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ORIGINAL PAPER

A propensity score matched valuation on feasibility of low frame rate fluoroscopy during primary percutaneous coronary intervention for patients with STEMI

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Abstract
The present study aimed to evaluate the feasibility of low frame rate fluoroscopy during primary percutaneous coronary intervention (PPCI) for patients with acute ST elevation myocardial infarction (STEMI). From January 2016 to December 2017, 165 consecutive patients with STEMI who underwent PPCI were retrospectively divided into two groups: the 7.5-frame group (fluoroscopy at 7.5 frames/s) and the 15-frame group (fluoroscopy at 15 frames/s), according to the frame rate of fluoroscopy used in their treatment. Reduction of radiation and safety of fluoroscopy at 7.5 frames/s were compared by a method of propensity score matching (PSM) with fluoroscopy at 15 frames/s. After PSM, there were 56 patients in each group. There were no differences in patients' baseline characteristics between two groups. The 7.5-frame protocol resulted in 48.9% reduction of DAP (9917 ± 5543 $cGycm^2$ vs. 14766 ± 7272 $cGycm^2$, $P < 0.001$) and 61.1% reduction of AK (1209 ± 562 mGy vs. 1948 ± 1105 mGy, $P < 0.001$) with comparable procedural time (38.1 ± 15.3 min vs. 38.8 ± 17.2 min, $P = 0.830$), fluoroscopy time (13.0 ± 7.2 min vs. 13.5 ± 8.1 min, $P = 0.703$) and contrast volume (122.3 ± 39.4 ml vs. 119.3 ± 49.4 ml, $P = 0.725$) to the 15-frame group. Meanwhile, this new protocol didn't increase the incidence of contrast-induced nephropathy (23.2% vs. 25.0%, OR = 0.907, 95% CI 0.381–2.157, $P = 0.825$) and peri-PPCI cumulative adverse events (30.4% vs. 28.6%, OR = 1.090, 95% CI 0.483–2.456, $P = 0.836$). In conclusion, low frame rate fluoroscopy at 7.5 frames/s is a safe and feasible strategy for reducing radiation during PPCI.

Keywords Percutaneous coronary intervention · ST elevation myocardial infarction · Radiation · Fluoroscopy

Abbreviations

PCI	Percutaneous coronary intervention
PPCI	Primary percutaneous coronary intervention
STEMI	ST elevation myocardial infarction
PSM	Propensity score matching
Scr	Serum creatinine
AK	Air kerma
DAP	Dose area product
MI	Myocardial infarction
CIN	Contrast-induced nephropathy
BMI	Body mass index
CABG	Coronary artery bypass graft
LVEF	Left ventricular ejection fraction
LAD	Left anterior descending artery
LCX	Left circumflex artery
RCA	Right coronary artery
SES	Sirolimus-eluting stent
ZES	Zotarolimus-eluting stent
AEs	Adverse events

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Introduction

With percutaneous coronary intervention (PCI) widely used in the treatment of coronary heart disease as a major strategy, potential risks have been concerned due to accumulation of daily radiation exposure, especially in a high-volume PCI center. Therefore, novel measure is required to effectively reduce the radiation dose. Recently, the use of a low-frame rate fluoroscopy at 7.5 frames/s during angiography could reduce radiation exposure without compromising image quality as an alterative protocol [1–4]. Meanwhile, previous studies also confirmed that use of such low-frame rate protocol is safe and effective during PCI for patients with B2/C lesion [5, 6] or chronic total occlusion (CTO) lesion [7]. However, there are limited data available on low frame rate fluoroscopy used in primary PCI (PPCI) for patients with ST elevation myocardial infarction (STEMI). Here, we retrospectively assessed the feasibility of a low frame rate fluoroscopy during PPCI with a method of propensity score matching (PSM).

