Chronic Total Occlusion Anatomy and Characteristics of Coronary Collaterals and Angiographic Features Predicting the Success of Chronic Total Occlusion Intervention

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Abstract

Background and Objective: Angiographic assessment of chronic total occlusion (CTO) anatomy and collateral characteristics of coronary arteries are necessary for CTO intervention. **Materials and Methods:** This was a hospital-based observational study of 100 coronary angiograms (CAG) with CTOs. CTO anatomy and collateral characteristics of coronary arteries were studied for predicting anterograde and retrograde CTO intervention. **Results:** Right coronary artery (RCA) CTO was the most common (62%), followed by left anterior descending (LAD). More than two-thirds of RCA and LAD CTO lesions were >20 mm and half were in mid-segment. Left circumflex artery (LCX) and RCA lesions were more frequently calcified. LAD CTOs often had blunt stump; LCX CTOs frequently had bending >45°. The mean J-CTO score was lowest in RCA CTOs (2.0 ± 1.19). There were 10 different types of collaterals in RCA CTOs, 8 in LAD CTOs, and only 4 in LCX CTOs. The most common RCA CTOs collateral was LAD septal to the right posterior descending artery (RPDA) (69.4%) and in LAD CTOs, the most common was septal collaterals from the RPDA to LAD (40.9%). RCA CTOs had a higher percentage of septal collaterals, less tortuosity, and favorable entry and exit angle when compared with other two arteries. **Conclusion:** RCA CTOs were the most common. Angiographic features in CTO lesions vary among three major coronary arteries. The RCA CTOs had lesser mean J-CTO score, more number of septal collaterals, less tortuous collaterals, and favorable entry and exit angle. RCA CTOs were better accessible for anterograde and retrograde intervention.

Keywords: Chronic total occlusion, coronary calcification, coronary collaterals, coronary intervention, right coronary artery

Introduction

A chronic total occlusion (CTO) is defined as an angiographically documented or clinically suspected complete interruption of antegrade coronary flow for >3 months.[1] The incidence of CTOs depends on the type of patients studied and ranges between 10% and 30% of all coronary angiograms (CAG).[2,3] Several scores have been developed to help in guiding the best initial percutaneous approach based on lesion characteristics. One of the most commonly used scores is the J-CTO score, developed from the Japanese Multicentre CTO Registry.[4]

Coronary collaterals are anastomotic connections without an intervening capillary bed between portions of the same or different coronary arteries.[5] Collateral circulation potentially offers an important alternative source of blood supply, when the original vessel fails to provide sufficient blood.[6] Coronary collateral circulation reduces the infarct size in the setting of acute ST-elevation myocardial infarction (STEMI)[7] and ensures the higher residual left ventricular ejection fraction.[8] Coronary artery disease (CAD) with significant coronary collaterals has lower risk of both short-term and long-term mortality.[9,10] Coronary collaterals in patients with CTO can be assessed angiographically by the Rentrop grading[11] or by Werner classification (CC grading).[12] Percutaneous coronary intervention (PCI) of CTOs

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remains one of the most challenging procedures for interventional cardiologists. Successful recanalization rates have improved to >80% in many reported series.[13] In cases of antegrade crossing failure, retrograde approach via collateral channel crossing with a guidewire is successfully achieved in 73–87% of cases.[14]

A number of studies[15-17] have been done on coronary CTOs and collaterals characteristics. Levin[18] first attempted to relate the anatomic distribution of coronary collaterals with collateral function. To the best of our knowledge, it has not been studied in the Indian population so far except for few articles.[19,20] We aimed to define the anatomy of CTOs and anatomical characteristics of coronary collaterals within a CTO population and features relevant to CTO intervention by anterograde or retrograde techniques. This will provide a reference for interventional cardiologists working within the subspecialty of PCI in CTO.

Materials and Methods

This was a hospital-based observational study of adult patients with CTO admitted in the Cardiology Department at tertiary care hospital in North India. The Institutional Ethics Committee approved the study.

