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Original Article

Procedural and follow-up clinical outcomes after chronic total occlusion revascularization: Data from an Indian public hospital

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ABSTRACT

Background: Chronic total occlusion (CTO) continues to be challenging lesion subset for percutaneous intervention. Last decade has seen tremendous increase in percutaneous coronary intervention (PCI) in this subset owing to improved understanding of the anatomy and enhanced skillset with availability of dedicated hardware. We sought to study the outcomes of CTO PCI in an Indian public hospital.
Methods: This was a single-center non-randomized descriptive follow-up study on CTO PCI. The endpoints were procedural success, immediate, and late adverse cardiovascular events [major adverse cardiac event (MACE)] and change in angina and left ventricular function at follow-up.
Results: A total 389 CTO lesions were treated with a success rate of 87% (339/389). The mean Japanese chronic total occlusion (J-CTO) score was 1.78 ± 0.12 (mean ± standard deviation). Multivariate analysis of different angiographic components of J-CTO score identified tortuosity ($p = 0.001$), calcifications ($p \leq 0.001$), and blunt stump ($p = 0.007$) as independent predictors of procedural failure. The periprocedural mortality was less than 1%, and the non-life threatening complications were about 4%. The MACE rate was significantly higher in the procedural failure group (60%) than in the procedural success group (5.3%, $p < 0.001$). An increase in left ventricular ejection fraction (LVEF) was noted following successful CTO PCI after complete revascularization.
Conclusions: The success rates for CTO PCI in this registry were about 87%. Immediate and long-term clinical outcomes were better with lower MACE (5%) after a successful procedure. A key outcome variable included an increase in LVEF among patients after a successful CTO PCI. The overall periprocedural complications were about 5.5%, but majority were non-life threatening.

1. Introduction

Chronic total occlusion (CTO) of a major epicardial vessel is seen in up to 20% patients undergoing diagnostic angiography and in up to 35% following an episode of acute coronary syndrome.[1,2,4] It is one of the most important indication for referral for coronary artery bypass surgery as well.[1–3,5] Of late, there are growing data, which indicate that successful treatment of CTOs results in improved symptoms, prolonged life, and improved left ventricular function status.[6–10] But the attainment of high-end technical skills, sophisticated hardwares, and dedicated training sessions with experts in this field have made a huge impact on the success rates of CTO in developed nations.[10–12] In developing countries such as India, the situations are different.[11,13,14] At one end, the country faces coronary artery disease (CAD) epidemic, and about 20% patients with diagnosed CAD shows the presence of CTO in one of the vessels.[13,15,16] At the other end, there is significant lag in attaining required technical skills and availing dedicated CTO hardware. We face many challenges in CTO percutaneous coronary intervention (PCI) especially as the procedure demands huge amount of resources in terms of multiple hardware and technical skill set. As there is no public insurance, all patients end up paying from their own, and poor patients face challenges in approaching private centers for treatment because of high treatment expenses owing to extra requirement of consumables.[17–19] Public hospitals in India thus receive large influx of patients for CTO PCI. We planned to study the procedural and clinical outcomes of CTO PCI in the public hospital set up in India assessing various clinical objectives such as incidence of procedural complications and major adverse cardiac

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events (MACEs) such as death, myocardial infarction (MI), and target lesion revascularization (TLR). Improvement in left ventricular function is noted following CTO PCI as many patients exhibit viable and hibernating myocardium supplied by the occluded vessel.[9,20–23] We also looked at improvement in left ventricular function status in patient groups who had successful and failed CTO PCI.

2. Methods

2.1. Objectives

We planned to assess the procedural and clinical outcomes in CTO PCI. We looked at angina relief, freedom from TLR, and changes in left ventricular function among success and failure groups.

2.2. Design and settings

A prospective study of patients undergoing percutaneous coronary angioplasty for totally occluded coronary artery, duration of which is at least 3 months with flow distal to the occlusion, assessed in thrombolysis in myocardial infarction (TIMI) flow grade, is 0 or 1. Any coronary CTO of more than 3 months duration or if duration is unknown but having symptoms suggestive of myocardial ischemia for more than 3 months were subjected to PCI at Department of Cardiology, at a tertiary care public hospital in South India, which caters to a population of approximately 2 million, and it performs on an average 800 PCIs an year. We included all patients with documented or symptomatic ischemia who underwent CTO PCI at the center during the 7-year period from April 2009 to June 2017 with clinical follow-up for improvement of symptoms, left ventricular function, and MACEs such as death, MI, and target vessel revascularization (TVR). The selection of cases for CTO PCI was as per the existing hospital protocol, and patients with left main and triple vessel disease were excluded. The study was conducted after the approval by institutional ethics committee.

2.3. Preprocedural evaluation

Preprocedural evaluation was done to screen for medical comorbidities such as diabetes mellitus, chronic kidney disease, and hematological abnormalities. Left ventricle function status was assessed in terms of ejection fraction (EF) calculated using M-mode measurements or Simpsons method as required in two-dimensional echocardiography. All diabetic individuals were taken care of their blood glucose along with the avoidance of metformin and optimal hydration prior to the procedure, as practised in our department. A detailed angiographic analysis including length of CTO, presence of side branch at proximal cap, calcification at proximal cap, ambiguous proximal cap, and Japanese CTO score were recorded. Japanese CTO score involved a 5-point scoring system as follows: (**1**) blunt stump, (**2**) calcification, (**3**) within lesion bending >45°, (**4**) occlusion length ≥20 mm, and (**5**) prior failed attempt to revascularize the CTO. Scores of 0 indicate easy, 1 indicative of intermediate, and ≥2 indicates difficult CTO for success. Angiographic characteristics as well as procedural outcomes were compared between success and failure groups.

