 1186 | 43.1 56.9 | 0.79 [0.49, 1.27] 0.71 [0.46, 1.10] | 4 |
| Total (95% CI) Total events Heterogeneity: $chi^2 = 0$. Test for overall effect: Z | 67 10, df = 1 (= 1.79 (P = | 1004 P = 0.75) = 0.07) | $^{115}_{I^2 = 0\%}$ | 1477 | 100.0 | 0.75 [0.54, 1.03] | <i>1</i> ◆ |
| MI | | | | | | | |
| Gao2014 Tian2017 | 1 7 | 291 713 | 7 11 | 291 1186 | 39.4 60.6 | 0.14 [0.02, 1.14] 1.06 [0.41, 2.74] | |
| Total (95% CI) Total events Heterogeneity: $Tau^2 = 1$ Test for overall effect: Z | 8 .45; chi ² = = 0.73 (P = | 1004 3.10, df = = 0.47) | 18 = 1 (P = 0. | 1477 (08); $I^2 =$ | 100.0 68% | 0.48 [0.07, 3.47] | |
| ST | | | | | | | |
| Gao2014 Tian2017 | 8 15 | 191 713 | 24 27 | 291 1186 | 47.1 52.9 | 0.31 [0.14, 0.71] 0.92 [0.49, 1.75] | |
| Total (95% CI) Total events Heterogeneity: $Tau^2 = 0$ Test for overall effect: Z | 23 .44; chi ² = = 1.09 (<i>P</i> = | 1004 4.15, df = = 0.28) | 51 = 1 (P = 0. | 1477 04); $I^2 =$ | 100.0 76% | 0.56 [0.19, 1.60] | |
| TLR | | | | | | | |
| Gao2014 Tian2017 | 10 29 | 291 713 | 29 42 | 291 1186 | 47.5 52.5 | 0.32 [0.15, 0.67] 1.15 [0.71, 1.87] | |
| Total (95% CI) Total events Heterogeneity: $Tau^2 = 0$ | 39 .72; chi ² = | 1004 8.12, df = | 71 = 1 (<i>P</i> = 0. | 1477 004); I ² = | 100.0 = 88% | 0.63 [0.18, 2.21] | |
| TVR | = 0.72 (P = | = 0.47) | | | | | |
| G202014 | E | 201 | 15 | 201 | 55.2 | 0 32 [0 12 0 00] | |
| Tian2017 | 5 7 | 713 | 15 | 1186 | 44.7 | 0.52 [0.12, 0.90] 0.73 [0.30, 1.77] | |
| Total (95% CI) Total events Heterogeneity: $chi^2 = 1$. | 12 37, df = 1 (| 1004 P = 0.24 | 31; $I^2 = 27\%$ | 1477 ó | 100.0 | 0.50 [0.26, 0.98] | |
| Cardica death | – 0.02 (P = | - 0.04) | | | | | 0.01 0.1 1 10 10 IVUS- angiography- guided PCI guided PCI |

FIGURE 7: In patients with left main artery disease, the forest plots of MACEs in 1 year. TLR: target lesion revascularization; MI: myocardial infarction; TVR: target vessel revascularization; ST: stent thrombosis; MACEs: major adverse cardiovascular events.

assessing the severity of the lesion. However, for IVUS, significant stenosis can be accurately evaluated [32, 33]. The study conducted by Ye et al. reported that the positive predictive value of angiography was only 35.1% [5]. However, the application of IVUS did not reduce the incidence of TVR or TLR. This might be related to the low incidence of events and individual differences of interventional physicians [34]. This may explain why high heterogeneity happens to the result of TVR and TLR in this meta-analysis.

In this study, to eliminate the bias caused by the study design of the included studies, we analyzed the relevant MACEs of observational trials and randomized controlled trials, respectively. For RCTs, the forest plot results of MACEs showed no significant difference (Figure 4). In the IVUS guidance in RCTs, attention should be given to the occurrence of cardiac death and all-cause death in 30 days, 1 year, and 3 years, which is lower compared with that in angiography-guided PCI. Although IVUS-guided PCI has

