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*Original Article*

# Application of post-dilation in ST-segment elevation myocardial infract patients undergoing primary percutaneous coronary intervention

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**Abstract:** Objectives: Primary percutaneous coronary intervention (PCI) is the optimal treatment approach for patients with ST-segment elevation myocardial infarction (STEMI). In the elective PCI procedure, post-dilation (PD) with a non-compliant (NC) balloon has been widely accepted. However, application of PD remains controversial. Methods: A total of 336 consecutive patients were divided into two groups based on PD procedure. In-hospital clinical events were recorded on a monthly basis. Those recorded in the first month were compared as well as those recorded from a month to a year. Primary endpoint was incidence of target vessel revascularization (TVR), caused by in-stent restenosis (ISR) or stent thrombosis (ST), observed from a month to a year. Results: Incidence of in-stent restenosis (ISR) (14.4% vs. 6.0%, P=0.02) and target vessel revascularization (5.6% vs. 0.8%, P=0.03) observed from a month to a year were significantly higher in the PD group. PD (odds ratio (OR) 3.08 (95% confidence interval (CI) 1.20~7.91), P=0.019), $T_2$DM (OR 4.04 (CI 1.70~9.62), P=0.002), and type of lesion (OR 2.98 (CI 1.29~6.89), P=0.011) were identified as independent predictors of one-year ISR. Conclusion: PD during primary PCI procedures causes impairment of TIMI flow after stent deployment. It also increases the probability of TVR and ISR within a year.

**Keywords:** Myocardial infraction, ST-segment elevation, percutaneous coronary intervention, post-dilation

## Introduction

An optical coherence tomography (OCT) study revealed that late ST and very late ST were mainly associated with stent malapposition (31%). Major mechanisms of acute ST and subacute ST are believed to be malapposition (48%) and under-expansion (26%) [1]. Stent under-expansion is a significant cause of in-stent restenosis (ISR) after stent implantation [2]. Malapposition and under-expansion are thought to be major factors contributing to adverse clinical outcomes caused by ST and ISR in the drug-eluting stent (DES) era. In elective percutaneous coronary intervention (PCI), post-dilation (PD) with non-compliant (NC) balloons at higher pressure optimizes stent deployment due to increased minimal lumen diameter (MLD). A previous study demonstrated that prolonged high pressure is required for optimal stent deployment [3]. For patients with STEMI, rapid revascularization by primary PCI is preferred [4]. However, whether PD is beneficial for STEMI patients undergoing primary PCI remains poorly understood. This present study aimed to evaluate the effects of PD on periprocedural and clinical outcomes in patients treated with DES.

## Materials and methods

### *Patients*

Patients presenting with STEMI, admitted to TEDA International Cardiovascular Hospital (TICH), from May 2014 to April 2016, for primary PCI, were enrolled in this study. Diagnostic criteria for STEMI have been described previously [4]. Exclusion criteria included severe left main disease, cardiac shock, severe haemodynamic instability, and bypass graft lesions. Informed consent was obtained from all patients

**Table 1.** Baseline clinical characteristics

| | PD (n=199) | Non-PD (n=137) | P |
|---|---|---|---|
| Gender (male) (%) | 157 (78.9%) | 105 (76.6%) | 0.69 |
| Age (years) | 59.4±10.9 | 61.0±11.3 | 0.89 |
| BMI (kg/m$^2$) | 25.3±2.8 | 25.3±3.4 | 0.92 |
| Hypertension (%) | 122 (61.3%) | 72 (52.6%) | 0.12 |
| $T_2$DM (%) | 46 (23.1%) | 31 (22.6%) | 1 |
| Hyperlipidemia (%) | 6 (3.0%) | 4 (2.9%) | 1 |
| Smoking history (%) | 124 (62.3%) | 91 (66.4%) | 0.49 |
| Family history (%) | 31 (15.6%) | 14 (10.2%) | 0.19 |
| OMI history (%) | 12 (6.0%) | 7 (5.1%) | 0.81 |
| PCI history (%) | 15 (7.5%) | 10 (7.3%) | 1 |
| CHF history (%) | 2 (1.0%) | 0 (0%) | 0.52 |
| Af history (%) | 3 (1.5%) | 3 (2.2%) | 0.69 |
| Cerebrovascular disease (%) | 27 (13.6%) | 16 (11.7%) | 0.74 |
| cTnI (ng/ml) | 41.04±31.9 | 43.42±35.97 | 0.52 |
| CK-MB (ng/ml) | 121.49±93.28 | 125.9±101.97 | 0.68 |
| HGB (g/l) | 16.66±10.62 | 18.17±9.73 | 0.19 |
| HCT (%) | 4.89±3.11 | 4.98±2.97 | 0.78 |
| WBC (*10E9) | 10.58±3.34 | 10.15±3.24 | 0.25 |
| NEUT (%) | 7.90±3.27 | 7.64±3.02 | 0.45 |
| Lp-PLA2 (ng/ml) | 212.63±90.01 | 212.14±82.55 | 0.96 |