2.4. Procedure

The procedure of PCI was done under standard protocol with certain variations in technical aspects as clinical and lesion characteristics warrant, which were noted and analyzed in the study. Techniques employed were antegrade guide wire escalation approach, antegrade parallel wire, and dissection/re-entry. The conventional approach was antegrade in this series. The indications for retrograde approach included failed antegrade approach to cross the CTO, which included longer and/or calcified CTO with persistent subintimal wire passage despite parallel wire and intra vascular ultrasound (IVUS)-guided true lumen entry techniques. Primary retrograde approach was chosen in cases with ambiguous proximal CTO and/or aorto-ostial CTO. The retrograde approach included direct wire crossing, kissing wire approach, reverse combined antegrade and retrograde technique (CART), and guide liner reverse CART as specified in the literature. The reverse CART procedures were further defined into classical and contemporary types depending upon the connection zone of antegrade and retrograde systems extending out of the CTO body segment and remaining within the CTO body segment, respectively. The procedural details such as fluoroscopy time, amount of contrast used, guide wires selected, techniques incorporated, restoration of coronary blood flow achieved, assessed in TIMI grades, and the nature of stents employed were studied and analyzed. The success and failure of CTO PCI was documented. Technical success was defined as restoration of TIMI flow grade 2 or 3 at the end of the procedure. Procedural success was defined as technical success without in-hospital cardiac events such as death, MI, urgent coronary artery bypass grafting (CABG), or urgent repeat PCI. The reasons for failure such as failure to cross, failure to track the balloon, and failure to dilate were noted and analyzed. The procedural outcome-related end-points examined in both the success and failed groups included the major complications which were grouped into coronary and non-coronary categories. Coronary complications included dissection, thrombosis, vessel wall hematoma, and perforation. Non-coronary complications involved acute pulmonary edema, heart failure, arrhythmias, and access-related vascular complications.

2.5. Predischarge evaluation

All patients were observed in postinterventional care unit. A 12-lead electrocardiography was done for all patients immediately after the procedure and before discharge. Routine renal function assay was done for all patients the day before discharge. Postinterventional therapy included dual antiplatelets and other secondary prevention drugs. Vascular access site care was given for all patients.

2.6. Follow-up

All patients who underwent either successful or failed interventions were followed up for 12 months either on outpatient basis or telephonic conversation every 3 months. Thereafter, the follow-up was every 6 months. Patients in either group were evaluated during their follow-up period for occurrence of clinical outcome–related end-points such as freedom or recurrence of angina, improvement in left ventricular function status, and TVR in the form of CABG or repeat PCI. Echocardiography was performed before and after the procedure and at 6 months intervals to record the changes, if any, in the left ventricular ejection fraction (LVEF) which was calculated using M-mode measurements or Simpson's method as required in two-dimensional echocardiography. While routine check angiography was not planned, patients who developed angina were subjected to coronary angiography with an intention to treat.

2.7. Statistical analysis

Categorical variables are expressed as numbers and percentages, and continuous variables are expressed as the

mean ± standard deviation (SD). After testing for normal distribution, differences were compared using the unpaired Student *t*-test, chi-square test, Mann–Whitney test, and/or analysis of variance (ANOVA) where appropriate. Univariable and multivariable logistic regression analyses were used to identify predictors of procedural success.

A propensity score was constructed using binary logistic regression where the dependent variable was procedural success, and predictors were clinical and angiographic variables [angiographic variables were adapted from the Japanese chronic total occlusion (J-CTO) score] that are known to be related to clinical outcomes (MACE): age, gender, diabetes mellitus, arterial hypertension, smoking, previous MI, previous PCI, coronary artery, CTO length, presence of calcifications, tortuosity, and stump morphology. The comparison of continuous variables between the procedural outcomes, clinical outcomes and also between the demographic and clinical factors was carried out by using independent Students t-test/Mann–Whitney *U* test or one-way ANOVA/Kruskal–Wallis test, whichever is appropriate based on the distribution of data and the number of groups. A propensity score-adjusted Cox regression was performed to assess the relation between procedural success and MACE, controlling for group differences.

Event-free survival curves for adverse cardiac events were estimated by Kaplan–Meier method and compared by the log-rank test. A *p* value less than 0.05 was considered as statistically significant. All statistical analyses were performed with SPSS, version 21.

3. Results

Study population: The study population consisted of 389 patients with chronic total coronary occlusions in whom percutaneous recanalization was performed.

The characteristics of the patients are summarized in Table 1. Based on procedural success, the patients were divided into two groups: a procedural successful group ($n = 339/389$, 87.8%) and a procedural failure group ($n = 50$, 12.8%). The mean J-CTO score was 1.78 ± 0.12 (mean ± SD). There were no statistically significant differences in demographic and clinical characteristics between the two groups, except for the higher incidence of a previous MI ($p = 0.023$) and lower incidence of unstable angina ($p < 0.001$) in the failure group of patients.

Angiographic characteristics(Table 2**):** Regarding angiographic characteristics, there were certain differences between the successful and failure groups—lesions longer than 20 mm, more tortuous vessels, and calcifications were all more frequent in the failure group. Procedural success was achieved in 339 lesions (87.8%). Based on these procedural outcomes, the lesions were divided into two groups: a procedural success group ($n = 339$) and failure group ($n = 50$). There were no statistically significant differences in procedural characteristics between the two groups. The mean J-CTO score in successful and failed groups were not different. However on analyzing different components of the score, longer CTO length (≥20 mm), severe calcification, blunt proximal cap, and tortuosity were more prevalent in the failed group. The periprocedural complication rate was similar in both groups (Table 3).