| Study or Subgroup | IVUS-gu Events | ided PCI Total | angio Events | graphy-g Total | uided PCI Weight (%) | Odds Ratio M-H, Random, 95% C | Odds Ratio I M-H, Random, 95% CI |
|---|-------------------------------------|-------------------------|-----------------|-------------------------|-------------------------|---------------------------------------|-------------------------------------|
| Hernandez 2014 | 77 | 505 | 128 | 505 | 27.0 | 0.53 [0.39, 0.73] | |
| Kim2010 | 17 | 122 | 36 | 74 | 18.9 | 0.17 [0.09, 0.34] | _ _ |
| Park2009 | 113 | 756 | 74 | 219 | 26.4 | 0.34 [0.24, 0.49] | |
| Tian2017 | 81 | 713 | 179 | 1186 | 27.7 | 0.72 [0.54, 0.95] | - |
| Total (95% CI) | | 2096 | | 1984 | 100.0 | 0.42 [0.26, 0.67] | • |
| Total events | 288 | | 417 | | | | |
| Heterogeneity: Tau ² = Test for overall effect: | $= 0.20; chi^2 = Z = 3.57 (P)$ | 20.62, df = 0.0004) | = 3 (P = 0) | 0.0001); I ² | 2 = 85% | | |
| MACEs | | | | | | | |
| Hernandez 2014 | 23 | 505 | 33 | 505 | 23.9 | 0.68 [0.39, 1.18] | |
| Kim2010 | 4 | 122 | 7 | 74 | 6.4 | 0.32 [0.09, 1.15] | |
| Park2009 | 56 | 756 | 24 | 219 | 26.1 | 0.65 [0.39, 1.08] | |
| Tian2017 | 37 | 713 | 81 | 1186 | 43.7 | 0.75 [0.50, 1.11] | |
| Total (95% CI) | | 2096 | | 1984 | 100.0 | 0.68 [0.52, 0.89] | • |
| Total events | 120 | | 145 | | | | |
| Heterogeneity: $chi^2 =$ Test for overall effect: | 1.56, df = 3 Z = 2.84 (P = 2.84) | (P = 0.67) = 0.005) | $I^2 = 0\%$ | | | | |
| MI | | | | | | | |
| Hernandez 2014 | 39 | 505 | 32 | 505 | 37.4 | 1.24 [0.76, 2.01] | |
| Kim2010 | 7 | 122 | 15 | 74 | 26.3 | 0.24 [0.09, 0.62] | _ _ |
| Tian2017 | 22 | 713 | 39 | 1186 | 36.3 | 0.94 [0.55, 1.59] | -+- |
| Total (95% CI) | | 1340 | | 1765 | 100.0 | 0.73 [0.34, 1.59] | - |
| Total events | 68 | | 86 | | | | - |
| Heterogeneity: Tau ² = Test for overall effect: | $= 0.35; chi^2 = Z = 0.82 (P)$ | 9.14, df = = 0.41) | 2(P=0. | 01); $I^2 = 2$ | 78% | | |
| TLR | | | | | | | |
| Kim2010 | 17 | 122 | 18 | 74 | 23.9 | 0.50 [0.24, 1.05] | |
| Park2009 | 86 | 756 | 19 | 219 | 34.1 | 1.35 [0.80, 2.28] | |
| Tian2017 | 43 | 713 | 71 | 1186 | 42.0 | 1.01 [0.68, 1.49] | + |
| Total (95% CI) | | 1591 | | 1479 | 100.0 | 0.94 [0.59, 1.50] | • |
| Total events | 146 | | 108 | | | | Ĩ |
| Heterogeneity: Tau ² = Test for overall effect: | $z = 0.10; chi^2 = Z = 0.24 (P)$ | 4.60, df = = 0.81) | 2(P=0. | 10); $I^2 = 5$ | 57% | | |
| TVR | | | | | | | |
| Hormondor 2014 | 27 | 505 | 65 | 505 | 20.0 | 0.54 [0.35, 0.82] | _ |
| Kim2010 | 5/ | 505 122 | 65 16 | 505 74 | 30.9 | 0.54 [0.35, 0.82] | |
| Park2009 | 34 | 756 | 29 | 219 | 26.8 | 0.31 [0.18, 0.52] | |
| Tian2017 | 21 | 713 | 46 | 1186 | 26.78 | 0.75 [0.45, 1.27] | |
| Total (95% CI) | | 2006 | | 1081 | 100.0 | 0.46 [0.30, 0.71] | |
| Total events | 101 | 2070 | 156 | 1704 | 100.0 | 0.40 [0.30, 0.71] | • I |
| Heterogeneity: $Tau^2 =$ Test for overall effect: | $= 0.11; chi^2 = Z = 3.57 (P)$ | 7.16, df = = 0.0004) | 3 (P = 0. | 07); $I^2 = 5$ | 58% | | |
| All-cause death | | , | | | | | |
| Hornondor 2014 | 17 | EOF | 20 | 505 | 24.2 | 0 55 [0 20 1 01] | |
| Kim2010 | 17 | 122 | 13 | 505 74 | 0 0 | 0.55 [0.50, 1.01] 0.16 [0.05 0.51] | |
| Park2009 | 23 | 756 | 21 | 219 | 34.0 | 0.30 [0.16, 0.55] | |
| Tian2017 | 13 | 713 | 32 | 1186 | 31.7 | 0.67 [0.35, 1.28] | |
| Total (95% CI) | | 1974 | | 1910 | 100.0 | 0 47 [0 29 0 77] | |
| Total events | 53 | 1//7 | 83 | 1710 | 100.0 | 0.17 [0.27, 0.77] | ▼ |
| Heterogeneity: Tau ² = | = 0.08; chi ² = | 3.63, df = | 2(P = 0. | 16); $I^2 = 4$ | 45% | | r |
| Test for overall effect: | Z = 3.01 (P = | = 0.003) | | | | 0. | 01 0.1 1 10 10 |
| Cardica death | | | | | | | IVUS- angiography- |
| | | | | | | | guided PCI guided PCI |

