Original Article

Intravascular Ultrasound in Percutaneous Coronary Intervention for Chronic Total Occlusion

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Background: Percutaneous coronary intervention (PCI) of chronic total occlusion (CTO) is one of the most challenging procedures in interventional cardiology. New techniques and devices have made possible to face these complex procedures. Intravascular ultrasound (IVUS) reveals special features and contributes greatly to procedural success.

Method: We analysed retrospectively IVUS contribution and findings in 23 cases of a total 46 CTOs PCI from February 2009 to August 2010 in our cath lab. Both true and functional CTO were included in this study. The procedure was considered successful when a TIMI III flow was reached in the occluded vessel after stent implantation with a residual stenosis less than 30%. IVUS features and contribution in CTO-PCI were analysed. All data were introduced in SPSS version 15 (SPSS Inc. Chicago, Illinois, USA). Continuous variables were described by mean ± SD and categorical variables were expressed as percentage. A $P<0.05$ was considered statistically significant.

Results: 46 PCIs in 34 patients were performed during 19 months in our centre. The procedure was successful in 28 cases (60.9%).. IVUS was performed in 23 (82.1%) of successful procedures. IVUS revealed calcium somewhere in 17 (73.9%). Despite wire angiographic verification in true lumen distally IVUS showed subintimal wire position in part of CTO segment in 6(26.1%). In 22(95.7%) of cases IVUS allowed both the wire position verification in true lumen and the vessel measurement before stent implantation. In 1(4.3%) case a second wire was introduced into true lumen guided by IVUS after realising that the first wire was in false lumen. We could not find significant relation between calcium presence and subintimal wire penetration in CTO segment (p: 0.14)

Conclusions: IVUS showed calcium in CTO segment in a high percentage of cases. It is not unusual to find wire penetration in subintimal space in part of CTO segment. IVUS has a key contribution in the step by step interpretation during PCIs of CTO. Wire position verification and more precise vessel measurement can be easily done by IVUS.

Keywords: Percutaneous Coronary Intervention, Chronic Total Occlusion, Intravascular Ultrasound

Introduction

A chronic total occlusion (CTO) is defined as a significant atherosclerotic vessel narrowing with lumen compromise resulting in either complete interruption of antegrade flow in coronary angiography with TIMI 0 (Thrombolysis in Myocardial Infarction) also known as “true CTO”, or with minimal contrast through CTO segment but without distal vessel opacification (TIMI I), which is known as “functional CTO”. The temporal criterion used to define CTO has varied widely in different studies ranging from >2 weeks[1-2] to >3 months.[3] In general the criterion of more than 3 months duration is accepted for CTO in most of publications. Duration of occlusion is assessed on the basis of a history of acute coronary syndrome with ECG-documented ischaemia in the area supplied by the occluded vessel or by taking into account the last coronary angiography, which revealed patent target artery. It is difficult to determine the true prevalence of CTO in general population because a proportion of these patients are asymptomatic or minimally symptomatic and never undergo diagnostic coronary angiography.

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However different investigators have analysed its prevalence. Kahn JK documented 1 or more CTOs in approximately one third of patients during 1-year period.[4] Other data suggest that near one-half of patients with significant coronary artery disease on angiography have at least one CTO.[5] Since the first coronary angioplasty performed in 1977 by Andreas Gruentzig great progress have been experienced in interventional cardiology enabling percutaneous approach of acute coronary syndrome, bifurcated and ostial lesions, left main and restenosis lesions. CTO recanalization still remains technically challenging for invasive cardiologists and the presence of a CTO has been the most important reason to refer patients to bypass surgery as a mode of coronary revascularization.[6] During the last decade the combination of selective guidewires, specific devices and operator technique and experience have increased significantly the CTO successful recanalization rate such that it has reached in some experienced centres approximately 80%,[7] even in some experienced Japanese centres this percentage is around 90%. Intravascular ultrasound (IVUS) provides tomographic images of a coronary artery. IVUS studies have demonstrated that the passage of a guidewire into a subintimal space is a strong negative predictor contributing to CTO unsuccessful recanalization.[8,9] IVUS has become a main tool to guide the step by step management of CTO, making possible to verify the wire positioning in true lumen after wire successful passage through CTO, to measure precisely the vessel before stent implantation, and to perform a few complex techniques like control antegrade and retrograde subintimal tracking (CART)[10] in retrograde approach.

