The clinical and angiographic outcomes of post-dilation after percutaneous coronary intervention in patients with acute coronary syndrome: a systematic review and meta-analysis

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Abstract

Background

Optimal stent deployment is closely related to the prognosis of patients with coronary artery disease, but the effect of post-dilation on clinical and angiographic outcomes in patients with acute coronary syndrome is still controversial. This meta-analysis aims to analyze the clinical and angiographic outcomes of post-dilation after percutaneous coronary intervention in patients with acute coronary syndrome.

Methods

PubMed, Embase, The Cochrane Library, Web of Science, CNKI and WANGFANG date-bases were searched from inception to August 30, 2020. Eligible studies from acute coronary syndrome patients treated with post-dilation were included. The primary clinical outcome was major adverse cardiovascular events (MACE), the secondary clinical outcomes were comprised of all-cause death, stent thrombosis, myocardial infarction, and target vessel revascularization, the angiographic outcomes were no reflow and slow reflow.

Results

A total of 11 studies enrolling 5663 patients met inclusion criteria. Our pooled analysis demonstrated that the post-dilation did not have significant impact on MACE (OR = 0.76, 95% CI 0.50–1.17; P = 0.21), stent thrombosis (OR = 0.71, 95% CI 0.40–1.26; P = 0.24), myocardial infarction (OR = 0.14, 95% CI 0.51–3.83; P = 0.51), and target vessel revascularization of clinical outcomes (OR = 0.61, 95% CI 0.21–1.80; P = 0.37) between post-dilation and non-post-dilation groups, but increased the risk of all-cause death (OR = 1.49, 95% CI 1.05–2.19; P = 0.03). There were no significant difference in no reflow (OR = 1.19, 95% CI 0.54–2.65; P = 0.66) and slow reflow (OR = 1.12, 95% CI 0.93–1.35; P = 0.24) of angiographic outcomes between two groups.

Conclusions

The post-dilation can increase the risk of all-cause death, without affecting the risks of MACE, stent thrombosis, myocardial infarction, target vessel revascularization, no reflow and slow reflow. However, more randomized controlled trials are required for investigating the benefits of post-dilation for patients with acute coronary syndrome (Registered by PROSPERO, CRD42020160748).

1. Background

Percutaneous coronary intervention (PCI) has been widely used for patients with acute coronary syndrome (ACS), and the optimum coronary stent deployment is crucial to improve prognosis in the current practice of PCI. Stent under-expansion is usually the failure to achieve a minimal in-stent dimension more than 80% of the average reference segment diameter in patients with PCI. Studies showed that late stent thrombosis and very late stent thrombosis are mainly related to malapposition (31%), while prominent mechanisms of acute stent thrombosis and subacute stent thrombosis are malapposition (48%) and under-expansion (26%) [1]. Under-expansion is a significant cause of restenosis [2]. Thus, the post-dilation of stent deployment is performed to achieve optimal stent expansion and complete the apposition of stent struts against the vessel wall [3, 4]. Studies indicated that the post-dilation with a non-compliant balloon at higher pressure could reduce the restenosis rate, improve minimal stent area and minimal lumen diameter in unselected patients with stents implantation [3, 5]. Prolonged inflation could increase stent expansion and strut apposition [6], although overexpansion could increase neointimal hyperplasia caused by the inflammatory response to vessel wall injury, and lead to an increased incidence of peri-procedural myocardial infarction due to thrombus or plaque debris embolization in patients except for myocardial infarction and restenosis of the coronary artery [7–9]. A recent meta-analysis demonstrated that the post-dilation of stent deployment did not improve clinical outcomes in patients with coronary artery disease, which suggested that the strategy should be selectively employed after stent implantation [10]. However, compared with stable coronary artery disease, the patients with ACS may have a higher risk of in-stent thrombosis due to increased platelet reactivity, lack of endothelialization of vascular endothelium, delayed healing, and exposed to inflammation and coagulation environment in patients with ACS [11]. In recent years, several studies suggested that the post-dilation reduced target vessel revascularization [12, 13], while others suggested that the strategy increased death [14, 15]. The benefits of post-dilation in patients with ACS remain controversial. Therefore, a hypothesis that the post-dilation is feasible after stent implantation in patients with ACS was performed. This meta-analysis was conducted to verify the hypothesis that the post-dilation could improve clinical and angiographic outcomes in patients with those.

