Intracoronary Glycoprotein IIb/IIIa Inhibitors Improve Short-Term Mortality and Reinfarction in East Asian Patients with ST-Segment Elevation Myocardial Infarction after Thrombus Aspiration: A Meta-Analysis

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Objective. Intracoronary (IC) glycoprotein IIb/IIIa inhibitors (GPIs) after thrombus aspiration (TA) for patients with ST-segment elevation myocardial infarction (STEMI), as compared with percutaneous coronary interventions (PCI) alone, is still on debate. To address this issue, we performed a meta-analysis of results from prospective or randomized controlled trials on the topic.

Methods. We searched electronic and printed sources (up to June 20, 2016) according to the selection criteria. Data were abstraction and meta-analysis was performed using RevMan 5.3 software.

Results. The cohorts involved 14 articles describing 1,918 participants were included. The incidence of the short-term major adverse cardiac events (MACE) was significantly reduced with intracoronary GPIs after TA (odds ratio [OR]: 0.29; 95% confidence interval [CI]: 0.13 to 0.65, p=0.003). Benefits were noted for short-term mortality (OR: 0.31; 95% CI: 0.17 to 0.57, p=0.0002) and reinfarction (OR: 0.28; 95% CI: 0.10 to 0.78, p=0.01) in subjects who received intracoronary GPIs after TA. Moreover, the Thrombolysis in Myocardial Infarction (TIMI) trial grade 3 postprocedure (OR: 2.29; 95% CI: 1.72 to 3.04, P < 0.00001) and complete ST-segment resolution (STR) rate (OR: 2.68; 95% CI: 1.85 to 3.87, P < 0.00001) were both improved with intracoronary GPIs after TA. As a result, left ventricular ejection fraction (LVEF) at short-term follow-up showed a significant difference (OR: 7.33; 95% CI: 5.60 to 9.06, p<0.0001) in favor of the TA and intracoronary GPIs administration.

Conclusions. Our study demonstrates that intracoronary GPIs may have a synergistic effect with thrombus aspiration on short-term mortality, reinfarction, and cardiac functional recovery.

1. Introduction

Primary percutaneous coronary intervention (PCI) has become the preferred reperfusion modality for patients with acute ST-segment elevation myocardial infarction (STEMI) [1]. As we all know, the possibility of distal embolization of atherosclerotic plaque and thrombus with subsequent microvascular injury and increased infarct size during primary PCI is associated with adverse cardiovascular events [2]. Thrombus aspiration (TA) has the potential of reducing distal embolization and improving microvascular perfusion during primary PCI. Even though numerous international studies have been reported, there are still conflicting results on the clinical impact of thrombus aspiration during primary PCI [3, 4]. Recent evidence from Routine Aspiration Thrombectomy With Percutaneous Coronary Intervention (PCI) Versus PCI Alone in Patients With ST-Segment Elevation Myocardial Infarction (STEMI) Undergoing Primary PCI (TOTAL) trial, the largest trial of thrombus aspiration in STEMI so far, suggested that routine thrombus aspiration, as compared with PCI alone, did not reduce the risk of major adverse cardiovascular events (MACE) within 180 days [5], consistent with those of Thrombus Aspiration during ST-Segment Elevation Myocardial Infarction (TASTE) trial [4] and the Intracoronary Abciximab and Aspiration Thrombectomy in Patients With Large Anterior Myocardial Infarction (Hindawi Evidence-Based Complementary and Alternative Medicine Volume 2018, Article ID 5174714, 11 pages https://doi.org/10.1155/2018/5174714)
Data Analysis.

The grade of study quality was assessed as the previous meta-\textit{tigator} (Chen Y.G.) and by referencing the original report. Data were extracted independently by 2 investigators (Li R.J. and Hao P.P.) using a standardized extraction form and compared. The short-term clinical outcome was less than three months and the long-term clinical outcome was defined as more than three months, and other 3 studies [7, 21, 22] reported the long-term clinical outcome (18 months, 12 months, and 6 months, respectively). Figure 1 reported study selection procedure, while Table 1 summarizes the most relevant characteristics of the selected studies.