Table 1
Demographics characteristics.

Characteristic [*n* (%)]	Total number of lesions ($n = 389$)	Procedure successful ($n = 339$)	Procedure failure ($n = 50$)	*p* value	OR (95% CI)
Age (years, mean ± SD)	58.5 ± 9.5	58.3 ± 9.6	58.8 ± 9.3	0.69	–
Male	318 (81%)	297 (88%)	40 (80%)	0.45	0.888 (0.423–1.471)
Family history of CAD	89 (22%)	47 (14%)	42 (84%)	0.47	1.291 (0.733–1.937)
Diabetes	101 (25.9%)	91 (27%)	10 (20%)	0.19	1.347 (0.826–2.642)
Insulin dependent	14 (3.5%)	11 (4%)	3 (6%)	0.65	0.676 (0.262–2.303)
Hypertension	313 (80.4%)	274 (81%)	39 (79%)	0.70	1.233 (0.616–2.046)
Hypercholesterolemia	313 (78%)	273 (80.8%)	40 (79.2%)	0.14	1.450 (0.870–2.728)
Smoking status					
Never	159 (41%)	138 (40.7%)	21 (42%)	0.99	1.003 (0.614–1.637)
Smoker	121 (31.1%)	108 (32%)	13 (26%)	0.30	1.226 (0.773–2.276)
Ex-smoker	110 (28.2%)	94 (28%)	16 (33%)	0.30	0.660 (0.451–1.281)
Previous MI	236 (60.6%)	200 (59%)	36 (72%)	0.02[a]	0.449 (0.326–0.925)
LVEF (%)	45 ± 13	46 ± 14	44 ± 12	0.188	–
LVEF < 40%	129 (33%)	111 (31%)	18 (37%)	0.281	0.857 (0.455–1.257)
Previous CABG	41 (11%)	36 (12%)	5 (10%)	0.55	1.371 (0.574–2.814)
Previous PCI					
Number	260 (67%)	223 (66%)	33 (67%)	0.82	0.842 (0.564–1.574)
Same artery	41 (11%)	36 (12%)	5 (10%)	0.73	1.243 (0.528–2.476)
Other artery	91 (23.3%)	69 (22%)	21 (22%)	0.99	1.1 (0.558–1.792)
Stable angina pectoris	151 (38.8%)	121 (58%)	30 (61%)	0.68	0.8 (0.550–1.473)
Unstable angina pectoris	98 (24.8%)	92 (27%)	6 (12%)	<0.01[a]	3.508 (1.689–7.285)
Number of diseased vessels					
1	178 (46%)	155 (46%)	23 (48%)	0.73	0.919 (0.566–1.490)
2	136 (35%)	122 (58%)	16 (33%)	0.72	1.096 (0.659–1.823)
3	73 (19%)	62 (19%)	11 (22%)	0.99	1.003 (0.543–1.854)
Concomitant therapy					
Beta-blocker	241 (62%)	210 (62%)	31 (63%)	0.859	1.046 (0.636–1.722)
ACE inhibitor and/or					
ARB	313 (81%)	271 (80%)	42 (84%)	0.401	1.312 (0.695–2.477)
Statin	331 (85%)	291 (86%)	40 (81%)	0.266	0.694 (0.364–1.324)
Nitrate	102 (26%)	74 (22%)	28 (27%)	0.363	1.296 (0.741–2.268)
DAPT	389 (100%)	339 (100%)	50 (100%)	–	–

LVEF, left ventricular ejection fraction; ACE, angiotensin converting enzyme; ARB, angiotensin receptor blocker; DAPT, dual antiplatelet therapy; OR, odds ratio; CI, confidence interval; SD, standard deviation; MI, myocardial infraction; PCI, percutaneous coronary intervention; CAD, coronary artery disease; CABG, coronary artery bypass grafting.
[a] $p \leq 0.05$.

Table 2
Angiographic and procedural characteristics.

Angiographic characteristic	No of CTO ($n = 389$)	Procedure successful ($n = 339$)	Procedure failure ($n = 50$)	p value
CTO artery [n (%)]				
RCA	177 (45.5)	152 (45)	25 (51)	0.390
LAD	113 (29)	101 (30)	12 (25)	0.393
Cx	92 (24)	81 (24)	11 (24)	0.909
Localization of CTO [n (%)]				
Ostial	36 (9)	33 (10)	3 (6)	0.139
Proximal	116 (29.1)	99 (31)	17 (35)	0.609
Middle	171 (44)	149 (44)	22 (44)	0.180
Distal	58 (15)	49 (14.5)	9 (16)	0.890
In-stent CTO [n (%)]	21 (5.5)	18 (5.3)	3 (6)	0.107
Duration of occlusion (months, mean ± SD)	36.6 ± 50.0	34.4 ± 44.6	39.8 ± 56.9	0.507
Diameter of CTO vessel (mm, mean ± SD)	3.0 ± 0.4	3.1 ± 0.4	3.0 ± 0.4	0.273
J-CTO score mean ± SD	1.78 ± 0.12	1.72 ± 0.17	2.0 ± 0.21	0.823
CTO length [n (%)]				
≤10 mm	86 (22)	65 (19)	21 (42)	0.281
10–20 mm	107 (25)	92 (27)	15 (30)	0.035
≥20 mm	186 (58)	156 (46.2)	30 (60)	0.003
Tortuosity [n (%)]	159 (41)	119 (35.1)	40 (80)	0.000
Calcification [n (%)]				
Mild	321 (82.5)	293 (75.3)	28 (56)	0.011
Moderate	25 (6.4)	16 (4.7)	9 (18)	0.015
Severe	43 (11)	6 (1.7)	37 (74)	0.000
Stump morphology (n (%))				
Blunt	117 (29.4)	100 (29.4)	17 (54)	0.000
Tapered	272 (69.9)	252 (74)	20 (40)	0.000
Side branch (n (%))	172 (44)	151 (44.5)	21 (44)	0.003
In-stent CTO (n (%))	21 (5)	18 (5.3)	3 (6)	0.107
Technical approach				
- Antegrade	351 (90.2)	304 (89.6)	47 (94)	0.057
- Retrograde	38 (9.8)	35 (10.1)	3 (6)	0.057
Number of wires per lesion	2.5 ± 0.9	2.54 ± 0.8	2.43 ± 0.8	0.447
Fluoroscopic time (minutes)	27.8 ± 22.3	29.3 ± 24.1	24.9 ± 18.2	0.090
Contrast volume (mL)	326 ± 176.9	346.2 ± 170.8	291.4 ± 183.5	0.008