Study subjects

The study recruited consecutive patients with clinical evidence (or a high likelihood) of coronary occlusion of duration ≥ 3 months and patients were admitted in the Department of Cardiology for CAG. The study was conducted for 2 years, from June 2017 to June 2019. All the subjects provided informed consent, and the research was conducted following the Declaration of Helsinki. The cardiac department maintains a compact disc (CD) library of all angiograms done at our center and patient records. At our center, approximately 140 CAGs are done monthly for coronary atherosclerosis, and we included 100 consecutive CAG with 100 single vessel CTOs. The exclusion criteria were (i) patients with the history of coronary artery bypass grafting (CABG), (ii) patients with the history of valvular heart disease, (iii) more than one vessel CTO, (iv) poor collaterals visualization due to short angiogram, and (v) primary PCI or unstable patients.

Study methodology

A CTO was defined as a lesion with thrombolysis in myocardial infarction (TIMI) grade 0 flow within the occluded segment and angiographic or clinical evidence (or a high likelihood) of an occlusion duration ≥ 3 months. Anatomical characteristics of CTOs such as entry shape (blunt stump or tapered), calcification (yes or no), bending > or <45°, length > or <20mm of CTOs were described, and the J-CTO score was calculated. CTO lesions were also classified for antegrade interventions on the basis of J-CTO score as easy (score 0), intermediate (score 1), difficult (score 2), and very difficult (score ≥3). Generally, a score of 0 predicts successful guidewire crossing of CTO lesion within 30 min in ≥ 90% of cases.[4] Each lesion was further stratified according to the major epicardial artery and segment of the epicardial coronary artery involved.

The grading of collateral connections (CC grade 0: no continuous connection, CC1: continuous thread-like connection, CC2: side branch-like connection) described by Werner *et al.*[12] was used for coronary collaterals. The presence of bridging collaterals was noted. CTOs were assessed to determine whether the collateral supply would permit retrograde access to the occluded vessel. This was demonstrated by an interventional cardiologist experienced in CTO techniques, on angiography, as at least one collateral channel suitable to deliver equipment from the donor vessel to the target vessel beyond the occluded segment. Other defining criteria included whether the collaterals were septal or epicardial. Channel tortuosity was defined as the presence of two or more high-frequency, successive curves (within 2 mm) in the context of epicardial collaterals and one or more high-frequency curves that failed to uncoil in diastole for septal channels. A high-frequency curve was defined as a curve that is >180° occurring within a segment length less than three times the diameter of the collateral. Channel size unlikely to permit the passage of a microcatheter without significant risk of collateral injury is generally <1 mm in diameter. Adverse channel entry and exit angle was defined as <45°. Multiple bifurcations particularly at points of marked curvature or just after collateral channel entry were recorded. All measurements were taken offline manually on Philips FD-10 Clarity CAG/PTCA machine.

Ethical approval

The study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki. It was carried out with patients verbal and analytical approval before sample was taken. The study protocol and the subject information and consent form were reviewed and approved by a local ethics committee according to the document number 14 (including the number and the date in 17/12/2020) to get this approval.

Statistical analysis

For continuous measurements, mean, standard deviation, minimum, and maximum were used to tabulate the data. For categorical measurements, absolute/relative frequencies and percentages were used to compute the data. Values were tabulated on Microsoft Office Excel 2010, and all the analyses were performed by the Statistical Software SPSS Version 20 (IBM SPSS Statistics for Windows, Armonk, NY, USA, IBM Corp.).

