

## RESEARCH ARTICLE

# Association of the long fluoroscopy time with factors in contemporary primary percutaneous coronary interventions

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## Abstract

### Background

Since the long fluoroscopy time in primary PCI for ST-segment elevation myocardial infarction (STEMI) could be an indicator of delayed reperfusion, it should be important to recognize which types of lesions require longer fluoroscopy-time in primary PCI. The purpose of this study was to investigate the association of the long fluoroscopy-time with clinical factors in primary percutaneous coronary interventions (PCI).

### Methods

A total of 539 patients who underwent primary PCI were divided into the conventional fluoroscopy-time group (Q1-Q4: n = 434) and the long fluoroscopy-time group (Q5: n = 105) according to the quintile of the total fluoroscopy time in primary PCI. Univariate and multivariate logistic regression analyses were performed to find associations between clinical variables and the long fluoroscopy-time.

### Results

In univariate logistic regression analysis, prevalence of diabetes mellitus, hemodialysis, and previous CABG were significantly associated with the long fluoroscopy-time. In addition, complex lesion characteristics such as lesion length, lesion angle, tortuosity, and calcification were associated with the long fluoroscopy-time. In multivariable logistic regression analysis, lesion length [per 10 mm incremental: odds ratio (OR) 1.751, 95% confidence interval (CI) 1.397–2.195,  $P < 0.001$ ], moderate-excessive tortuosity (vs. mild tortuosity: OR 4.006, 95% CI 1.498–10.715,  $P = 0.006$ ), and moderate to severe calcification (vs. none-mild calcification: OR 1.865, 95% CI 1.107–3.140,  $P = 0.019$ ) were significantly associated with the long fluoroscopy-time.

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## Conclusions

In primary PCI for STEMI, diffuse long lesion, tortuosity, and moderate-severe calcification were associated with the long fluoroscopy-time. These complex features require special attention to reduce reperfusion time in primary PCI.

## Introduction

Primary percutaneous coronary intervention (PCI) has dramatically reduced the mortality of ST-segment elevation myocardial infarction (STEMI) [1, 2]. Although most of the culprit lesions for STEMI are totally occluded, it is technically easier to achieve successful reperfusion in primary PCI as compared to PCI to chronic total occlusion (CTO), which are also totally occluded [3, 4]. However, it is sometimes difficult to achieve successful reperfusion even in primary PCI [5]. Delayed reperfusion, which results in poor clinical outcomes [6, 7], can consequently lead to long fluoroscopy-time in primary PCI. Moreover, long fluoroscopy-time would be associated with increased rates of periprocedural complications including early mortality, emergent CABG, contrast-induced nephropathy [6]. Thus, it is important for better patient's outcomes to recognize which types of lesions require long fluoroscopy-time in primary PCI. The purpose of this study was to investigate the association of the long fluoroscopy-time with clinical factors in primary PCI.

## Methods

### Study lesions

We identified consecutive 624 patients with STEMI in the Saitama Medical Center, Jichi Medical University from January, 2015 to December, 2018. We excluded cases that did not have PCI to the culprit lesion, because of medical therapy alone or surgical therapy to the culprit lesion. We also excluded non-emergent PCI cases, unsuccessful PCI cases, and cases in which  $\geq 2$  vessels were treated simultaneously. We defined the long fluoroscopy-time group as the longest quintile of fluoroscopy time (Q5), and defined the conventional fluoroscopy-time group as the other quintiles of fluoroscopy time (Q1-Q4). This study was approved by the Institutional Review Board of Saitama Medical Center, Jichi Medical University, and written informed consent was waived because of the retrospective study design.

### Primary PCI procedures

PCI procedures were performed on a biplane fluoroscopy system (Artis zee BC and Artis zee BA, Siemens, Munich, Germany), with three magnetic fields (16 cm, 20 cm, and 25 cm for Artis zee BC; 16 cm, 22 cm, and 32 cm for Artis zee BA) and a standard image acquisition program at 15 frames per second during cine acquisition and 7.5 frames per second during fluoroscopy. Primary PCI was performed using standard techniques via the radial artery, femoral artery, or rarely brachial artery. First, we advanced a conventional guidewire across the lesion, and used a small (2.0-mm diameter) balloon or thrombus aspiration catheter. The choice of devices was at the discretion of the interventional cardiologist. Activated coagulation time was maintained for  $>250$  seconds during PCI. IVUS was routinely used for almost all lesions.

## Definition

Acute myocardial infarction (AMI) was defined based on universal definition of myocardial infarction [7]. STEMI was diagnosed in the presence of new ST elevation at the J point in at least 2 contiguous leads  $\geq 2$  mm (0.2 mV) [8, 9]. Hypertension was defined as medical treatment for hypertension and/or a history of hypertension before admission [10]. Dyslipidemia was defined as a total cholesterol level  $\geq 220$  mg/dL or low-density lipoprotein cholesterol level  $\geq 140$  mg/dL or medical treatment for dyslipidemia or a history of dyslipidemia [10]. Diabetes mellitus was defined as a hemoglobin A1c level  $\geq 6.5\%$  (as NGSP value) or medical treatment for diabetes mellitus or a history of diabetes mellitus [10]. We calculated the estimated glomerular filtration rate (eGFR) from the serum creatinine level, age, weight, and gender using the following formula:  $eGFR = 194 \times Cr^{-1.094} \times age^{-0.287}$  (male),  $eGFR = 194 \times Cr^{-1.094} \times age^{-0.287} \times 0.739$  (female) [11].

