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Value of Pre-Procedural Multi-Detector Computed Tomography Angiography Prediction Outcome in Retrograde Approach Recanalization for Coronary Chronic Total Occlusion

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ABSTRACT
Background: Computed tomography coronary angiography(CTCA) can be useful in procedure planning for CTO PCI by identifying factors known to influence PCI success rates, such as calcification, severe tortuosity and length of the occluded segment. Percutaneous coronary intervention for CTO is considered to be one of the most challenging procedures of interventional cardiology, and in the earlier studies, successful recanalization rates of CTO ranged from 51% to 74%. However, with improved operator experience and the development of novel equipment and techniques, procedural success rates have been increased, which brings an increasing number of CTO into a treatable category.
Patients and Methods: An exploratory pilot study was conducted on 40 patients using retrograde wire approach with various strategies by highly experienced CTO operators in Ain Shams University hospitals and in Kobry Elkobba Military hospital from August 2015 to 2017.
Results: According to the results CTOs were divided into two groups, group1 with successful retrograde PCI in 32 pts. (80%), and group 2 with failed-retrograde PCI in 8 pts. (20%) All CTOs were correctly identified by MIP,MPR,cMPR images. Most of the CTOs were located in the proximal 21 patients 52.5% then mid 14 patients 35% ostial 3 patients 7.5% and lastly distal 2 patients 5%. In failed group there were more calcified plaques. There was more calcification in the CTOs segments (p=0.005). Ten arc-calcified and two circular-calcified lesions were identified only 4 from ten patients (40%) had arc calcified Plaques which were successfully recanalized and 6 patients 60% failed. *In circular-calcified lesions* one patient (50%) succeeded and one failed. Proximal artery tortuosity between two groups showed a significant difference (p=0.000). **Conclusion:** Complex CTO lesion morphology is still an important issue for CTO-PCI procedural success, and further improvement of technologies (MDCT) and medical devices, such as guide wires and catheters are required to improve the success rate.
Keywords: Multi-Detector, **Computed Tomography**, **Coronary Chronic Total Occlusion**

INTRODUCTION
Chronic total occlusion (CTO) recanalization still represents the final frontier in percutaneous coronary intervention (PCI).

Jeroudi *et al.* reviewed 1699 consecutive patients who underwent coronary angiography at a Veterans Affairs hospital and reported that the prevalence of CTO among coronary artery disease (CAD) patients with and without prior coronary artery bypass graft (CABG) surgery was 89% and 31%, respectively [1] higher than that reported in a recent large Canadian registry (54% and 18.4%, respectively),[2] but similar to other prior studies [3,4]. Successful recanalization of CTO lesions in patients with viable myocardium not only facilitates the reduction of angina symptoms, avoid bypass surgery and decrease incidence of myocardial infarction, but also may improve long –term survival [5,6]. An analysis of 25 years of experience in the Mayo Clinic showed that the procedural success rate for CTO remained around 70%[7]. Multi –detector computed tomography (MDCT) can visualize the coronary artery lumen, artery wall, and atherosclerotic plaque; even the lipid pool can be visualized, which is fibrous,calcified, and heavily laden with cholesterol [8,9]. CT coronary angiography is a useful tool to optimize PCI strategy as it is possible to characterize the length, course, and composition of an occluded artery and allow visualization of the distal runoff and side branches [10].

Retrograde approach has been described initially via the bypass grafts [11], and more recently the use of septal collaterals has been described to be safe and effective [12]. Retrograde approach for recanalization of CTO has gained popularity recently with improved success rates as shown in several case reports and small series of selected patients [13].

Aim of the Work
The goal of this study is to evaluate the imaging results from Multi-detector Computed Tomography angiography (MDCT) in chronic coronary total occlusion (CTO) before retro grade approach in percutaneous coronary intervention (PCI).

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PATIENTS AND METHODS

Patient selection

An exploratory pilot study that was conducted on 40 patients using retrograde wire approach with various strategies by highly experienced CTO operators, in Ain Shams University hospitals and in Kobry Elkobba Military hospital from August 2015 to 2017. The study included patients who have CTO of at least one coronary artery as estimated by Clinical events, and or proven by previous coronary angiography.

CTO diagnostic criteria:

A CTO was defined as an obstruction of a native coronary artery with no luminal continuity and with thrombolysis in myocardial infarction (TIMI) flow grade0 or 1 and >3 months' duration.