Methods

Participants

From January 2016 to December 2017, 165 consecutive patients with STEMI with symptom onset within the prior 12 h who underwent PPCI in our center were retrospectively collected, and then divided into two groups: the 7.5-frame group (fluoroscopy at 7.5 frames/s) and the 15-frame group (fluoroscopy at 15 frames/s), according to the frame rate of fluoroscopy that used in their treatment. All procedures performed in studies involving human participants were in accordance with the ethical standards of our institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All patients gave written informed consent.

Procedure

The interventional procedure team in the hospital consists of interventional cardiologist, nurses and radiologic technologists who are responsible for adjusting and delivering radiation doses and also for supervision of radiation protection procedures. All procedures were performed via radial pathway and under same flat panel detector X-ray system (GoldSeal refurbished Innova 2100 systems, GE healthcare, USA). The coronary intervention procedures were performed using standard techniques. The use of low rate fluoroscopy and angiography views was taken according to operators' discretion. Image acquisition was performed with a method of storing fluoroscopy combined with angiography under coronary mode (but not electrophysiologic mode) during PCI. Generally, angiography was used when assessing stent positioning, stent expansion or blood flow. The procedural time was defined as the time from sheath in to sheath out. The contrast volume was recorded at immediate after every procedure finished. Blood samples were collected in all patients for determination of serum creatinine (Scr) before intervention, and post-procedural 24 and 48 h. For the post-procedural Scr, the higher one was included into final analysis.

Radiation dose assessment

The fluoroscopy time was defined as the time that fluoroscopy used during a procedure. Every exposure time was controlled at least three cardiac cycles in cine-angiography model. The total air kerma (AK, mGy) at the interventional reference point was defined as the cumulative AK at the interventional reference point and dose area product (DAP, $cGycm^2$) as the absorbed dose multiplied by the area irradiated [8, 9]. These two radiation-monitoring values, which were required on interventional X-ray systems, were generated by the angiographic system for each case and recorded in the database.

Events assessment

Every intra-procedural complication was recorded, including no-flow or slow flow, coronary dissection or perforation, any arrhythmia that led to hemodynamics unstable, loss of side branch, guidewire fracture, stents deloading, death, and son on. Angiographic (anatomic) success was defined as a minimal stenosis diameter reduction to $<20\%$ for stenting or to $<50\%$ for just angioplasty or thrombus aspiration together with grade 3 TIMI flow after the procedure [10]. Procedural success was defined as an angiographic success without in-hospital major clinical adverse events, e.g., death, myocardial infarction (MI) or acute stent thrombus, emergency revascularization [11]. Contrast-induced nephropathy (CIN) is defined as the impairment of renal function—measured as either a 25% increase in Scr from baseline or a 0.5 mg/dl (44 μmol/l) increase in absolute SCr value within 48–72 h after intravenous contrast administration [12].

Statistical analysis

All analyses were performed with SPSS 20.0 (SPSS Inc., Chicago, USA). Discrete or categorical variables are presented as numbers (percentages), continuous variables as mean ± standard deviation.

We used a method of PSM to reduce the treatment selection bias and the impact of potential confounding factors from the baseline characteristics. The propensity score were calculated with a logistic regression model without regard to outcome variables. All clinical, lesions' factors that were associated with the treatment assignment on univariate analysis were considered as candidate variables. All variables with $P<0.20$ were retained. The reliability of the model was evaluated using the Hosmer–Lemeshow test. According to the nearest match algorithm, we created PSM pairs without replacement at a ratio of 1:1.

To compare differences of the variables between two groups, the Chi square test or Fisher's exact test was employed for the discrete variables, and one way analysis of variance for the continuous variables, followed by t test. All probability values were 2-sided. Level of significance was 5%.