2. Methods

2.1 Search strategy and eligible criteria

The systematic review and meta-analysis was performed in accordance with the reporting items for systematic review and meta-analysis guidelines [16]. The review protocol was registered by PROSPERO, CRD42020160748. A literature search was systematically performed in PubMed, Embase, The Cochrane Library, Web of Science, CNKI and WANGFANG date-bases from inception to August 30, 2020, using the following terms “acute coronary syndrome” OR “ST segment elevation myocardial infarction” AND “percutaneous coronary intervention” OR “angioplasty” AND “post-dilation” without restrictions on region, publication type or language. Moreover, relevant reviews and meta-analyses to identify other eligible studies were searched manually. The following criteria had to be met to consider a study qualified for this meta-analysis: (1) all patients presenting with ACS including ST-segment elevation myocardial infarction (STEMI), non-ST-segment elevation myocardial infarction (NSTEMI) and unstable angina; (2) reporting coronary thrombolysis in myocardial infarction (TIMI) flow grade or one...
of the following clinical outcomes: MACE, all-cause death, stent thrombosis, myocardial infarction, and target vessel revascularization; (3) comparison of post-dilation group and non-post-dilation group; (4) randomized controlled trials or observational studies; (5) only studies enrolling patients with ACS were included, studies involving other patients were excluded.

2.2 Outcomes and definitions

The primary clinical outcome was MACE. The secondary clinical outcomes were composed of all-cause death, stent thrombosis, myocardial infarction, and target vessel revascularization. The definition of composited outcome, MACE, was derived from original studies (Supplemental Tab S1). All-cause death was defined as death caused by any reason including cardiac death and non-cardiac death. The stent thrombosis was defined as definite, probable or possible thrombosis [17]. The angiographic outcome was coronary TIMI flow grade after the post-dilation. TIMI 0–1 flow was defined as no reflow and slow reflow was defined as failed to achieve TIMI 3 flow.

2.3 Data extraction and quality assessment

Two researchers (LY and LXY) independently reviewed the titles, abstracts and full-texts of all searched literature to determine eligible studies. In addition, the baseline characteristics, procedural characteristics, and outcomes were extracted by the two researchers separately. A standard data extraction form was designed before extraction. The risk of bias was appraised by the other two researchers (ZWJ and QX) independently in the method and result section. Any differences or uncertainties shall be resolved by consensus or, if necessary, by a third party (WZL). The Cochrane tool of collaboration was used for the quality assessment of randomized controlled trials [18] and the Newcastle–Ottawa scale [19] for observational studies. It should be resolved through negotiation when there were divergences and, if necessary, interfered by a third party (WZL). As all analyses were based on previously published studies, ethical approval and informed consent of patients are exempt.

2.4 Statistical analysis

Review Manager Version (RevMan) 5.3 (The Nordic Cochrane Center, The Cochrane Collaboration, 2014, Copenhagen, Denmark) and Stata version 12.0 (STATA Corporation, College Station, TX, USA) were used to perform statistical analysis. Continuous variables of baseline characteristics were presented as mean ± standard deviation (SD). Dichotomous variables were presented as count or percentages. All outcomes were calculated with odds ratio (OR) of DerSimonian and Laird and 95% confidence intervals (95% CI) by means of Mantel-Haenszel method. All tests were two-sided P-values, a P < 0.05 was considered statistically significant. Heterogeneity of the eligible studies was assessed by the Cochrane Q statistic with Pearson chi-square test and the Higgins I² test. Random-effects model was performed to calculate the pooled OR if there was a significant heterogeneity (I² ≥ 50%), otherwise fixed-effects model was used. Sensitivity analysis was carried out to evaluate its impact on pooled value by excluding each study when heterogeneity was obvious (I² ≥ 50%) and subgroup analysis was performed to explain sources of heterogeneity. The outcome was analyzed by an intention-to-treat analysis. Publication bias test will not be performed in less than 10 studies.