Seven studies depicting baseline characteristics were summarized in Table 2. For these studies, baseline characteristics were not significantly different between the two groups. Choi’s study was an abstract from ANGIOPLASTY SUMMIT in 2009 [22], and we could not obtain accurate baseline characteristics although we have contacted the corresponding author. Other 6 studies described those baseline characteristics were balanced between two groups in papers, while no accurate data of baseline characteristics were obtained from [15–20].

There were 8 studies which reported short-term MACE after the procedure [10–12, 14, 16–18, 20]. The analysis for the short-term MACE revealed that the incidence of MACE was significantly lower in the patients treated with intracoronary GPIs after TA than those with PCI alone (1.86\% versus 6.06\%; odds ratio (OR): 0.29; 95\% confidence interval (CI): 0.13 to 0.65, p=0.003; Figure 2(a)). In terms of short-term mortality, 7 studies reported the results [11–13, 15, 16, 18, 19]. The incidence of short-term mortality was significantly reduced in subjects who received TA and IC GPIs treatment (3.06\% versus 8.59\%; OR: 0.31; 95\% CI: 0.17 to 0.57, p=0.0002; Figure 2(b)). Eight studies reported the short-term reinfarction rates [10, 12–16, 18, 19]. An obviously decreased risk of short-term reinfarction was observed in the TA and IC GPIs group compared with the PCI group (0.85\% versus 3.37\%; OR: 0.28; 95\% CI: 0.10 to 0.78, p=0.01; Figure 2(c)).

Looking at the long-term MACE reported by 3 studies, our analysis did not show a significant difference between the two groups (6.41\% versus 9.65\%; OR: 0.69; 95\% CI: 0.20 to 2.34, p=0.55; Figure 3(a)) [7, 21, 22]. Similarly, no significant difference was noted in long-term mortality between the two groups (1.28\% versus 6.81\%; OR: 0.94; 95\% CI: 0.11 to 8.04; p=0.95; Figure 3(b)) [7, 21, 22]. The analysis of long-term reinfarction rate was unable to be performed due to only two studies reporting [7, 21].
| Study        | Year | Location       | Study design | Patients included, PPCI or not | MACE                                                                 | Mortality reported | Follow up (months) | TA catheter      | Study quality |
|--------------|------|----------------|--------------|-------------------------------|----------------------------------------------------------------------|-------------------|-------------------|------------------|---------------|
| Choi         | 2009 | Republic of Korea | Retrospective | STEMI, PPCI                   | mortality                                                            | Yes               | 18                | Export           | Fair          |
| Liu XY       | 2013 | Mainland China  | Randomized   | STEMI, PPCI                   | death, reinfarction, TLR                                            | Yes               | 12                | ZEEK             | Good          |
| Liu CP       | 2013 | Taiwan          | Randomized   | STEMI, non-PPCI               | death, reinfarction, TLR, and stroke cardiac death, non-fatal MI, unstable angina and new-CHF | Yes               | 6                 | Thrombuster II   | Good          |
| Chen CW      | 2013 | Mainland China  | Randomized   | STEMI, PPCI                   |                                                                      | No                | 1                 | NR               | Fair          |
| Dong PS      | 2011 | Mainland China  | Prospective  | STEMI, PPCI                   | death, reinfarction, TLR, and new-CHF                                | Yes               | 1                 | ZEEK             | Fair          |
| Guo YS       | 2011 | Mainland China  | Prospective  | STEMI, PPCI                   | Cardiac death, reinfarction and acute HF cardiac death, non-fatal MI, unstable angina and new-CHF | Yes               | In hospital       | GOODMAN         | Fair          |
| Huang S      | 2013 | Mainland China  | Prospective  | STEMI, PPCI                   |                                                                      | Yes               | In hospital       | ZEEK             | Fair          |
| Huang WG     | 2010 | Mainland China  | Randomized   | STEMI, PPCI                   |                                                                      | Yes               | In hospital       | ZEEK             | Fair          |
| Jia XG       | 2009 | Mainland China  | Prospective  | STEMI, PPCI                   |                                                                      | Yes               | In hospital       | ZEEK             | Fair          |
| Zhou DH      | 2012 | Mainland China  | Randomized   | STEMI, PPCI                   |                                                                      | No                | 3                 | Driver C.E.      | Fair          |
| Liu W        | 2012 | Mainland China  | Prospective  | STEMI, PPCI                   |                                                                      | No                | In hospital       | Driver C.E.      | Fair          |
| Pan G        | 2011 | Mainland China  | Randomized   | STEMI, PPCI                   | death, reinfarction, and new-CHF                                      | Yes               | In hospital       | Driver C.E.      | Fair          |
| Wang XM      | 2012 | Mainland China  | Randomized   | STEMI, PPCI                   | death, reinfarction, TLR                                            | Yes               | 1                 | NR               | Fair          |
| Yang WM      | 2014 | Mainland China  | Randomized   | STEMI, PPCI                   | death, reinfarction, TLR, and new-CHF                                | Yes               | In hospital       | EXPORT           | Fair          |