Results

Baseline characteristics

In the total of 165 primary PCI procedures, 75 procedures were performed with 7.5-frame rate protocol and 90 procedures performed with 15-frame rate protocol, respectively. Before PSM, male patients were significant less in the 7.5-frame group when compared with the 15-frame group (76.0% vs. 90.0%, P = 0.016). The body mass index (BMI) in the 7.5-frame group was significant smaller (22.7 ± 2.5 vs. 23.6 ± 3.4 of the 15-frame group, P = 0.042). Meanwhile, 37 patients (49.3%) accepted a treatment with Gp 2b/3a antagonist in the 7.5-frame group in the procedure of primary PCI, which were significant less than that of the 15-frame group (vs. 65.6%, P = 0.035). Although there were no significant difference in patients' age, diabetes, dyslipidemia and stent type between two groups, there were a trend of higher age (64.3 ± 12.8 vs. 61.0 ± 10.9, P = 0.067), less patients with diabetes mellitus (24.0% vs. 34.4%, P = 0.144), dyslipidemia (41.3% vs. 52.2%, P = 0.163) or of more patients accepted sirolimus-eluting stent implantation (66.7% vs. 53.3%, P = 0.085) in the 7.5-frame group. Otherwise, there were no significant differences in other baseline clinical and procedure-associated variables, such as hypertension, heart rate, current smoking, and so on. Based on a P value < 0.2, variables used to determine the PSM model included male, age, BMI, diabetes mellitus, dyslipidemia, stent type used, and gp2b/3a antagonist. Finally, there were 56 patients in each group after PSM. There were no significant differences in any baseline clinical and procedure-associated variables (Tables 1, 2).

Radiation dose comparison

The radiation-associated results were shown in Table 3. Before PSM, the DAP was 9750 ± 5369 $cGycm^2$ and AK was 1220 ± 593 mGy in the 7.5-frame group, respectively, which were significant less than those of the 15-frame group (16489 ± 10821 $cGycm^2$ and 2190 ± 1344 mGy, all P < 0.001). After PSM, the 7.5-frame protocol resulted in 48.9% reduction of DAP (9917 ± 5543 $cGycm^2$ vs. 14766 ± 7272 $cGycm^2$, P < 0.001) and 61.1% reduction of AK (1209 ± 562 mGy vs. 1948 ± 1105 mGy, P < 0.001). There was no significant difference in fluoroscopy time between two groups either before PSM (13.0 ± 7.3 min vs. 14.5 ± 9.2 min, P = 0.254) or after PSM (13.0 ± 7.2 min vs. 13.5 ± 8.1 min, P = 0.703).

Peri-procedural outcomes

The results of peri-procedural adverse events (AEs) were presented in Table 4. For the intra-PPCI AEs, no device-associated complications (i.e., guidewire fracture, stent deloading, perforation and air embolism) happened except one patient of the 15-frame group experienced dissection. Slow flow or no flow was not unfrequent though there was no significant difference between two groups (P = 0.373). There were thirteen cases (17.3%, two cases simultaneously complicated by ventricular tachycardia and one case by ventricular fibrillation)

Table 1 Baseline clinical characteristics

Variables	Before PSM			After PSM		
	7.5 frames (n = 75)	15 frames (n = 90)	P value	7.5 frames (n = 56)	15 frames (n = 56)	P value
Male, n (%)	57 (76.0)	81 (90.0)	0.016	46 (82.1)	47 (83.9)	0.801
Age (years)	64.3 ± 12.8	61.0 ± 10.9	0.067	63.2 ± 13.4	62.3 ± 11.3	0.727
Body mass index (kg/m^2)	22.7 ± 2.5	23.6 ± 3.4	0.042	23.2 ± 2.2	23.2 ± 3.8	0.959
Heart rates (min^{-1})	76.7 ± 16.3	77.5 ± 13.9	0.740	73.9±15.3	76.8 ± 14.6	0.313
Hypertension, n (%)	39 (52.0)	52 (57.8)	0.457	29 (51.8)	33 (58.9)	0.447
Diabetes, n (%)	18 (24.0)	31 (34.4)	0.144	14 (25.0)	14 (25.0)	1.000
Current smoking, n (%)	45 (60.0)	56 (62.2)	0.771	34 (60.7)	29 (51.8)	0.341
Dyslipidemia, n (%)	31 (41.3)	47 (52.2)	0.163	26 (46.4)	24 (42.9)	0.704
History of PCI or CABG[a], n (%)	3 (4.0)	5 (5.5)	0.792	3 (5.4)	4 (7.2)	1.000
LVEF (%)	49.0 ± 9.2	50.6 ± 7.9	0.231	49.6 ± 7.8	51.3 ± 7.5	0.264