3. Results

3.1 Search results and study characteristics

The literature search yielded 1351 articles, 821 of them were excluded after screening titles and abstracts, 60 of full-texts were reviewed. Ultimately, 11 studies (eight observational studies and three randomized controlled trials) enrolling 5663 patients met the inclusion criteria and are included in this meta-analysis (Fig. 1) [12–15, 20–26]. All studies were published between 2010 and 2019, six of them were multicenter studies and five were single-center studies. Among them, seven studies provided data of clinical and angiographic outcomes, two studies provided only clinical outcomes, and two studies provided only angiographic data. Among all eligible patients, there were 4347 (76.8%) patients with STEMI and the rest of them were patients with ACS including NSTEMI, NSTEMI, and unstable angina. The post-dilation strategy of stent deployment was received in 2514 (44.4%) of all patients, and 1937 (77.0%) of them were patients with STEMI. However, 3149 (55.6%) of all patients did not receive the post-dilation strategy, of whom 2410 (76.5%) were patients with STEMI. The sample sizes of studies varied from 124 to 1358. The majority of patients were males with age varying from 56.4 to 63.6 years. Hypertension accounted for 3149 (55.6%) of all patients did not receive the post-dilation strategy, of whom 2410 (76.5%) were patients with STEMI. The angiographic outcome was coronary TIMI flow grade after the post-dilation. TIMI 0–1 flow was defined as no reflow and slow reflow was defined as failed to achieve TIMI 3 flow.
### Table 1
Baseline characteristics of studies included.