PCI: percutaneous coronary intervention; PPCI: primary PCI; STEMI: ST-elevation myocardial infarction; MACE: major adverse cardiac events; TA: thrombus aspiration; CHF: congestive heart failure; TLR: target lesion revascularization; NR: not reported.
Table 2: Baseline and procedural characteristics in 7 reported studies.

| Characteristics                      | Liu XY (2013) | Liu CP (2013) | Chen CW (2013) | Huang S (2013) | Huang WG (2010) | Jia XG (2009) | Wang XM (2012) |
|--------------------------------------|---------------|---------------|---------------|---------------|----------------|--------------|---------------|
|                                      | GTA (n=40)    | GPCI (n=40)   | GTA (n=28)    | GTA (n=23)    | GTA (n=46)     | GTA (n=31)   | GTA (n=42)    |
| Mean Age (years)                     | 64.5          | 66.7          | 59            | 57            | 61             | 52.6         | 51.7          |
| Male (n, %)                          |               |               | 21 (87.0%)    | 20 (87.0%)    | 28 (80.7%)     | 25 (80.6%)   | 28 (80.7%)    |
| Hypertension (n, %)                  |               |               | 13 (46.4%)    | 16 (53.6%)    | 21 (54.3%)     | 21 (64.2%)   | 21 (64.2%)    |
| DM (n, %)                            |               |               | 7 (25.0%)     | 10 (35.7%)    | 16 (40.0%)     | 17 (51.6%)   | 17 (51.6%)    |
| Hypercholesterolemia (n, %)          |               |               | 7 (32.1%)     | 10 (45.5%)    | 24 (52.2%)     | 21 (67.7%)   | 21 (67.7%)    |
| Current smoker (n, %)                |               |               | 16 (57.1%)    | 17 (63.0%)    | 18 (39.1%)     | 12 (38.7%)   | 12 (38.7%)    |
| Infarct location, anterior/inferior and posterior wall (n) | 2 (31.7%) | 24 (16) | 11 (17) | 12 (11) | 22 (22) | 24 (22) | - | - |
| Postoperative TIMI grade 3 flow (n, %) | 36 (90.0%) | 36 (90.0%) | 27 (96.4%) | 18 (78.3%) | 41 (93.2%) | 36 (78.3%) | 29 (93.5%) | 39 (92.9%) |
| Postoperative LVEF in hospital or follow-up (%) | 53.6 | 45.6 | 57 | 53 | 51.2 | 48.25 | 56.7 | 55.8 |