Results

Figure 1 shows the enrollment of study participants. The mean age was 63.6 ± 8.47 years (44–80) and 94% were males. Majority of patients were between 60 and 69 years in this group. Table 1 demonstrates the location of CTOs as per vessel involved. CTO most commonly involved the right coronary artery (RCA) in 62%, left

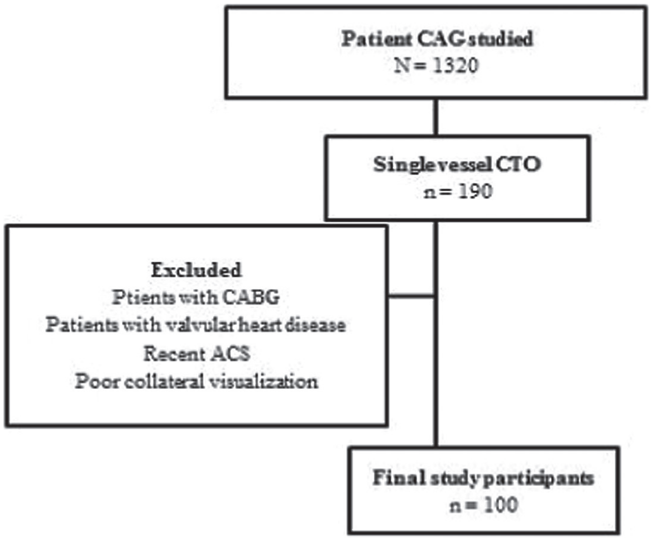

Figure 1: Flow diagram of study participants. CAG = coronary angiograms, CTO = chronic total occlusion, CABG = coronary artery bypass grafting, ACS = acute coronary syndrome

Table 1: Location of CTOs as per vessel involved in study patients

Vessel involved	Total	Location	Frequency	Percentage
LCX	16%	Proximal	8	50.0
		Distal	8	50.0
RCA	62%	Proximal	25	40.3
		Distal	5	8.1
		Mid	32	51.6
LAD	22%	Proximal	9	40.9
		Distal	0	0.0
		Mid	13	59.1

LCX = left circumflex, RCA = right coronary artery, LAD = left anterior descending

anterior descending (LAD) in 22%, and left circumflex artery (LCX) in 16%. In RCA and LAD, majority of the occlusions were located in the mid-segment, 51.6% and 59.1%, respectively. In LCX, half of the lesions were located in both proximal and distal segments.

The overall angiographic characteristics of the CTOs showed that 65% had blunt stump, whereas 35% had tapered entry shape, 42% of CTOs had calcification present, 69% had length >20 mm, and 30% have bending >45°. CTO lesions length >20 mm was seen in 71% in RCA, 81.8% in LAD, and 43.8% in LCX. Furthermore, LCX and RCA lesions were more frequently calcified than LAD. Blunt stump was more prevalent in LADCTO (90%). LCX CTOs frequently had bending >45°, as shown in Table 2.

Table 3 demonstrates the J-CTO score as per vessel involved. The mean J-CTO score was 2.1 ± 1.34 in LCX, 2.0 ± 1.19 in RCA, and 2.3 ± 0.83 in LAD. LCX and LAD CTOs had J-CTO score of 3 in 50% of the patients, whereas in RCA CTOs, it was seen in 27.4% of the patients.

Table 2: Angiographic characteristics of CTOs according to coronary artery involved

Vessel involved			No.	Percentage
LCX	Entry shape	Blunt	10	62.5
		Tapered	6	37.5
	Calcification	Yes	8	50.0
		No	8	50.0
	Bending	Yes	8	50.0
		No	8	50.0
	Length	< 20 mm	9	56.3
		> 20 mm	7	43.8
RCA	Entry shape	Blunt	35	56.5
		Tapered	27	43.5
	Calcification	Yes	26	41.9
		No	36	58.1
	Bending	Yes	18	29.0
		No	44	71.0
	Length	< 20 mm	18	29.0
		> 20 mm	44	71.0
LAD	Entry shape	Blunt	20	90.9
		Tapered	2	9.1
	Calcification	Yes	8	36.4
		No	14	63.6
	Bending	Yes	4	18.2
		No	18	81.8
	Length	< 20 mm	4	18.2
		> 20 mm	18	81.8

LCX = left circumflex, RCA = right coronary artery, LAD = left anterior descending