PSM propensity score matching, *PCI* percutaneous coronary intervention, *CABG* coronary artery bypass graft, *LVEF* left ventricular ejection fraction

[a]Fisher's exact test

Table 2 Procedure-associated characteristics

Variables	Before PSM			After PSM		
	7.5 frames (n = 75)	15 frames (n = 90)	P value	7.5 frames (n = 56)	15 frames (n = 56)	P value
Culprit vessel[a], n (%)			0.850			0.957
Left main	5 (6.7)	4 (4.4)		2 (0.0)	2 (0.0)	
LAD	42 (56.0)	51 (56.7)		31 (58.9)	29	
RCA	22 (29.3)	25 (27.8)		18 (32.2)	18	
LCX	6 (8.0)	10 (11.1)		5 (8.9)	7	
Revascularization strategy[a], n (%)			0.334			0.292
Balloon dilation + stenting	57 (76.0)	76 (84.4)		40 (71.4)	46 (82.1)	
Thrombus aspiration + stenting	9 (12.0)	4 (4.4)		8 (14.3)	2 (3.6)	
Only balloon dilation	7 (9.3)	7 (7.8)		6 (10.7)	6 (10.7)	
Only thrombus aspiration	2 (2.7)	3 (3.3)		2 (3.6)	2 (3.6)	
Stent type[a], n (%)			0.085			1.000
None	9 (12.0)	10 (11.1)		8 (14.3)	8 (14.3)	
SES	50 (66.7)	48 (53.3)		34 (60.7)	34 (60.7)	
ZES	15 (20.0)	32 (35.6)		13 (23.2)	14 (25.0)	
Other	1 (1.3)	0 (0.0)		1 (1.8)	0 (0.0)	
Num. of stent used	1.11 ± 0.65	1.22 ± 0.76	0.301	1.02 ± 0.59	1.14 ± 0.70	0.308
Stent length (mm)	29.2 ± 18.5	32.1 ± 20.3	0.354	27.1 ± 17.8	30.2 ± 18.9	0.384
Stent diameter (mm)	2.66 ± 1.03	2.71 ± 1.02	0.755	2.58 ± 1.10	2.53 ± 1.10	0.787
Gp 2b/3a antagonist, n (%)	37 (49.3)	59 (65.6)	0.035	32 (57.1)	33 (58.9)	0.848

LAD left anterior descending artery, *LCX* left circumflex artery, *RCA* right coronary artery, *SES* sirolimus-eluting stent, *ZES* zotarolimus-eluting stent

[a]Fisher's exact test

Table 3 Comparison of radiation dose between the 7.5-frame group and the 15-frame group

Variables	Before PSM			After PSM		
	7.5 frames (n = 75)	15 frames (n = 90)	P value	7.5 frames (n = 56)	15 frames (n = 56)	P value
DAP (cGycm^2)	9750 ± 5369	16489 ± 10821	< 0.001	9917 ± 5543	14766 ± 7272	< 0.001
AK (mGy)	1220 ± 593	2190 ± 1344	< 0.001	1209 ± 562	1948 ± 1105	< 0.001
Fluoroscopy time (min)	13.0 ± 7.3	14.5 ± 9.2	0.254	13.0 ± 7.2	13.5 ± 8.1	0.703