GTA: the group for intracoronary glycoprotein IIb/IIIa inhibitors after thrombus aspiration; GPCI: the group for percutaneous coronary interventions alone; DM: diabetes mellitus; LVEF: left ventricular ejection fraction; TIMI: thrombolysis in myocardial infarction trial.
Thirteen studies reported the postprocedural flow grades based on the Thrombolysis in Myocardial Infarction (TIMI) trial [7, 10–15, 17–22]. The incidence of postprocedural TIMI flow grades 3 was higher in patients treated with TA and IC GPIs compared with those who did not (81.9% versus 63.6%; OR: 2.29; 95% CI: 1.72 to 3.04, P < 0.00001; Figure 4(a)). Seven studies reported complete ST-segment resolution (STR) rate at 60 minutes–90 minutes after the procedure [7, 11, 12, 14, 16, 20, 22]. The incidence of postprocedural complete STR significantly increased in patients treated with TA and IC GPIs (79.8% versus 59.2%; OR: 2.68; 95% CI: 1.85 to 3.87, P < 0.00001; Figure 4(b)). Subgroup analysis, according to TA catheter, showed that both postprocedural TIMI flow 3 and MACE were improved in studies using ZEEK aspiration catheter (Zeon Medical Inc., Tokyo, Japan) and EXPORT aspiration catheter (Medtronic, Minneapolis, Minnesota), whereas no benefit of MACE was observed in studies using Driver C.E. aspiration catheter (Invatec, Brescia, Italy) (Table 3).

Importantly, the analysis of left ventricular ejection fraction (LVEF) before discharge or at short-term follow-up (reported by 11 studies) showed a significant difference (54.5% versus 47.0%; OR: 7.33; 95% CI: 5.60 to 9.06, p<0.0001) in favor of the TA and IC GPIs administration route (Figure 4(c)) [7, 10–14, 16, 18–21]. There were no significant differences in the major bleeding and minor bleeding events between the two groups (4.22% versus 3.77%; OR: 1.16; 95% CI: 0.63 to 2.15, p=0.64; Figure 5) [7, 12–19, 21].

In heterogeneity testing and sensitivity analysis, we also found no significant heterogeneity for studies reporting short-term MACE, death, and reinfarction, and exclusion of any single study did not alter the overall finding. The funnel plot assessing the publication bias is shown in Figure 6. We calculated the Nfs0.05 for MACE, death, and recurrent MI of the short term was 10.29, 14.93, and 2.97, whereas those of long term were -0.99, -0.99, and -0.82, which indicated publication bias that might influence the meta-analysis results.

**Table 3: Subgroup meta-analysis of postoperative TIMI grade 3 flow and MACE according to TA catheter.**

| TA catheter | Number of studies | Postoperative TIMI grade 3 flow | MACE |
|-------------|-------------------|---------------------------------|------|
|             |                   | OR (95% CI) | P value | OR (95% CI) | P value |
| ZEEK        | 5                 | 2.52 (1.01, 6.31) | P=0.05 | 0.22 (0.14, 0.35) | P<0.0001 |
| Driver C.E. | 3                 | 4.97 (2.03, 12.15) | P=0.0004 | 0.22 (0.02, 2.14) | P=0.19 |
| EXPORT      | 2                 | 8.75 (2.92, 26.26) | P=0.0001 | 0.38 (0.14, 1.0) | P=0.05 |

TA: thrombus aspiration; OR: odds ratio; 95% CI: 95% confidence interval; TIMI: thrombolysis in myocardial infarction trial; MACE: major adverse cardiac events.

4. Discussion

The main findings of the present meta-analysis are as follows: (1) a combination of thrombus aspiration and intracoronary GPIs seemed to be superior to PCI alone in terms.
of enhancing myocardial perfusion, as assessed by post-procedural TIMI flow 3, and complete STR rate. Importantly, cardiac function at short-term follow-up, analyzed by LVEF, showed much better to be in the thrombus aspiration and intracoronary GPIs group over the PCI group.

(2) The incidence of short-term MACE was significantly reduced with intracoronary GPIs after thrombus aspiration, including death and reinfarction, whereas there was no trend towards better outcome in studies with long-term MACE.