Table 3: J-CTO score as per vessel involved in study patients

Vessel involved	J-CTO score as per vessel involved	J-CTO score	*n* (%)
LCX	2.1 ± 1.3 (0–4)	0	3 (18.8)
		1	3 (18.8)
		2	1 (6.3)
		3	8 (50.0)
		4	1 (6.3)
RCA	2.0 ± 1.2 (0–4)	0	8 (12.9)
		1	14 (22.6)
		2	17 (27.4)
		3	17 (27.4)
		4	6 (9.7)
LAD	2.3 ± 0.8 (1–3)	0	0
		1	5 (22.7)
		2	6 (27.3)
		3	11 (50.0)
		4	0

LCX = left circumflex, RCA = right coronary artery, LAD = left anterior descending

CTO collateral pattern

Table 4 demonstrates the coronary collateral connections. A total of 108 collaterals (mean 1.75 collateral pathways per CTO) in 62 CTOs of the RCA were identified with

Table 4 : Collateral pathway as per CC Grade in CTO patients

Vessel involved	Collateral pathway	*n* (%)	CC Grade	*n* (%)
RCA [*n*=62]	LAD Septal-RPDA	43 (69.4)	Grade ≥ 1	42 (67.7)
	LAD Septal-PLV	3 (4.8)	Grade ≥ 1	2 (3.2)
	Apical LAD-RPDA	9 (14.5)	Grade ≥ 1	9 (14.5)
	LCX-PLV	23 (37.1)	Grade ≥ 1	13 (20.9)
	RV-RPDA	5 (8.1)	Grade ≥ 1	3 (4.8)
	BRIDG	14 (22.6)	Grade ≥ 1	14 (22.6)
	RA-RCA	4 (6.5)	Grade ≥ 1	3 (4.8)
	OM-PLV	4 (6.5)	Grade ≥ 1	0
	LPDA-RV	2 (3.2)	Grade ≥ 1	0
	PLV-LAD	1 (1.6)	Grade ≥ 1	0
LAD [*n*=22]	RPDA-LAD	9 (40.9)	Grade ≥ 1	7 (31.8)
	RV-LAD	6 (27.3)	Grade ≥ 1	6 (27.3)
	OM-D	5 (22.7)	Grade ≥ 1	5 (22.7)
	CONUS-LAD	1 (4.5)	Grade ≥ 1	0
	RAMUS-D	3 (13.6)	Grade ≥ 1	3 (13.6)
	D-LAD	4 (18.2)	Grade ≥ 1	4 (18.2)
	RPDA-Apical LAD	1 (4.5)	Grade ≥ 1	1 (4.5)
	PLV-LAD	3 (13.6)	Grade ≥ 1	0
LCX [*n*=16]	OM-OM	5 (31.3)	Grade ≥ 1	4 (25.0)
	D-OM	6 (37.5)	Grade ≥ 1	4 (25.0)
	PLV-LCX	5 (31.3)	Grade ≥ 1	5 (31.3)
	pLCX-dLCX	4 (25.0)	Grade ≥ 1	4 (25.0)

RCA = right coronary artery, LAD = left anterior descending, LCX = left circumflex, RPDA = right posterior descending artery, PLV = posterior left ventricular, RV = right ventricular, BRIDG = bridging, RA = right atrial, OM = obtuse marginal, LPDA = left posterior descending artery, pLCX = proximal LCX, dLCX = distal LCX