prior to commencement of this study. The study was approved by the local Ethics Committee.

*Medication and PCI procedure*

Primary PCI was performed according to international guidelines. For dual antiplatelet therapy, 300 mg aspirin combined with 300 mg clopidogrel or 180 mg ticagrelor was initiated at the time of admission, followed by 100 mg aspirin and 75 mg clopidogrel daily or 90 mg ticagrelor twice a day. Dual antiplatelet therapy was recommended for at least one year. Anticoagulation was achieved with unfractionated heparin (100 IU/kg to maintain an activated clotting time between 250 and 300 seconds) or bivalirudin (0.75 mg/kg bolus, 1.75 mg/kg/h infusion for up to 4 hours after the procedure as clinically warranted). Tirofiban and low-molecular-weight heparin (LMWH) were administrated to each patient after primary PCI. Choices regarding thrombus aspiration catheter and pre-dilation were left to the operator. Patients were divided into two groups, according to the PD procedure undertaken at the operator's discretion. PD was performed with a NC balloon larger (0.25-0.5 mm) than the stent balloon, inflated at higher pressures (>14 bars).

*Baseline data*

Basic clinical characteristics included gender, age, body mass index (BMI), history of hypertension, type 2 diabetes mellitus ($T_2$DM), hyperlipidemia, smoking, family history of cardiovascular disease (CAD), old myocardial infarction (OMI), chronic heart failure (CHF), history of PCI, atrial fibrillation (Af), and cerebrovascular disease. Blood parameters, such as peak value of cardiac troponin I (cTnI), creatine kinase-MB (CK-MB), variation of hemoglobin (HGB), hematocrit (HCT) and the number of white blood cell (WBC), neutrophilic granulocyte (NEUT), and lipoprotein-associated phospholipase (LP-PLA2), after hospitalization, were recorded.

*Procedural data*

Infarct related artery (IRA), number of lesions, residual lesions, type of IRA, characteristic of IRA, thrombolysis in myocardial infarction (TIMI) flow grade (assessed as previously defined by the TIMI study group [5]) before pre-dilation, TIMI flow after pre-dilation, length of overall stent, number of stents, type of stents, immediate TIMI flow after stent implantation, immediate TIMI flow after PD, and final TIMI flow were evaluated from coronary angiography (CAG) records. Angiographic images were reviewed by two experienced interventional cardiologists blinded to the study.

*Clinical outcomes*

Duration of stays in the hospital was 7-10 days and events of heart failure (HF), occurrence of ventricular aneurysms, ST, cardiac death, non-cardiac death, and severe hemorrhages were recorded. Scheduled follow-ups for 30 days were carried out. ST, TVR, occurrence of MACE (hospitalization caused by angina pectoris, dyspnea, ventricular thrombus), cardiac death, non-cardiac death, and severe hemorrhages were recorded. One-year follow-ups were performed. ST, ISR, TVR, cardiac death, non-cardiac death, severe hemorrhages, left ventricular