RCA, right coronary artery; CTO, chronic total occlusion; SD, standard deviation; LAD, left anterior descending artery; J-CTO, Japanese chronic total occlusion.

The CTO techniques included antegrade approach in 351 patients (90.2%) [successful in 304 patients (89.6%) patients] (Tables 2 and 3). The different antegrade and retrograde techniques that were involved are detailed in Table 3. No statistically significant association was seen between the occluded vessel targeted for intervention and the procedural success ($p = 0.13$ by chi-square test). The distribution of de novo occlusion and in-stent re-occlusion did not affect the procedural outcome ($p = 1.0$ by Fishers exact test) as well. Miracle series (37%) and Gaia series (35%) wires were the frequently used for the antegrade approach and SION and Fielder XT series for the retrograde channel crossing (all from ASAHI, Nagoya, Japan). The guide wire details are given in Fig. 1. The mean stent length ± SD was 41.02 ± 19.61 mm. Of 339 lesions which were stented, 244 (72.1%) had single stent, 86 (25.4%) had two overlapping stents, and eight (2.5%) had three stents. The reasons for the procedural failure ($n = 50$) included failure to cross in 42 patients (84%), failure to track the balloon in two (4%), failure to dilate the balloon in three (6%), and no-reflow in three patients (6%). Figs. 2 and 3 show successful retrograde techniques used for CTO PCI.

Table 3
CTO techniques used among successful cases ($n = 339$).

Technique	n (%)
Antegrade wire escalation	216 (63.71)
Parallel wire technique	90 (26.54)
Antegrade dissection and re entry	18 (5.32)
IVUS-guided proximal cap penetration	5 (1.43)
Retrograde wire direct crossing	3 (0.88)
Retrograde wire kissing technique	5 (1.43)
Reverse CART (classical)	19 (5.60)
Reverse CART (contemporary)	6 (1.96)
Retrograde rendezvous	2 (0.58)
Guide liner reverse CART	3 (0.88)

IVUS, intravascular ultrasound; CART, controlled antegrade and retrograde tracking; CTO, chronic total occlusion.

By univariate analysis (Table 4), the following factors were identified as predictors of procedural failure: previous MI ($p = 0.023$), occlusion length > 10 mm ($p = 0.037$), occlusion length > 20 mm ($p = 0.003$), presence of tortuosity ($p < 0.001$), mild calcified lesions ($p = 0.012$), moderately calcified lesions ($p = 0.025$), severe calcified lesions ($p = 0.001$), presence of a side branch at the site of occlusion ($p = 0.004$), and blunt morphology of the occlusion ($p < 0.001$). Unstable angina pectoris ($p = 0.001$) and tapered stump morphology ($p = 0.001$) were identified as a predictors of procedural success.

Multivariate analysis of different angiographic components of J-CTO score showed tortuosity ($p = 0.001$), calcifications ($p \leq 0.001$), and blunt stump ($p = 0.007$), as independent predictors of procedural failure. With regards to clinical variables, a history of unstable angina pectoris was found to be a predictor of procedural success ($p = 0.009$).

3.1. Periprocedural complications (Table 5)

There were three procedural deaths in the whole cohort. While performing left anterior descending artery (LAD)-CTO, one patient had left main thrombosis and cardiac arrest on table. One patient had severe hypotension and no reflow after stenting the right coronary artery (RCA). On IVUS examination, a large intramural hematoma was detected. There was no pericardial collection.

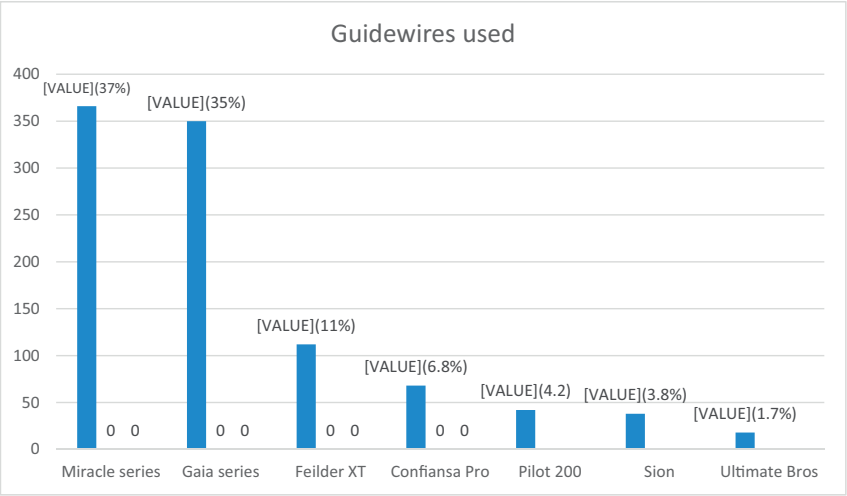

Fig. 1. Guide wires used for the CTO PCI. CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