FIGURE 8: In patients with left main artery disease, the forest plots of MACEs, TLR, and TVR in 3 years. TLR: target lesion revascularization; TVR: target vessel revascularization; MACEs: major adverse cardiovascular events.

better performance in reducing the occurrence of mortality, we still cannot ignore the cost of IVUS-guided PCI. After spending a lot of treatment fees, who would benefit the most from IVUS guidance? This is an important issue that cannot be ignored, especially in developing countries. Therefore, it is necessary to identify those who would suffer. In this study, we performed a meta-analysis on the related MACEs in the population with long lesion disease, but the results showed



FIGURE 9: The funnel plots of MI (30 days), ST (1 year), MI (1 year), cardiac death (1 year), TLR (1 year), TVR (1 year), all-cause death (1 year), and MACEs (1 year). TLR: target lesion revascularization; TVR: target vessel revascularization; MACEs: major adverse cardiovascular events.



FIGURE 10: Begg's funnel plot of MI (30 days), MI (1 year), cardiac death (1 year), and MACEs (1 year). MI: myocardial infarction; MACEs: major adverse cardiovascular events.

no significant statistical difference. Moreover, IVUS showed beneficial effects for patients with left main disease, but only 2 studies were included in this meta-analysis. This suggests that we need to include more populations for meta-analysis in the future to determine patients who would benefit most from IVUS guidance despite the cost of treatment.

At the 3-year follow-up period, the result of MACE analysis showed a great heterogeneity. We then carried out a sensitivity analysis to evaluate the stability of the relevant research. After reading the full text of the article carefully and discussing it with all researchers, the reason for the large heterogeneity was related to the study design. There was great heterogeneity in the result of cardiac death. After the sensitivity analysis, the OR of cardiac death in 3 years was 0.47 (95% CI: 0.29–0.77, P = 0.16, $I^2 = 45\%$). After carefully reading the full text and discussing with all of the researchers, the reason for the greater heterogeneity was related to the population differences [35]. The results of allcause death also had a greater heterogeneity. We used the same method after deleting studies that caused greater heterogeneity. The OR of all-cause death at the 3-year follow-up was 0.64 (95% CI: 0.47–0.86, P = 0.40, $I^2 = 0$ %). After reading the full text, we believed that the reasons for the greater heterogeneity were related to the study design and the heterogeneity of populations.

In previous meta-analyses, IVUS-guided treatment could reduce the incidence of MACEs in patients with complex lesions [36]. In this meta-analysis, IVUS-guided therapy played a better role in reducing the incidence of MACEs, TLR, and TVR [37]. The beneficial effects of IVUS were not limited to reducing the incidence of MACEs. It can also reduce clinical events such as stent thrombosis and death [38]. Moreover, IVUS-guided treatment played a beneficial role in reducing the incidence of acute myocardial infarction in patients with left main coronary artery disease [34]. However, we found that no one analyzed the long-term prognosis of IVUS-guided therapy. In this meta-analysis, we first classified the follow-up time of these studies and discussed the 30-day prognosis, 1-year prognosis, 2-year prognosis, and 3-year prognosis of IVUS-guided therapy. The results showed that IVUS-guided therapy had a better long-term prognosis. Interestingly, IVUS-guided therapy could reduce the incidence of TLR and TVR in 1 year, but there was no significant difference between the two strategies in 30 days, 2 years, and 3 years.