**Table 2.** Procedural data

| | PD (n=199) | Non-PD (n=137) | P |
|---|---|---|---|
| Clopidogrel (%) | 176 (88.4%) | 124 (90.5%) | 0.59 |
| Radial artery approach (%) | 191 (96.0%) | 133 (97.1%) | 0.77 |
| Bivalirudin (%) | 21 (10.6%) | 14 (10.2%) | 1 |
| IRA | | | |
| LAD (%) | 97 (48.7%) | 57 (41.6%) | 0.43 |
| LCX (%) | 26 (13.1%) | 10 (7.3%) | 0.14 |
| RCA (%) | 76 (38.2%) | 70 (51.1%) | 0.29 |
| Residual lesion (%) | 86 (43.2%) | 58 (42.3%) | 0.91 |
| Type A of lesion (%) | 144 (72.4%) | 117 (85.4%) | 0.005 |
| Characteristic of lesion | 175 (89.7%) | 121 (88.3%) | 1 |
| D2B (min) | 59.42±22.32 | 57.45±27.59 | 0.47 |
| S2B (min) | 352.85±274.65 | 343.71±270.34 | 0.76 |
| Thrombus aspiration (%) | 28 (14.1%) | 35 (25.5%) | 0.01 |

Residual lesion: any artery stenosis ≥50%, type of lesion: ACC/AHA lesion type A or B/C; characteristic of lesion: thrombus or not; D2B: door to balloon time; S2B: symptom to balloon time.

**Table 3.** TIMI flow characteristics

| | PD (n=199) | Non-PD (n=137) | P |
|---|---|---|---|
| Before pre-dilation | | | |
| 0 | 138 (69.3%) | 95 (69.3%) | 0.38 |
| 1 | 17 (8.5%) | 8 (5.8%) | |
| 2 | 15 (7.5%) | 17 (12.4%) | |
| 3 | 29 (14.6%) | 17 (12.4%) | |
| After pre-dilation | | | |
| 0 | 1 (0.5%) | 1 (0.7%) | 0.96 |
| 1 | 8 (4.0%) | 7 (5.1%) | |
| 2 | 49 (24.6%) | 33 (24.1%) | |
| 3 | 141 (70.9%) | 96 (70.1%) | |
| After stent implantation | | | |
| 0 | 0 (0) | 0 (0) | 0.87 |
| 1 | 4 (2%) | 1 (0.7%) | |
| 2 | 23 (11.6%) | 25 (18.2%) | |
| 3 | 172 (86.4%) | 111 (81.1%) | |
| Number of stents | | | |
| 1 | 173 (86.9%) | 124 (90.5%) | |
| 2 | 24 (12.1%) | 13 (9.5%) | 0.37 |
| 3 | 2 (1.0%) | 0 (0%) | |
| Type of stents | | | |
| 1 | 147 (73.9%) | 114 (83.2%) | |
| 2 | 33 (16.6%) | 15 (10.9%) | 0.13 |
| 3 | 19 (9.5%) | 8 (5.8%) | |
| Length of stents (mm) | 30.84±12.17 | 27.86±10.11 | 0.19 |

Type of stent: 1, coated with everolimus; 2, coated with zotarolimus; 3, coated with sirolimus.

ejection fraction (LVEF), and abnormality of ventricular wall motion were monitored.

*Statistical analysis*

Statistical analysis was performed using SPSS 22.0 software (SPSS, Inc., Chicago, IL, USA). *P* values <0.05 are considered statistically significant. Continuous variables are recorded as mean ± standard deviations (SD) and categorical are reported as percentages. Categorical and continuous variables between the two groups were compared by Chi-square test and unpaired t-test, respectively. For correlation analysis, Pearson's correlation test was performed to evaluate the relationship between data and nonparametric distribution. Multivariate linear regression analysis was employed to assess the relationship between ISR within a year and explanatory variables.

## Results

*Baseline clinical characteristics*

A total of 336 patients were enrolled in this prospective study, with 199 (59.2%) undergoing PD. There were no statistical differences in terms of gender, age, BMI, history of hypertension, $T_2$DM, hyperlipidemia, smoking, and family history of CAD, OMI, CHF, PCI, AF, and cerebrovascular disease between the two groups (**Table 1**). Blood-related parameters were also not significantly different.