DAP dose area product, *AK* air kerma

in the 7.5-frame group and nineteen cases (21.1%, one case complicated by ventricular tachycardia and one resulted from dissection) in the 15-frame group, respectively. After treated by intra-coronary injection with nitroprusside and/or gp2b3a antagonist or additional stenting, the final coronary flow of all these cases recovered to TIMI grade 3. Six cases (8.0%) experienced malignant arrhythmia that led hemodynamics unstable including four cases with ventricular fibrillation, one with ventricular tachycardia and one with sinus arrest, which was not more than that of the 15-frame group (vs. 5.6%, P = 0.531). One case experienced acute heart failure during PPCI in the 7.5-frame group, respectively. Only one death happened in the 15-frame group, and this patient died of cardiac rupture. So, the incidence of cumulative AEs was 22.7% in the 7.5-frame group and 24.4% in the 15-frame group during PPCI with no significant difference between two groups (P = 0.789). For the in-hospital AEs, there were three cases of death in the 7.5-frame group, of which one case died of VT, one case died of cardiac shock and one case died of cardiac rupture, respectively. In the 15-frame group, there were two cases of death (both died of cardiac rupture) and one case experienced in-stent thrombus and was treated by emergency percutaneous coronary intervention successfully. So, there was no significant difference in the incidence of cumulative in-hospital AEs between two groups (4.0% of the 7.5-frame group vs. 3.3% of the 15-frame group, P = 1.000). The incidence of total peri-PPCI cumulative CAEs was 26.7% in the 7.5-frame group and 27.8% in the 15-frame group (OR = 0.945, 95% CI 0.475–1.883, P = 0.873). After PSM, there were no significant differences in the incidence of no-flow/ slow-flow (21.4% vs.

Table 4 Peri-procedural AEs

Variables	Before PSM			After PSM		
	7.5 frames (n = 75)	15 frames (n = 90)	P value	7.5 frames (n = 56)	15 frames (n = 56)	P value
Intra-PPCI AEs, n (%)						
No-flow or slow-flow	13 (17.3)	19 (21.1)	0.373	12 (21.4)	13 (23.2)	0.820
Dissection[a]	0 (0.0)	1 (1.1)	1.000	0 (0.0)	1 (1.8)	1.000
Malignant arrhythmia	6 (8.0)	5 (5.6)	0.531	6 (10.7)	4 (7.1)	0.742
Acute heart failure[a]	1 (1.3)	0 (0.0)	0.455	0 (0.0)	0 (0.0)	1.000
Cardiac rupture[a]	0 (0.0)	1 (1.1)	1.000	0 (0.0)	0 (0.0)	1.000
Death[a]	0 (0.0)	1 (1.1)	1.000	0 (0.0)	0 (0.0)	1.000
Cumulative AEs	17 (22.7)	22 (24.4)	0.789	15 (26.8)	15 (26.8)	1.000
In-hospital AEs[a], n (%)						
Malignant arrhythmia	1 (1.3)	0 (0.0)	0.455	1 (1.8)	0 (0.0)	1.000
Cardiac shock	1 (1.1)	0 (0.0)	0.455	0 (0.0)	0 (0.0)	1.000
Cardiac rupture	1 (1.3)	2 (2.2)	1.000	1 (1.8)	2 (3.6)	1.000
MI or stent thrombus	0 (0.0)	1 (1.1)	1.000	0 (0.0)	1 (1.8)	1.000
Emergency revascularization	0 (0.0)	1 (1.1)	1.000	0 (0.0)	1 (1.8)	1.000
Death	3 (4.0)	2 (2.2)	0.660	2 (3.6)	2 (3.6)	1.000
Cumulative AEs	3 (4.0)	3 (3.3)	1.000	2 (3.6)	3 (5.4)	1.000
Peri-PPCI cumulative AEs, n (%)	20 (26.7)	25 (27.8)	0.873	17 (30.4)	16 (28.6)	0.836
Angiographic success rate[a], %	100	98.9	1.000	100	100	1.000
Procedural success rate[a], %	96.0	95.6	1.000	96.4	94.6	1.000
Procedural time (min)	38.2 ± 14.8	37.8 ± 16.1	0.876	38.1 ± 15.3	38.8 ± 17.2	0.830
Contrast volume (ml)	128.5 ± 52.2	123.7 ± 51.2	0.561	122.3 ± 39.4	119.3 ± 49.4	0.725
Serum creatinine (μmol/l)						
Before procedure	79.8 ± 26.2	80.6 ± 33.2	0.867	80.7 ± 25.4	83.5 ± 39.4	0.653
After procedure	90.7 ± 31.2	92.8 ± 44.7	0.727	92.1 ± 30.9	96.8 ± 52.5	0.553
Change of creatinine	10.9 ± 13.6	12.2 ± 18.5	0.601	11.4 ± 13.8	13.4 ± 20.6	0.543
Contrast induced nephropathy, n (%)	17 (22.7)	21 (23.3)	0.919	13 (23.2)	14 (25.0)	0.825