<table>
<thead>
<tr>
<th>Study</th>
<th>Follow up duration</th>
<th>N  (n)</th>
<th>STEMI (n)</th>
<th>Mean Age (y)</th>
<th>Male (%)</th>
<th>Hypertension (%)</th>
<th>Hyperlipidemia (%)</th>
<th>Diabetes (%)</th>
<th>Current Smoking (%)</th>
<th>DES (%)</th>
<th>Stent Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saadat et al. 2019</td>
<td>348 Ds</td>
<td>500/724</td>
<td>500/724</td>
<td>58.4 ± 11.4/ 57.0 ± 12.1</td>
<td>76.0/77.0</td>
<td>60.0/60.0</td>
<td>28.0/26.0</td>
<td>8.0/11.0</td>
<td>74.5/70.9</td>
<td>26.5 ± 8</td>
<td>22.5 ± 6</td>
</tr>
<tr>
<td>Gao et al. 2018</td>
<td>12 M</td>
<td>199/137</td>
<td>199/137</td>
<td>59.4 ± 10.9/ 61.0 ± 11.3</td>
<td>78.9/76.6</td>
<td>61.3/52.6</td>
<td>3.0/2.9</td>
<td>NA</td>
<td>62.3/66.4</td>
<td>100/100</td>
<td>30.84 ± 12.17/2 ± 10.11</td>
</tr>
<tr>
<td>Karjalainen et al. 2017</td>
<td>5 Y</td>
<td>357/470</td>
<td>135/186</td>
<td>63.6 ± 11.3/ 62.5 ± 12.3</td>
<td>75.9/76.2</td>
<td>50.7/49.6</td>
<td>45.4/58.9</td>
<td>82.1/83.8</td>
<td>67.5/65.5</td>
<td>100/100</td>
<td>18.8 ± 5</td>
</tr>
<tr>
<td>Tasal et al. 2013</td>
<td>6 M</td>
<td>214/191</td>
<td>214/191</td>
<td>57.5 ± 11.8/ 56.4 ± 13.0</td>
<td>73.4/75.9</td>
<td>30.8/30.4</td>
<td>49.5/52.9</td>
<td>18.7/22.5</td>
<td>41.2/35.5</td>
<td>100/100</td>
<td>23.4 ± 6</td>
</tr>
<tr>
<td>Biswas et al. 2012</td>
<td>10.5 M</td>
<td>71/89</td>
<td>71/89</td>
<td>61.0 ± 12.6/ 62.9 ± 14.1</td>
<td>78.9/75.3</td>
<td>43.7/60.7</td>
<td>35.2/48.3</td>
<td>22.5/25.8</td>
<td>46.5/40.5</td>
<td>26.8/23.6</td>
<td>NA</td>
</tr>
<tr>
<td>Zhang et al. 2010</td>
<td>12 M</td>
<td>586/772</td>
<td>316/413</td>
<td>61.7 ± 12.9/ 60.1 ± 12.7</td>
<td>62.8/63.0</td>
<td>67.2/63.9</td>
<td>NA</td>
<td>2.60/23.0</td>
<td>NA</td>
<td>57.9/48.6</td>
<td>NA</td>
</tr>
<tr>
<td>Imori et al. 2016</td>
<td>2 Y</td>
<td>148/153</td>
<td>63/57</td>
<td>60.1 ± 12.7/ 61.0 ± 12.8</td>
<td>80.4/74.5</td>
<td>57.4/63.2</td>
<td>50.7/31.6</td>
<td>10.1/13.8</td>
<td>45.9/50.0</td>
<td>0</td>
<td>22.2 ± 5</td>
</tr>
<tr>
<td>Wang et al. 2019</td>
<td>1 Y</td>
<td>228/114</td>
<td>228/114</td>
<td>61.7 ± 8.4/ 63.6 ± 6.8</td>
<td>68.9/76.3</td>
<td>41.2/46.5</td>
<td>18.4/14.9</td>
<td>26.8/22.8</td>
<td>43.9/69.3</td>
<td>NA</td>
<td>29.6 ± 7</td>
</tr>
<tr>
<td>Qin et al. 2019</td>
<td>1 M</td>
<td>76/319</td>
<td>76/319</td>
<td>61.7 ± 12.3/ 60.0 ± 12.3</td>
<td>82.9/82.5</td>
<td>54.0/51.4</td>
<td>38.2/36.7</td>
<td>23.7/18.5</td>
<td>44.7/18.5</td>
<td>NA</td>
<td>26.75 ± 7.65/24.68 ± 1</td>
</tr>
<tr>
<td>Soylu et al. 2018</td>
<td>No</td>
<td>62/62</td>
<td>62/62</td>
<td>60.9 ± 13.2/ 60.2 ± 13.9</td>
<td>75.8/72.6</td>
<td>56.5/50.0</td>
<td>NA</td>
<td>30.6/27.4</td>
<td>59.7/58.1</td>
<td>100/100</td>
<td>26.75 ± 7.65/24.68 ± 1</td>
</tr>
</tbody>
</table>

Notes: 1. STEMI: ST-elevation myocardial infarction; 2. DES: Drug eluting stent; 3. D: day; M: month; Y: year; 4. NA: not available
Table 2

<table>
<thead>
<tr>
<th>Study</th>
<th>Follow up duration</th>
<th>N (n)</th>
<th>STEMI (n)</th>
<th>Mean Age (y)</th>
<th>Male (%)</th>
<th>Hypertension (%)</th>
<th>Hyperlipidemia (%)</th>
<th>Diabetes (%)</th>
<th>Current Smoking (%)</th>
<th>DES (%)</th>
<th>Stent Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yamaji et al. 2017</td>
<td>No</td>
<td>73/118</td>
<td>73/118</td>
<td>59.4 ± 9.7/ 58.2 ± 10.4</td>
<td>80.8/83.5</td>
<td>39.7/39.8</td>
<td>NA</td>
<td>16.4/16.9</td>
<td>54.8/44.9</td>
<td>34.2/60.2</td>
<td>NA</td>
</tr>
</tbody>
</table>

Notes: 1. STEMI: ST-elevation myocardial infarction; 2. DES: Drug eluting stent; 3. D: day; M: month; Y: year; 4. NA: not available