*Procedural data*

Procedural data are summarized in **Table 2**. ACC/AHA lesion type A was more frequently seen in non-PD group (85.4% vs. 72.4%, P=0.005), while usage of thrombus aspiration catheters was more frequent in non-PD group (25.5% vs. 14.1%, P=0.01) (**Table 2**). However, there were no statistical differences in terms of medication of antiplatelet, anticoagulation, procedural approach,

**Table 4.** Clinical outcomes

| | PD (n=199) | Non-PD (n=137) | P |
|---|---|---|---|
| In-hospital | | | |
| HF (%) | 57 (28.6%) | 46 (33.6%) | 0.34 |
| Ventricular aneurysm (%) | 16 (8.1%) | 13 (9.7%) | 0.69 |
| ST (%) | 0 | 0 | |
| Cardiac death (%) | 3 (1.5%) | 3 (2.2%) | 0.69 |
| Non-cardiac death (%) | 0 | 0 | |
| severe hemorrhage | 2 (1.0%) | 4 (2.9%) | 0.23 |
| Within a month | | | |
| ST (%) | 2 (1.0%) | 1 (0.8%) | 1 |
| TVR (%) | 2 (1.0%) | 2 (1.5%) | 1 |
| MACE (%) | 12 (6.2%) | 9 (6.8%) | 0.82 |
| Cardiac death (%) | 1 (0.5%) | 1 (0.7%) | 1 |
| Non-cardiac death (%) | 0 (0.0%) | 1 (0.7%) | 0.41 |
| Severe hemorrhage (%) | 0 (0.0%) | 2 (1.5%) | 0.16 |
| From a month to a year | | | |
| ST (%) | 0 | 0 | |
| TVR (%) | 11 (5.6%) | 1 (0.8%) | 0.03 |
| MACE (%) | 28 (14.4%) | 8 (6.0%) | 0.02 |
| Cardiac death (%) | 3 (1.5%) | 1 (0.8% | 0.65 |
| Non-cardiac death (%) | 0 (0.0%) | 1 (0.8%) | 0.41 |
| Severe hemorrhage (%) | 10 (5.2%) | 4 (3.1%) | 0.42 |
| LVEF (%) | 57.3±6.0 | 57.4±6.5 | 0.98 |
| VWMA (%) | 168 (87.5%) | 116 (88.5%) | 0.86 |

Definitions: HF: patients presenting with heart failure with or without elevation of B-type natriuretic peptide (BNP); ST: classified as definite, probable, or possible according to definitions proposed by the Academic Research Consortium. ISR: a luminal diameter stenosis >50% by quantitative coronary angiography located within a stent or within 5 mm of the stent edge. TVR: either PCI or coronary artery bypasses grafting surgery because of ISR (a luminal diameter stenosis >75%) or ST of the target lesion that included the proximal and distal edge segments and the ostia of side branch.

**Table 5.** Logistic regression analysis for variables associated with one-year ISR

| | B | OR (95% CI) | P |
|---|---|---|---|
| PD | 1.126 | 3.082 (1.201~7.910) | 0.019 |
| $T_2DM$ | 1.397 | 4.044 (1.701~9.618) | 0.002 |
| Type of lesion | 1.092 | 2.981 (1.290~6.888) | 0.011 |

IRA, residual lesions, percentage of thrombus lesions, D2B times, and S2B times.

*TIMI flow data*

TIMI flow before pre-dilation, TIMI flow after pre-dilation, length of overall stent, number of stents, type of stents, immediate TIMI flow after stent implantation, and final TIMI flow displayed similar profiles in both groups (P> 0.05, respectively) (**Table 3**). However, it was found that immediate TIMI flow was significantly slower after was PD carried out, compared with TIMI flow after stent implantation (2.60±0.56 vs. 2.84±0.41, P<0.001).

