Clinical, Electrocardiographic, and Angiographic Characteristics as Predictors of Procedural Success in Patients with Coronary Chronic Total Occlusions A Single-Center Experience

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ABSTRACT:

BACKGROUND:

Percutaneous coronary intervention for chronic total occlusion lesions is technically difficult despite equipment advances. Changes in electrocardiographic patterns such as Q wave during total occlusion can provide information about procedural success and myocardial viability.

OBJECTIVE:

The aims of study are to investigate clinical, electrocardiographic and procedural characteristics of chronic total occlusion and the relation of these variables to the procedural success rate.

PATIENTS AND METHODS:

In this study, clinical, electrocardiographic and coronary angiographic data of (100) patients with chronic total occlusion lesions who underwent percutanous coronary intervention between May 2010 and March 2011 at the Iraqi center for heart diseases were analyzed. The clinical data were collected using the patients' files and angiographic data by the observation of their films. Chronic total occlusion was diagnosed from clinical events including myocardial infarction or worsening of their symptoms or previous angiography.

RESULTS:

There were 100 patients with chronic total occlusion. Successful recanalization with stent deployment was accomplished in 65 patients (65%), while unsuccessful recanalization was found in 35 patients (35%). No major cardiovascular events occurred among both groups. The success rate of PCI was significantly more in lesions shorter than 15 mm, presence of tapered stump, angulations less than 45 degree, duration less than 3 months and TIMI 1 flow grade (p values were significant). Presence of Q wave was associated with severe angina , decreased left ventricular ejection fraction, critical lesions other than chronic total occlusion, T wave inversion and more regional wall motion abnormalities (p values were significant). The most common cause of procedural failure was inability of guide wire to cross through the totally occluded segment.

CONCLUSION:

Percutaneous coronary intervention is a safe and useful procedure for revascularization of coronary chronic total occlusion lesion. The procedural success rate was related to certain features of the totally occluded lesions.

KEYWORDS: coronary chronic total occlusion.

INTRODUCTION:

Chronic total occlusions (CTOs) are found in approximately one-third of the patients with significant coronary disease who undergo angiography. Despite the introduction of novel technologies, newer guide wires, and a tremendous advancement of technical skills, percutaneous coronary intervention (PCI) for CTO remains a challenge. Indeed, the most common reason for referral to bypass surgery or exclusion from clinical studies comparing outcomes of angioplasty to bypass surgery has been the presence of a CTO [1,2].

Anatomically, CTOs typically consist of a hard fibro-calcific proximal cap, a distal cap with generally less fibrotic material, and a central area of organized thrombus[3]. Indications for opening CTOs include relief of angina, evidence of ischemia in asymptomatic patients, to improve left

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ventricular (LV) function, and to improve long-term survival. Recently the focus has been shifted to patients with documented ischemia, and reconsideration of the need for recanalyzing CTOs that do not contribute to ischemia [4]. The fibro-calcific nature of these CTOs is responsible for the somewhat lower success rates in opening these lesions, predominantly by increasing the difficulty in passing the occlusion with a guide wire. Newer technology, primarily new wires, has improved the ability to cross these previously uncrossable lesions, thereby improving the acute success rates of opening them. Stenting has improved long-term patency rates for these lesions, and now drug-eluting stents (DESs) have made the late restenosis rates similar to those seen for non occluded arteries. Therefore, the clinical imperative for opening these arteries has increased [5, 6].

Chronic total occlusions are defined as occlusions in the coronary arteries with thrombolysis in myocardial infarction (TIMI) 0 flow or functional occlusions with TIMI 1 flow (penetration of contrast without filling of the distal vessel) of at least 1-month duration. Some extend the definition to 3 months of occlusion. Age criteria for total occlusion vary among studies – from 2 weeks to 3 months – but are difficult to assess unless serial angiograms are available. Thus, age is often difficult to define and is dependent on clinical history [7]. A prior history of myocardial infarction (MI) was present in 42–68% of the patients who had angiographically documented CTOs [8]. Not surprisingly, the incidence of CTOs seems to increase with patient age, especially in the left anterior descending (LAD) coronary artery distribution [9].

