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Percutaneous Coronary Intervention

Retrograde Approach is as Effective and Safe as Antegrade Approach in Contemporary Percutaneous Coronary Intervention for Chronic Total Occlusion: A Taiwan Single-Center Registry Study

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Background: In percutaneous coronary intervention (PCI) for chronic total occlusion (CTO), most experts regard the antegrade approach as the default initial strategy, reserving the retrograde approach for reattempts following antegrade failure. In this study, we aimed to compare the efficacy and safety between the antegrade and retrograde approaches in CTO PCI.

Results: Between 2012 and 2013, patients that underwent 321 consecutive attempts by high-volume operators (> 75 total CTO PCI cases during the period) in a tertiary university-affiliated hospital were enrolled. The antegrade approach was used in 152 patients, and retrograde in 169 patients. The duration of occlusion was significantly longer and the J-CTO score higher in the retrograde group. Technical success was achieved in 148 patients of the antegrade group (97.4%), and 163 patients in the retrograde group (96.4%) ($p = 0.75$). A major procedural complication occurred in 3 patients of the antegrade group (2.0%) and in 6 patients of the retrograde group (3.6%) ($p = 0.51$). In-hospital major adverse cardiac events (MACE) rates (antegrade 0.7%, n = 152; retrograde 0.6%, n = 169) were comparable. The procedure and fluoroscopy times were significantly longer, with more radiation exposure and contrast medium consumption, in the retrograde group. In the retrograde group, similar success, procedural complication and in-hospital MACE rates were achieved in the 3 collateral subgroups.

Conclusions: In selected cases and with highly experienced operators, retrograde approach in CTO PCI is as effective and safe as antegrade approach at the expense of longer procedure time, more radiation exposure and contrast medium consumption. For retrograde approach, either septal, epicardial or AV groove collaterals can be used with similarly success, complication and in-hospital MACE rates.

Key Words: Chronic total occlusion • Collateral channel • Percutaneous coronary intervention

INTRODUCTION

Chronic total occlusion (CTO) occurs in approximately 35% of patients undergoing coronary angiography.[1] Percutaneous coronary intervention (PCI) for CTO is technically challenging, and comprised approximately 5% of all PCI procedures.[2] Studies have demonstrated that successful CTO PCI reduces the need for coronary artery bypass grafting (CABG), relieves angina, improves left ventricular ejection fraction, and long-term survival.[1,3-7] With recent advances in interventional devices, procedural techniques, and operator experience, the technical success rate of modern CTO PCI is consistently above 90%, with low procedural complica-

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tion rate.[8-12] The retrograde approach has been developed and utilized worldwide in recent years, thanks to the development of modern guide-wires and micro-catheters allowing aggressive collateral channel tracking. However, many experts still use the antegrade approach as the default initial strategy, and reserve the retrograde approach only for reattempts.[13-15] We aimed to compare the efficacy and safety between the antegrade and retrograde approaches for CTO PCI in the contemporary era.

METHODS

Patient population

We prospectively recorded detailed clinical, angiographic, and procedural information in 321 consecutively attempted CTO PCI procedures by high-volume operators (> 75 total CTO PCI cases during the study period)[16] between January 2012 and November 2013 in a tertiary university-affiliated center (National Taiwan University Hospital) in Taiwan.

Study endpoints and definitions

Coronary CTO was defined as an angiographic finding of total occlusion with thrombolysis in myocardial infarction (TIMI) flow grade 0 or 1, and duration of at least 3 months. Estimation of occlusion duration was based on the following: 1) first onset of anginal symptoms; 2) previous history of myocardial infarction in the target vessel territory; 3) comparison with a prior angiogram.[8]

Technical success was defined as successful CTO recanalization with < 50% residual stenosis within the treated segment, and restoration of TIMI grade 3 antegrade flow. Procedural complications included any of the following adverse events before hospital discharge: death from any cause, Q-wave myocardial infarction, recurrent angina requiring urgent repeat target vessel revascularization with PCI or coronary bypass surgery, cardiac tamponade requiring pericardiocentesis or surgery, and puncture site bleeding requiring transfusion of surgical management. In-hospital major adverse cardiac events (MACE) were defined as in-hospital death, in-hospital or peri-procedural MI (non-Q wave), or urgent revascularization during the same admission.[17]