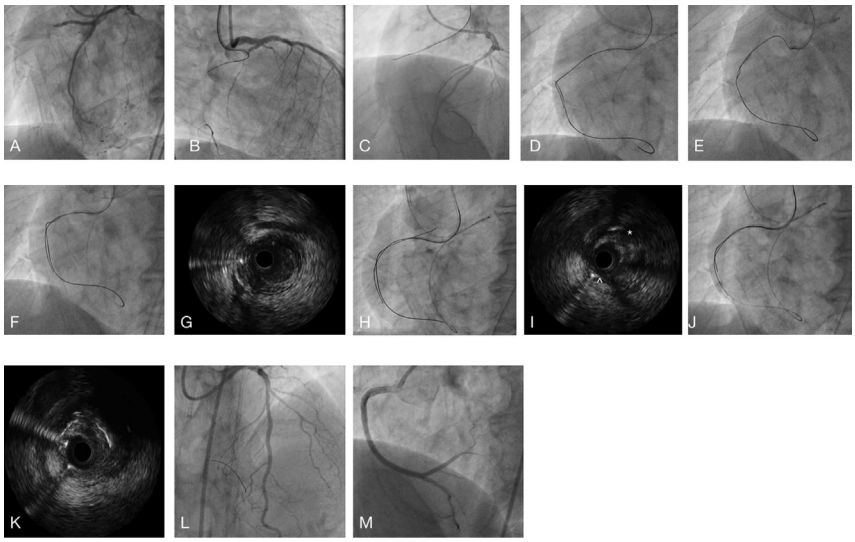

Fig. 2. Successful retrograde CTO PCI of the right coronary artery (RCA) by reverse CART technique. **(A)** Total occlusion of proximal RCA; **(B)** right anterior oblique view showing septal collateral channels and PDA connection; **(C)** antegrade vessel preparation with miracle 12 gm wire with a microcatheter (fine cross) support and retrograde microcatheter in the PDA; **(D)** retrograde wire changed to stiffer Gaia 2nd and antegrade–retrograde wire overlap established; **(E)** reverse CART with balloon inflation in the CTO segment (contemporary reverse CART); **(F)** retrograde wire advanced further proximal; **(G)** IVUS image showing retrograde wire confirmation at 3′o clock inside the plaque; **(H)** retrograde wire advanced further proximal to aorta; **(I)** antegrade wire at 12′oclock and IVUS catheter in the false lumen superiorly and to the right whereas retrograde wire in the lumen at 7′oclock, * denotes false lumen and ˆ denotes true lumen; **(J)** wire positioning changed; **(K)** IVUS now shows both wires in the same lumen space; **(L)** donor vessel angiogram showing intact vessel; **(M)** RCA after stenting. CTO, chronic total occlusion; PCI, percutaneous coronary intervention; IVUS, intravascular ultrasound; CART, combined antegrade and retrograde technique; PDA, posterior descending artery.

Patient succumbed to cardiac arrest. The third patient had sudden death on the first postoperative day in the recovery ward. Coronary perforations were noted in nine (3.1%) patients, and large intramural hematoma with no reflow was documented in 12 (2.01%) patients. Cardiac tamponade occurred in two (1.4%) patients. Vascular complications included retroperitoneal hematoma1 (0.2%), femoral artery thrombosis in two (0.5%), and femoral artery pseudoaneurysm in four (1.02%) patients. Four patients had stent occlusions (1%) in the first year of follow-up.

3.2. Follow-up analysis

The median follow-up period was 63 months (interquartile range: 59–74). The total number of MACE was 48/389 (12.3%), and there were significantly higher adverse events in failure group ($p < 0.001$) (Table 6). The MACE rate was significantly higher in the failure group (60%) than in success group (5.3%, $p < 0.001$). The rate of TVR (both PCI and CABG) was statistically higher in the procedural failure group ($p = 0.009$). Non-adjusted analysis showed procedural success was found to be a significant predictor of MACE by univariable Cox regression analysis [hazards ratio (HR): 0.423; 95% confidence interval (CI): 0.243–0.739; $p = 0.002$]. Propensity score-adjusted Cox regression showed that procedural success remained a significant predictor of MACE (adjusted HR: 0.402; 95% CI: 0.196–0.824; $p = 0.013$). Kaplan–Meier curves showed significantly better survival without MACE in the group of patients with successful treatment of CTO. Average survival-free time from MACE in the procedural success group was 69 ± 2 months and 46 ± 3