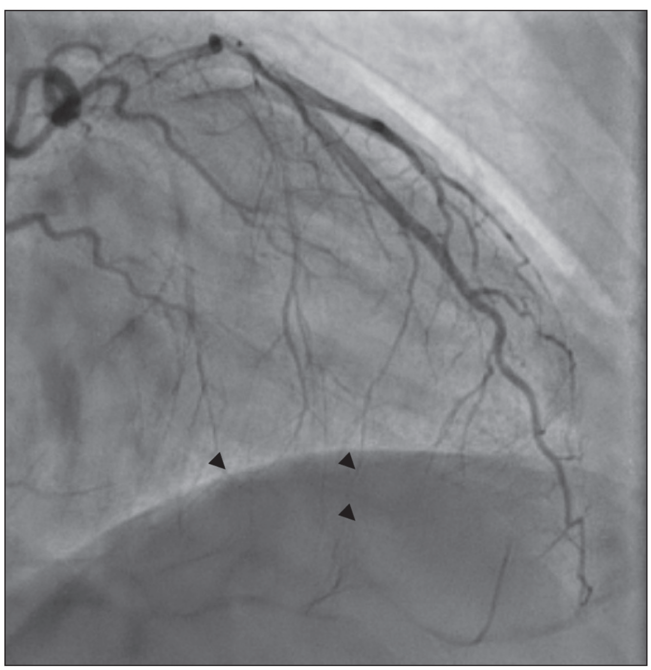

Figure 2: Angiographic RCA CTO showing collateral from LAD septal to PDA branch of RCA (black arrows show septal collaterals to RCA)

10 discrete filling patterns. About 69.4% had collaterals from LAD septal to the right posterior descending artery (RPDA) [as can be seen in Figure 2], whereas 37.1% had collaterals from the LCX artery to the posterolateral ventricular (PLV) branch of the RCA. The prevalence of collateral grade CC ≥ 1 was highest in LAD septal to RPDA (67.7%). A total of 32 collaterals (mean 1.45 collateral pathways per CTO) were identified with 8 discrete filling patterns in LAD CTOs. About 40.9% of all LAD CTOs had collaterals from RPDA to LAD,

whereas 27.3% had right ventricular (RV) branch to LAD collaterals; 22.7% had obtuse marginal (OM) to diagonal collaterals and 18.2% had diagonal branch collaterals to a more distal segment of the LAD (auto-collateral). Conal branch of RCA to LAD was seen in 4.5% [as shown in Figure 3]. The prevalence of collateral grade CC ≥ 1 was highest in RPDA-LAD (31.8%). A total of 20 collaterals (mean 1.25 collateral pathways per CTO) in 16 LCX CTOs were identified, with 4 discrete filling patterns. About 37.5% of all LCX CTOs had collaterals from the diagonal branch of LAD to the OM branch of LCX, and 31.3% had proximal OM branch to more distal OM branch (auto-collaterals). The prevalence of collateral grade CC ≥ 1 was highest in PLV-LCX (31.3%).

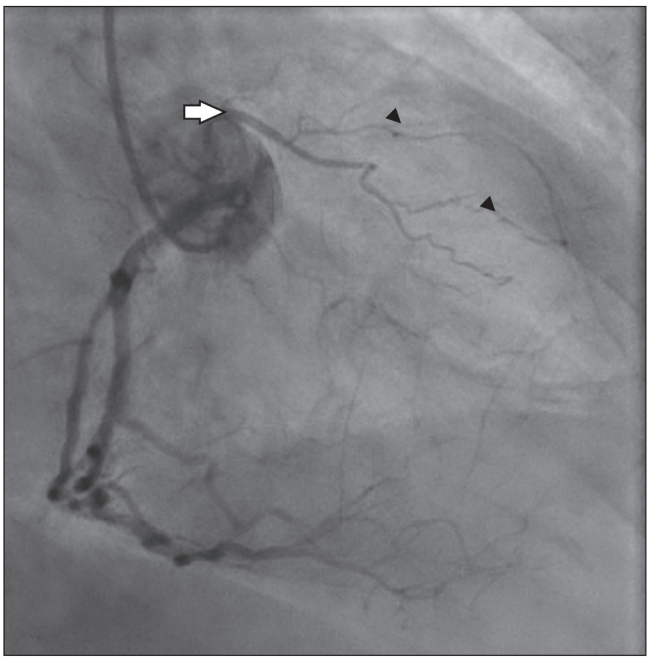

Figure 3: Angiographic LAD CTO showing collateral from conal branch of RCA to LAD (white arrow, conal branch; black arrows, collaterals from conal branch to LAD)