Table 2

<table>
<thead>
<tr>
<th>Procedural characteristics of studies included.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study</td>
</tr>
<tr>
<td>------------------------------</td>
</tr>
<tr>
<td>Saadat et al. 2019</td>
</tr>
<tr>
<td>Qin et al. 2019</td>
</tr>
<tr>
<td>Gao et al. 2018</td>
</tr>
<tr>
<td>Soylu et al. 2018</td>
</tr>
<tr>
<td>Yamaji et al. 2017*</td>
</tr>
<tr>
<td>Tasal et al. 2013</td>
</tr>
<tr>
<td>Biswas et al. 2012</td>
</tr>
</tbody>
</table>

Notes: 1. LM: left main; 2. LAD: left anterior descending; 3. LCX: left circumflex; 4. RCA: right coronary artery; 5. TIMI: thrombolysis in myocardial infarction; 6. PCI: percutaneous coronary intervention; 6.*: Number of lesions n = 120.

3.2 The primary clinical outcome

The risk of MACE was reported in seven studies, and there is no significant difference between post-dilation and non-post-dilation groups (OR = 0.76, 95% CI 0.50–1.17; P = 0.21, I² = 66%) (Fig. 2). The study producing heterogeneity was not found by sensitivity analysis (Supplemental Fig S2a). The subgroup analysis shows that there was no significant difference between the two groups after regrouping according to classification of diseases (STEMI or any ACS) and duration of follow-up (< 12 months or ≥ 12 months) (Supplemental Fig S4a).

3.3 The secondary clinical outcomes

The risk of all-cause death is higher in post-dilation group than that in non-post-dilation group in patients with ACS (OR = 1.49, 95% CI 1.05–2.19; P = 0.03, I² = 10%) (Fig. 3a), but there are no significant difference in stent thrombosis (OR = 0.71, 95% CI 0.40–1.26; P = 0.24, I² = 15%), myocardial infarction (OR = 0.140, 95% CI 0.31–6.73; P = 0.51, I² = 61%), and target vessel revascularization (OR = 0.61, 95% CI 0.21–1.80; P = 0.37, I² = 70%) (Fig. 3b). There was obvious heterogeneity in myocardial infarction (I² = 61) and target vessel revascularization (I² = 70%). Two studies producing heterogeneity were determined by sensitivity analysis [12, 23] (Supplemental Fig S2b and S2c). The heterogeneity decreased and the statistical significance changed (OR = 2.03, 95% CI 1.18–3.50; P = 0.01, I² = 0%) (Supplemental Fig S3a) after removing the study [12], which suggested that the post-dilation increased the incidence of myocardial infarction. The heterogeneity and statistical significance of target vessel revascularization also changed after omitting the study of Gao et al. [23] (OR = 0.34, 95% CI 0.18–0.63; P = 0.0007, I² = 0%) (Supplemental Fig S3b), indicating that the post-dilation decreased the incidence of target vessel revascularization. There were no significant differences in stent thrombosis and myocardial infarction in two groups when subgroup analysis was carried out according to...
classification of diseases and duration of follow-up. The post-dilation did not affect all-cause death in patients with STEMI but reduced the risk of target vessel revascularization in patients with any ACS (Supplemental Fig S4b). Furthermore, the post-dilation did not increase the risk of all-cause death but reduced the risk of target vessel revascularization in patients with ACS within 12 months when regrouping according to duration of follow-up (Supplemental Fig S4c).

3.4 The angiographic outcomes

The no reflow and slow reflow were reported in seven studies involving 2837 patients with ACS, which indicates that there were no significant difference between post-dilation and non-post-dilation groups (OR = 1.19, 95% CI 0.54–2.65; P = 0.66, I² = 0%; OR = 1.12, 95% CI 0.93–1.35; P = 0.24, I² = 44%) (Fig. 4).

4. Discussion

This systematic review and meta-analysis first assesses the clinical and angiographic outcomes of post-dilation after coronary stent implantation in patients with ACS, which shows that the post-dilation of stent deployment was associated with an increase of all-cause death but not related to MACE, stent thrombosis, myocardial infarction, and target vessel revascularization of clinical outcomes. In addition, the rate of no reflow and slow reflow in post-dilation group are similar to that in non-post-dilation group.