## Angiographical analysis

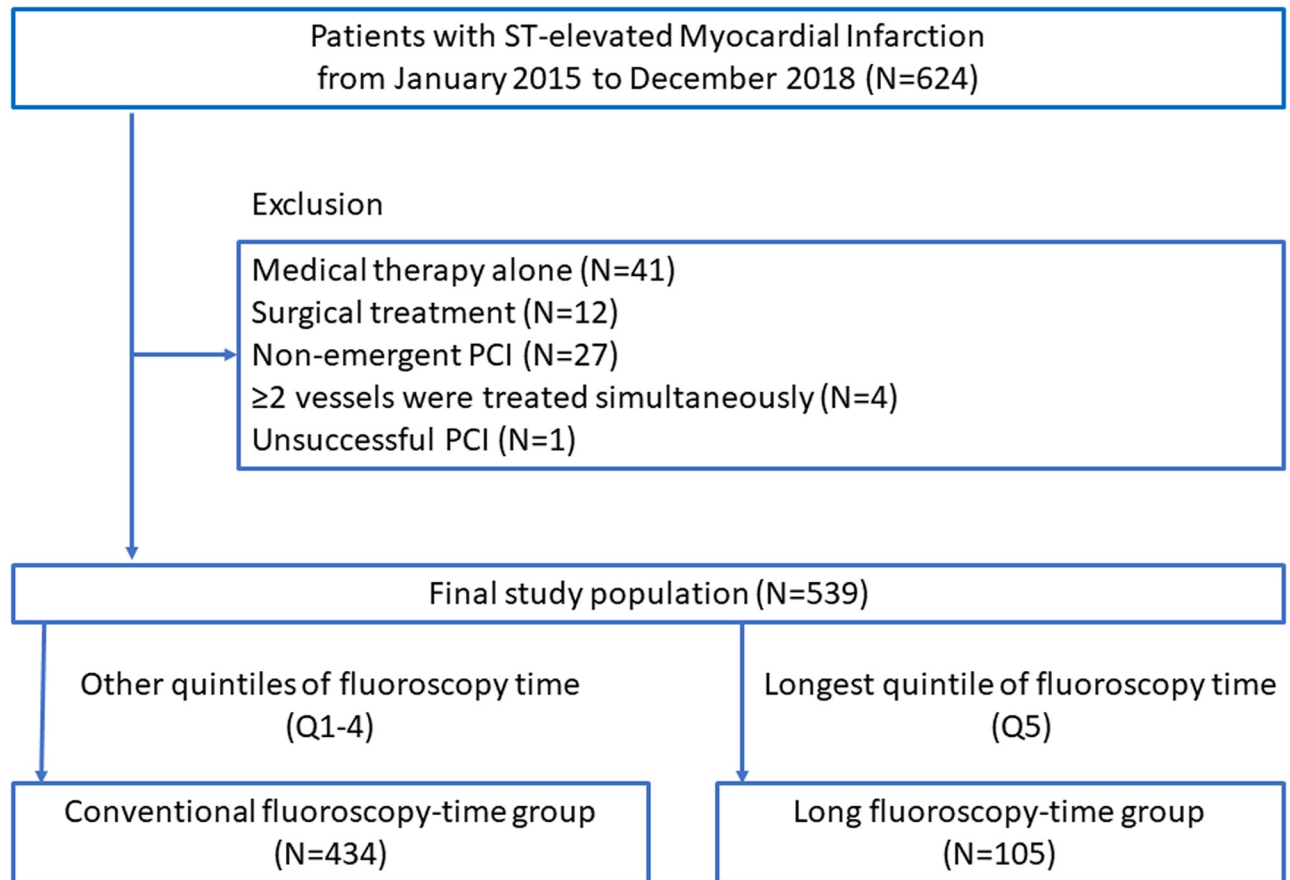
Quantitative coronary angiography (QCA) parameters were measured using a cardiovascular angiography analysis system (QAngio XA 7.3, MEDIS Imaging Systems, Leiden, Netherlands). The definition of lesion characteristics including lesion length, eccentricity, tortuosity, lesion angle, ostial lesion, bifurcation lesion has been previously described [12]. In an original ACC/AHA definition, tortuosity was defined as follows: stenoses distal to two bends were defined as moderately tortuous, and those distal to three or more bends were defined as excessive tortuosity [12]. However, since the above definition of tortuosity has poor objectivity, we additionally defined tortuosity as follows: " $\leq 1$ " moderate to excessive bend ( $< 120^\circ$ ) was defined as mild tortuosity, " $2$ " moderate to excessive bends ( $< 120^\circ$ ) was defined as moderate tortuosity, and " $\geq 3$ " moderate to excessive bends ( $< 120^\circ$ ) was defined as excessive tortuosity. Calcification was identified as readily apparent radiopacities within the vascular wall at the site of the stenosis, and was classified as none/mild, moderate (radiopacities noted only during the cardiac cycle before contrast injection), and severe (radiopacities noted without cardiac motion before contrast injection generally compromising both sides of the arterial lumen) [13].