This meta-analysis proved that IVUS-guided PCI improved the short- and long-term prognoses of patients with PCI. Thus, we conclude that IVUS-guided therapy is superior to angiography-guided therapy in terms of reducing MACEs. However, we cannot deny the limitations of this meta-analysis. Only three of the studies were RCTs, while 17 were retrospective trials. Moreover, the number of studies related to the patients with long coronary artery disease and left main coronary artery disease was relatively small, leading to some degree of deviation. Thus, more clinical trials are needed to prove the accuracy of our results.

5. Conclusions

Compared with angiography-guided PCI, IVUS-guided PCI improves the short- and long-term prognoses of patients with PCI. In patients with long coronary lesions or left main artery disease, IVUS-guided PCI also manifests potential benefits.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Qun Zhang and Bailu Wang contributed equally to this work. Qun Zhang and Shujian Wei wrote the draft. Bailu Wang provided methodology and software. Yu Han and Shukun Sun contributed to data curation. Ruijuan Lv reviewed and edited the article.

Acknowledgments

This study was supported by the National Natural Science Foundation of China (82072141), Key R & D Program of Shandong Province (2019GSF108261), Natural Science Foundation of Shandong Province (ZR2020MH030), and Clinical Research Foundation of Shandong University (2020SDUCRCC014).

References

- D. L. Bhatt, "Percutaneous coronary intervention in 2018," *Journal of the American Medical Association*, vol. 319, no. 20, pp. 2127-2128, 2018.
- [2] D. R. Holmes Jr. and D. P. Taggart, "Revascularization in stable coronary artery disease: a combined perspective from an interventional cardiologist and a cardiac surgeon," *European Heart Journal*, vol. 37, no. 24, pp. 1873–1882, 2016.
- [3] J. Torrado, L. Buckley, A. Durán et al., "Restenosis, stent thrombosis, and bleeding complications: navigating between Scylla and charybdis," *Journal of the American College of Cardiology*, vol. 71, no. 15, pp. 1676–1695, 2018.
- [4] T. Kubo, T. Shinke, T. Okamura et al., "Optical frequency domain imaging vs. intravascular ultrasound in percutaneous coronary intervention (OPINION trial): one-year angiographic and clinical results," *European Heart Journal*, vol. 38, no. 42, pp. 3139–3147, 2017.
- [5] Y. Ye, M. Yang, S. Zhang, and Y. Zeng, "Percutaneous coronary intervention in left main coronary artery disease with or

without intravascular ultrasound: a meta-analysis," *PLoS One*, vol. 12, no. 6, Article ID e0179756, 2017.