The ESC guideline recommended that the majority of patients with ACS should use the invasive PCI, and primary PCI is the preferred reperfusion strategy for STEMI patients [27]. In the bare metal stents era, the restenosis rate caused by neointimal hyperplasia was between 20% and 30% [28]. With the advancement of stents technology, the drug-eluting stents improve restenosis compared with bare-metal stents [29]. However, complications after stent implantation, such as in-stent thrombosis, no reflow and others still occur. The majority of non-fatal myocardial infarction and 45% of death were included in the clinical sequelae of stent thrombosis [30]. The post-dilation is a treatment strategy with non-compliant balloon of appropriate size [31], which could improve stent under-expansion and incomplete stent apposition, in turn reducing in-stent restenosis and target vessel revascularization [3]. The POSTIT trial, aiming to evaluate the necessity of post-dilation after coronary stent deployment, manifested that only 29% of patients achieved the optimum stent deployment (minimal stent diameter ≥ 90% of the average reference lumen diameter assessed by intravascular ultrasound), 71% of patients were under-expansion [3]. The CRUISE (Can Routine Ultrasound Influence Stent Expansion) study showed that target vessel revascularization had been reduced by 44% and the final minimum stent area had been increased by 14% after the post-dilation with the guidance of intravascular ultrasound [32]. During the bioresorbable vascular scaffolds and sirolimus-eluting stents implantation, the post-dilation with high-pressure non-compliant balloon and large sizes balloon (balloons > 1 mm larger than the stent nominal size) also demonstrated safe clinical and angiographic results [33, 34]. There were a few studies on the post-dilation at present, the majority of them were observational studies and excluded patients with ACS, only patients with stable coronary artery disease, long lesions or calcification lesions were included. Recently, a meta-analysis (conference abstract) including seven observational studies for patients with coronary artery disease indicated that the post-dilation could not reduce the risk of MACE, all-cause death, myocardial infarction and target vessel revascularization, and recommended that the post-dilation should be performed in selective patients but not in all patients undergoing PCI [10]. However, due to the high pro-inflammatory risk, thrombotic environment and coronary spasm caused by circulating vasoconstrictors in patients with acute myocardial infarction, the conclusions of post-dilation in patients with coronary artery disease can not be extended to patients with ACS. Therefore, it is necessary to explore the benefits of post-dilation in patients with ACS.

