JACC: CARDIOVASCULAR INTERVENTIONS VOL. 2, NO. 9, 2009
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ISSN 1936-8798/09/$36.00
PUBLISHED BY ELSEVIER INC. DOI: 10.1016/j.jcin.2009.06.012

Intravascular Ultrasound Comparison of the Retrograde Versus Antegrade Approach to Percutaneous Intervention for Chronic Total Coronary Occlusions

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Objectives We sought to evaluate the results of the antegrade versus retrograde chronic total occlusion (CTO) technique with intravascular ultrasound (IVUS) imaging.

Background The most common failure mode of CTO interventions remains the inability to successfully cross the occlusion with a guidewire. Recently, the retrograde approach through collateral channels has been introduced to cross complex CTOs.

Methods Between October 2002 and April 2008, IVUS was performed in 48 de novo CTO lesions after guidewire crossing ± pre-dilation with a 1.5- to 2.0-mm balloon. Twenty-three lesions were treated via the antegrade approach (Ante), and 25 lesions were treated via the retrograde approach (Retro).

Results Right coronary artery (RCA) CTOs were treated more frequently via the Retro technique. Although the CTO length was much longer in the Retro group (45 ± 26 mm vs. 18 ± 9 mm, $p < 0.0001$), at the end of the procedure Thrombolysis In Myocardial Infarction flow grade 3 was obtained in all patients. There were no significant differences between the 2 groups in minimum stent area and stent expansion. However, the incidence of the composite end point—subintimal wiring, angiographic extravasation, coronary hematoma, or IVUS-detected coronary perforation—was higher in the Retro group (68% vs. 30%, $p = 0.01$); and the guidewire was more often subintimal in the Retro group (40% vs. 9%, $p = 0.02$).

Conclusions The retrograde approach is a promising option for complex CTO segments, especially long RCA CTOs. Intravascular ultrasound can be a useful tool for the detection of procedure-related vessel damage and subintimal wire tracking. (J Am Coll Cardiol Intv 2009;2:846–54) © 2009 by the American College of Cardiology Foundation

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Manuscript received February 14, 2009; revised manuscript received May 26, 2009, accepted June 25, 2009.

Successful treatment of chronic total (coronary) occlusions (CTOs) leads to an improvement in anginal status, improvement of left ventricular function, avoidance of bypass surgery, and lower mortality (1–6). Procedural success rates of percutaneous coronary intervention (PCI) in CTOs have increased steadily because of greater operator experience, equipment improvements, and newer procedural techniques (4,7). Concomitantly, there has been a reduction in the CTO restenosis rate with the advent of drug-eluting stents (8–11). Despite these observations, CTOs remain the lesion subtype in which PCI is most likely to fail, primarily because of the inability to advance a guidewire across the lesion into the true distal vessel lumen of the distal vessel (12,13). Instead, the guidewire enters a subintimal space, often making it impossible to re-enter the distal true lumen. The retrograde approach through collateral channels is the newest PCI technique for CTO lesions (14). Its procedural efficacy and safety have not yet been well-studied. We used intravascular ultrasound (IVUS) to compare: 1) guidewire manipulation-related vessel injury; and 2) acute results between the conventional antegrade approach and the innovative retrograde approach to CTO-PCI.

Methods

Study population and patient demographic data. From October 2002 to April 2008, 332 de novo native coronary artery CTO lesions were treated by a single expert interventional cardiologist (MO) at 11 Asian and Italian hospitals. Successful recanalization was obtained in 287 lesions (86%). To compare guidewire manipulation-related vessel injury, exclusion criteria included use of a novel penetration device (Tornus, Asahi Intecc, Nagoya, Japan), rotational atherectomy, and >2-mm balloon dilation before IVUS imaging. Overall, 51 lesions (49 patients) underwent both post-recanalization (after guidewire crossing ± pre-dilation with a 1.5- to 2.0-mm balloon) and final (post-stent) IVUS imaging. We excluded 2 lesions in which the IVUS catheter could not be advanced into the distal vessel (beyond the CTO) and 1 lesion with inadequate IVUS images. Finally, 48 lesions (46 patients) were included in the current study. At the discretion of the operator, 23 lesions were treated via the antegrade approach (Ante) and 25 via the retrograde approach (Retro). Indications for the retrograde approach included: 1) occlusion length >20 mm (visual evaluation); 2) visible, continuous collaterals; 3) healthy collateral-supplying vessel; and 4) reattempt after previous CTO-PCI failure. In 1 Retro patient wiring was switched from antegrade to retrograde, because the antegrade guidewire entered a false lumen; there were no other "cross-overs."