There was a 56% ($p < 0.001$) reduction in relative risk for mortality over 7 years' follow-up in the British Columbia Cardiac Registry in which 1458 patients with CTO were treated [10]. The Total Occlusion Angioplasty Study-Societa Italiana di Cardiologia Invasiva (TOAST-GISE) showed a similar result in a smaller cohort of patients (369 patients) over a shorter follow-up (1 year), with a reduced incidence of cardiac death or MI with successful procedures (1.1% versus 6.2%; $p = 0.005$) [7]. In the only study incorporating stent use to a significant degree, the Thorax Center reported 5-year follow-up of 885 consecutive patients who had CTO treated from 1992 through 2002. There was a 65.1% success rate in these patients. Successful procedures were again associated with improved 5-year survival (93.5% versus 88.0%; $p = 0.02$) [11]. Besides a survival benefit seen from of treating CTOs, improvements in clinical symptoms, improvements in left ventricular (LV) function, and a reduced need for late coronary bypass surgery (CABG) have been associated with successful opening of CTOs. There was a greater freedom from angina in TOAST-GISE for successful procedures (88.7% versus 75.0%; $p = 0.008$) [7]. Left ventricular function improved in a series of 95 patients studied at baseline and at 6.7 ± 1.4 months. Left ventricular ejection fraction (LVEF) increased from 62.5 ± 13% to 67.5 ± 11% ($p < 0.001$) with the opening of these occluded arteries [12]. Certain angiographic and clinical features have been associated with higher success rates for opening totally occluded coronary arteries [20].

Long-term success rates traditionally have been less than ideal, with high restenosis- and re-occlusion rates compared with PCI of non-occluded vessels. Various randomized trials comparing percutaneous Trans luminal coronary angioplasty with bare metal stenting have provided insight into these long-term outcomes. Restenosis rates for balloon angioplasty of CTOs have ranged from 33% to 74%. Additionally, the re-occlusion rates have been high, ranging from 7% to 34% in various studies. The use of stents has improved these outcomes markedly[13].

What mechanisms explain the benefits of opening CTOs? Late reopening of an occluded infarct-related artery (IRA) may improve LV function provided viable myocardium is present within the zone supplied by the artery. Available data suggest that viable myocardium can survive only a few weeks after an acute event. However, collateral flow may prolong this time window due to the so-called "hibernating" myocardium. Recently, a team of investigators in Italy showed that late restoration of IRA patency (6 months after an acute event) improved LV function, prevented LV dilatation, and reduced cardiac death [14]. The open artery hypothesis suggests that late patency of an infarct artery is associated with improved LV function, increased electrical stability, and provision of collateral vessels to other coronary beds for protection against future events [15]. Preclinical studies have suggested that late opening of an occluded infarct artery may reduce adverse LV remodeling and preserve LV volumes. However, previous clinical studies in have demonstrated inconsistent improvement in LVEF or LV end-systolic and end-diastolic volumes after PCI [16, 17]. Since CTO is a procedure involving high doses of radiation and contrast, selection of patients should

be done carefully based on proven ischemia related to the occluded vessel and evidence of favorable anatomy, which can improve the success [17].

PATIENTS AND METHODS:

In this cross sectional descriptive study, clinical, electrocardiographic and coronary angiography data of 100 patients with CTO who underwent PCI between May 2010 and March 2011 at the Iraqi center for heart diseases were analyzed. The indication for PCI attempt for all those patients with CTO lesions was anginal pain despite maximum medical therapy. All patients were subjected to detailed history and clinical examination focusing on the presence and severity of anginal symptoms, past medical history regarding myocardial infarction with concentration on duration (more or less than 1 month), hypertension, diabetes mellitus, hyperlipidemia and smoking status and drug history (anti-platelets, anti-ischemic, anti-failure and lipid-lowering agents).

A 12-leads resting electrocardiography (ECG) was performed at time of admission to catheterization laboratory. The presence of Q waves in the leads II, III, and AVF was regarded as infarction area due to RCA occlusion, while Q waves in leads V3 and V4 was regarded as infarction due to LAD occlusion and Q waves in V5, V6, I, and AVL regarded as infarction due to LCX occlusion [18]. Patients with LBBB were excluded from ECG analysis.

Echocardiographic study was done to assess wall motion abnormality and visually assess systolic wall thickening and inward wall motion. Each segment was scored semi-quantitatively using a five scoring point system: Normal (more than 40% thickening with systole), hypokinesia (10- 30% thickening), akinesia (less than 10% thickening), dyskinesia (systolic thinning and outward systolic motion), aneurysmal (systolic thinning and outward motion during systole and diastole).

Echocardiography was also used to assess systolic function by estimation of ejection fraction (more than or equal to 50% was considered normal).