This meta-analysis suggested that there were no significant difference in MACE, myocardial infarction and target vessel revascularization between post-dilation group and non-post-dilation group, which was similar to the results of the meta-analysis by Chen et al in 2018 [10]. However, The heterogeneity of MACE, myocardial infarction and target vessel revascularization in this study was obvious. The sensitivity analysis of MACE did not find study producing heterogeneity. Therefore, the result of MACE in this study should be interpreted with caution. The sensitivity analysis of target vessel revascularization found that the heterogeneity came from the study of Gao et al [23]. The target lesions were more complex and immediate TIMI flow was impaired in the post-dilation group in this study, finial TIMI flow was same in two groups due to the use of intracoronary vasodilator agents. However, it may be associated with further adverse clinical outcomes. Meanwhile, the subgroup analysis showed that the target vessel revascularization could be reduced after the post-dilation within 12 months, and patients with any ACS could also benefit from this strategy. The sensitivity analysis of myocardial infarction displayed that the heterogeneity was derived from the study by Imoril et al [12]. The bioabsorbable scaffolds were used in this study, which was different from drug-eluting stents and bare-metal stents used in other studies. The post-dilation increased myocardial infarction after excluding this study, which indicated that the post-dilation was more suitable for bioabsorbable scaffolds. This may be due to the fact that the stent platform materials of bare-metal stent and drug-eluting stent are stainless steel, chrome-cobalt, platinum–chromium, or nickel/titanium alloy, which have a stable structure that provides reliable, compliant struts expansion without the risk of disruption. However, the bioabsorbable scaffolds use polylactic acid and other polymer materials as scaffolds to provide temporary mechanical support for stenotic or occluded coronary arteries. It represents a potential risk for clinical outcomes because of the relatively thick struts and limited expansion. Five-year follow-up from the ABSORB III Trial indicated that rate of target lesion failure was increased compared with everolimus-eluting stents [35]. The post-dilation after the use of bioabsorbable scaffolds appears to be effective. Meanwhile, this meta-analysis suggested that the post-dilation did not reduce thrombosis, which was consistent with the conclusion of Hong et al in 2017 (HR = 0.39,CI 0.07–2.31, P = 0.279) [36]. The study by Chen et al. also found that the post-dilation did not change all-cause death, which was different from the conclusion that the post-dilation increased all-cause death in this study. This may be related to the inclusion criteria of that study [10]. All patients with coronary artery disease undergoing PCI were included in that meta-analysis, including patients with stable coronary artery disease. The levels of troponin I and highly sensitive creatine protein were elevated after stent expansion, suggesting more myocardial damage and inflammation [37]. The primary lesion in patients with acute coronary syndrome is more unstable due to more necrotic cores and fewer fibrous fatty plaques than in patients with stable coronary artery disease [38]. The elevation of cardiac troponin occurs in lesions with a large necrotic core area and in lipid-rich lesions [39, 40]. Therefore, patients with ACS may suffer more myocardial damage. This may be the reason for increase of all-cause death rate in ACS patients with stent post-dilation. Interestingly, there was no increase in all-cause death in ACS patients within 12 months after post-dilation. At present, dual antiplatelet therapy is mainly used in ACS patients for 12 months after PCI. After 12 months, aspirin...
monotherapy or dual antiplatelet therapy regimen should be depended on the specific conditions of patients, which may affect long-term all-cause death. In addition, studies have shown that the levels of plasma B-type natriuretic peptide significantly increase following the post-dilation, which is a biomarker of heart failure [37]. Long-term heart failure can also cause an increase death. Moreover, previous studies lacked a uniform definition of reflow, making no reflow rate and slow reflow rate fluctuate between 1% and 30% [24], which was difficult to guide clinical practice. Therefore, this study unified the definition of no reflow and slow reflow and concluded that the post-dilation had no effect on no reflow and slow reflow.

However, these results should be interpreted carefully. Firstly, whether or not to receive the post-dilation strategy after stent deployment mainly depends on the individual situation of patients and the wills of operator. Secondly, different definitions of outcomes and baseline characteristics of studies included will affect clinical outcomes. For example, in the pooled analysis of MACE, the study by Gao et al. defined MACE as hospitalization caused by angina pectoris, dyspnea, ventricular thrombus, which is quite different from other studies. Similarly, for repeat revascularization, the definition was vague and the outcome cannot be evaluated. Furthermore, the complications of PCI are not only related to the stent under-expansion, but also to thrombus aspiration, thrombolytic drugs for intracoronary injection or vasodilator, and antiplatelet drug compliance. Finally, although some studies have shown coronary TIMI flow grade after PCI, only a few studies compared no reflow or slow reflow between two groups. Therefore, further randomized controlled trials are needed to verify the benefits of post-dilation.

5. Limitations

The limitations of this study should be recognized. Firstly, this meta-analysis mainly included retrospective studies (7/11), which were more likely to include selection, observation, or publication bias, and confounding factors. Due to the limitation of the number of post-dilatation studies, studies with different designs and sample sizes should not be excluded. Secondly, the definition of outcome varies in each study, and the definition from the original study was adopted. Thirdly, three post hoc analyses were included in this study, which might have lost some of the raw data. Fourthly, because detailed datas on bare metal stents, drug-eluting stents and bioresorbable scaffolds of study included were not available, a subgroup analysis of stent type was not performed. Finally, patients are expected to receive dual antiplatelet therapy for at least one year after PCI in the studies included, but the details of whether patients regularly take antiplatelet agents are still unclear, which is also the key to clinical efficacy in the future.