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**Figure 2:** (a) The meta-analysis of MACE at the short-term follow-up; (b) the meta-analysis of death at the short-term follow-up; (c) the meta-analysis of reinfarction at the short-term follow-up. MACE: major adverse cardiac events; TA: thrombus aspiration; IC: intracoronary; GPIs: glycoprotein IIb/IIIa inhibitors; PCI: percutaneous coronary interventions.
Thrombus aspiration during primary PCI is controversial, especially after the TOTAL trial which showed that routine thrombus aspiration did not reduce the risk of long-term MACE, as compared with PCI alone, and the findings are consistent with those of the INFUSE-AMI trial. However, a subgroup analysis of the INFUSE-AMI trial showed that thrombus aspiration plus intracoronary administration of GPIs improved myocardium perfusion and resulted in a better clinical prognosis [6]. A recent meta-analysis, summarizing the conflicting randomized controlled trials (RCTs) of comparing thrombus aspiration with the control arm, showed that thrombus aspiration along with GPIs is associated with improved 30-day mortality [23]. However, the authors performed metaregression and compared the studies with a higher proportion of glycoprotein IIb/IIIa inhibitor use and those with lower glycoprotein IIb/IIIa inhibitor use in the thrombus aspiration arm [23]. In contrast, we pooled the studies which directly compared thrombus aspiration plus GPIs with PCI alone, especially intracoronary administration. Our meta-analysis could demonstrate a reduced incidence of short-term MACE in the intracoronary GPIs after thrombus aspiration group, as compared to the PCI group. Further analysis showed that the benefit comes from reduced short-term mortality and reinfarction. Nonetheless, it has to be underlined that no benefit of long-term MACE was observed.

Ahn et al. found that distal embolization was less likely to occur in patients undergoing intracoronary abciximab and thrombus aspiration as assessed by on-site measurement of the index of microcirculatory resistance (IMR) after primary PCI [24], which suggested that combination treatment using GPIs and thrombus aspiration may synergistically improve myocardial perfusion in patients with STEMI undergoing primary PCI. It was suggested that direct intracoronary injection of GPIs might be superior to its intravenous injection for improving myocardial perfusion due to creating a higher local concentration of around the coronary thrombus, and high local concentration may facilitate thrombus disaggregation and improve microvascular perfusion [24, 25]. Our meta-analysis found that intracoronary GPIs after thrombus aspiration provided significant benefits in postprocedural TIMI flow grade 3, complete STR when compared with PCI alone. STR is a simple and reliable marker of effective myocardial reperfusion which correlates with cardiac functional recovery [26]. In the present meta-analysis, complete STR tends to be better in the intracoronary GPIs after thrombus aspiration group than that in the PCI alone group. This result coincided with the improvement in left ventricular function measured by LVEF and resulted in a trend towards better clinical outcomes.

A subgroup analysis of INFUSE-AMI [6] and a meta-analysis [27] suggest that a combination of thrombus aspiration and GPIs treatment is effective in decreasing infarct size and mortality as compared to each treatment alone or PCI alone. These findings are consistent with those of our meta-analysis. If most thrombotic materials are retrieved by thrombus aspiration catheter, GPIs could further dissolve residual thrombus and microemboli in the microvasculature.
Figure 4: (a) Meta-analysis of postoperative TIMI grade 3 flow between thrombus aspiration plus intracoronary GPIs and PCI alone; (b) meta-analysis of postoperative complete ST resolution (STR) between thrombus aspiration plus intracoronary GPIs and PCI alone; (c) meta-analysis of LVEF before discharge or at the short-term follow-up between thrombus aspiration plus intracoronary GPIs and PCI alone. TIMI: the Thrombolysis in Myocardial Infarction trial; LVEF: left ventricular ejection fraction; TA: thrombus aspiration; IC: intracoronary; GPIs: glycoprotein IIb/IIIa inhibitors; PCI: percutaneous coronary interventions.
| Study or Subgroup          | TA+IC GPIs | PCI | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---------------------------|------------|-----|--------|------------------------------|
| Dong PS et al. 2011       | 5          | 4   | 160    | 1.11 [0.29, 4.22]            |
| Guo YS et al. 2011        | 3          | 2   | 61     | 1.48 [0.24, 9.15]            |
| Huang WG et al. 2010      | 3          | 2   | 42     | 1.54 [0.24, 9.71]            |
| Jia XG 2009               | 0          | 2   | 32     | 0.17 [0.01, 3.62]            |
| Liu CP et al. 2013        | 1          | 0   | 23     | 2.56 [0.10, 65.96]           |
| Liu W 2012                | 0          | 48  | 42     | Not estimable                |
| Liu XY et al. 2013        | 5          | 4   | 40     | 1.29 [0.32, 5.19]            |
| Pan G et al. 2011         | 1          | 30  | 1      | 1.00 [0.06, 16.76]           |
| Wang XM et al. 2012       | 5          | 32  | 4      | 1.30 [0.31, 5.35]            |
| Yang WM et al. 2014       | 0          | 46  | 0      | Not estimable                |
|                           | Total (95% CI) | 545 | 504    | 1.16 [0.63, 2.15]            |