## Statistical analysis

Data are shown as the mean  $\pm$  SD or percentage. Categorical variables are presented as numbers (percentage), and were compared using the Pearson  $\chi^2$  test. Continuous variables were compared between the groups using the unpaired Student's *t* test. Univariate and multivariate logistic regression analyses were performed to find the association between clinical variables and the long fluoroscopy-time. In this model, the long fluoroscopy-time, which was defined as  $\geq 33$  minute, was used as the dependent variable. In the multivariate stepwise logistic regression model, the selection of independent variables was derived from the results of univariate logistic regression analysis ( $P < 0.05$  in univariate analysis). However, variables with missing values were not included in the model. The multivariate logistic regression analysis with likelihood ratio statistical criteria using backward elimination method was performed. The odds ratio (OR) and the 95% confidence interval (CI) were also calculated. A *P* value  $< 0.05$  was considered statistically significant. We analyzed all data by SPSS ver. 24 for Windows (SPSS, Inc., Chicago, Illinois).

## Results

During the study period, we had 624 STEMI cases in our medical center. We excluded 53 cases that did not have PCI to the culprit lesion, 27 non-emergent PCI cases, 4 cases in which



**Fig 1. The study flow chart.** Abbreviations: CAG = coronary angiography, PCI = percutaneous coronary intervention.

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≥2 vessels were treated simultaneously, and 1 unsuccessful PCI case. Our final study population was 539 patients, and divided into the long fluoroscopy-time group ( $n = 105$ ) and the conventional fluoroscopy-time group ( $n = 434$ ). The study flowchart is shown in Fig 1.

The comparison of clinical, lesion and procedural characteristics is shown in Table 1. The lesion length was significantly longer in the long fluoroscopy-time group ( $22.5 \pm 13.6$  mm) than in the conventional fluoroscopy-time group ( $15.9 \pm 7.2$  mm) ( $P < 0.001$ ). Similarly, there were significant differences in lesion angle, tortuosity, and calcification between the 2 groups.

The univariate logistic regression models to find the factors associated with the long fluoroscopy-time are shown in Table 2. The prevalence of diabetes mellitus, hemodialysis, and previous CABG was significantly associated with the long fluoroscopy-time. In addition, complex lesion characteristics such as lesion length, lesion angle, tortuosity, and calcification were associated with the long fluoroscopy-time. Furthermore, some procedural characteristics such as size of guiding catheter, use of intra-aortic balloon pumping, and use of veno-arterial extracorporeal membranous oxygenation were also associated with the long fluoroscopy-time.

The multivariate stepwise logistic regression analysis to find the factors associated with the long fluoroscopy-time is shown in Table 3. The stepwise model included the following variables: previous CABG, serum creatinine levels, hemoglobin levels, Killip class, cardiac arrest at prehospital or emergency room, number of narrowed coronary arteries, left main trunk lesion, lesion length, lesion angle, tortuosity, calcification, and size of guiding catheters. Serum creatinine (OR 1.139, 95% CI 1.016–1.277,  $P = 0.026$ ), cardiac arrest at prehospital or ER (OR 2.594,

**Table 1. Comparison of patient's characteristics between the conventional fluoroscopy-time group and the long fluoroscopy-time group.**

|  | Conventional fluoroscopy-time group, n = 434 | Long fluoroscopy-time group, n = 105 | p-value |
|--|--|--------------------------------------|---------|
| Age, years                                   | 69.2 ± 13.3                                  | 68.9 ± 13.6                          | 0.865   |
| Female, n (%)                                | 100 (23.0)                                   | 21 (20.0)                            | 0.503   |
| Physical examination                         |  |                                      |         |
| Height (cm)                                  | 162.0 ± 9.7 (n = 428)                        | 163.7 ± 10.4 (n = 104)               | 0.141   |
| Body weight (kg)                             | 63.1 ± 13.7 (n = 429)                        | 64.9 ± 13.7 (n = 103)                | 0.234   |
| Systolic blood pressure at admission (mmHg)  | 136.8 ± 32.2 (n = 418)                       | 138.3 ± 38.5 (n = 97)                | 0.714   |
| Diastolic blood pressure at admission (mmHg) | 80.6 ± 20.1 (n = 411)                        | 82.1 ± 21.1 (n = 96)                 | 0.531   |
| Heart rate at admission (beat per minute)    | 79.4 ± 21.6 (n = 424)                        | 84.6 ± 25.3 (n = 101)                | 0.079   |
| Underlying disease                           |  |                                      |         |
| Hypertension, n (%)                          | 327/423 (77.3)                               | 81 (77.1)                            | 0.972   |
| Diabetes mellitus, n (%)                     | 164/426 (38.5)                               | 54/102 (52.9)                        | 0.008   |
| Dyslipidemia, n (%)                          | 233/416 (56.0)                               | 55/103 (53.4)                        | 0.633   |
| Hemodialysis, n (%)                          | 17 (3.9)                                     | 10 (9.5)                             | 0.018   |
| History of previous PCI, n (%)               | 55/433 (12.7)                                | 15/104 (14.4)                        | 0.640   |
| History of previous CABG, n (%)              | 2 (0.5)                                      | 3 (2.9)                              | 0.022   |
| History of previous MI, n (%)                | 41/433 (9.5)                                 | 10/104 (9.6)                         | 0.963   |
| Current smoker, n (%)                        | 160/422 (37.9)                               | 36/103 (35.0)                        | 0.577   |
| Medication before admission                  |  |                                      |         |
| Aspirin, n (%)                               | 72/405 (17.8)                                | 19/96 (19.8)                         | 0.645   |
| Thienopyridine, n (%)                        | 36/404 (8.9)                                 | 11/96 (11.5)                         | 0.442   |
| Beta-blocker, n (%)                          | 49/400 (12.3)                                | 19/96 (19.8)                         | 0.054   |
| ACE-inhibitor, ARB, n (%)                    | 132/400 (33)                                 | 42/96 (43.8)                         | 0.047   |
| Calcium channel blocker, n (%)               | 146/401 (36.4)                               | 37/96 (38.5)                         | 0.697   |
| Statin, n (%)                                | 90/401 (22.4)                                | 24/96 (25.0)                         | 0.593   |
| Diuretic, n (%)                              | 35/402 (8.7)                                 | 11/96 (11.5)                         | 0.403   |
| Hypoglycemic agents, n (%)                   | 85/402 (21.1)                                | 32/96 (33.3)                         | 0.011   |
| Insulin, n (%)                               | 18/404 (4.5)                                 | 7/97 (7.2)                           | 0.262   |
| Laboratory data at admission                 |  |                                      |         |
| Serum creatinine (mg/dl)                     | 1.1 ± 1.4                                    | 1.9 ± 2.6                            | 0.004   |
| Estimated GFR (ml/min/1.73m <sup>2</sup> )   | 67.3 ± 28.3 (n = 433)                        | 61.7 ± 45.9 (n = 105)                | 0.009   |
| Hemoglobin (g/dl)                            | 13.6 ± 2.0                                   | 13.1 ± 2.1                           | 0.023   |
| BNP (pg/ml)                                  | 281 ± 527 (n = 415)                          | 457 ± 641 (n = 95)                   | 0.002   |
| Onset to hospitalization time, n (%)         |  |                                      |         |
| 0–24 hours                                   | 393 (90.6)                                   | 85 (81.0)                            | 0.006   |
| Longer than 24 hours                         | 26 (6.0)                                     | 9 (8.6)                              |         |
| Unknown                                      | 15 (3.5)                                     | 11 (10.5)                            |         |
| Killip class                                 |  |                                      |         |
| 1 or 2                                       | 347 (80.0)                                   | 74 (70.5)                            | 0.075   |
| 3  | 32 (7.4)                                     | 9 (8.6)                              |         |
| 4  | 55 (12.7)                                    | 22 (21.0)                            |         |
| Cardiac arrest at prehospital or ER, n (%)   | 25 (5.8)                                     | 15 (14.3)                            | 0.003   |
| Shock vital at prehospital or ER, n (%)      | 66/427 (15.5)                                | 19/105 (18.1)                        | 0.509   |
| Culprit lesion                               |  |                                      |         |