- [6] D. Dash, "Optical coherence tomography is a kid on the block: I would choose intravascular ultrasound," *Indian Heart Journal*, vol. 69, no. 3, pp. 407–410, 2017.
- [7] S.-J. Hong, B.-K. Kim, D.-H. Shin et al., "Usefulness of intravascular ultrasound guidance in percutaneous coronary intervention with second-generation drug-eluting stents for chronic total occlusions (from the Multicenter Korean-Chronic Total Occlusion Registry)," *The American Journal of Cardiology*, vol. 114, no. 4, pp. 534–540, 2014.
- [8] J.-S. Kim, M.-K. Hong, Y.-G. Ko et al., "Impact of intravascular ultrasound guidance on long-term clinical outcomes in patients treated with drug-eluting stent for bifurcation lesions: data from a Korean multicenter bifurcation registry," *American Heart Journal*, vol. 161, no. 1, pp. 180–187, 2011.
- [9] A. Chieffo, A. Latib, C. Caussin et al., "A prospective, randomized trial of intravascular-ultrasound guided compared to angiography guided stent implantation in complex coronary lesions: the AVIO trial," *American Heart Journal*, vol. 165, no. 1, pp. 65–72, 2013.
- [10] Y.-W. Yoon, S. Shin, B.-K. Kim et al., "Usefulness of intravascular ultrasound to predict outcomes in short-length lesions treated with drug-eluting stents," *The American Journal* of Cardiology, vol. 112, no. 5, pp. 642–646, 2013.
- [11] K. W. Park, S.-H. Kang, H.-M. Yang et al., "Impact of intravascular ultrasound guidance in routine percutaneous coronary intervention for conventional lesions: data from the EXCELLENT trial," *International Journal of Cardiology*, vol. 167, no. 3, pp. 721–726, 2013.
- [12] B. E. Claessen, R. Mehran, G. S. Mintz et al., "Impact of intravascular ultrasound imaging on early and late clinical outcomes following percutaneous coronary intervention with drug-eluting stents," *JACC: Cardiovascular Interventions*, vol. 4, no. 9, pp. 974–981, 2011.
- [13] J. M. de la Torre Hernandez, J. A. Baz Alonso, J. A. Gómez Hospital et al., "Clinical impact of intravascular ultrasound guidance in drug-eluting stent implantation for unprotected left main coronary disease: pooled analysis at the patient-level of 4 registries," *JACC: Cardiovascular Interventions*, vol. 7, no. 3, pp. 244–254, 2014.
- [14] J.-S. Kim, T.-S. Kang, G. S. Mintz et al., "Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses," *JACC: Cardiovascular Interventions*, vol. 6, no. 4, pp. 369–376, 2013.
- [15] S. G. Ahn, J. Yoon, J. K. Sung et al., "Intravascular ultrasoundguided percutaneous coronary intervention improves the clinical outcome in patients undergoing multiple overlapping drug-eluting stents implantation," *Korean Circulation Journal*, vol. 43, no. 4, pp. 231–238, 2013.
- [16] S.-L. Chen, F. Ye, J.-J. Zhang et al., "Intravascular ultrasoundguided systematic two-stent techniques for coronary bifurcation lesions and reduced late stent thrombosis," *Catheterization and Cardiovascular Interventions*, vol. 81, no. 3, pp. 456–463, 2013.
- [17] X.-F. Gao, J. Kan, Y.-J. Zhang et al., "Comparison of one-year clinical outcomes between intravascular ultrasound-guided versus angiography-guided implantation of drug-eluting stents for left main lesions: a single-center analysis of a 1,016patient cohort," *Patient Preference and Adherence*, vol. 8, pp. 1299–1309, 2014.
- [18] S.-J. Hong, B.-K. Kim, D.-H. Shin et al., "Effect of intravascular ultrasound-guided vs. angiography-guided everolimus-

eluting stent implantation," Jama, vol. 314, no. 20, pp. 2155–2163, 2015.