Patient demographic data were confirmed by hospital chart review. Coronary risk factors included diabetes mellitus (diet-controlled, oral agent, or insulin-treated), hypertension (medication-treated only), hyperlipidemia (medication-treated or a measurement >220 mg/dl), cigarette smoking, and family history of coronary artery disease. Written informed consent was obtained from all patients.

A CTO was an obstruction of a native coronary artery with no luminal continuity and with Thrombolysis In Myocardial Infarction (TIMI) flow grade 0 having an estimated occlusion duration of ≥3 months (15) determined as the interval from the last diagnostic coronary angiogram documenting a CTO (n = 23) or from the first onset of ischemic clinical symptoms in patients without a previous angiogram (n = 25).

Retrograde approach. Details regarding the retrograde approach have been reported (15). Briefly, retrograde wiring is performed with a dedicated, microcatheter-supported slippery guidewire from the collateral-supplying vessel through the collaterals into the distal vessel. Then, the retrograde guidewire is steered proximally through the CTO to the antegrade guiding catheter (retrograde wire crossing technique) (Fig. 1A). Alternatively, the retrograde guidewire is used as a marker to cross the CTO from the antegrade direction (kissing wire technique) (Fig. 1B). If the retrograde guidewire enters a false lumen, controlled antegrade and retrograde subintimal tracking (CART) technique can be used; balloons are advanced over the antegrade and/or retrograde guidewires, followed by aggressive dilation to create dissections to connect the antegrade-wired and retrograde-wired lumens (14).

IVUS imaging and analysis. The IVUS was performed immediately after crossing with an antegrade guidewire in 5 lesions or after dilation with a 1.5- to 2.0-mm balloon and 0.1 to 0.2 mg of intracoronary nitroglycerin in 43 lesions with commercially available IVUS systems (Boston Scientific Corp., Natick, Massachusetts; Volcano Therapeutics, Inc., Rancho Cordova, California). The IVUS catheter was advanced beyond the CTO segment and withdrawn at a pullback speed of 0.5 or 1.0 mm/s automatically. The IVUS images were recorded onto digital media for offline analysis. All studies were reviewed frame by frame. Qualitative IVUS analysis was performed by independent experienced observers (K.T. and A.M.), and the consensus interpretation was included in the analysis. Qualitative and quantitative analysis was done according to the American College of Cardiology Clinical Expert Consensus Document on Standards for Acquisition, Measure-

Abbreviations and Acronyms

Ante = antegrade approach

CART = controlled antegrade and retrograde subintimal tracking

CI = confidence interval

CSA = cross-sectional area

CTO = chronic total (coronary) occlusion

EEM = external elastic membrane

IVUS = intravascular ultrasound

MSA = minimum stent area

OR = odds ratio

PCI = percutaneous coronary intervention

Retro = retrograde approach

TIMI = Thrombolysis In Myocardial Infarction

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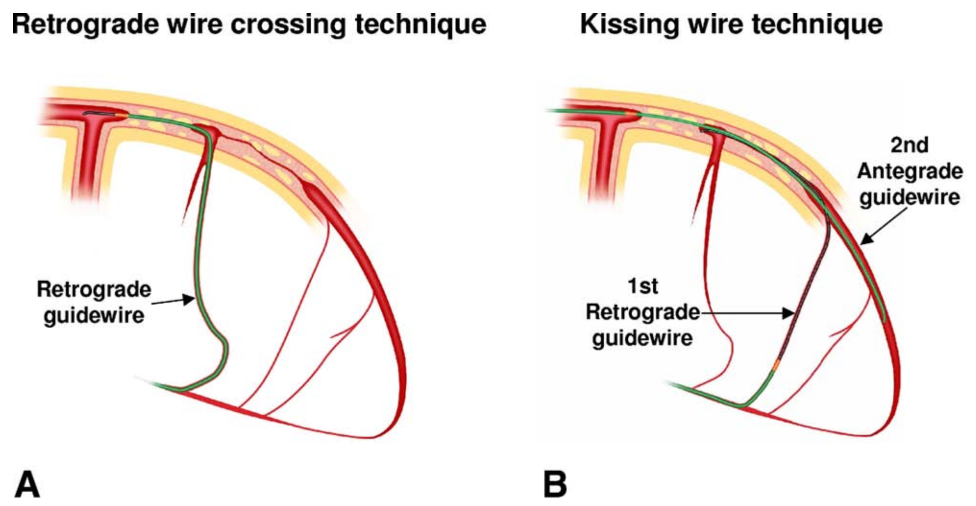