Exclusion criteria

Patients having one or more of the following criteria will be excluded

1. **From the study:** Acute coronary syndromes cardiogenic shock, baseline renal impairment, and patients with an irregular cardiac rhythm, (EF < 30%). Patients who were proved to have non-viable myocardium in the territory supplied by the chronic totally occluded artery [Thallium scanning or stress Echocardiography].

METHODOLOGY

The research was approved by Ain Shams Hospital ethics committee.

All patients were provided with written informed consent to be included in this study.

All patients in the study were subjected to the following:

A- Before the percutaneous coronary intervention:

1. Proper history taking including clinical and demographic data (age, sex, DM, hypertension, smoking status), previous ischaemic events

Proper analysis of the previously done coronary angiography

1. Presence or absence of proximal stump.
2. Shape of the artery before the CTO segment
3. Side branches at the site of total occlusion-
4. Antegrade or retrograde filling of distal segment.

Level of difficulty assessment [J-SCORE] easy (0) intermediate (1) difficult (2) very difficult>3

MDCT:

MDCT data acquisition done in all patients before PCI. using a dual source CT machine (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany) using 2 x-ray tubes and 2 detectors arranged at an angular offset of 95°.

All subjects received 5 mg sublingual isosorbide dinitrate before imaging to achieve maximal coronary hyperemia.

Patients with heart rate ≥ 70 bpm received a beta-blocker (Atenolol 50– 100 mg) orally half an hour before the study to control heart rate.

Data sets for quantification of coronary artery calcium were rendered using half-scan reconstruction algorithm with 3.0 mm slice thickness, 1.5 mm increment and a medium sharp reconstruction kernel (Siemens B35f). Acquired datasets were reconstructed by 3D volume rendered (VR), thin-slab MIP and MPR images

MDCT data were analyzed by experienced operator regarding the following variables:

▪ ***Characters of the artery proximal to the total occlusion****:*

○ **Tortuosity, side branches at the site of CTO, proximal stump** and its size if found**: Tapered** or **blunt**.

○ **Shape of the vessel before CTO**: Atherosclerotic or healthy.

▪ ***Characters of the totally occluded segment:***

○ **Which** coronary artery?
○ **Site** in the artery
○ **Length of CTO segment**, **Evidence of filling within CTO segment. Proximal cap calcification** and its extent if present either **eccentric** (<180^0 arc) or **circumferential** (> 180^0 arc).
○ **Side branches from within the CTO segment**.

Distal cap calcification and its, calcification within CTO segment: ***Characters of the artery after the totals occluded segment:***

○ Visualized or not, diseased or not, size.

B- PCI:

▪ PCI was done by operators highly skilled in CTO interventions and the following variables regarding PCI procedures were registered:

▪ Antegrade or retrograde approach (used when antegrade approach fails according to the decision of the operator).

○ Procedural success: defined as attainment of a residual diameter stenosis <20% and a TIMI flow rate of grade 2 or 3. Causes of failure in failed procedures.
○ Procedural complications.
○ Equipments used: wires, OTW devices, balloons and stents.

C- Post PCI:

All patients were followed up after PCI procedure for immediate post procedural complications.

The following variables were registered for all patients during the Procedure:

1. Duration of the procedure Equipments used (PTCA wires, catheters, microcatheters, balloons, stents, etc…), Procedural complications, Outcome of the procedure (**Angiographicaly** successful TIMI 3 flow restoration in the previously totally occluded artery). Failed procedure with registration of the cause of failure , The amount of radiation

After the percutaneous coronary intervention:

The following variables will be registered for all patients after the procedure, kidney functions test-, short term complications

The study was done after approval of ethical board of Ain Shams university.

RESULTS

Table 1: Baseline characteristics of patients.