The duration of total occlusion was calculated on the basis of clinical data. In patients with single-vessel disease who had myocardial infarction in the territory of the occluded vessel, the duration of occlusion was estimated from the date of infarction.

Coronary angiographic films were analyzed to assess the length of occlusion, presence or absence of a stump, bridging collaterals, presence or absence of side-branch, TIMI flow grade, target vessel with CTO lesion, critical lesions other than CTO lesion and number of diseased vessels with CTO occlusion. Significant coronary artery disease was defined as more than or equal to 70% luminal diameter stenosis. Total coronary artery occlusion was defined as 100% luminal diameter stenosis without ante-grade flow. CTO was defined as total artery occlusion of more than or equal to one month in duration. Inclusion criteria included the presence of CTO (TIMI flow grade 0 or 1) and evidence of viable myocardium. Because of the unavailability of myocardial viability studies in our center, the presence of myocardial viability was roughly judged from the presence of other features (severe angina with single totally occluded vessel and no evidence of regional wall motion abnormality, normal myocardial wall motion of the region supplied by the totally occluded artery, preserved left ventricular systolic wall thickness of the region supplied by the totally occluded artery, absence of Q waves or Q waves with positive T waves, the presence and extent of angiographic collateral flow). Exclusion criteria were: patients who were candidates for coronary artery bypass graft (CABG), patients with CTO of saphenous venous graft (SVG), LMS artery stenosis more than or equal to 50%, patients with contraindication for PCI (e.g severe comorbid disease), patients with a CTO of an artery supplying non viable myocardium.

Coronary angiography was performed with the use of standard catheters and techniques, each coronary artery was selectively viewed in multiple projections. Before patient selection for PCI, the procedural effectiveness, probable risks and complications were explained to the patients. All patients received standard antiplatelet drugs before and after procedure. All PCI procedures were performed using standard femoral approach. The type of catheter was judged by the interventionist to get the best support for the procedure. Coated and non coated guide wires were used with variable stiffness. The balloon catheters with the smallest profile were always used at the initial pre-dilatation and stent deployment was performed for all successful CTO lesion dilatation with preference for drug-eluting stents (DES) when available.

The technical success of the procedure was defined as restoration of TIMI III flow with residual stenosis less than or equal to 10% and successful stent deployment in CTO segment without a major adverse cardiac events (MACE) which included in-hospital death, myocardial infarction, urgent or

emergent coronary artery by-pass graft surgery and cerebrovascular accident.

Statistical analysis:

All data were coded and entered to computer by using statistical package for social science (SPSS 14). Summarizing of data was done by using numbers, percentages, and means ± SD. Association between different variables was measured by Chi-square test. P value < 0.05 was considered as the level of significance.

RESULTS:

A total of 100 patients had total occlusion lesions, for which percutaneous coronary interventions were attempted. Successful re-canalization with stent deployment was accomplished in 65 patients versus unsuccessful re-canalization in 35 patients.

Table (1) shows the clinical characteristics of patients with CTO in PCI success group versus PCI failure group. There were no statistically significant differences among these variables.

Table (2) shows procedural and angiographic analysis of CTO characteristics in PCI success group vs. PCI failure group. There were statistically significant differences among the 2 groups regarding the length of the lesion, angle of the lesion, presence of stump, duration of occlusion and grade of TIMI flow, where the success rates were significantly higher for lesions with lengths shorter than 15mm, angulations less than 45 degree, presence of tapered stump morphology, duration less than 3 months and with TIMI 1 flow grade. The target vessel was the LAD in 50 patients, RCA in 40 patients and LCX in 10 patients. The success rate of PCI was higher in LAD (53%), while the success rates were (38%) and (7%) in RCA and LCX respectively; this proved to be statistically not significant compared to failure group. In patients with single vessel disease, the success rate was more frequent than patients with multi-vessel disease (62% vs. 38%); this also proved to be statistically not significant compared to failure group. The guide-wires used in success group were soft wire in 45(69%) patients, stiff wire in 15(23%) patients and shenobi wire in 5(7%) patients which are statistically not significant compared to failure group.

Table 1: Clinical characteristics of patients with chronic total occlusion.