*Clinical follow-ups*

In-hospital events were recorded. Duration of stays in the hospital was 7-10 days. HF, occurrence of ventricular aneurysm, ST, cardiac death, non-cardiac death, and severe hemorrhages displayed no significant differences between the two groups (P>0.05, respectively) (**Table 4**). Follow-ups at 30 days after the procedure were obtained in the Outpatient Department. Patients administered for any reason within a month were evaluated and related clinical events were recorded. No differences were obtained regarding ST, TVR, MACE, cardiac death, non-cardiac death, and severe hemorrhages. Follow-up angiographies, after a year, were performed on each subject. ST, cardiac death, non-cardiac death, severe hemorrhages, left ventricular ejection fraction (LVEF), and abnormality of ventricular wall motion abnormality (VWMA) showed no differences, regardless of PD procedure. Incidence of ISR (14.4% vs. 6.0%, P=0.02) and TVR (5.6% vs. 0.8%, P=0.03) was significantly higher in the PD group, however (**Table 4**). PD (OR 3.08 (CI 1.20~7.91), P=0.019), $T_2DM$ (OR 4.04 (CI 1.70~9.62), P=0.002), and type of lesion (OR 2.98 (CI 1.29~6.89), P=0.011) were identified as independent predictors for one-year ISR (**Table 5**).

## Discussion

Apart from incidence of TVR and ISR, there were no significant differences between the two groups of patients in terms of clinical outcomes. However, ST was rare in both groups. These results may be attributed to usage of tirofiban and LMWH. The major finding of this study was that PD procedure increased incidence of TVR and ISR at one-year follow ups.

Immediate TIMI flow could be impaired after PD was carried out, compared with TIMI flow after stent implantation (2.60±0.56 vs. 2.84±0.41, P<0.001). Final TIMI flow showed no significant differences due to the intracoronary vasodilator agents. It was concluded that deceleration of TIMI flow after the PD procedure might result in adverse clinical events. Thus, TIMI flow improvement by intracoronary vasodilator agents might be temporary. How the PD procedure affects TIMI flow after stent implantation remains unclear. An intravascular ultrasound (IVUS) study revealed that, for patients presenting with acute myocardial infarction treated with stents, angiographic no-reflow was more frequently observed in the overexpansion group than the non-overexpansion group. In addition, IVUS found that no-reflow patients had more fissure/dissection [6]. Other studies have pointed out that the lack of achievement of PD with non-compliant balloon within the borders of stents might cause edge dissection, geographic miss, or even coronary perforation [7, 8]. Otherwise, aggressive mechanical expansion was a risk factor for distal embolization and microvascular injuries, especially for patients with AMI [9, 10], which might explain the differences in angiographic outcomes between primary PCI and elective PCI. Recently, a case reported by Yashaima revealed that no-flow could be caused by in-stent dissection from an OCT view [11]. Vessel injuries caused by stent implantation or the PD procedure jeopardizes TIMI flow. In the ear of DES, incidence of ISR remains 10-15%, consistent with present results. Histology studies have shown that for DES the main cause of ISR is the proliferation of vascular smooth muscle cells (VSMCs). High pressure from PD accelerates proliferation of VSMCs. Endothelial cells regulate proliferation of vessel endothelium by releasing cytokines. Its dysfunction, induced by pharmaceutical or mechanical changes, is an underlying cause of ISR [12, 13]. One of the main mechanisms of AMI is endothelial injuries caused by plaque rupture. It is believed that the PD procedure aggravates damage of the endothelium, especially NC balloon. Under high pressure, the extent of damage varies and the form of damage takes segmented patterns. Watanabe et al. pointed out that the ratio of stent to post-balloon size >1.10 was associated with increased risk of proximal right coronary artery ISR [14]. This might be due to stent fractures caused by PD. Contradictory to present findings, a retrospective study indicated that PD decreased the probability of TVR and ST at 6-month follow-ups. The limitation of this study was the absence of 6 month follow-up angiographies [15]. In the present study, there was more frequent usage of thrombus aspiration catheters (14.1% vs. 25.5%, P=0.01) in the non-PD group. Previous studies have demonstrated that application of distal protection devices or thrombus aspiration catheters do not improve long-term outcomes [9, 16]. Compared to the non-PD group in the present study, PD patients had more complex lesions. Restenosis of DES has been reported, up to 20%, in high-risk patients as well as patients with complex lesions [17]. Statistical regression analysis indicated that ACC/AHA type lesion B/C was identified as an independent predictor of one-year ISR.

In conclusion, PD decreased immediate TIMI flow, compared to TIMI flow after stent implantation. It is likely to increase the probability of TVR and ISR within one year.