*(Continued)*

Table 1. (Continued)

|  | Conventional fluoroscopy-time group, n = 434 | Long fluoroscopy-time group, n = 105 | p-value |
|--|--|--------------------------------------|---------|
| Left main-left anterior descending artery, n (%) | 232 (53.5)                                   | 52 (49.5)                            | 0.782   |
| Right coronary artery, n (%)                     | 159 (36.6)                                   | 42 (40.0)                            |         |
| Left circumflex, n (%)                           | 41 (9.4)                                     | 11 (10.5)                            |         |
| Graft / other, n (%)                             | 0 (0)  | 0 (0)                                |         |
| Not determined, n (%)                            | 2 (0.5)                                      | 0 (0)                                |         |
| Number of narrowed coronary arteries             |  |                                      |         |
| 1 vessel disease, n (%)                          | 212 (48.8)                                   | 40 (38.1)                            | < 0.001 |
| 2 vessel disease, n (%)                          | 147 (33.9)                                   | 26 (24.8)                            |         |
| 3 vessel disease, n (%)                          | 75 (17.3)                                    | 39 (37.1)                            |         |
| Left main trunk lesion, n (%)                    | 32 (7.4)                                     | 16 (15.2)                            | 0.011   |
| Left main trunk bifurcation lesion, n (%)        | 17 (3.9)                                     | 8 (7.6)                              | 0.106   |
| Ostia lesion, n (%)                              | 21 (4.8)                                     | 8 (7.6)                              | 0.257   |
| Bifurcation lesion, n (%)                        | 88 (20.3)                                    | 29 (27.6)                            | 0.101   |
| Initial TIMI flow grade of culprit               |  |                                      |         |
| 0  | 243 (56.0)                                   | 56 (53.3)                            | 0.823   |
| 1  | 44 (10.1)                                    | 13 (12.4)                            |         |
| 2  | 78 (18.0)                                    | 17 (16.2)                            |         |
| 3  | 69 (15.9)                                    | 19 (18.1)                            |         |
| Lesion length (mm)                               | 15.9 ± 7.2                                   | 22.5 ± 13.6                          | < 0.001 |
| Reference diameter (mm)                          | 2.7 ± 0.7                                    | 2.6 ± 0.8                            | 0.194   |
| Lesion angle                                     |  |                                      |         |
| Mild (150° <)                                    | 192 (44.2)                                   | 33 (31.4)                            | 0.003   |
| Moderate(120° < angle ≤ 150°), n (%)             | 201 (46.3)                                   | 51 (48.6)                            |         |
| Severe (≤ 120°), n (%)                           | 41 (9.4)                                     | 21 (20.0)                            |         |
| Tortuosity                                       |  |                                      |         |
| Mild tortuosity, n (%)                           | 404 (93.1)                                   | 93 (88.6)                            | 0.011   |
| Moderate tortuosity, n (%)                       | 19 (4.4)                                     | 3 (2.9)                              |         |
| Excessive tortuosity, n (%)                      | 11 (2.5)                                     | 9 (8.6)                              |         |
| Eccentricity                                     |  |                                      |         |
| Concentric, n (%)                                | 414 (95.4)                                   |                                      | 0.386   |
| Eccentric, n (%)                                 | 20 (4.6)                                     | 98 (93.3)                            |         |
| Calcification                                    |  |                                      |         |
| None-mild, n (%)                                 | 352 (81.1)                                   | 66 (62.9)                            | < 0.001 |
| Moderate, n (%)                                  | 54 (12.4)                                    | 21 (20.0)                            |         |
| Severe, n (%)                                    | 28 (6.5)                                     | 18 (17.1)                            |         |
| Occurrence of slow flow in PCI, n (%)            | 36 (8.3)                                     | 10 (9.5)                             | 0.686   |
| Approach site                                    |  |                                      |         |
| Trans-radial coronary intervention, n (%)        | 273/428 (63.8)                               | 56/104 (53.8)                        | 0.033   |
| Trans-femoral coronary intervention, n (%)       | 9/428 (2.1)                                  | 0/104 (0)                            |         |
| Trans-brachial coronary intervention, n (%)      | 146/428 (34.1)                               | 48/104 (46.2)                        |         |
| Change of approach site, n (%)                   | 26 (6.0)                                     | 19 (18.1)                            | < 0.001 |
| PCI procedure                                    |  |                                      |         |