Clinical Variables	CTO-PCI Success (65 patients) No.(%)	CTO-PCI Failure (35 patients) No.(%)	P value
Age (years)m	57.3 ±7.55	60.6 ± 6.75	NS
Male	45 (69)	20 (57)	NS
Female	20 (30)	15 (42)	
Hypertension	30 (46)	25 (71)	NS
Diabetes mellitus	23 (35)	15 (42)	NS
Abnormal lipid profile	30 (46)	18 (51)	NS
Smoking	7 (10)	8 (22)	NS
Chronic stable angina	56 (86)	30 (85)	NS
Unstable angina	9 (13)	5 (14)	NS
Total No	65(100)	35(100)	

NS: not significant; CTO: chronic total occlusion; PCI: percutaneous coronary intervention

Table 2: Angiographic analysis and procedural characteristics of chronic total occlusion (CTO) lesions relevant to technical success.

P. value	PCI-failure group (35 patients) No.(%)	PCI-success group (65 patients) No.(%)	Variables
NS	15 (42) 15 (42) 5 (14)	35 (53) 25 (38) 5 (7)	Target vessel LAD RCA LCX
0.001	33 (94) 2 (05)	20 (30) 45 (69)	Length (mm) ≥15 ≤15
0.01	5 (14) 30 (85)	50 (76) 15 (23)	Angle ≤ 45 ≥ 45
0.02	10 25	50 15	Duration (mon.) <3 >3
0.006	15 (42) 20 (57)	50 (76) 15 (23)	Stump + ve - ve
0. 001	10 (28) 25 (71)	40 (61) 25 (38)	TIMI flow grade 1 0
NS	17 (48) 18 (51)	30 (46) 35 (53)	Side branch +ve - ve
NS	7 (2) 28 (8)	15 (23) 50 (76)	Bridge collaterals + ve - ve
NS	25 (75) 10 (28)	40 (61) 25 (38)	Single-vessel disease Multi-vessel disease
NS	20 (75) 11(30) 4 (11)	45 (69) 15(23) 5 (7)	Guide wire Soft Stiff Shenobi
	35(100%)	65(100%)	Total No.

NS: not significant; PCI: percutaneous coronary intervention; LAD: left anterior descending; RCA: right coronary artery; LCX: left circumflex; TIMI: thrombolysis in myocardial infarction.

Table (3) shows clinical, elecrocardiographic, echocardiographic and procedural characteristics according to the presence of Q wave among the 2 groups. The presence of Q wave was significantly associated with severe angina, decreased left ventricular ejection fraction, presence of critical lesions other than CTO lesion, T wave inversion and more regional wall motion abnormality but were not related to the procedural success.

Table 3: Clinical, electrocardiographic, echocardiographic and procedural characteristics according to the presence of Q wave in chronic total occlusion lesions.

P. value	No Q wave NO.(%)	Q wave NO.(%)	Variables
0.02	20 (36)	37 (82)	CSA class III -IV
0.01	5 (1) 50 (9)	35 (77) 10 (22)	EF ≤50 ≥50
0.01	10 (18)	30 (66)	RWMA
0.01	10 (18)	30 (66)	Critical lesion other than CTO
0.001	5(9)	40(88)	T wave inversion
NS	35 (63)	30 (66)	Successful Rate(revascularization)
	55/100	45/100	Total No.

NS: not significant; CSA: chronic stable angina; EF: ejection fraction; RWMA: residual wall motion abnormality; CTO: chronic total occlusion

Figure 1 shows the causes of failure to re-canalize CTO. The most common causes of procedural failure was inability of guide wire to cross the lesion in 31 patients (88%); other causes included inability to cross the lesion with balloon in 2 patients (6%) and inability to dilate the lesion with balloon in 2 patients(6%).

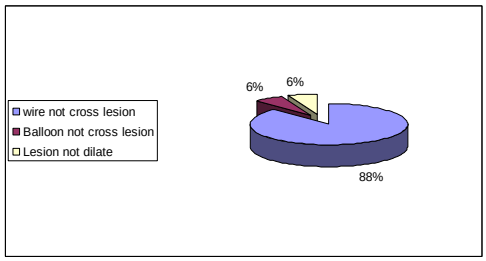

Figure 1: Shows causes of procedural failure in chronic total occlusion–PCI failure group.

Regarding major adverse cardiac events (MACE), there were no complications among patients in success group and failure group.