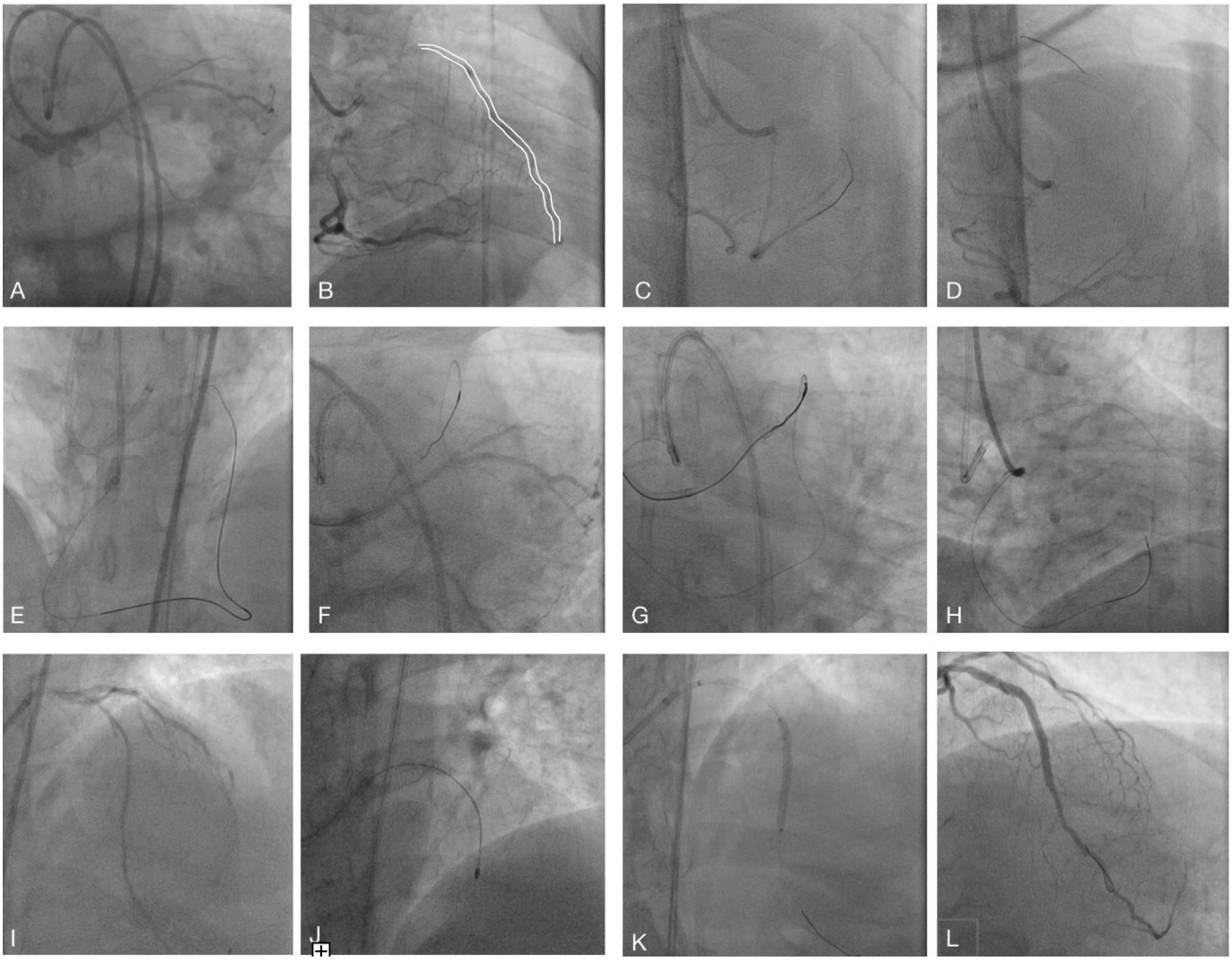

Fig. 3. Successful retrograde CTO PCI of the left anterior descending coronary artery (LAD) by kissing wire technique. Patient had failed antegrade approach earlier due to ambiguous proximal CTO cap. (**A)** Angiogram showing chronic total occlusion of LAD; (**B)** retrograde CC1 channels filling LAD (vessel course marked); (**C)** right anterior oblique view showing channel tracking with Sion wire and Caravel micro catheter; (**D)** successful channel negotiation in to CTO segment; (**E)** wire exchange for Fielder XTR to penetrate the CTO body and wire kept as a marker; (**F)** antegrade wire advancement with Gaia 2nd in the direction of retrograde wire; (**G)** kissing wire technique with antegrade and retrograde wire overlap; (**H)** antegrade wire advancement and removal of the retrograde gear; (**I)** angiogram after 1.25 mm balloon dilatation showing diffusely calcified LAD; (**J)** rotational atherectomy with 15 mm burr; (**K)** LAD stenting with guide liner mother and child catheter assistance; (**L)** TIMI3 flow after stenting proximal LAD. CTO, chronic total occlusion; PCI, percutaneous coronary intervention; IVUS, intravascular ultrasound; TIMI, thrombolysis in myocardial infarction.

months in the failure group (log rank: 15.247, $p < 0.001$; HR: 2.7, 95% CI: 1.610–4.163, $p < 0.001$). Although opening a CTO of a target vessel was associated with increased average MACE free time, there was no difference regarding a treated coronary artery [log rank 2.098, $p = 0.350$; LAD compared with circumflex artery (LCx) (HR: 2.4, 95% CI: 0.690–0.8.060, $p = 0.171$); RCA compared with the LCx (HR: 0.796, 95% CI: 0.313–2.021, $p = 0.631$); and LAD compared with the RCA (HR: 1.4, 95% CI: 0.787–2.441, $p = 0.259$)]. Fig. 4 shows the Kaplan–Meier survival curves with respect to CTO PCI success or failure according to MACE-free survival. It was significantly better without MACE between CTO PCI success and CTO PCI failure in patients with CTO of the left LAD. In LAD patients, average survival free of MACE time in the procedural success group was 59.8 ± 2.4 months and 41.9 ± 6.8 months in the procedural failure group (log rank 14.638, $p < 0.001$). There were no differences between CTO PCI success and CTO PCI failure in patients with CTO of the RCA (log rank 2.850, $p = 0.091$) or LCx (log rank 1.149, $p = 0.284$).