Patients and Methods

From February 2009 to August 2010 we performed 46 PCIs of CTO in 34 patients. The selection of cases was based on accepted definition of CTO both in term of angiographic findings and duration criterion. Patients without viability evidence in occluded vessel territory were excluded from this study. If there was evidence of even very mild amount of heterocoronary collaterals, contralateral injection was carried out with a 5F guiding catheter through radial approach, and the simple injection was reserved for patients with the only presence of homocollaterals. 7F o 8F guiding catheter by femoral approach was used to engage the occluded coronary artery. A floppy wire, in the majority of cases BMW (Abbott Vascular, USA), was advanced up to CTO proximal cap supported by a microcatheter (Finecross: Terumo Corporation, Tokyo, Japan; Corsair: Asahi Intecc, Aichi, Japan) or OTW balloon (Ryujin Plus OTW 1.25x10 mm: Terumo Coropora-

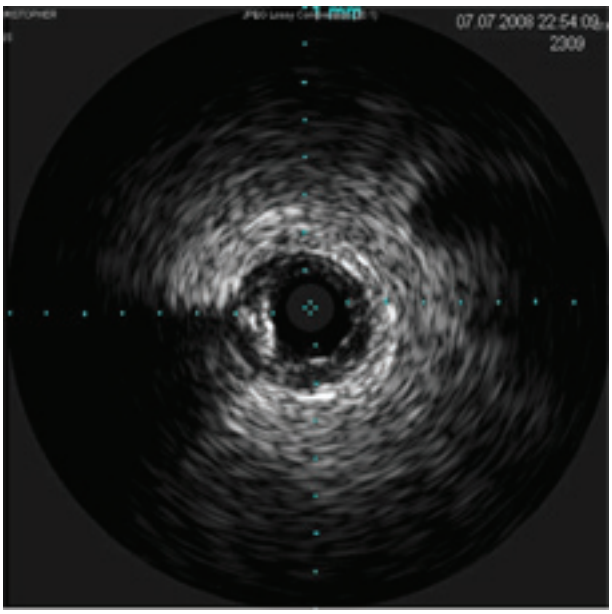

Figure 1. IVUS catheter is in true lumen surrounded by 3 layers intima, media and adventitia. The arrow shows a calcified plaque with its corresponding acoustic shadowing beyond arterial structures.

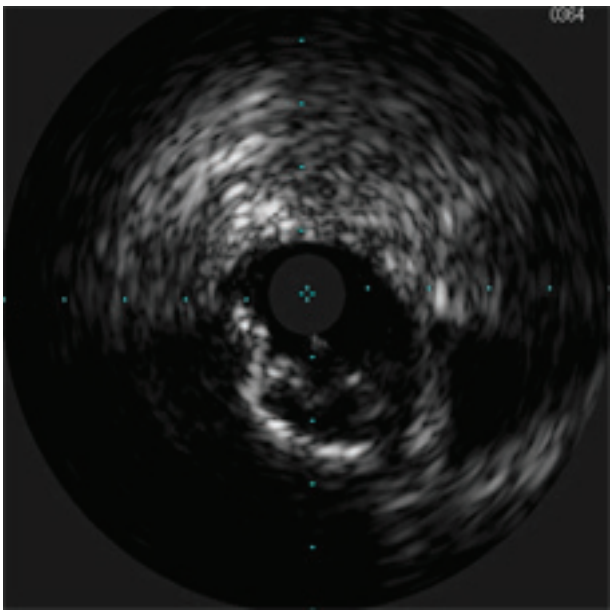

Figure 2. IVUS catheter is localised in false lumen in part of CTO segment. The arrow shows true lumen compressed by false lumen between 5 and 7 o'clock.