Angiographic features predicting the success of antegrade and retrograde coronary CTO intervention

Antegrade CTO intervention is predicted angiographically by the J-CTO score. If the J-CTO score is "0" it means easy intervention and score "4" means very difficult intervention. In our study, the mean J-CTO score was more in LAD than LCX followed by RCA (2.3 ± 0.83 > 2.1 ± 1.34 >2.0 ± 1.19), so the predicted order of success was better in RCA and least in LAD.

Eighty study participants with angiographically visible collaterals (CC ≥ 1) were studied for retrograde interventional suitability. The total number of collaterals which were assessed for various angiographic characteristics were 99, of which 63 collaterals were of RCA CTOs, 25 were of LAD CTOs, and 11 were of LCX CTOs. The various angiographic features are shown in Table 5. RCA CTOs had the highest percentage of septal collaterals (61.9%) than epicardial collaterals (38.1%). LCX and LAD CTOs had more number of epicardial collaterals. LCX CTOs had a higher percentage of tortuous collateral. Adequate size collaterals were common in RCA.

Discussion

Angiographic characteristics predict the success rate of PCI in CTO. The success rates are not uniform for all three major coronary arteries. Some angiographic characteristics have been reported to correlate with unsuccessful CTO PCI.[21] A report from European Registry of CTO (ERCTO)[12] describes that blunt occlusion stump, longer lesion length, and presence of calcification were associated with unsuccessful anterograde CTO PCI. In addition to these three predictors, angulation (> 45°) was reported as an independent predictor of unsuccessful

Table 5: Angiographic characteristics of collaterals

		LCX vessel (*n*=10)	RCA vessel (*n*=50)	LAD vessel (*n*=20)
		n (%)	*n* (%)	*n*(%)
Type	Septal	1 (9.1)	39 (61.9)	10 (40.0)
	Epicardial	10 (90.9)	24 (38.1)	15 (60.0)
Tortuosity	Yes	10 (90.9)	24 (38.1)	21 (84.0)
	No	1 (9.1)	39 (61.9)	4 (16.0)
Size	< 1	5 (45.5)	20 (31.7)	14 (56.0)
	> 1	6 (54.5)	43 (68.3)	11 (44.0)
Entry angle	< 45	6 (54.5)	15 (23.8)	10 (40.0)
	> 45	5 (45.5)	48 (76.2)	15 (60.0)
Exit angle	< 45	5 (45.5)	12 (19.0)	12 (48.0)
	> 45	6 (54.5)	51 (81.0)	13 (52.0)
Multiple bifurcations	Yes	7 (63.6)	32 (50.8)	11 (44.0)
	No	4 (36.4)	31 (49.2)	14 (56.0)

LCX = left circumflex, RCA = right coronary artery, LAD= left anterior descending

CTO PCI from the JCTO (Multicenter CTO Registry of Japan) registry.[4] The collateral circulation is a practical route to access the distal coronary bed beyond the occlusive segment efficiently.[22,23] It is therefore critical to delineate the anatomy of collaterals, which will facilitate intervention.

CTO characteristics

In the present study, CTOs most commonly involved the RCA (62%), followed by LAD (22%) and LCX (16%). In a study by Deshmukh *et al*.,[19] frequency of CTOs was highest in RCA (52.14%), followed by LAD (34.18%) and LCX (13.67%), and similar frequency pattern was seen in Hasegawa *et al.*[15] and other studies.[16,17,24] The mean age was 63.6 ± 8.47 years and majority were males; this is similar to the trend seen globally.[20,24-26]