(Continued)

Table 1. (Continued)

|   | Conventional fluoroscopy-time group, n = 434 | Long fluoroscopy-time group, n = 105 | p-value |
|---|--|--------------------------------------|---------|
| Plain old balloon angioplasty, n (%)        | 19 (4.4)                                     | 10 (9.5)                             | 0.136   |
| Aspiration only, n (%)                      | 4 (0.9)                                      | 1 (1.0)                              |         |
| Drug coating balloon angioplasty, n (%)     | 7 (1.6)                                      | 1 (1.0)                              |         |
| Bare metal stent, n (%)                     | 16 (3.7)                                     | 0                                    |         |
| Drug eluting stent, n (%)                   | 382 (88.0)                                   | 93 (88.6)                            |         |
| POBA and aspiration, n (%)                  | 2 (0.5)                                      | 0                                    |         |
| Other, n (%)                                | 4 (0.9)                                      | 0                                    |         |
| Size of guiding catheter (Fr)               |  |                                      |         |
| 6   | 320 (73.7)                                   | 55 (52.4)                            | < 0.001 |
| 7   | 114 (26.3)                                   | 48 (45.7)                            |         |
| 8   | 0 (0)  | 2 (1.9)                              |         |
| Number of guiding catheters                 |  |                                      |         |
| 1   | 421 (97.0)                                   | 81 (77.1)                            | < 0.001 |
| 2   | 13 (3.0)                                     | 21 (20)                              |         |
| ≥3  | 0 (0.0)                                      | 3 (2.9)                              |         |
| Number of guide wires                       |  |                                      |         |
| 1   | 275  | 22                                   | < 0.001 |
| 2   | 142  | 52                                   |         |
| ≥3  | 17   | 31                                   |         |
| Number of stents                            |  |                                      |         |
| 0   | 41 (9.4)                                     | 13 (12.4)                            | < 0.001 |
| 1   | 371 (85.5)                                   | 60 (57.1)                            |         |
| 2   | 22 (5.1)                                     | 31 (29.5)                            |         |
| ≥3  | 0 (0.0)                                      | 1 (1.0)                              |         |
| Number of balloons                          |  |                                      |         |
| 0   | 22 (5.1)                                     | 1 (1.0)                              | < 0.001 |
| 1   | 227 (52.3)                                   | 28 (26.7)                            |         |
| 2   | 158 (36.4)                                   | 46 (43.8)                            |         |
| ≥3  | 27 (6.2)                                     | 30 (28.6)                            |         |
| Use of guide-extension-catheter, n(%)       | 15 (3.5)                                     | 26 (24.8)                            | < 0.001 |
| Use of microcatheter, n(%)                  | 77 (17.7)                                    | 62 (59.0)                            | < 0.001 |
| Aspiration, n (%)                           | 106 (24.4)                                   | 32 (30.5)                            | 0.202   |
| Rotablator, n (%)                           | 0 (0.0)                                      | 1 (1.0)                              | 0.042   |
| IVUS guide, n (%)                           | 428 (98.6)                                   | 105 (100.0)                          | 0.226   |
| OCT/OFDI guide, n (%)                       | 1 (0.2)                                      | 0 (0.0)                              | 0.622   |
| Temporary pacemaker, n (%)                  | 39 (9.0)                                     | 12 (11.4)                            | 0.443   |
| Intra-aortic balloon pumping support, n (%) | 38 (8.8)                                     | 24 (22.9)                            | < 0.001 |
| V-A ECMO, n (%)                             | 14 (3.2)                                     | 8 (7.6)                              | 0.041   |
| Amount of contrast media (ml)               | 120 ± 35                                     | 171 ± 59                             | < 0.001 |

Data are expressed as the mean ± SD or number (percentage). A Student's t test was used for normally distributed continuous variables, a Mann-Whitney U test was used for abnormally distributed continuous variables, and a chi-square test was used for categorical variables. There are some missing values for several covariates. In that case, we added sample sizes in the format (N = \*\*\*).