Total events 23

Heterogeneity: Ch$^2 = 1.97$, df = 7 (P = 0.96); $I^2 = 0$
Test for overall effect: Z = 0.47 (P = 0.64)

Figure 5: Meta-analysis of the major bleeding or minor bleeding events before discharge between thrombus aspiration plus intracoronary GPIs and PCI alone. TA: thrombus aspiration; IC: intracoronary; GPIs: glycoprotein IIb/IIIa inhibitors; PCI: percutaneous coronary interventions.

Figure 6: Funnel plot of publication bias for the short-term MACE (a), death (b), and reinfarction (c). MACE: major adverse cardiac events.

This might interpret why our results of the meta-analysis were different from other studies [4, 5]. Notably, subgroup analysis showed that the type of aspiration catheter might influence the clinical outcomes and, in this aspect, ZEEK catheter and EXPORT catheter, which present a stronger aspiration capacity for moderate to large thrombi, were superior to Driver C.E. catheter [28]. Differences in aspiration capacity between ZEEK, EXPORT, and Diver
C.E. in this setting might influence the short-term outcome.

We found there was no significant difference between the number of bleeding events in the intracoronary GPIs group and those in the control group, despite GPIs’ antiplatelet activity and the risk of bleeding. This might be due to the type of GPIs–tirofiban, which was mostly used in our meta-analysis (92.9% used tirofiban). Tirofiban is a representative of small molecule glycoprotein IIb/IIIa inhibitor with reliable platelet inhibition and reversibility [29]. Tirofiban, the most applied glycoprotein IIb/IIIa inhibitor in East Asia now, was found in 13 included studies (Choi's study not mentioned due to the abstract in ANGIOPLASTY SUMMIT).

There were also some limitations in this meta-analysis. First, few studies were found in other countries of East Asia, and we could not perform analyses in other populations. Second, we calculated the Nfs0.05 to assess the publication bias and found the results of long-term MACe, death, and reinfarction were -0.99, -0.99, and -0.82, which indicated publication bias and might influence the meta-analysis results. Third, 92.9% studies in our meta-analysis used tirofiban, and subgroup analysis of different type of GPIs was unable to be performed.

5. Conclusions

Our study demonstrates that intracoronary use of glycoprotein IIb/IIIa inhibitors may have a synergistic effect with thrombus aspiration on short-term mortality, reinfarction, and cardiac functional recovery. Future RCTs are needed to assess the impact of concomitant glycoprotein IIb/IIIa inhibitors with thrombus aspiration on the long-term outcomes of patients with STEMI.

Data Availability

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

Conflicts of Interest

The authors have no conflicts of interest to declare.

Authors’ Contributions

Jia-hong Wu and Yu-guo Chen contributed to the study concept and design. Rui-jian Li and Pan-pan Hao drafted the manuscript. All authors revised the article and approved the final version to be published.

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