In our study, majority of the RCA occlusions were located in the mid-segment (51.6%), followed by proximally (40.9%) which is comparable to the study by Gopakumar *et al.*[20] but contradictory to other studies.[15,16] In LAD CTOs, 59.1% of the lesions were present in mid-segment and rest proximally; a similar pattern was seen in a study by Hasegawa *et al.*,[15] whereas another study[16] found 51% LAD CTOs in the proximal part and 44% in the mid-segment. In our study, 50% of the LCX CTOs were located in both proximal and distal segments, which is similar to the studies by Christopoulos *et al.*[16] and Garcia *et al.*,[27] but different from another study.[15]

In our study, CTO lesions of length >20 mm were significantly higher in RCA (71%) and LAD (81.8%) when compared with LCX (43.8%). Other studies[15,16] also found that RCA CTOs had longer occlusion length than the LAD and LCX CTOs. Furthermore, in our study, LCX and RCA lesions were more frequently calcified than LAD. Christopoulos *et al.*[16] found a similar percentage (50%) of calcification in all vessels. Blunt stump was found in 90% of LAD CTOs followed by LCX and RCA, whereas another study[15] also revealed an increased frequency of blunt stump in LAD CTOs, but in contrast to another study[16] in which blunt stump was equally distributed. Christopoulos *et al.*[16] found that LCX CTOs were more likely to have bending compared with RCA and LAD (58% vs. 32% vs. 15%, respectively), which is similar to our study.

CTO collateral pattern

Our study revealed that in RCA CTOs, collaterals from LAD septal to the RPDA and from the LCX to the PLV branch of the RCA are the most common. While the original work by Levin[18] found the same patterns, the absolute incidence was considerably higher in our study. Indeed, the high incidence of these two collateral patterns has important implications for the feasibility of retrograde access. This lower number of collateral pathways and the failure to identify some important collateral pathways in Levin's work[18] may be partially explained by that it was carried out without reference to cranial or caudal angulation. It is important to consider that imaging technology and techniques have improved significantly in the past two decades. Collaterals from the OM to the PLV were less frequent in our analysis (6.5%) when compared with other study[18] (16%), and three different collateral patterns were reported in our population, not described by Levin [LAD septal to the PLV (4.8%), RV-RPDA (8.1%), and right atrial (RA)-RCA (6.5%)]. The study by McEntegart *et al.*[17] found a total of 591 collaterals (mean 2.1 collateral pathways per CTO) and identified 20 discrete filling patterns in RCA and also showed that the most common collateral in RCA CTOs comes from LAD septal to RPDA.

In our study, eight different types of collateral pathways in LAD CTOs were found, of which the most common was septal collaterals from the RPDA to LAD (40.9%). While in a study by Levin[18] septal collaterals were found only in 4.3%, the difference likely due to advancement in technology and in Levin's study arteries supplying the anterior and diaphragmatic aspects of the left ventricle is best demonstrated by ventriculography in the right anterior oblique projection and arteries supplying the posterolateral aspect of the ventricle, an area not well visualized in this projection. This is the vital collateral pathway which can be utilized for the retrograde treatment of LAD CTOs. The relative frequencies of OM-D and RPDA-apical LAD collaterals were broadly similar to those described by Levin.[18] PLV to LAD collaterals and ramus to diagonal collateral seen in our LAD CTOs were not previously described. There is less need for CTO intervention if there are more collaterals, and more suitable collaterals increase the success of CTO intervention. McEntegart *et al.*[17] identified 13 discrete filling patterns in LAD and also showed that the most common collateral in LAD CTOs comes from PDA septal to LAD (52.3%).