PCI indicates percutaneous coronary intervention; CABG, coronary artery bypass grafting; MI, myocardial infarction; STEMI, ST elevation myocardial infarction; NSTEMI, Non-ST elevation myocardial infarction; ACE, Angiotensin converting enzyme; ARB, Angiotensin II receptor blocker; GFR, glomerular filtration rate; BNP, brain natriuretic peptide; ER, emergency room; TIMI, Thrombolysis in myocardial infarction; IVUS, intravascular ultrasound; OCT/OFDI, optical coherence tomography/optical frequency domain imaging; V-A ECMO, veno-arterial extra-corporeal membranous oxygenation.

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**Table 2. Univariate logistic regression analysis to find association with the long fluoroscopy time ( $\geq 33$  minutes).**

| Dependent variable: long fluoroscopy time ( $\geq 33$ minutes) |            |                         |         |
|--|------------|-------------------------|---------|
| Independent variables  | Odds ratio | 95% confidence interval | P value |
| <i>Patient characteristics</i>                                 |            |                         |         |
| Age  | 0.998      | 0.982–1.014             | 0.835   |
| Female sex   | 1.198      | 0.706–2.030             | 0.503   |
| Underlying disease   |            |                         |         |
| Height (per 10cm incremental)                                  | 1.156      | 0.938–1.424             | 0.174   |
| Body weight (per 10kg incremental)                             | 1.112      | 0.954–1.296             | 0.173   |
| Systolic blood pressure (mmHg) (per 10mmHg incremental)        | 1.015      | 0.951–1.084             | 0.650   |
| Diastolic blood pressure (mmHg) (per 10mmHg incremental)       | 1.038      | 0.932–1.157             | 0.494   |
| Heart rate (beat per minute) (per 10bpm incremental)           | 1.103      | 1.003–1.213             | 0.043   |
| Underlying disease   |            |                         |         |
| Hypertension   | 0.991      | 0.595–1.649             | 0.972   |
| Diabetes mellitus  | 1.797      | 1.163–2.777             | 0.008   |
| Dyslipidemia   | 0.900      | 0.584–1.387             | 0.633   |
| Hemodialysis   | 2.582      | 1.146–5.817             | 0.022   |
| History of previous MI   | 1.017      | 0.492–2.104             | 0.963   |
| History of previous PCI  | 1.158      | 0.626–2.144             | 0.640   |
| History of previous CABG                                       | 6.353      | 1.048–38.516            | 0.044   |
| Current smoker   | 0.880      | 0.561–1.380             | 0.577   |
| Medication before admission                                    |            |                         |         |
| Aspirin  | 1.141      | 0.650–2.004             | 0.646   |
| Thienopyridine   | 1.323      | 0.647–2.705             | 0.443   |
| Beta-blocker   | 1.768      | 0.985–3.171             | 0.056   |
| ACE-inhibitor, ARB   | 1.579      | 1.003–2.486             | 0.049   |
| Calcium channel blocker  | 1.095      | 0.692–1.733             | 0.697   |
| Statin   | 1.152      | 0.686–1.934             | 0.593   |
| Diuretic   | 1.357      | 0.662–2.781             | 0.404   |
| Hypoglycemic agents  | 1.865      | 1.146–3.035             | 0.012   |
| Insulin  | 1.668      | 0.676–4.113             | 0.267   |
| Laboratory data at admission                                   |            |                         |         |
| Serum creatinine (mg/dl)                                       | 1.212      | 1.095–1.342             | <0.001  |
| Estimated GFR (ml/min/1.73m <sup>2</sup> )                     | 0.994      | 0.987–1.001             | 0.108   |
| Hemoglobin (g/dl)  | 0.893      | 0.806–0.989             | 0.029   |
| BNP (pg/ml) (per 100pg/ml incremental)                         | 1.047      | 1.011–1.083             | 0.009   |
| Onset to hospitalization time                                  |            |                         |         |
| Longer than 24hours vs. 0–24 hours                             | 0.625      | 0.283–1.381             | 0.245   |
| Killip class   |            |                         |         |
| 3–4 vs. 1–2  | 1.827      | 1.055–3.161             | 0.031   |
| Cardiac arrest at prehospital or ER                            | 2.727      | 1.382–5.380             | 0.004   |
| Shock vital at prehospital or ER                               | 1.208      | 0.689–2.120             | 0.509   |
| <i>Lesion characteristics</i>                                  |            |                         |         |
| Culprit lesion   |            |                         |         |
| Left main—left anterior descending artery vs. Others           | 0.854      | 0.558–1.309             | 0.469   |
| Number of narrowed coronary arteries                           |            |                         |         |
| 3 vessel disease vs. 1 or 2 vessel disease                     | 2.828      | 1.772–4.515             | <0.001  |
| Left main trunk lesion   | 2.258      | 1.188–4.294             | 0.013   |
| Left main trunk bifurcation lesion                             | 2.023      | 0.849–4.823             | 0.112   |

(Continued)