	Group1(Success)	Group 2(Failure)
Age	58±7.3	61+_8.1
D.M	10(76.9%)	3(23.1%)
HTN.	23(85.2%)	4(14.8%)
SMOKING	17(77.3%)	5(22.7%)
Dyslipidemia	25(78.1%)	7(21.9%)
PERVIOUS myocardial infarction	7(63.6%)	4(36.4%)
Pervious failed Trial	12(85.7%)	2(14.3%)

Table (2): CT angiography characteristics

		Group (1) success	Group (2) failure	P-Value
Length of CTO		55.3±19.2	36.5±17.2	NS
Number of diseased vessels	**1**	5 (100%)	0 (0%)	0.009
	2	18 (94.7%)	1 (5.3%)	
	3	9 (56.2%)	7 (43.8%)	
Size of vessels distal to CTO		25.1± 3.1	21.3 ±2.9	0.11
	Tourtuisity	5 (41.7 %)	7 (58.3%)	0.001
Degree of calcium of distal CAP	**NO**	8 (100%)	0 (0%)	0.001
	SPOT	9 (100%)	0 (0%)	
	ECC	9 (100%)	0 (0%)	
	ARC	4 (33.3%)	8 (66.7%)	
proximal CAP calcium	**Yes**	19 (70.4%)	8 (29.6%)	0.028
	No	13 (100%)	0 (100%)	
Side branch at CTO	**Yes**	27 (87.1%)	4 (12.9%)	0.039
	No	5 (62.5%)	3 (37.5%)	
	Bridging collateral	0 (0%)	1 (100%)	
Proximal stump	**Tapered**	18 (85.7%)	3 (14.5%)	0.34
	BLUNT	14 (73.2%)	5 (26.8%)	
Artery of CTO	**LAD**	8 (80%)	2 (20%)	0.004
	RCA	24 (88.8%)	3 (11.2%)	
	LCX	0 (0%)	2 (100%)	
	OM	0 (0%)	1 (100%)	
Vessel before CTO	**Healthy**	8 (100%)	0 (0%)	0.11
	Diseased	24 (75%)	8 (25%)	
Degree of calcium of cto segment	**NO**	9 (100%)	0 (0%)	0.001
	SPOT	9 (100%)	0 (0%)	
	ECC	9 (100%)	0 (0%)	
	ARC	4 (33.3%)	7 (66.7%)	
	Circumferential	1 (50%)	1 (50%)	
J-CTO score	**1**	5 (100%)	0 (0%)	0.003
	2	22 (91.7%)	2 (8.3%)	
	3	5 (45.5%)	6 (54.5%)	

Table (3): PCI procedure characteristics.

		Group (1) success	Group (2) failure	P-Value
Density of coll	**CC1**	16 (69.6%)	7 (30.4%)	0.55
	CC2	16 (94.1%)	1 (5.9%)	
0TW	**No**	1 (100%)	0 (0%)	0.86
	Corsaire	13 (76.5%)	4 (23.5%)	
	Finecross	7 (87.5%)	1 (12.5%)	
	C+F	10 (76.9%)	3 (23.1%)	
USE OF Imaging	**IVUS**	12 (92.3%)	1 (7.7%)	0.3
	NO	19 (73.1%)	7 (26.9%)	
	OCT	1 (100%)	0 (0%)	
Fluroscopic time		70.1±20.7	83.3±13.5	NS
Procedural time		140.9±42.7	187.5±42.7	
Contrast volume		333.9±62.7	416±40.5	
Radiation dose		4640.8	5803.7	
Complication	**No**	30(93.8%)	2(6.3%)	0
	Septal perforation	1(25%)	3(75%)	
	Dissection	1(37.3%)	2(66.7%)	
	Thrombosis	0(0%)	1(100%)	

Presence of a ***marked curve*** at the CTO with respect to the native vessel **(57%** of successful procedures vs **95%** failures, **P<.0001**), ***negative remodeling*** at the proximal end of the CTO (**44%** of successful procedures vs **88%** of failures, **P=.0005**), and ***severe calcification,*** defined by high-density plaques (>500 HU) affecting nearly 360 degree of the vessel circumference **(71%** of successful procedures vs **88%** of failures**, P=.0356**).

Discussion

In this study, we tried to extract significant MDCT factors affecting the outcome for retrograde recanalization approach of the CTO.

Such factors when become settled as definite predictors may help the operator to choose which approach to start with directly saving a lot of time and effort in addition to decreasing radiation and contrast load.

The current study data was obtained from 40 patients presenting with clinically or angiographically confirmed types of CTO.

Analysis of demographic and clinical characteristic

Our study was performed on 40 CTO patients with successful retrograde PCI in **32** (**80%**) of patients and found that **no** significant effect of patient's **age** on the procedure outcome.