There was a lower frequency of collaterals in LCX CTOs in our study population, the reason for which likely remains smaller sample size in our study compared with other study.[18] Levin described five collateral patterns, while we observed four distinct patterns.[18] The most frequent LCX CTO collaterals in our study were diagonal branch of LAD to OM branch of LCX seen in 37.5% of occlusions when compared with 23.8% in other study.[18] McEntegart *et al.*[17] identified 12 discrete filling patterns in LCX and also showed that the most common collateral in LCX CTOs comes from the diagonal branch of LAD to OM branch of LCX (32.2%). It is interesting to speculate whether this lower frequency of a wide variety of predominantly epicardial collaterals in our study may explain the lower procedural success rates in CTOs of the LCX treated by a retrograde approach.[28]

Angiographic assessment of coronary collateral of CTOs

Various expert panels have given guiding principles for CTO PCI.[24,29,30] The Asia Pacific CTO club proposes an algorithm that determines whether the primary approach is antegrade or retrograde: (1) is there proximal cap ambiguity; (2) is the distal vessel of poor quality; and (3) are there interventional collaterals present? In contrast to the hybrid algorithm, various factors (ambiguity of the vessel course, severe calcification, tortuosity, length, and previous failure) determine the choice of either a wire escalation strategy or a dissection re-entry strategy rather than occlusion length alone.[30] Successful revascularization improves long-term clinical outcome in patients with chronic coronary total occlusion.[31] Coronary perforation is observed in a non-negligible proportion of CTO PCIs (4.1–5.5%), often requires intervention, and is associated with tamponade and mortality in a minority of patients.[32]

RCA CTOs had the highest percentage of septal collaterals than epicardial collaterals, whereas LCX and LAD CTOs had more number of epicardial collaterals. The study revealed that LCX CTOs tend to have relatively more epicardial ipsilateral collateral circulation than RCA and LAD CTOs.[15] This observation could be linked to the anatomic course and characteristics of the artery. The study reported that LAD and RCA (posterior-descending artery) tend to have numerous small connections through septal perforators, which can explain more percentage of septal collateral in RCA and LAD CTOs.[33] The study revealed collateral circulation between LAD and RPDA through septal perforators, which is the most common pathway developed in RCA CTO, and also RCA CTO has more collaterals than those of LAD and LCX.[34]

RCA CTOs had a less tortuous and more adequate size of collaterals and higher percentage of favorable entry and exit angles, so it appeared to be more suitable for retrograde CTO intervention in our study. This was also reported in other study.[16] In agreement, Rathore *et al.*[28] also published that the procedure was successful by retrograde approach in 65.6% of the cases. Continuous thread-like connection, collateral tortuosity <90°, and angle with recipient vessel <90° were significant predictors of success. The study found that 64% of CTOs were supplied by at least one collateral that appeared suitable for use as part of a retrograde procedure.[17] Understanding these differences can aid the operators in planning appropriate strategy, such as retrograde approach, and anticipation of difficulty during the procedure. For an RCA CTO, the focus should be on the utility of LAD septal to RPDA and LCX to PLV collaterals; for an LAD CTO, RPDA septal to LAD and RV marginal to LAD collaterals; and for LCX CTO, PLV to LCX and diagonal to OM collaterals.

The main limitation of our study was that non-simultaneous, single-catheter injection was done in all cases, which often provides suboptimal visualization of the CTO segment, and other was that it was a single-center study with relatively small sample size. Small vessel CTOs (< 2.5 mm) were not included in the assessment. There could be observer bias which may have affected the assessment of CAG. The complications were also not ascertained in the present study. Rapid technological developments in the area of CTO PCI have led to expansion of collateral pattern knowledge. A large multi-center study would be required to accurately delineate the angiographic characteristics in patients with CTO in India subset.

Conclusion

The most commonly involved in CTO was RCA, followed by LAD and LCX. Most of the LAD CTOs were having proximal and mid-segment lesions with longer lesion length, blunt stump, and more angulation, but less frequently calcified. The mean J-CTO score was highest for LAD followed by LCX and RCA. The RCA lesion had better collateral circulation, more number of septal collaterals, less tortuous collaterals, and more percentage of favorable entry and exit angles. RCA CTOs are more suitable for both antegrade and retrograde CTO intervention. There were several differences in angiographic findings of CTO lesions among the three major coronary arteries. Understanding these differences can aid the operators in planning appropriate strategies, such as retrograde approach, and anticipation of difficulty during the procedure.

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Conflicts of interest

There are no conflicts of interest.

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