DISCUSSION:

In this study we measured the clinical, electrocardiographic and procedural characteristics of CTO lesions. While the technical and procedural success rate of PCI in CTO have steadily increased over the last 15 years because of greater operator experience and improvement in equipments and procedural techniques, PCI of CTO lesions still has a relatively low success rate and is technically difficult [15,16]. In a series of 1074 consecutive patients undergoing PCI, the primary success rate was 90% in non-occluded lesion, 78% in functional total occlusion (TIMI flow grade 1), and 63% in true CTO (TIMI flow grade 0)[16]. Contemporary series found procedural success rate from 55% to 80%, with the variability reflecting differences in operator techniques and experiences, availability of advanced guide-wires, and CTO definition and case selection [17,19].

In this study, a total number of 100 patients with CTO of coronary arteries were studied. Regarding the success rate, it was 65% while unsuccessful rate was 35%. Other authors reported the success rate of PCI for CTO to be in the range of 47-69%[20]. In Han YA –Ling, *et al.* study, the success rate was 88.9% [21]. Our result was comparable to other results and the slight difference might be due to differences in selection criteria of patients,

availability of materials, number of patients and operators' experiences.

In our study, there were no significant differences in the baseline clinical characteristics of patients with CTO among success group vs. failure group, in agreement with studies conducted by Olivert AL Abbott *et al*., and Invanhoe *et al.* [22,23].

Multiple angiographic features have been suggested to be predictive of percutaneous re-canalization failure including longer lesion, angulations of the lesion, blunt vs. tapered stump, true vs. functional occlusion, presence of bridging collaterals, longer duration of occlusion and presence of side-branch at the site of occlusion [24,25,26]. In this study, the most powerful predictors of percutaneous re-canalization failure were longer lesion (more than 15mm vs. shorter than 15mm), TIMI 0 vs. TIMI 1 flow grade , duration of occlusion more than 3 months and blunted stump vs. tapered end, in agreement with most prior studies as Barlis *et al*., and Stone *et al*., who have consistently reported that increasing age of the occlusion, ostial occlusion, greater lesion length, presence of a non tapered stump, origin of the side-branch at the occlusion site, excessive vessel and lesion tortuousity, calcification and lack of visibility of the distal vessel coarse negatively affect the ability to successfully cross a CTO lesion.[27, 28]. In another study, only two independent factors affected successful rate of PCI adversely, the lesion length and the presence of bridge collaterals [29].

In our study, the CTO lesions and the successful rate were more in LAD vessel and more in single vessel than multi-vessel disease although both results were statistically not significant in agreement with study reported by Cohen HA *et al* [9], while a study reported by Chan Seok *et al*., showed that the rate of a CTO lesion was more in RCA vessel and in multi-vessels disease but re-canalization was most frequently attempted for LAD [30].

According to our data, patients with Q waves showed more severe angina (CCS III-IV), decreased left ventricular ejection fraction, presence of critical lesions other than CTO, T wave inversion and more wall motion abnormalities as observed by echocardiography. The Q wave was not related to the procedural success rate. Our study agrees with studies reported by Chan seok *et al.*, and LA Pierad *etal.* [30,31].

In our study the ante-grade approach was the strategy applied to open the CTO lesion in all cases. Operators applied step-up approach using wires of moderate stiffness at the beginning with subsequent shift to wires of greater stiffness. Combolo A et al recommended going from light to heavy wires, always starting with a soft tip changing it to harder and stiffer wires if the lighter and softer wires do not work [32]. Reasons of procedural failure in our study were inability to cross the lesion with guide-wire, inability to cross with balloon and inability to dilate the lesion respectively. The most common cause was inability to cross the lesion with guide-wire in agreement with a study done by Chan seok *et al*. which reported the same reasons of failure [30]. Parallel wire technique is the best method to locate the true lumen while minimizing the risk of extensive dissection and perforation.[33]

No major adverse cardiovascular events (MACE) were detected during the procedure, similar to another study by Chan seok *et al*.,[30] in which death occurred only in one patient. This finding suggests that PCI for CTO lesions is safe treatment option when the operator is comfortable with the procedure and the case is carefully selected.

Our technical success was relatively acceptable because all these procedures were done in our limited facilities and equipments including absence of suitable wide varieties of CTO guide- wires, shortage of smaller balloon catheters and new devices like Tornus in ante-grade and retro-grade techniques [34].

CONCLUSION:

Percutaneous coronary intervention is a safe and useful procedure for revascularization of chronic total occlusion lesions of coronary arteries with high success rate and low incidence of complications. The procedural success rate is related to angiographic characters of the lesions but not related to the presence of Q waves. The most common cause of procedural failure was inability to cross through the lesion with guide wire.

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