3.3. Left ventricular function

Left ventricular function assessed in terms of EF in percentage (%) improved from 51.66 ± 12.1% at baseline to 54.6 ± 10.34% at 12 months clinical follow-up in patients ($n = 339$) who met procedural success (increase in the order of 4 ± 5 percentage points).

Whereas, it showed a declining trend from 51.12 ± 9.67% at baseline to 46.5 ± 10.1% at 12 months in patients ($n = 50$) who met procedural failure (decrease in the order of 4.3 ± 5 percentage points) as shown in Fig. 5.

4. Discussion

This study attempts to look at the procedural and clinical outcomes of CTO PCI in a public hospital set up in a developing nation such as India. Patients with triple vessel disease and left main involvement were excluded. The overall success rate for the CTO was about 87%. This was slightly lower than published series from

Table 4
Univariate analysis of predictors of procedural failure.

Variable	Odds ratio	95% CI	*p* value
Male	1.321	0.672–2.340	0.577
Age	0.987	0.973–1.023	0.969
Family history of CAD	1.086	0.733–1.973	0.479
Diabetes mellitus	1.566	0.826–2.642	0.387
Hypertension	1.121	0.616–2.046	0.706
Hypercholesterolemia	1.321	0.870–2.728	0.237
Smoking status			
Smoker	1.386	0.808–2.340	0.340
Ex-Smoker	0.689	0.435–1.218	0.326
Previous MI	0.523	0.326–0.925	0.033
LVEF	1.109	0.978–1.073	0.302
Stable angina	0.987	0.574–1.516	0.780
Unstable angina	3.342	1.600–6.559	0.001
Previous CABG	1.765	0.574–2.814	0.654
Previous PCI			
Same artery	1.075	0.547–2.562	0.668
Other artery	1.068	0.599–1.906	0.823
No. of diseased vessels			
1	0.980	0.577–1.500	0.767
2	1.056	0.642–1.737	0.830
3	1.036	0.562–1.911	0.909
Concomitant therapy			
Beta-blocker	0.491	0.137–1.763	0.276
ACE inhibitor and/or			
ARB	1.062	0.224–5.024	0.140
Statin	0.656	0.138–3.134	0.598
Nitrate	0.607	0.128–2.880	0.530
CTO			
RCA	0.774	0.481–1.247	0.293
LAD	1.336	0.780–2.298	0.391
LCx	1.033	0.592–1.802	0.909
Occlusion duration	0.998	0.992–1.004	0.507
CTO vessel diameter	0.856	0.488–1.500	0.587
J-CTO score parameters			
CTO length			
≤10 mm	1.580	0.805–3.100	0.183
10–20 mm	1.857	1.038–3.321	0.037
≥20 mm	0.474	0.228–0.781	0.003
Tortuosity	0.390	0.237–0.640	0.001
Calcification			
Mild	0.520	0.312–0.865	0.012
Moderate	0.214	0.056–0.825	0.025
Severe	0.125	0.035–0.450	0.001
Stump morphology			
Blunt	0.154	0.090–0.263	0.001
Tapered	6.085	3.603–10.278	0.001
Side branch	0.498	0.301–0.793	0.004
In-stent CTO	2.750	0.766–9.880	0.121
CTO localization			
Ostial	2.026	0.783–5.241	0.145
Proximal	0.510	0.509–1.398	0.510
Medial	0.994	0.616–1.605	0.980
Distal	0.914	0.471–1.774	0.790
Technical approach			
Anterograde	0.311	0.088–1.101	0.070
Retrograde	3.212	0.908–11.362	0.070
Number of wires per lesion	1.114	0.844–1.471	0.446
Fluoroscopic time	1.011	0.998–1.024	0.094
Contrast volume	1.002	1.001–1.004	0.009

MI, myocardial infarction; LVEF, left ventricular ejection fraction; CABG, coronary artery bypass grafting; ACE, angiotensin converting enzyme; ARB, angiotensin receptor blocker; J-CTO, Japanese chronic total occlusion; LCx, circumflex artery; CAD, coronary artery disease; CI, confidence interval; LAD, left anterior descending coronary artery; RCA, right coronary artery; PCI, percutaneous coronary intervention.

Japan and Western literature.[5,23–25] We attribute this to the lesser usage of very complex techniques such as IVUS-guided true lumen puncture after sub-intimal entry (only 1% in this series). However, the results are comparable to the Indian series published recently.[9] Interestingly, our retrograde numbers were also lesser (up to 10%) as against Japanese cohorts (up to 30%).[5,25] We already have data

Table 5
Periprocedural complicationss.

n (%)	Total (389)	Success	Failure	*p* value
Death	3	2	1	0.9
MI	2 (0.7)	1 0.6)	1 (2)	0.597
Coronary perforation	7 (1.7)	4 (1.0)	3 (6)	0.068
Cardiac tamponade	3 (0.7)	1 (0.5)	2 (4)	0.719
Vascular complication	7 (1.9)	5 (1.4)	2 (4)	0.613
Donor vessel dissection	2 (0.5)	1 (0.4)	1 (2)	0.719

MI, myocardial infarction.

showing improved success rates in complex CTO with hybrid/retrograde approaches.[26,27] The mean J-CTO score was 1.7 marginally higher in failed cases (1.7 vs. 2) ($p = 0.7$), but when individual components of J-CTO score were compared against success and failure and tortuous and calcified CTOs, they showed higher failure rates in the multivariate analysis**.** CTO PCI improved symptoms, and a successful attempt reduced the MACE as shown in the previous studies.[28–30] Developing economies such as India have logistic issues as well in accessibility for dedicated CTO tools for complex retrograde procedures which often have an impact on the outcomes.[24,30]