tion, Tokyo, Japan). After withdrawing the floppy wire a specific wire designed for CTO as Miracle family, Confianza pro 9-12 and Fielder XT (Asahi Intecc, Aichi, Japan) was advanced through microcatheter or OTW balloon trying to penetrate the CTO segment. In all cases the distal wire position was checked in two different orthogonal angiographic views in order to confirm or rule out the wire positioning in true lumen. Just after ensuring that the wire was distally in true lumen the CTO segment was tried to be crossed either by microcatheter or by OTW balloon. If the lesion was an uncrossable balloon one or the operator considered the CTO segment very tough a specific device like Tornus and/or Corsair(Asahi Intecc, Aichi, Japan) with counterclockwise rotation was used to penetrate and cross the CTO. After crossing the CTO segment the wire was exchanged immediately with a BMW or Runthrough NS Hypercoat (Terumo Corporation, Tokyo, Japan) through the microcatheter or OTW balloon and the procedure was continued over an atraumatic wire. The predilation with a small monorail balloon, normally 1.5 mm before IVUS examination was done. IVUS was performed in procedures with successful wire passage through CTO. The IVUS used in our cath lab was that of Volcano Corporation. IVUS catheter withdrawal was done from beyond CTO distal cap up to before proximal cap. The guidewire and IVUS catheter were considered to be in true lumen when 3 layers of intima, media and adventitia were all in a fully circumferential (360º) image. Calcium produced bright echoes, brighter than reference adventitia, with acoustic shadowing of deeper arterial structures (Fig. 1). IVUS images were reviewed many times after finishing the procedure in order to detect different morphologic features. IVUS contribution during procedure was studied as well. Finally the relation between calcium deposit in CTO segment and guidewire subintimal penetration was evaluated. The procedure was defined as successful when a TIMI III flow was reached in the occluded vessel after stent implantation with a residual stenosis less than 30%. Written informed consent was obtained from all patients.

Statistical analysis

Continuous variables were described by mean±SD and categorical variables were expressed as percentage. Chi-Square or Fisher's exact test was used to determine the relation between categorical variables. For data analysis SPSS version 15 (SPSS Inc. Chicago, Illinois, USA) was used. P less than 0.05 was considered statistically significant.

Results

Baseline and procedural characteristics are shown in Table 1. 43 (93.5%) of cases were males, 32 (69.6%) had hypertension, 37 (80.4%) hypercholesterolemia, 28 (60.9%) diabetes, and 35 (76.1%) were smoker or former smoker. The mean age was 61±11 years (36-78 years). In 27 (58.7%) of cases bilateral injection was used during the procedure in order to visualize distally occluded vessel through heterocollaterals provided by donor artery and in 19 (41.3%) just one side injection was carried out. Amid 46 procedures 42 were performed by antegrade approach, 1 by retrograde and 3 by both antegrade and retrograde access. The distribution of vessel treated was the following: LAD 15 (32.6%), LCX 12 (26.1) and RCA 19 (41.3%). In 32 (69.6%) of cases the wire successfully crossed the CTO segment up to distal segment and in 14 (30.4%) the wire did not cross the CTO. In 19 (41.3%) of cases special devices like Tornus and/or Corsair (Asahi Intecc, Aichi, Japan) were used to penetrate and cross CTO segment after wire successful passage into distal part of occluded vessel. The procedure was successful in 28 (60.9%) of cases. As a few patients had more than one attempt to recanalize a CTO the success rate per patients