PPCI primary percutaneous coronary intervention, *AEs* adverse evevts.

[a]Fisher's exact test

23.2%, P = 0.820), of intra-PPCI cumulative AEs (26.8% vs. 26.8%, P = 1.000), of in-hospital cumulative AEs (3.6% vs. 5.4%, P = 1.000) and of peri-PPCI cumulative AEs (30.4% vs. 28.6%, OR = 1.090, 95% CI 0.483–2.456, P = 0.836). Finally, the 7.5 frame group had similar high procedure success rate as the 15-frame group either before PSM (96.0% vs. 95.6%, P = 1.000) or after PSM (96.4% vs. 94.6%, P = 1.000). Meanwhile, there was no significant difference in the procedural time between two groups before PSM (38.2 ± 14.8 min in the 7.5-frame group vs. 37.8 ± 16.1 min in the 15-frame group, P = 0.876) and after PSM (38.1 ± 15.3 min in the 7.5-frame group vs. 38.8 ± 17.2 min in the 15-frame group, P = 0.830). When compared with the 15-frame group, the contrast volume in the 7.5-frame group did not remarkably increase either before PSM (128.5 ± 52.2 ml vs. 123.7 ± 51.2 ml, P = 0.561) or after PSM (122.3 ± 39.4 ml vs. 119.3 ± 49.4 ml, P = 0.725). Also, we assessed the change of Scr of every patient after procedure. The results showed that there was no significant difference in baseline value, post-procedural value and the change of Scr between two groups (before procedure: 79.8 ± 26.2 μmol/l vs. 80.6 ± 33.2 μmol/l, P = 0.867; after procedure: 90.7 ± 31.2 μmol/l vs. 92.8 ± 44.7 μmol/l, P = 0.727; change of Scr: 10.9 ± 13.6 μmol/l vs. 12.2 ± 18.5 μmol/l, P = 0.601). Similar results were found after PSM ($P > 0.05$). According to increase in Scr, the incidence of CIN in the 7.5-frame group was 22.7%, which was not more than that of the 15-frame group (23.3%, OR = 0.963, 95% CI 0.465–1.996, P = 0.919). After PSM, there was still no difference when compared with the 15-frame group (23.2% vs. 25.0%, OR = 0.907, 95% CI 0.381–2.157, P = 0.825).

Discussion

This is the first study to test safety and efficacy of low frame rate fluoroscopy at 7.5 frames/s for PPCI by using real-world clinically practical data. The present study demonstrated a remarkable reduction of radiation dose during PPCI using the low rate fluoroscopy and this effect was not at the expense of increase in fluoroscopy time, the contrast volume and peri-procedural adverse events.

Currently, the following strategies were used for reduction of medical radiation exposure: minimizing beam on time and magnification, use of beam collimation, optimizing distance from source to the patient, varying the entry site of radiation, and fluorography with retrospective fluoroscopic image storage instead of cine-angiography. However, these above methods cannot meet with increase of catheter intervention volume and potentially high risk of radiation-induced adverse outcomes (i.e., skin damage, malignancy and teratogenicity [13–15]) can never be ignored still.