Table 2. (Continued)

| Dependent variable: long fluoroscopy time ( $\geq 33$ minutes)  |            |                         |         |
|---|------------|-------------------------|---------|
| Independent variables   | Odds ratio | 95% confidence interval | P value |
| Ostia lesion  | 1.622      | 0.698–3.771             | 0.261   |
| Bifurcation lesion  | 1.500      | 0.921–2.443             | 0.103   |
| Initial TIMI flow grade of culprit                              |            |                         |         |
| 3 vs. 0–2   | 1.169      | 0.668–2.045             | 0.585   |
| Lesion length (mm) (per 10mm incremental)                       | 1.791      | 1.448–2.216             | <0.001  |
| Reference diameter (mm)   | 0.813      | 0.595–1.112             | 0.195   |
| Lesion angle  |            |                         |         |
| Severe ( $\leq 120^\circ$ ) vs. Mild-moderate ( $120^\circ <$ ) | 2.396      | 1.347–4.264             | 0.003   |
| Tortuosity  |            |                         |         |
| Moderate-excessive tortuosity vs. Mild tortuosity               | 3.605      | 1.454–8.942             | 0.006   |
| Eccentricity  |            |                         |         |
| Eccentric vs. Concentric  | 1.479      | 0.608–3.595             | 0.388   |
| Calcification   |            |                         |         |
| Moderate-severe vs. None-mild                                   | 2.537      | 1.596–4.031             | <0.001  |
| Occurrence of slow flow in PCI                                  | 1.164      | 0.558–2.428             | 0.686   |
| <b>Procedural characteristics</b>                               |            |                         |         |
| Approach site   |            |                         |         |
| Trans radial coronary intervention vs. TFI or TBI               | 0.662      | 0.430–1.021             | 0.062   |
| Change of approach site   | 3.467      | 1.836–6.546             | <0.001  |
| PCI procedure   |            |                         |         |
| Drug eluting stent vs. Others                                   | 1.055      | 0.541–2.056             | 0.875   |
| Size of guiding catheter  |            |                         |         |
| $\geq 7$ vs. 6Fr  | 2.552      | 1.646–3.957             | <0.001  |
| Number of guiding catheter                                      |            |                         |         |
| $\geq 2$ vs. 1  | 9.595      | 4.691–19.627            | <0.001  |
| Number of wire  |            |                         |         |
| $\geq 2$ vs. 1  | 6.525      | 3.922–10.855            | <0.001  |
| Number of stent   |            |                         |         |
| $\geq 2$ vs. 0–1  | 8.209      | 4.513–14.916            | <0.001  |
| Number of balloon   |            |                         |         |
| $\geq 3$ vs. 0–2  | 6.030      | 3.392–10.719            | <0.001  |
| Use of extension guide catheter                                 | 9.193      | 4.660–18.136            | <0.001  |
| Use of micro catheter   | 6.685      | 4.219–10.593            | <0.001  |
| Use of aspiration catheter                                      | 1.356      | 0.848–2.170             | 0.203   |
| Temporary pacemaker   | 1.307      | 0.659–2.593             | 0.444   |
| Intra-aortic balloon pumping support                            | 3.088      | 1.756–5.428             | <0.001  |
| V-A ECMO  | 2.474      | 1.010–6.063             | 0.048   |

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95% CI 1.205–5.584,  $P = 0.015$ ), triple vessels disease (vs. 1 or 2 vessel diseases: OR 1.772, 95% CI 1.052–2.983,  $P = 0.031$ ), lesion length (per 10 mm incremental: OR 1.751, 95% CI 1.397–2.195,  $P < 0.001$ ), moderate-excessive tortuosity (vs. mild tortuosity: OR 4.006, 95% CI 1.498–10.715,  $P = 0.006$ ), moderate to severe calcification (vs. none-mild calcification: OR 1.865, 95% CI 1.107–3.140,  $P = 0.019$ ), and size of guiding catheter  $\geq 7$  Fr (vs. 6 Fr: OR 1.751, 95% CI 1.064–2.883,  $P = 0.028$ ) were significantly associated with the long fluoroscopy-time in this final model.

**Table 3. Multivariate logistic regression analysis model to find association with the long fluoroscopy time ( $\geq 33$  minutes).**

| Dependent variable: long fluoroscopy time ( $\geq 33$ minutes) |            |                         |         |
|--|------------|-------------------------|---------|
| Independent variables  | Odds ratio | 95% confidence interval | P value |
| Serum creatinine (mg/dl)                                       | 1.139      | 1.016–1.277             | 0.026   |
| Cardiac arrest at prehospital or ER                            | 2.594      | 1.205–5.584             | 0.015   |
| Triple vessels disease (vs. 1 or 2 vessel diseases)            | 1.772      | 1.052–2.983             | 0.031   |
| Lesion length (mm) (per 10mm incremental)                      | 1.751      | 1.397–2.195             | <0.001  |
| Moderate-excessive tortuosity (vs. mild tortuosity)            | 4.006      | 1.498–10.715            | 0.006   |
| Moderate-severe calcification (vs. none-mild)                  | 1.865      | 1.107–3.140             | 0.019   |
| Size of guiding catheter $\geq 7$ Fr (vs. 6 Fr)                | 1.751      | 1.064–2.883             | 0.028   |

The stepwise model includes the following variables: History of previous CABG, Serum creatinine (mg/dl), Hemoglobin (g/dl), Killip class, Cardiac arrest at prehospital or ER, Number of narrowed coronary arteries, Left main trunk lesion, Lesion length (mm) (per 10mm incremental), Lesion angle, Tortuosity, Calcification, Size of guiding catheter.

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## Discussion

The present study included 539 patients who underwent primary PCI for STEMI, which were divided into the conventional fluoroscopy-time group ( $n = 434$ ) and the long fluoroscopy-time group ( $n = 105$ ). In the multivariate stepwise logistic regression analysis, serum creatinine, cardiac arrest at prehospital or ER, three vessel disease, diffuse long lesion, moderate to excessive tortuosity, moderate to severe calcification, and big size of guiding catheter were associated with the long fluoroscopy-time, suggesting that complex lesion characteristics required longer fluoroscopy-time in primary PCI.