Table 1. Baseline and procedural characteristics

		PCI (n= 46)
Male		43 (93.5%)
Age		61±11
Smoker/former smoker		35 (76.1%)
Diabetes mellitus		28 (60.9%)
Hypertension		32 (69.6%)
Hypercholesterolemia		37 (80.4%)
Treated vessel	**LAD**	15 (32.6%)
	LCX	12 (26.1%)
	RCA	19 (41.3%)
Injection	**Bilateral**	027(58.7%)
	Unilateral	19(41.3%)
Approach	**Antegrade**	42(91.3%)
	Retrograde	1(2.2%)
	Antegrade and retrograde	3(6.5%)
CTO wire passage		32(69.6%)
Procedural success rate		28(60.9%)
Special devices (Tornus and/or Corsair)		19(41.3%)

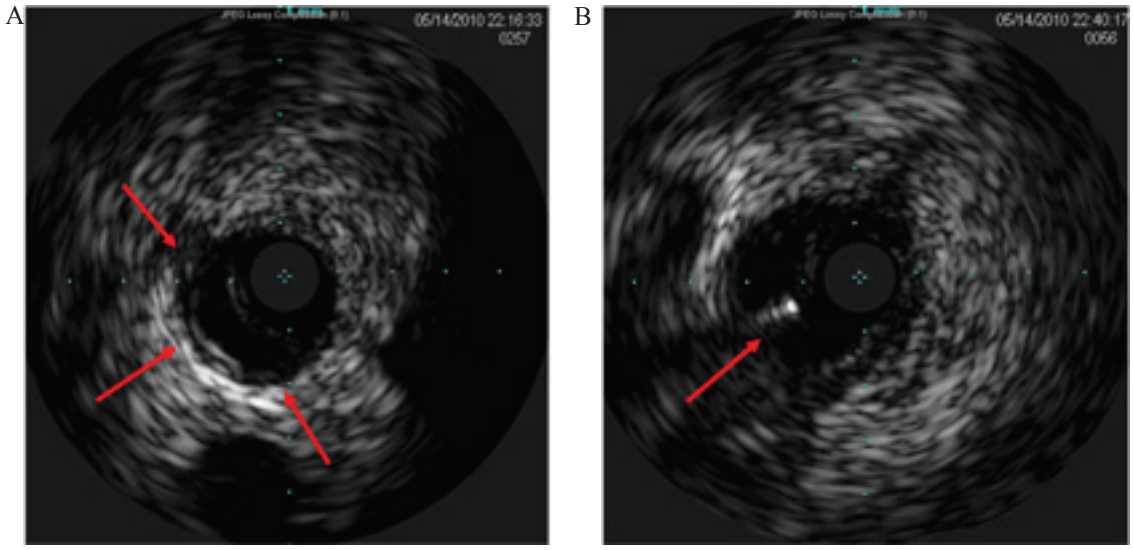

Figure 3. 3A. IVUS catheter is in false lumen. The arrow shows true lumen separated by intima from false lumen. 3B. A second wire is being addressed into true lumen guided by IVUS

was 82%. IVUS was performed in 23 (82.1%) of a total 28 successful procedures. (Table 2) IVUS found calcium somewhere in 17 (73.9%) of cases. In 17 (73.9%) of cases the wire was localised entirely in true lumen in CTO segment and in remaining 6 (26.1%) cases the wire entered into subintimal space in part of CTO segment (Fig. 2) and re-entered more distally into true lumen. In all these 6 cases IVUS showed calcium in some part of CTO segment. Between 17 (73.9%) cases with wire position in true lumen in CTO segment 6(35.3%) did not showed calcium by IVUS examination and in 11(64.7%) there was evidence of calcium. We did not find any statistical relation between the presence of calcium and subintimal wire penetration in CTO segment (N: 0.14). In 22 (95.7%) of cases IVUS allowed both the wire positioning verification in true lumen and the precise vessel measurement before stent implantation. In 1 (4.3%) case a second wire was introduced into true lumen guided by IVUS after realising that the first wire was in false lumen. (Fig. 3)