- [19] B. K. Kim, D. H. Shin, M. K. Hong et al., "Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation: randomized study," *Circulation. Cardio*vascular interventions, vol. 8, no. 7, Article ID e002592, 2015.
- [20] Y. H. Kim, A.-Y. Her, S.-W. Rha et al., "Three-year major clinical outcomes of angiography-guided single stenting technique in non-complex left main coronary artery diseases," *International Heart Journal*, vol. 58, no. 5, pp. 704–713, 2017.
- [21] S.-J. Park, Y.-H. Kim, D.-W. Park et al., "Impact of intravascular ultrasound guidance on long-term mortality in stenting for unprotected left main coronary artery stenosis," *Circulation: Cardiovascular Interventions*, vol. 2, no. 3, pp. 167–177, 2009.
- [22] P. Roy, D. H. Steinberg, S. J. Sushinsky et al., "The potential clinical utility of intravascular ultrasound guidance in patients undergoing percutaneous coronary intervention with drugeluting stents," *European Heart Journal*, vol. 29, no. 15, pp. 1851–1857, 2008.
- [23] Q. Tan, Q. Wang, D. Liu, S. Zhang, Y. Zhang, and Y. Li, "Intravascular ultrasound-guided unprotected left main coronary artery stenting in the elderly," *Saudi Medical Journal*, vol. 36, no. 5, pp. 549–553, 2015.
- [24] J. Tian, C. Guan, W. Wang et al., "Intravascular ultrasound guidance improves the long-term prognosis in patients with unprotected left main coronary artery disease undergoing percutaneous coronary intervention," *Scientific Reports*, vol. 7, no. 1, Article ID 2377, 2017.
- [25] A. Maehara, G. S. Mintz, B. Witzenbichler et al., "Relationship between intravascular ultrasound guidance and clinical outcomes after drug-eluting stents," *Circulation. Cardiovascular interventions*, vol. 11, no. 11, Article ID e006243, 2018.
- [26] Y. J. Youn, J. Yoon, J.-W. Lee et al., "Intravascular ultrasoundguided primary percutaneous coronary intervention with drug-eluting stent implantation in patients with ST-segment elevation myocardial infarction," *Clinical Cardiology*, vol. 34, no. 11, pp. 706–713, 2011.
- [27] N. R. Smilowitz, D. Mohananey, L. Razzouk, G. Weisz, and J. N. Slater, "Impact and trends of intravascular imaging in diagnostic coronary angiography and percutaneous coronary intervention in inpatients in the United States," *Catheterization and Cardiovascular Interventions*, vol. 92, no. 6, pp. E410–e415, 2018.
- [28] K. Fujii, S. G. Carlier, G. S. Mintz et al., "Stent underexpansion and residual reference segment stenosis are related to stent thrombosis after sirolimus-eluting stent implantation: an intravascular ultrasound study," *Journal of the American College of Cardiology*, vol. 45, no. 7, pp. 995–998, 2005.
- [29] S.-J. Kang, J.-M. Ahn, H. Song et al., "Comprehensive intravascular ultrasound assessment of stent area and its impact on restenosis and adverse cardiac events in 403 patients with unprotected left main disease," *Circulation: Cardiovascular Interventions*, vol. 4, no. 6, pp. 562–569, 2011.
- [30] L. M. Zir, S. W. Miller, R. E. Dinsmore, J. P. Gilbert, and J. W. Harthorne, "Interobserver variability in coronary angiography," *Circulation*, vol. 53, no. 4, pp. 627–632, 1976.
- [31] P. K. Bundhun, C. M. Yanamala, and F. Huang, "Comparing the adverse clinical outcomes associated with fraction flow reserve-guided versus angiography-guided percutaneous coronary intervention: a systematic review and meta-analysis of randomized controlled trials," *BMC Cardiovascular Disorders*, vol. 16, no. 1, Article ID 249, 2016.

- [32] M. Ragosta, "Left main coronary artery disease: importance, diagnosis, assessment, and management," *Current Problems in Cardiology*, vol. 40, no. 3, pp. 93–126, 2015.
- [33] K. Sano, G. S. Mintz, S. G. Carlier et al., "Assessing intermediate left main coronary lesions using intravascular ultrasound," *American Heart Journal*, vol. 154, no. 5, pp. 983–988, 2007.
- [34] Y. Wang, G. S. Mintz, Z. Gu et al., "Meta-analysis and systematic review of intravascular ultrasound versus angiography-guided drug eluting stent implantation in left main coronary disease in 4592 patients," *BMC Cardiovascular Disorders*, vol. 18, no. 1, Article ID 115, 2018.
- [35] S.-H. Kim, Y.-H. Kim, S.-J. Kang et al., "Long-term outcomes of intravascular ultrasound-guided stenting in coronary bifurcation lesions," *The American Journal of Cardiology*, vol. 106, no. 5, pp. 612–618, 2010.
- [36] Z. G. Fan, X. F. Gao, X. B. Li et al., "The outcomes of intravascular ultrasound-guided drug-eluting stent implantation among patients with complex coronary lesions: a comprehensive meta-analysis of 15 clinical trials and 8,084 patients," *The Anatolian Journal of Cardiology*, vol. 17, no. 4, pp. 258–268, 2017.
- [37] C. Bavishi, P. Sardar, S. Chatterjee et al., "Intravascular ultrasound-guided vs. angiography-guided drug-eluting stent implantation in complex coronary lesions: meta-analysis of randomized trials," *American Heart Journal*, vol. 185, pp. 26–34, 2017.
- [38] Y. Zhang, V. Farooq, H. M. Garcia-Garcia et al., "Comparison of intravascular ultrasound versus angiography-guided drugeluting stent implantation: a meta-analysis of one randomised trial and ten observational studies involving 19,619 patients," *EuroIntervention*, vol. 8, no. 7, pp. 855–865, 2012.
- [39] B.-K. Kim, D.-H. Shin, M.-K. Hong et al., "Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation," *Circulation: Cardiovascular Interventions*, vol. 8, no. 7, 2015.
- [40] B. Witzenbichler, A. Maehara, G. Weisz et al., "Relationship between intravascular ultrasound guidance and clinical outcomes after drug-eluting stents," *Circulation*, vol. 129, no. 4, pp. 463–470, 2014.