6. Conclusion

In conclusion, the post-dilation strategy has an adverse effect on all-cause death in patients with ACS, but no effect on other clinical outcomes and coronary TIMI flow grade. Therefore, it is not necessary for all patients with ACS undergoing PCI to receive post-dilation. Meanwhile, more specialized randomized controlled trials are demanded of confirming this conclusion.

Abbreviations

MACE: major adverse cardiovascular events; PCI: Percutaneous coronary intervention; ACS: acute coronary syndrome; STEMI: ST-segment elevation myocardial infarction; NSTEMI: non-ST-segment elevation myocardial infarction; TIMI: thrombolysis in myocardial infarction; OR: odds ratio; SD: standard deviation; CI: confidence interval.

Declarations

Ethics approval and consent to participate

Not Applicable.

Consent for publication

Not Applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

Funding

No funding was received for conducting this study.

Authors’ contributions
LY: study designing and manuscript writing; LXY: data collection and data extraction; ZWJ: data analysis and interpretation; QX: software operation. WZL supervised the study.

Acknowledgements

Not Applicable.

References


26. 10.1002/ccd.28396


Figures
Figure 1

Flow chart of study selection.

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Events</th>
<th>Total</th>
<th>Non-post-dilation</th>
<th>Total</th>
<th>Weight</th>
<th>Odds Ratio M.H. Random</th>
<th>95% CI</th>
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<tbody>
<tr>
<td>Bloos et al 2012</td>
<td>8</td>
<td>71</td>
<td>10</td>
<td>89</td>
<td>10.5%</td>
<td>1.00 [0.37, 2.69]</td>
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<tr>
<td>Goet et al 2018</td>
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<td>17</td>
<td>216</td>
<td>16.2%</td>
<td>1.78 [0.98, 3.28]</td>
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<tr>
<td>Iron et al 2018</td>
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<td>145</td>
<td>19</td>
<td>164</td>
<td>11.7%</td>
<td>0.95 [0.41, 2.09]</td>
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<tr>
<td>Najafizadeh et al 2017</td>
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<td>397</td>
<td>71</td>
<td>468</td>
<td>20.6%</td>
<td>1.05 [0.71, 1.53]</td>
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</tr>
<tr>
<td>Sawat et al 2018</td>
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<td>672</td>
<td>62</td>
<td>734</td>
<td>22.1%</td>
<td>0.62 [0.44, 0.89]</td>
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<tr>
<td>Tass et al 2018</td>
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<td>21</td>
<td>238</td>
<td>15.7%</td>
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<tr>
<td>Wang et al 2019</td>
<td>2</td>
<td>237</td>
<td>7</td>
<td>244</td>
<td>5.5%</td>
<td>0.34 [0.04, 0.66]</td>
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<tr>
<td>Total (95% CI)</td>
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<td>1878</td>
<td>100.0%</td>
<td>1978</td>
<td></td>
<td>0.76 [0.50, 1.17]</td>
<td></td>
</tr>
</tbody>
</table>

Total events: 100, 227

Heterogeneity: \( I^2 = 0.19 \) \( P < 0.003 \), \( P = 0.66 \)

Test for overall effect: \( Z = 1.24 (P = 0.21) \)

Figure 2

Forest plot of primary clinical outcome between post-dilation and non-post-dilation group. Notes: MACE= major adverse cardiac events.
Figure 3
Forest plots of secondary clinical outcomes between post-dilation and non-post-dilation groups.

No reflow

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>Events Post-dilation</th>
<th>Events Non-post-dilation</th>
<th>Total Events</th>
<th>Total Weight</th>
<th>M-H Risk Ratio 95% CI</th>
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<tr>
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<td>0.27</td>
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<tr>
<td>Sun et al 2019</td>
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<td>0.63</td>
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<tr>
<td>Total</td>
<td>23</td>
<td>8</td>
<td>31</td>
<td>0.63</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Total events: 31

Figure 4
Forest plots of angiographic outcomes between post-dilation and non-post-dilation groups.
Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx
- PRISMAchecklist.doc