These data were similar to those obtained by **Suzuki *et al*.[14]** who performed a similar study on **1,656** retrograde CTO-PCIs, with successful PCI in **1,276** procedures (success rate of collateral channel crossing **(77.1%)** of patients and found that patient's **age** had **no** significant effect on procedure outcome.

Baykan *et al.*[15] performed similar study on **173** patients underwent PCI for CTO. There were **144** patients in the CTO **success group** and **29** in the CTO **failure group**. The clinical characteristics were similar between the groups, with **no** significant difference

These data were similar to those obtained by **Li *et al.*** [16] who performed a similar study on **74 CTO** patients with successful PCI in **57** (**77%)** of patients and found that patient's age had no significant effect on procedure outcome.

These data were different from those obtained by ***Garcia-Garcia et al***. [17] who performed a similar study on **142** patients with a PCI success rate of **62.7%** and showed that older patients had significantly more incidence of calcification occupying **>50%** of vessel cross sectional area (CSA), longer calcification segments, more calcium at entry and exit of **CTO.**

In our study Regarding **DM**, **HTN**, **smoking** habits and history of previous **MI**; **all** failed to prove significant effect on PCI outcome.

Suzuki *et al*. recorded no significant differences in clinical characteristics (HTN, smoking, pervious MI, dyslipidemia, age) between retrograde **success group** and the **failure group** although the rates of previous CABG, multivessels disease(MVD), and diabetes mellitus (DM) tended to be **higher** in the **failure group**.

<u>**Regarding MDCT characters**</u> of the vessel before CTO**, our study did not** prove significant effect of shape of proximal stump (**blunt or tapered**) on PCI outcome.

These results were concordant with those of ***Garcia-Garcia et al.*** who found **no** significant effect of **presence** and **size** of proximal stump or side branches at CTO site.

Also, these results were concordant with those obtained by **Martin-Yuste *et al.*[18]** who performed a similar study on **69** patients with a **success rate** of **62%** (taking into consideration that the study used success of guidewire passage to distal lumen as an indicator of success without considering any further steps taken to revascularize the artery).

In contrast, our study proved significant effect of presence of **side branches** at the CTO site **increase** procedural success rate (**p=0.03**).**This may be explained by the fact that** side branches may help to introduce IVUS probe, using anchoring technique and using double lumen catheter to increase rate of success.

Our results showed **a tendency towards** significance when the size of artery distal to CTO was compared to the outcome of the retrograde approach with more success of this approach with larger size distally (**p=0.11**).

Naveeda *et al*. [19] demonstrated that the patients having calcified plaque had failure rate of the procedure of around 46 %.The multiple wires were used to cross the lesion in patient having calcified plaque.

Cho *et al.* [20] reported that the regional calcium score and other parameters studied were significantly associated with technical failure, upon multivariate analysis the only factor showing a high positive predictive power was the amount of calcification in the vessel cross section.

Martı´n-Yuste *et al.* described that the only factor significantly associated with revascularization failure was the presence of calcium affecting more than 50% of the vessel circumference in the proximal and middle thirds of the CTO.

These results are similar to our study where the parameters that were **significantly associated with technical failure** are **calcification** and **tortuosity**.

In our study we found a significant difference of proximal **tortuosity** between the native vessel and the CTO on MDCT **p=0.00001**

Martı´n-Yuste *et al.* were unable to adequately assess the presence of a curve between the native vessel and the CTO on MDCT, but on angiography this was the only independent factor predictive of failure, which concurs with the findings of **Ehara *et al.***

The study of **Hsu *et al*. [22]** performed in **82** CTOs, evaluated the calcification length ratio, defined as the length of calcification density >130 HU/ occlusion length.

An expert performed the procedures and the successful revascularization rate was **80.5%.**

Calcification length ratio >0.5 was found in **77.8%** of technical failures and **50%** of procedure failures (**P<.001**).

J-CTO score is the most useful in grading the severity of CTO and influence the success rate.

In our study success progressively significant falls with an increase of the score (**p=003**) and increase in numbers of diseased vessels was associated with more failure (p=009).

Morino *et al.* [23] success progressively falls with an increased score with "difficult -"J-CTO score equal or greater than 3- lesions having a 73.3% success rate and demanding a prolonged time for crossing.