Although there were several studies to find determinants of the long fluoroscopy time in PCI [14, 15], there were few studies to find that in primary PCI for STEMI. In the present study, lesion length was significantly associated with the long fluoroscopy time. Since the very beginning of PCI, lesion length has been considered to be an important feature reflecting the difficulty of PCI [12, 16]. We previously reported that total fluoroscopy time was clearly stratified according to the ACC/AHA type classification of coronary lesions such as type A, type B, and type C [17], and lesion length has been a main component of the ACC/AHA type classification system. Even in the current PCI, strong back-up support should be necessary to deliver devices to the diffuse long lesion, which sometimes requires guide-extension-catheters, buddy wire technique, and anchoring technique [18]. Furthermore, diffuse long lesion may require an additional stent to cover the whole lesion. Therefore, diffuse long lesion would require longer fluoroscopy time.

In the present study, moderate-excessive tortuosity was also associated with the long fluoroscopy time. Severe vessel tortuosity has been identified as a predictor of unsuccessful PCI [19]. Nikolsky et al. analyzed the reasons of stent deployment failure using 151 cases, and reported that the dominant reason (92%) of stent deployment failure was unsuccessful to deliver the stent to the lesion site, because of severe tortuosity and/or calcification [20]. Ho, et al. reported that the current thin-strut stent had better deliverability to coronary lesions, but required “five-in-six” system to facilitate stent delivery for severely tortuous lesions [21]. Thus, stent delivery to excessive tortuous lesions still requires additional efforts and the additional fluoroscopy time. Our results suggest that excessive tortuosity can be a problem even in contemporary primary PCI.

Similarly, calcification was significantly associated with the long fluoroscopy time in the present study. Since severe calcification was closely associated with difficulty of device delivery [18, 21], it was expected that longer fluoroscopy time was required in severely calcified lesions. Furthermore, severe calcification can be a cause of balloon underexpansion or balloon rupture [22, 23], which may require additional non-compliant balloons, scoring balloons, or debulking devices [24]. Such additional procedures should require longer fluoroscopy time. Since only 1 case (0.2%) required rotator in our study population, even calcification that did not need rotator could be a cause of difficulty in primary PCI.

Serum creatinine was associated with the long fluoroscopy-time. Increased serum levels is known to be associated with advanced atherosclerosis [25, 26]. Advance atherosclerosis could be a cause of complex coronary lesions, which might require additional fluoroscopy time. Cardiac arrest at prehospital or ER was also significantly associated with the long fluoroscopy-time. If vital signs were unstable in catheter laboratories, it should be necessary to stabilize severe conditions using vasopressor agents, IABP, or V-A ECMO, which also require some fluoroscopy time. Gupta N et al. showed that patients with cardiac arrest had more complex coronary lesions [27]. Similarly, triple vessel disease was associated with the long fluoroscopy-time. Triple vessel disease indicates the progression of coronary atherosclerosis. Sorajja P et al. reported that extensive disease in vessels remote from the infarct-related artery was associated with unsuccessful reperfusion in primary PCI [28], which would require longer fluoroscopy time. Lastly, larger size of guiding catheter was significantly associated with the long fluoroscopy-time. However, interpretation of this result should be careful. Since larger guiding catheter size has strong back-up force, we selected larger guiding catheter for lesions with more complex disease. Therefore, larger size of guiding catheter would probably be an effect rather than a cause of longer fluoroscopy-time.

Clinical implications of the present study should be noted. Since primary PCI is performed irrespective of on/off-hours [29], junior operators often perform primary PCI with or without senior operators. Although most lesions may be managed by junior operators, some lesions would require experienced senior operators. In fact, Chen, et al. reported that the significant reduction of in-hospital death was observed when primary PCI was performed by trained operators as compared to untrained operators [30]. However, it may be difficult for junior operators to differentiate which lesions are really difficult. The present study may provide practical information which lesions are really difficult for junior operators in primary PCI. If the lesion are diffuse long, severely tortuous, or severely calcified in coronary angiography, junior operators should ask senior operators of backup support, if possible. Otherwise, junior operators should discuss the strategy to such tough lesions in primary PCI with senior operators beforehand.

### Study limitations

First, because this study was a single-center retrospective observational study, there is a risk of patient selection bias. Second, we arbitrary defined the long fluoroscopy-time as the longest quintile of the fluoroscopy time, because there were no established cut-off points for the long fluoroscopy time, which were also used in early literatures [31–33]. Moreover, if we defined the long fluoroscopy-time as the longest quartile or the longest sextile, the main parameters such as lesion length, tortuosity, and calcification remained significant determinants of the long fluoroscopy time (data was only shown in the peer review process). Third, since total occlusion was frequently observed in the culprit lesion of STEMI, QCA parameters were measured after the acquisition of reperfusion (after ballooning or thrombectomy). Therefore, these QCA parameters might not reflect the original occlusion length or reference diameter.

## Conclusions

In primary PCI for STEMI, serum creatinine, cardiac arrest at prehospital or ER, three vessel disease, diffuse long lesion, moderate-excessive tortuosity, severe calcification were associated with the long fluoroscopy-time. These complex features require special attention to reduce reperfusion time in primary PCI.

## Supporting information

**S1 File.**  
(XLSX)

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