Interventional strategies

Diagnostic coronary angiography was performed via the femoral route. Medications used in the procedure and details of the interventional technique are similar to those reported in previous literature.[18]

Selection of the initial strategy was generally based on each patient's coronary anatomy (proximal cap ambiguity, quality of the distal target vessel, lesion length, presence of appropriate collateral channels, etc.), which was often evaluated by simultaneous bilateral injection. Generally, the antegrade approach was adopted if the anatomy was favorable with a low J-CTO score.[19] If the patient's coronary anatomy was unfavorable with a high J-CTO score, especially in re-attempt cases, the retrograde approach was chosen as the initial strategy if a suitable collateral channel was present. After the initial approach was chosen, switch from one approach to the other was essentially not allowed during the same index procedure. The anatomic collaterals' pathway was categorized into 3 subgroups: septal, epicardial and atrioventricular groove collateral channels (Figure 1-3). If several interventional collateral channels were identified, the choosing criteria were: less tortuosity, less angulations to its donor/receiver vessels, and longer dis-

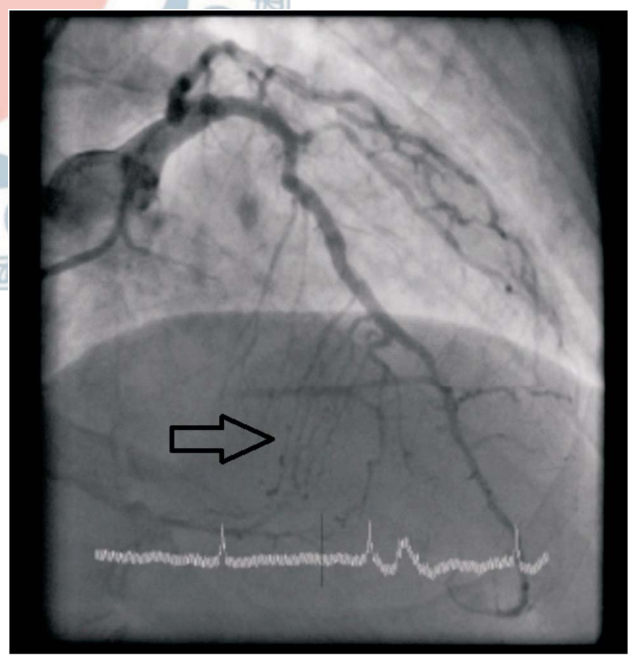

Figure 1. The patient had right coronary artery chronic total occlusion. Left coronary angiogram (right anterior oblique cranial view) showed the presence of several septal collateral channels from left anterior descending artery to distal right coronary artery area.

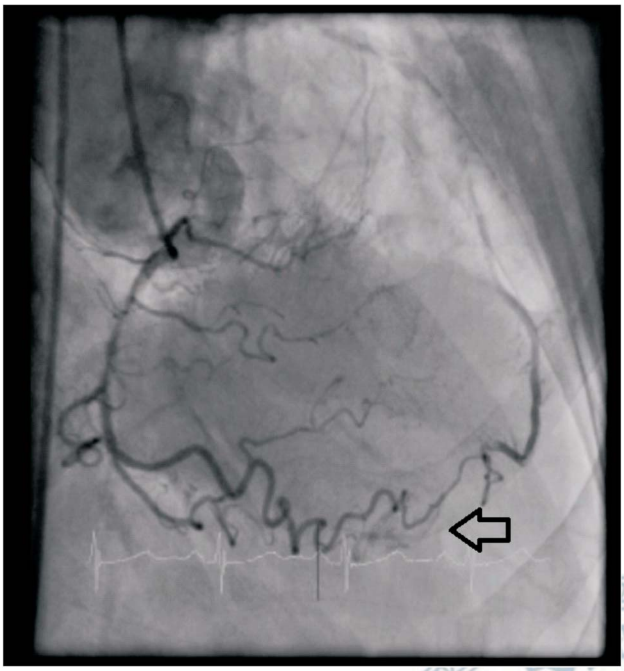

Figure 2. *The patient had left anterior descending artery chronic total occlusion. Right coronary angiogram (right anterior oblique view) showed the presence of epicardial collateral channel from right coronary artery to distal left anterior descending artery area.*