### Limitations

The present study was a non-randomized trial in which the PD procedure was left to the operator's choice. It had a limited number of patients enrolled due to its single-center study nature. One-year follow-ups were supposed to be arranged for each subject, but coronary angiographies were not performed for each patient. A small portion of enrolled subjects (6.8%) refused the angiography, thus an alternative of computed tomography coronary angiography (CTCA) was used. Usually, ISR is defined as a clinically relevant angiographic stenosis in a previously implanted stent, assessed by visual estimate (50% diameter stenosis) [18]. In this study, stenosis ≥50% of implanted stents were accepted, which may have influenced the assessment of ISR. Other studies have recommended CTCA as an alternative non-invasive assessment of ISR [19]. In addition, coronary flow was assessed by TIMI flow grade, which is inferior to the corrected TIMI frame count [20] or myocardial blush grade [21]. Further randomized controlled trials with a large population size are required to confirm present results. This study suggests that new-generation DES, accurate estimation of stent diameter, and

appropriate expansion pressure are crucial for the primary PCI procedure. PD is recommended only if necessary.

## Disclosure of conflict of interest

None.

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## References

[1] Souteyrand G, Amabile N, Mangin L, Chabin X, Meneveau N, Cayla G, Vanzetto G, Barnay P, Trouillet C, Rioufol G, Range G, Teiger E, Delaunay R, Dubreuil O, Lhermusier T, Mulliez A, Levesque S, Belle L, Caussin C, Motreff P; PESTO Investigators. Mechanisms of stent thrombosis analysed by optical coherence tomography: insights from the national PESTO French registry. Eur Heart J 2016; 37: 1208-16.

[2] Fujii K, Mintz GS, Kobayashi Y, Carlier SG, Takebayashi H, Yasuda T, Moussa I, Dangas G, Mehran R, Lansky AJ, Reyes A, Kreps E, Collins M, Colombo A, Stone GW, Teirstein PS, Leon MB, Moses JW. Contribution of stent under-expansion to recurrence after sirolimus-eluting stent implantation for in-stent restenosis. Circulation 2004; 109: 1085-1088.

[3] Cook JR, Mhatre A, Wang FW, Uretsky BF. Prolonged high-pressure is required for optimal stent deployment as assessed by optical coherence tomography. Catheter Cardiovasc Interv 2014; 83: 521-527.

[4] Windecker S, Kolh P, Alfonso F, Collet JP, Cremer J, Falk V, Filippatos G, Hamm C, Head SJ, Juni P, Kappetein AP, Kastrati A, Knuuti J, Landmesser U, Laufer G, Neumann FJ, Richter DJ, Schauerte P, Sousa Uva M, Stefanini GG, Taggart DP, Torracca L, Valgimigli M, Wijns W, Witkowski A. 2014 ESC/EACTS guidelines on myocardial revascularization: the task force on myocardial revascularization of the european society of cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS) developed with the special contribution of the european association of percutaneous cardiovascular interventions (EAPCI). Eur Heart J 2014; 35: 2541-2619.

[5] Ganz W. The thrombolysis in myocardial infarction (TIMI) trial. N Engl J Med 1985; 313: 1018.

[6] Maekawa Y, Asakura Y, Anzai T, Ishikawa S, Okabe T, Yoshikawa T, Ogawa S. Relation of stent overexpansion to the angiographic no-reflow phenomenon in intravascular ultrasound-guided stent implantation for acute myocardial infarction. Heart Vessels 2005; 20: 13-18.

[7] Tahara S, Bezerra HG, Kyono H, Carrigan T, Mehanna E, Wang W, Costa MA. Impact of acute gain on clinical outcomes of patients treated with sirolimus-eluting stent. - A sub-analysis study from the STLLR trial. Circ J 2011; 75: 2113-2119.

[8] Karabulut A, Topcu K. Coronary perforation due to sirolimus-eluting stent's strut rupture with post-dilatation. Kardiol Pol 2011; 69: 183-186; discussion 187.

[9] Stone GW, Webb J, Cox DA, Brodie BR, Qureshi M, Kalynych A, Turco M, Schultheiss HP, Dulas D, Rutherford BD, Antoniucci D, Krucoff MW, Gibbons RJ, Jones D, Lansky AJ, Mehran R; Enhanced Myocardial Efficacy and Recovery by Aspiration of Liberated Debris (EMERALD) Investigators. Distal microcirculatory protection during percutaneous coronary intervention in acute ST-segment elevation myocardial infarction - A randomized controlled trial. JAMA 2005; 293: 1063-1072.