In the past few years, extensive attentions have been aroused by low frame rate of fluoroscopy as a simple method of reducing radiation dose. In a randomized study comparing low rate fluoroscopy at 7.5 frames/s with conventional 15 frames/s for reduction of radiation dose, the results demonstrated that 7.5 frames/s reduced the operator radiation dose by 28% and reduced the patient radiation dose by 19% for PCI (PCI type not stratified), respectively [5]. In another study enrolled a vast number of patients with B2/C lesion (around account for 85%) [6]. Sadamatsu and Nakano have reported that use of low frame rate fluoroscopy at 7.5 frames/s reduced the radiation dose associated with the procedure by approximately 25%. Moreover, a study aiming PCI for CTO lesion also showed that the new protocol achieved 72.5% reduction of AK value and 69.8% reduction of DAP value [7]. In the present study aiming PPCI, we found that use of 7.5 frames/s can reduce AK value by 61.1% and reduce DAP by 48.9% after adjusted male, age, BMI, diabetes mellitus, dyslipidemia, stent type used, and gp2b/3a antagonist with a method of PSM, of which some variables (i.e., BMI, age, sex) have an impact on radiation dose [16, 17]. Taken together these results of above, use of 7.5 frames/s fluoroscopy is simple strategy for reduction of radiation dose.

Nevertheless, this new protocol has not been adopted as a routine model by most interventional cardiologists still. One of the major concerns is that the reduced frame rate may worsen the image quality due to some flickering, which may lead to increase of fluoroscopy time and procedure risk. Indeed, with update of the dynamic image processing software, the adverse effects of such flickering on procedure can be minimized to a level enough to be ignored. Previous studies on this topic have confirmed that the image quality with low frame rate fluoroscopy was comparable to that with routine frame fluoroscopy [1–4]. Another key problem is that use of low frame rate fluoroscopy at 7.5 frames/s may increase fluoroscopy time and procedure risk. In fact, this concern did not occur in the setting of diagnostic angiography and routine PCI [5, 6]. Even in the CTO–PCI setting, there were no significant differences in the fluoroscopy and procedural time, procedural success rate, and complications [7]. In the present study, we also provided a group of comparable data either before PSM or after PSM when low frame rate fluoroscopy used in the setting of PPCI. Especially in terms of procedural safety, use of low frame rate fluoroscopy did not increase any events including death, MI, emergency revascularization or other operating-associated complication. Although the intra-procedural no flow or slow flow was not un-frequent, there was no significant difference between use of low frame rate and routine frame rate fluoroscopy. In addition, we also assessed the effect of low frame rate fluoroscopy on CIN. Based on a definition of a 25% increase in SCr from baseline or a 0.5 mg/dl (44 μmol/l) increase in absolute SCr value within 48–72 h after contrast administration, use of low frame rate fluoroscopy did not result in increase of the contrast volume and the incidence of CIN. So, it is feasible to apply low frame rate fluoroscopy at 7.5 frames/s in the setting of PPCI.

Study limitations

The non-randomized nature of this observational study constitutes its limitation. Although a method of PSM was used to adjust the baseline differences and confounders, we cannot exclude the potential that other hidden confounders (i.e., interventional cardiologists' preference) affect this study's outcomes and only small size of pairs were included into analysis. Furthermore, differences in operator skill for PPCI may have influenced radiation dose delivered. Finally, although diminishing patient radiation exposure is an important way of reducing scatter radiation to medical staff [18], operator radiation doses were not evaluated. Therefore, a controlled, randomized, larger population study is required for further assessing the feasibility of low frame rate fluoroscopy used in the setting of PPCI.

In summary, the present study demonstrated that use of low frame rate fluoroscopy in the setting of PPCI for patients with STEMI can effectively reduce radiation dose and doesn't increase procedural and fluoroscopic time and peri-procedural adverse events.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Fujian Medical University Union Hospital ethics committee approval was obtained.

Informed consent All patients in the present study gave written informed consent. Written informed consent for the screening patients were waived by the hospital ethics committee.

Consent for publication All of authors have given their consent for publication.

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