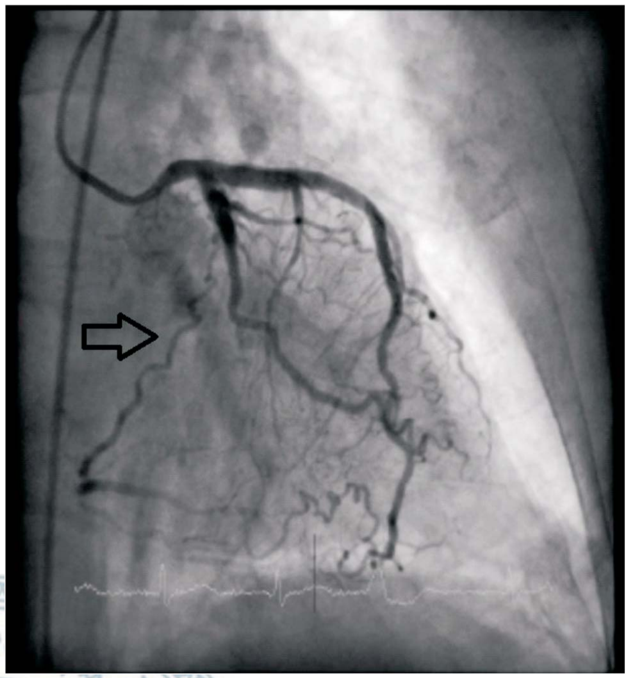

Figure 3. *The patient had right coronary artery chronic total occlusion. Left coronary angiogram (right anterior oblique view) showed the presence of atrioventricular groove collateral channel from left circumflex artery to distal right coronary artery area.*

tance from its confluence to the distal cap. Operators made individualized plans according to not only the above-mentioned factors but also based upon their own clinical judgment.

Statistical analyses

Continuous data were presented as means ± standard deviations (SD), and differences were compared using a Student's t test. Discrete variables were expressed as counts and percentages, and differences were assessed using the chi-square test. All statistical tests were two-tailed, and a p value of < 0.05 was considered statistically significant. All analyses were performed using SPSS version 20 statistical software (SPSS Inc., Chicago, Illinois, USA).

RESULTS

From January 2012 to November 2013, a total of 321 attempted PCI for CTO lesions were enrolled. The mean age of patients was 63.6 ± 11.2 years, and 86.3% were male. Multi-vessel disease was noted in 88.5%, and 85.0% of patients had hypertension. Prior MI was documented in 15%, and prior CABG in 2.2%. The target CTO lesions were located in right coronary artery (RCA) in 48.6% of the patients, left anterior descending artery (LAD) in 34.9%, and left circumflex artery (LCX) in 15.6%. The CTO was ostial in 4.4%, and in-stent in 8.7%. The mean occlusion duration and J-CTO score (19) were 19.4 ± 22.9 months and 3.31 ± 1.5, respectively. Failed PCI attempt for the target CTO was documented in 48.6% (prior strategies: antegrade in 96.8%, retrograde in 3.2%).

The technical success rate was 96.9% (311/321), and the procedural complication rate was 2.8%. In-hospital MACE rate was 0.6%. The retrograde approach was adopted in the index procedure in 52.6%. Higher incidence of male gender and cigarette smoking, and younger age, were noted in the retrograde group. Additionally, significantly longer CTO duration and higher J-CTO score were seen the retrograde group (Table 1). Retrograde approach was used in 63 LAD CTO lesions (55.3%), and in 94 RCA CTO lesions (60.3%). In contrast, for LCX CTO lesions, the retrograde approach was used less frequently (12/51, 23.5%) ($p < 0.001$). Technical success, procedural complication and in-hospital MACE rates were comparable between the antegrade and retrograde groups (Table 2). There were significantly longer procedure time, more radiation exposure, and contrast medium consumption in the retrograde group.

In the retrograde group, septal, epicardial, and atrioventricular (AV) groove collateral channels were used in 82 (48.5%), 63 (37.3%), and 24 (14.2%) procedures, respectively (Table 3). There were no significant demographic or angiographic differences among the 3 collateral channel subgroups (Table 3). Technical success, procedural complication and in-hospital MACE rates were also comparable (Table 4). Procedure and fluoroscopy time, radiation exposure, and contrast medium consumption were similar among these 3 subgroups. There was a trend (p = 0.05) toward more cardiac tamponade in the AV groove subgroup, but the difference was not statistically significant.