The predominant CTO crossing technique was antegrade wire escalation (60%) followed by parallel wire technique (26%) in the antegrade approach, while reverse CART formed the major technique in the retrograde approach (5.6%). We believe the success rate can be even higher with more routine usage of retrograde techniques which could prove crucial in complex CTO success.[5,24,25] The Japanese multicenter CTO registry showed higher success rates up to 95%.[31].The registry has quoted up to 30% retrograde channel approach.[32]

The periprocedural mortality was less than 1%, and the non-life threatening complications were about 4%. The clinical outcomes were acceptable and durable in this series. We had low MACE (5.3%) after a successful CTO PCI. The TLR rates were also acceptable in the relatively longer follow-up interval compared with previous studies from India by KsG et al and Goel et al.[10,24] Although opening a CTO of a target vessel was associated with increased average MACE-free time, there was no difference regarding a treated coronary artery which was similar to previously published literature.[5,9,33,34]

The important finding of the study was the positive impact of successful CTO PCI on left ventricular function. There was an improvement in the LVEF following successful CTO PCI at 6 months of follow-up contrary to the declining trend in the LVEF following failed CTO PCI. This improvement in LVEF was maintained at 24 months. This objective finding with statistical significance attests to the clinical outcome of CTO PCI as shown in earlier studies.[32,34] We feel this is an important outcome, as it will stimulate CTO PCI programs in countries where facilities for such resource demanding procedures are not routinely met.

5. Limitations of the study

This study is mainly limited by the fact that it is a single-center non-randomized data. The number of patients was small enough to draw powerful long-term data. The study did not use any qualitative and quantitative intravascular ultrasound assessments, and therefore angiographic predictors of outcome cannot be discerned. Non-invasive stress testing test was not performed to objectively assess angina symptoms and performance. Absence of significant angina (CCS class III/IV; postprandial angina) at follow-up qualified to be considered as symptomatic benefit in our study

Table 6
Major adverse cardiovascular events.

MACE [*n* (%)]	No of patients ($n = 389$)	Procedure		*p* value
		Successful ($n = 339$)	Failed ($n = 50$)	
CV Death	5 (1.2)	3 (0.8)	2 (0.02)	0.038
MI	2 (0.5)	2 (0.5)	0 (0)	0.134
TVR	41 (10.5)	13 (3.8)	28 (36)	0.009
PCI	24 (6.1)	11 (3.2)	13 (26)	0.046
CABG	17 (3.9)	2 (0.5)	15 (30)	0.05
Total MACE	48 (12.3)	18 (5.3)	30 (60)	0.001

MACE, major adverse cardiovascular events; CV death, cardiovascular death; MI, myocardial infarction; TVR, target vessel revascularization; PCI, percutaneous coronary intervention; CABG, coronary artery by-pass grafting.

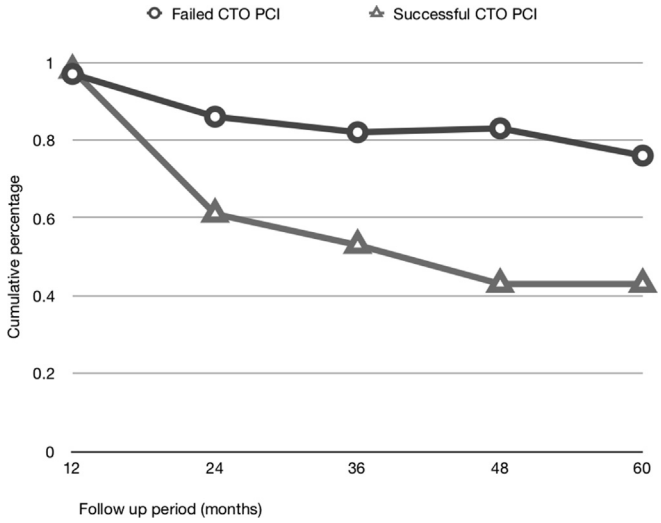

Fig. 4. Event-free survival rates following CTO PCI. CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

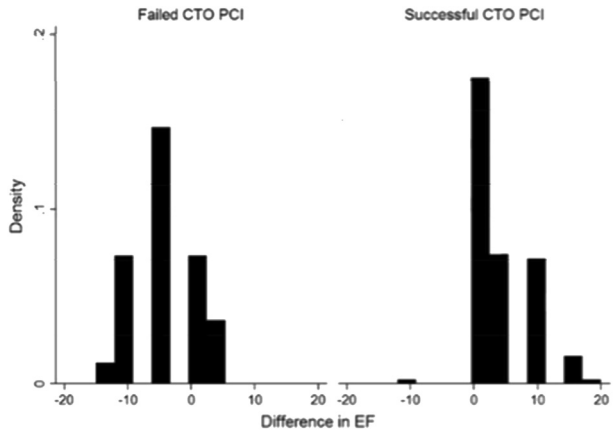

Fig. 5. Left ventricular ejection fraction change after successful CTO PCI. CTO, chronic total occlusion; PCI, percutaneous coronary intervention; EF, ejection fraction.

besides taking into account the patients' symptom status at presentation. Myocardial viability assessment was not done in our study, but we have included only patients with symptom limiting daily activities, which indirectly corroborates for presence of viable myocardium downstream. The absence of a surgical arm of revascularization (CABG) is another limitation of this study.

6. Conclusions

The success rates for CTO PCI in this registry was about 87%. Immediate and long-term clinical outcomes were better with lower MACE (5%) after a successful procedure. A key outcome variable included an increase in LVEF among patients after a successful CTO PCI. The overall periprocedural complications were about 5.5%, but majority were non-life threatening.

Conflicts of interest

All authors have none to declare.

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