In our study the **occlusion length** of CTOs between the two groups **did not** show any significant difference. These data is in contrast with **Baykan *et al.* who found** that the long occlusive segment often predicted a low success rate.

Puma *et al.* [24] showed that an occlusion length **>15** mm detected by conventional angiography was associated with procedural failure.

Regarding PCI procedure

In our study retrograde approach was described in 40 cases and reported success rates in 80% of the patients.The reasons for failure were mainly inability to cross CTOs segments **15%.** And failure to cross the small septal collaterals **5%.**

Thompson *et al*. [25] reported that retrograde wire advancement to the distal CTO cap through the collateral channel was successful in **81.1%** of retrograde CTO-PCI procedures, and the technical success rate of retrograde CTO-PCI was **86.9%** after successful placement of a retrograde wire through the collateral channel into the target vessel distal to the occlusion. **Sheiban *et al.* [25]** described retrograde approach in **18** cases and reported success rates in **67%** of the patients. The reasons for failure were mainly inability to cross the small septal collaterals and inability to deliver the balloon or dissection in the CC. **Surmely *et al.* [26]** described successful usage of septal CCs for the retrograde approach and described successful crossing in **90%** of the patients and successful dilation in **81%** of the patients. They have reported low complication rates.

Naveeda *et al*. reported that inability to cross the lesion with a guide wire was the reason for failure in **>75%** of unsuccessful attempts.

In our study Corsair and finecross were mainly used for collateral channel crossing.

Similarly, Suzoki *et al.* demonstrated that ASAHI Corsair was mainly used for collateral channel crossing.

In our study successful crossing of septal CCs in **95%** for the retrograde approach and successful dilation in **97%** of the patients with one case of septal perforation was treated with coil in success group and 3 pts with minor perforations in failure group with no long term sequels. Minor dissection in CC occurred in 3 pts in success group and 2 pts in failure group with no long term sequels.

Saito *et al.* [27] reported the results of retrograde attempts in **45** patients, which were performed by a single experienced operator. He has reported the success rate of **69%** in this group of patients. The retrograde CC was crossed with the wire in **82%** of the patients and the septal collaterals (**93%)** were used in a majority of the cases.

He has reported the minor perforation in **13%** of the patients with no long-term sequelae.

In our study IVUS guidance was applied in **32%** of the retrograde cases and with success rate **92.3%.**

Sianos *et al*.[28] reported the results of European experience with the retrograde approach for the recanalization of the coronary artery CTOs. They have reported overall success rates of **83.4%** and the guidewire crossed the CC successfully in **80.6%** of the cases. The collateral perforation rates were reported at **6.9%** the success rates of CTO recanalization has increased from **90%** to **95%** with the use of retrograde methods and further increased to **97%** with the application of IVUS guided reverse CART in the hands of experienced operators

In our study the final retrograde concept was reverse CART in **24** Patients and Retrograde Wiring in **5** cases, Knuckele Retrograde **1** case and Kissing Wire in **2** cases (**p=0.001**).

Rathore *et al*.[29] Reverse CART was applied to a majority of the patients, except 2 patients in whom the antegrade balloon could not be delivered to the CTO segment because of severe tortuosity. IVUS was used in all patients except 1, because of non availability, to guide the antegrade balloon size. With the use of septal collaterals, the collateral perforation could be seen in 5% to 10% of patients.

The majority of septal channel perforations are benign and require abandoning that channel and trying other channel. Due to the complex procedure and vague route of CTO segments, the procedure often needed a long exposure time and a large amount of contrast. There was no significant difference in procedural time irrespective of procedure was successful or not[(140.9±42.7) vs. (187.5±41.6) min, Respectively, p>0.05]. **Flourscopic** time tendency to **increase** in failed group (70.1 vs 83.3) min.

Contrast volume and **radiation** dose had tendency to **increase** in failed groups (356 ml **VS** 416 ml),(4692Gym **VS** 5803 Gym) respectively.

These data are similar to **Suzuki *et al.*** who detected the procedure time and fluoroscopic time were significantly longer in the RF group than the RS group.

CONCLUSION

- MDCT coronary angiography of CTO is possible before a planned PCI for evaluation of plaque morphology, lesion length and post occlusion vessel assessment. Complex CTO lesion morphology is still an important issue for CTO-PCI procedural success, and further improvement of technologies for medical devices, such as guide wires and catheters are required to improve the success rate.

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