Major complications occurred in 9 patients (2.8%). In the antegrade group, complications included 1 death (due to retroperitoneal bleeding) and 2 instances of cardiac tamponade. In the retrograde group, 1 patient died of donor vessel thrombosis. The other complications included 4 instances of cardiac tamponade (2 due to tar-

Table 1. Patients' demographicand angiographic characteristics In different approaches

Variables	Overall (n = 321)	Antegrade (n = 152)	Retrograde (n = 169)	p value
Age, yrs	63.6 ± 11.2	65.6 ± 11.1	61.8 ± 11.1	0.002
Male gender	277 (86.3%)	122 (80.3%)	155 (91.7%)	0.003
Diabetes mellitus	103 (32.1%)	52 (34.2%)	51 (30.2%)	NS
Hypertension	273 (85.0%)	135 (88.8%)	138 (81.7%)	NS
Hyperlipidemia	135 (42.1%)	58 (38.2%)	77 (45.6%)	NS
Smoking	93 (29.0%)	31 (20.4%)	62 (36.7%)	0.001
History of CABG	7 (2.2%)	4 (2.6%)	3 (1.8%)	NS
History of MI	48 (15.0%)	20 (13.2%)	28 (16.6%)	NS
CTO target vessel				< 0.001
LAD	114	51	63	
RCA	156	62	94	
LCX	51	39	12	
CTO duration, month	19.4 ± 22.9	16.3 ± 19.2	22.2 ± 25.6	0.02
J-CTO score	3.3 ± 1.5	2.3 ± 1.5	4.2 ± 0.9	< 0.001
Prior failed attempt	156 (48.6%)	55 (36.2%)	101 (59.8)	< 0.001

CABG, coronary artery bypass graft; J-CTO score, J-Chronic Total Occlusion Score; LAD, left anterior descending artery; LCX, left circumflex artery; MI, myocardial infarction; NS, non-significant; RCA, right coronary artery.

Table 2. Procedural outcomesin different approaches

Variables	Overall (n = 321)	Antegrade (n = 152)	Retrograde (n = 169)	p value
Technical success	311 (96.9%)	148 (97.4%)	163 (96.4%)	NS
Major complication	9 (2.8%)	3 (2.0%)	6 (3.6%)	NS
Death	2 (0.6%)	1 (0.7%)	1 (0.6%)	NS
Tamponade	6 (1.9%)	2 (1.3%)	4 (2.4%)	NS
Major bleeding	1 (0.3%)	0 (0.0%)	1 (0.6%)	NS
Peri-procedural MI	0 (0.0%)	0 (0.0%)	0 (0.0%)	NS
Urgent revascularization	0 (0.0%)	0 (0.0%)	0 (0.0%)	NS
In-hospital MACE	2 (0.6%)	1 (0.7%)	1 (0.6%)	NS
Procedure time, min	104.9 ± 41.8	85.3 ± 35.0	122.5 ± 39.7	< 0.001
Fluoroscopy time, min	42.0 ± 19.4	33.1 ± 16.7	50.0 ± 18.2	< 0.001
Fluoroscopy dose, Gy	5.5 ± 2.7	4.3 ± 2.4	6.5 ± 2.5	< 0.001
Contrast medium, ml	265.5 ± 78.2	241.3 ± 78.4	287.3 ± 71.4	< 0.001

MACE, major adverse cardiac events.

Table 3. Patients' demographic and angiographic characteristics comparing different collateral channels in retrograde approach

Variables	AV groove (n = 24)	Epicardial (n = 63)	Septal (n = 82)	p value
Age, yrs	64.7 ± 9.2	63.1 ± 11.4	60.1 ± 11.0	NS
Male gender	23 (95.8%)	55 (87.3%)	77 (93.9%)	NS
Diabetes mellitus	7 (29.2%)	21 (33.3%)	23 (29.0%)	NS
Hypertension	17 (70.8%)	52 (82.5%)	69 (84.1%)	NS
Hyperlipidemia	10 (41.7%)	27 (42.9%)	40 (48.8%)	NS
Smoking	9 (37.5%)	18 (28.6%)	35 (42.7%)	NS
History of CABG	1 (4.2%)	1 (1.6%)	1 (1.2%)	NS
History of MI	4 (16.7%)	14 (22.2%)	10 (12.2%)	NS
CTO target vessel				< 0.001
LAD	0	26	37	
RCA	21	28	45	
LCX	3	9	0	
CTO duration, month	22.0 ± 23.6	23.4 ± 26.6	21.3 ± 25.6	NS
J-CTO score	4.5 ± 0.7	4.1 ± 1.0	4.2 ± 0.8	NS
Prior failed attempt	17 (70.8%)	33 (52.4%)	51 (62.2%)	NS