Table 2. IVUS features and contribution analysis

		IVUS/successful PCI (n=23/28)
IVUS performance	Yes	23 (82.1)
	No	5 (17.9)
Calcium	Yes	17 (73.9)
	No	6 (26.1)
Wire position in CTO segment	True lumen	17 (73.9)
	False lumen	6 (26.1)
IVUS contribution	WPV* and VM**	22 (95.7)
	IVUS guided wire reentrance	1 (4.3)

*Wire position verification in true lumen; ** vessel measurement

Discussion

PCI of CTOs is very different from other kind of angioplasty even in patients with complex anatomy in terms of technical aspects, procedural time, radiation exposure and complications. CTO-PCI requires its own training and the need of performing a minimum procedure volume per year in order to maintain the operator skills. In some experienced centres the presence of CTO is not yet a determinant factor to refer patients to bypass surgery. Many new techniques made possible percutaneous approach of complex CTOs. Retrograde approach using septal collaterals has become a usual practice in experienced hands. By this way septal collaterals provided by donor artery are used to lead to occluded vessel after wire crossing from donor artery to occluded artery distal segment and after septal dilation with a 1.25 mm balloon at low atmosphere.[11] The combination of antegrade and retrograde approach has still increased more the success rate of CTO-PCI. René J et al.[12] studied 1417 patients admitted to hospital for ST-elevation myocardial infarction (STEMI) undergoing primary angioplasty and they hypothesized that the effect

of multivessel disease (MVD) on mortality is due to the presence of a CTO in a noninfarct- related artery. They concluded that patients with STEMI and MVD have higher 1-year mortality rate compared with patients with single vessel disease (SVD) which is mainly determined by the presence of a CTO in a noninfarct-related artery. Zoran Olivar et al.[13] studied 12 months follow up of successful CTO recanalization comparing with that of unsuccessful CTO opening in 376 patients and they showed that patients with successful CTO-PCI had significantly lower incidence of cardiac deaths or myocardial infarction, reduced need for coronary bypass surgery and were more frequently free of angina than those whose PCI was unsuccessful. PCI of CTO has its own technical difficulties and in many cases a large segment of coronary artery occluded should be covered by stent. IVUS provides many important additional information and allows interventional cardiologists to optimize the final results. In the present study IVUS has been used in 82% of all successful PCIs which we consider a high percentage and it is similar to that used in a few centres where IVUS has become a routine exploration during PCI of CTO. The precise vessel measurement by IVUS and finally an adequate stent size selection is a very important point in PCI of CTOs taking into account that the operator is treating an artery which has been hypoperfused for a long time and angiographically it may look smaller than its real size. This should be considered technically very important and one of the IVUS contributions to PCI of CTOs. IVUS shows additional information about the calcification in CTO segment and we found calcium somewhere in 73% of cases although we did not define the calcium load. The interesting point and this is probably a peculiarity of CTO-PCI, is that despite the distal vessel wire position in true lumen IVUS examination showed that in 26% of cases the wire had entered into subintimal space in part of CTO segment. Kennichi Fujii et al.[14] in a study of 67 CTOs examined by IVUS detected calcium somewhere in 96% and the evidence of intramural haematoma in 34% suggesting that the wire frequently entered the medial space during successful racanalization. They also found a significant relation between long calcified lesions and the incidence of intramural haematoma formation indicative of guidewire penetration into the medial space during the CTO procedure. In one case of our study we observed that the guidewire was distally apparently positioned in true lumen according to angiographic view but IVUS revealed that guidewire was in false lumen in a large segment beyond CTO segment and we could reintroduce a new wire guided by IVUS into true lumen withdrawing the first wire with subsequent stent implantation with good final angiographic result (Fig. 4). This technique has been described and used by Japanese interventional cardiologists and consists of positioning the IVUS catheter as more proximally as possible trying to find the point where the wire entered in false lumen and to penetrate a second wire guided by IVUS into true lumen and finish the procedure over this second wire. This interesting and complex technique allows us to avoid stent implantation in false lumen and an eventual vessel occlusion distally. Our study findings are similar to those in which IVUS examination showed that subintimal space wire penetration just in part of CTO segment due to specific and penetrating guidewires use in this kind of procedures is not unusual. Also, in the same time it reveals the safety of balloon predilation and stent implantation after ensuring angiographically and by IVUS that the guidewire is in true lumen beyond CTO segment. There are various limitations