[10] Limbruno U, De Carlo M, Pistolesi S, Micheli A, Petronio AS, Camacci T, Fontanini G, Balbarini A, Mariani M, De Caterina R. Distal embolization during primary angioplasty: histopathologic features and predictability. Am Heart J 2005; 150: 102-108.

[11] Yashima F, Yuasa S, Maekawa Y, Kimura M, Akita K, Yanagisawa R, Tanaka M, Hayashida K, Kawakami T, Kanazawa H, Fujita J, Fukuda K. In-stent dissection causes no flow during percutaneous coronary intervention. JACC Cardiovasc Interv 2016; 9: 102-103.

[12] Togni M, Windecker S, Cocchia R, Wenaweser P, Cook S, Billinger M, Meier B, Hess OM. Sirolimus-eluting stents associated with paradoxic coronary vasoconstriction. J Am Coll Cardiol 2005; 46: 231-236.

[13] Togni M, Raber L, Cocchia R, Wenaweser P, Cook S, Windecker S, Meier B, Hess OM. Local vascular dysfunction after coronary paclitaxel-eluting stent implantation. Int J Cardiol 2007; 120: 212-220.

[14] Watanabe Y, Takagi K, Naganuma T, Kawamoto H, Fujino Y, Ishiguro H, Tahara S, Kurita N, Hosawa K, Nakamura S. Independent predictors of in-stent restenosis after drug-eluting stent implantation for ostial right coronary artery lesions. Int J Cardiol 2017; 240: 108-113.

[15] Tasal A, Bacaksiz A, Vatankulu MA, Turfan M, Erdogan E, Sonmez O, Kul S, Ertas G, Sevgili E, Goktekin O. Is postdilatation with a noncompliant balloon necessary after coronary stent deployment during primary angioplasty? J Interv Cardiol 2013; 26: 325-331.

[16] Frobert O, Lagerqvist B, Gudnason T, Thuesen L, Svensson R, Olivecrona GK, James SK. Thrombus aspiration in st-elevation myocardial infarction in scandinavia (TASTE trial). A multicenter, prospective, randomized, controlled clinical registry trial based on the Swedish angiography and angioplasty registry (SCAAR) platform. Study design and rationale. Am Heart J 2010; 160: 1042-1048.

[17] Cosgrave J, Agostoni P, Ge L, Iakovou I, Chieffo A, Biondi-Zoccai GGL, Sangiorgi GM, Montorfano M, Michev I, Airoldi F, Carlino M, Corvaja N, Bonizzoni E, Colombo A. Clinical outcome following aleatory implantation of paclitaxel-eluting or sirolimus-eluting stents in complex coronary lesions. Am J Cardiol 2005; 96: 1663-1668.

[18] James SK, Stenestrand U, Lindback J, Carlsson J, Schersten F, Nilsson T, Wallentin L, Lagerqvist B; SCAAR Study Group. Long-term safety and efficacy of drug-eluting versus bare-metal stents in Sweden. N Engl J Med 2009; 360: 1933-1945.

[19] Tsuda T, Ishii H, Ichimiya S, Kanashiro M, Watanabe J, Takefuji M, Aoyama T, Suzuki S, Tanaka A, Matsubara T, Murohara T. Assessment of in-stent restenosis using high-definition computed tomography with a new gemstone detector. Circ J 2015; 79: 1542-1548.

[20] Gibson CM, Cannon CP, Daley WL, Dodge JT, Alexander B, Marble SJ, McCabe CH, Raymond L, Fortin T, Poole WK, Braunwald E. TIMI frame count: a quantitative method of assessing coronary artery flow. Circulation 1996; 93: 879-888.

[21] Henriques JP, Zijlstra F, van't Hof AW, de Boer MJ, Dambrink JH, Gosselink M, Hoorntje JC, Suryapranata H. Angiographic assessment of reperfusion in acute myocardial infarction by myocardial blush grade. Circulation 2003; 107: 2115-2119.