AV groove, atrioventricular groove; CABG, coronary artery bypass graft; J-CTO score, J-Chronic Total Occlusion Score; LAD, left anterior descending artery; LCX, left circumflex artery; MI, myocardial infarction; RCA, right coronary artery.

Table 4. Procedural outcomes comparing different collateral channels in retrograde approach

Variables	AV groove (n = 24)	Epicardial (n = 63)	Septal (n = 82)	p value
Technical success	22 (91.7%)	61 (96.8%)	80 (97.6%)	NS
Major complication	2 (8.3%)	3 (4.8%)	1 (1.2%)	NS
Death	0 (0.0%)	0 (0.0%)	1 (1.2%)	NS
Tamponade	2 (8.3%)	2 (3.2%)	0 (0.0%)	0.05
Major bleeding	0 (0.0%)	1 (1.6%)	0 (0.0%)	NS
Peri-procedural MI	0 (0.0%)	0 (0.0%)	0 (0.0%)	NS
Urgent revascularization	0 (0.0%)	0 (0.0%)	0 (0.0%)	NS
In-hospital MACE	0 (0.0%)	0 (0.0%)	1 (1.2%)	NS
Procedure time, min	130.0 ± 42.1	124.7 ± 46.5	118.7 ± 32.7	NS
Fluoroscopy time, min	52.8 ± 18.3	52.2 ± 21.6	47.5 ± 14.9	NS
Fluoroscopy dose, Gy	7.1 ± 2.4	6.6 ± 2.8	6.4 ± 2.3	NS
Contrast medium, ml	294.2 ± 67.8	287.1 ± 72.6	285.4 ± 72.2	NS

AV groove, atrioventricular groove; MACE, major adverse cardiac events.

get vessel perforation, and 2 due to collateral channel damage) and 1 major bleeding (retroperitoneal).

DISCUSSION

Successful CTO PCI provides significant clinical benefits, with a higher frequency of technical success and low procedural complication rates.[1,3-7] The overall technical success and procedural complication rates of the present study were comparable to those reported previously, but to our best knowledge, the percentage of such rates in the retrograde approach were the highest.[8,20-22] We failed to cross CTO lesion in 4 patients of the antegrade group. In the retrograde group, we failed crossing the distal caps in 3 patients. This occurred although we had advanced guide-wires and microcatheters into distal true lumens. Procedures were stopped because of collateral vessel damage and tamponade in 2 patents. Microcatheter could not be advanced through an occluded segment, although we had passed guide-wires in 1 patient.

Several prior studies demonstrated the efficacy of the retrograde approach,[15,23] but concerns regarding procedural safety limited its wide adoption.[24] Complications unique to the retrograde approach include donor vessel flow impairment and collateral channel damage, which might progress to life-threatening conditions.[9] Donor vessel thrombosis occurred in 1 patient in the present study (0.6%), and the patient died despite timely and adequate resuscitation. Collateral channel damage resulting in cardiac tamponade occurred in 2 cases (1.2%), but both were managed with pericardiocentesis and coil embolization and later discharged. Therefore, the overall technical success and procedural complication rates were similar between the antegrade and retrograde approaches, demonstrating that the retrograde approach is as effective and safe as the antegrade approach if conducted by an experienced practitioner. Nonetheless, more procedure and fluoroscopy time, radiation exposure, and contrast medium consumption were noted in the retrograde group. The reasons might include longer time engaged in collateral channel tracking, and greater CTO complexity (higher J-CTO score) in the retrograde group. Therefore, if a patient has favorable anatomy, i.e., a lower J-CTO score, the antegrade approach might be the initial approach of choice for its lower procedure/fluoroscopy time, radiation exposure, and contrast medium consumption. On the other hand, if the anatomy is unfavorable and the J-CTO score high, an initial choice of retrograde approach is very reasonable.