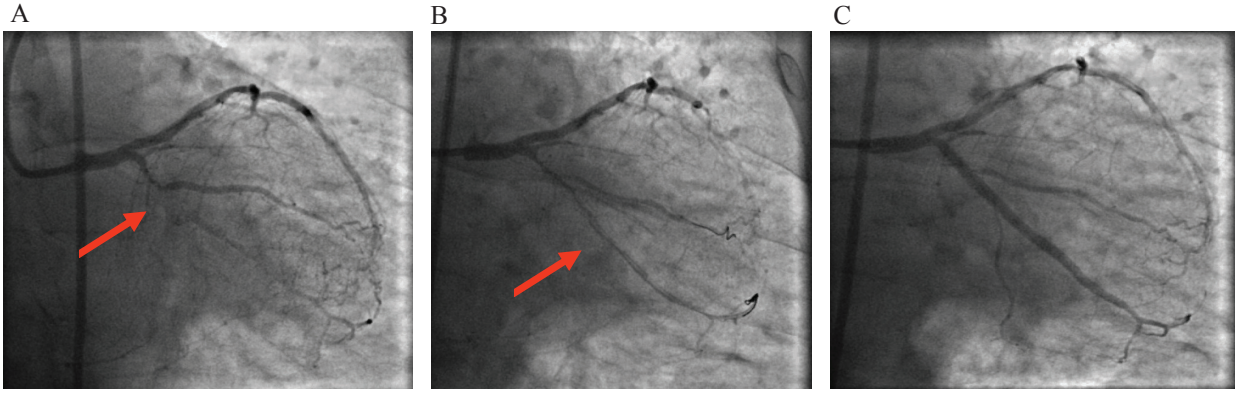

Figure 4. 4A. left circumflex proximal segment total occlusion with homocollaterals filling in distal segment. 4B. A second wire is reintroduced into true lumen guided by IVUS after detecting a large dissection. 4C. Angiographic final result after stent implantation over the second wire.

in our study. The small number of its patients and the fact that it is a retrospective study and we have not sought prospectively calcium deposits by IVUS and its correlation with angiographic calcium visualization. Besides in Kennichi Fujii et al. study calcium deposit was measured taking into consideration the largest arc of each calcium deposit graded on a scale 1 to 4 (expressed from 0º to 360º) and calcium length graded on 1 to 3 (ranging from 1 to >10 mm). Finally the calcium index for each calcium deposit was determined as the arc multiplied by the length grade. This is a more precise method to measure and grade calcium presence in CTO segment which has not been used in our study. The higher calcium percentage in Kennichi Fujii et al. study comparing with that of our study is probably due to more precise method to determine calcium index in their study. The reduced number of cases in our study could explain the absence of calcified lesion relation with the guidewire penetration into false lumen.

In conclusion IVUS highlights many key points during PCI of CTOs, allows precise vessel measurement, detects calcium deposit, determines wire position in and beyond CTO segment, and permits appropriate stent size selection. Besides, IVUS makes possible in some cases to re-enter a second guidewire after verifying the first wire positioning in false lumen. IVUS utilization makes CTO-PCI safer and optimizes the final results and finally avoids eventual complications. We do believe that its use should be more frequent in PCI of CTOs.

Conflicts of Interest no declare.

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