The CTO duration and J-CTO score was longer and higher in the retrograde approach in the present study, but there was no significant difference in either technical success or procedural complication rates between antegrade and retrograde approaches. The J-CTO score has been used as a useful predictor for antegrade guidewire crossing within defined procedure time.[19] In the current study, however, higher J-CTO score in the retrograde group was not associated with lower technical success. Recent studies have demonstrated that characteristics of collateral channels are important factors for the feasibility of retrograde approach,[13,18] but these are not included in the J-CTO scoring system since it was derived from a case series mainly using the antegrade approach. A new scoring system that specifically predicts retrograde CTO PCI success is needed to guide the initial selection of intervention strategy in CTO PCI. Compared with previous retrograde CTO series,[8,20,25,26] the percentage of patients with prior CABG in our patient population was much lower. Prior CABG might be associated with greater lesion complexity,[27] and this might be one of the reasons for higher success rate in our retrograde procedures compared with that reported in previous series in literature. However, there was no significant difference in the percentage of patients with previous CABG between our antegrade and retrograde groups.

There is no consensus on the selection of collateral channels in retrograde approach, when multiple possibilities exist. In addition, there were few studies comparing efficacy and safety among septal, epicardial, and AV groove collateral channels in the literature. Previous authors mostly suggested septal collateral channels as the first choice, mainly due to a safety issue.[15,28] Septal channel rupture is usually benign, resulting in septal hematoma with or without ventricular septal defect formation.[29] However, septal channel injury may also lead to cardiac tamponade,[30] and other rare but catastrophic conditions. If the hematoma is large in size and located in the proximal septum, it may lead to acute left ventricular outflow tract obstruction and refractory hemodynamic compromise.[31,32] Or if the size of the hematoma is large, protruding into the ventricular chamber and reducing the diastolic volume, "dry" tamponade may also occur.[33] Although most of these extremely fatal conditions were reported after coronary bypass surgery or surgical repair for ventricular septal defect, theoretically they may also complicate retrograde approach using septal collateral channels. In the present study, epicardial and AV groove collateral channels were used in more than half of the retrograde procedures. Our proportion of non-septal collateral channel usage was higher than in previous retrograde CTO series,[8,25,26,34,35] and there were no significant differences in efficacy and safety among these 3 collateral subgroups. However, there was a trend that the septal group has the lowest major complication rate (1.2%), followed by epicardial (4.8%) and AV groove (8.3%) group. Besides, our sample size was relatively small to attenuate the statistical power. Therefore, we should evaluate the characteristics of collateral channels in more detail before intervention. The most important characteristics include channels tortuosity, angulations to donor/receiver vessels, and the distance from channel confluence to the distal CTO cap, etc, which should be taken into consideration for the correct initial choice of collateral channels.

Study limitations

First, this study was not a randomized controlled study and the sample size was relatively small. Second, all the procedures were performed only by high-volume operators, and therefore the results observed in this study may not be extrapolated without caution. Third, the percentage of patients with previous CABG in this study was relatively low, so the results of procedures might be different in other populations with a higher percentage of patients with prior CABG. Fourth, there were no definite criteria for strategy selection, except for operators' experience, skills, and clinical judgments. Fifth, our study only focused on acute procedural outcomes and did not evaluate long-term prognosis after CTO PCI. Last but not least, the cost-effectiveness of these 2 approaches was not analyzed in the present study.

CONCLUSIONS

In selected cases and with highly experienced operators, the retrograde approach in CTO PCI is as effective and safe as the antegrade approach at the expense of more procedure time, radiation exposure, and contrast medium consumption. For retrograde approach, either septal, epicardial, or AV groove collateral channels can be used with high rate of success, low procedural complication and in-hospital MACE rates.

ABBREVIATION LIST

AV groove: atrioventricular groove
CTO: chronic total occlusion
CABG: coronary artery bypass grafting
J-CTO score: J-Chronic Total Occlusion Score
LAD: left anterior descending artery
LCX: left circumflex artery
MACE: major adverse cardiac events
MI: myocardial infarction
PCI: percutaneous coronary intervention
RCA: right coronary artery
TIMI: thrombolysis in myocardial infarction

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