Figure 1. Basic Concept of Retrograde Approach

(A) Retrograde wire crossing technique: retrograde wiring is performed with a dedicated slippery guidewire with microcatheter from the collateral-supplying vessel into the distal vessel. Then, the retrograde guidewire is steered proximally, ideally to the antegrade guiding catheter. **(B)** Kissing wire technique: the retrograde guidewire can also be used as a marker when crossing the chronic total occlusion lesion from the antegrade direction. Finally, both the antegrade and retrograde guidewires link up with each other; and the antegrade guidewire is advanced to the distal vessel. Figure is courtesy of Dr. M. Ochiai.

ment, and Reporting of Intravascular Ultrasound Studies (16). With planimetry software (EchoPlaque, INDEC Systems, Inc., Mountain View, California), quantitative IVUS analysis was performed at the CTO and proximal and distal reference segments to include: external elastic membrane (EEM), lumen, plaque and media (EEM minus lumen) cross-sectional area (CSA), and plaque burden (plaque and media divided by EEM). Lengths were calculated from the pullback speed and duration. Post-stenting minimum stent CSA (MSA) was measured, and stent expansion (MSA divided by average reference lumen area) and stent symmetry index (minimum divided by maximum stent diameter) were calculated.

Representative IVUS images are shown in Figure 2. Subintimal wiring was an IVUS catheter location in the subintimal space—a lumen without all 3 arterial wall layers accompanied by collapse of the true lumen. Intravascular ultrasound–detected coronary perforation was blood speckle outside the vessel and/or tear of the adventitia. Hematoma was an accumulation of a typical, crescent-shaped homogeneous, hyperechoic blood-containing structure either within or outside the media. Calcium was bright echoes (brighter

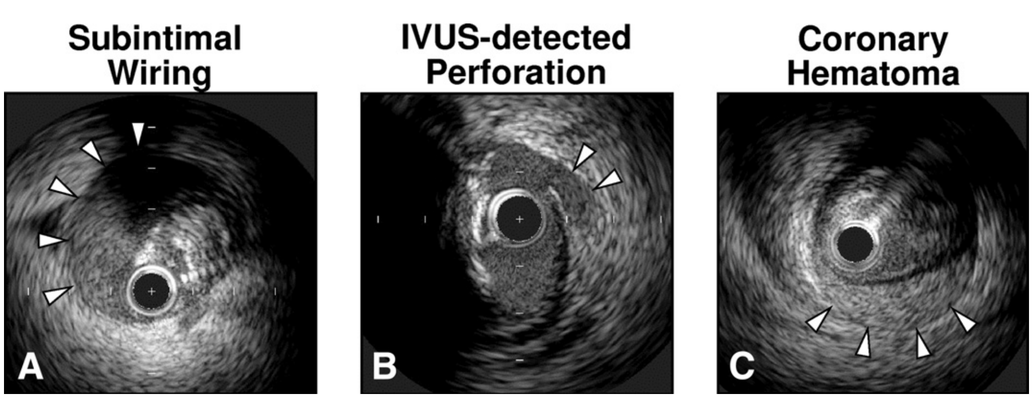

Figure 2. Representative IVUS Images

(A) Subintimal wiring was defined as the intravascular ultrasound (IVUS) catheter located in the subintimal space (**arrowheads**, absence of arterial wall 3 layers) (note the collapsed true lumen at 2 o'clock). **(B)** The IVUS-detected coronary perforation was defined as blood speckle outside the vessel **(arrowheads)** and/or tear of the adventitia despite a lack of angiographic extravasation. **(C)** Coronary hematoma was defined as an accumulation of blood **(arrowheads)** recognized typically as a crescent-shaped homogeneous hyperechoic structure with straightening of the internal elastic membrane.

than the adventitia) that shadowed deeper tissues; the maximum arc of calcium was measured with an electronic protractor centered on the lumen (16).

Angiographic analysis. Cineangiograms were analyzed with a computer-assisted, automated edge-detection algorithm (CMS, Medis, Leiden, the Netherlands) by independent observers unaware of the clinical and IVUS data. The length of occlusion was measured with either antegrade or retrograde (during bilateral simultaneous injection) filling of the distal vessel (8). Collateral flow was graded according to Rentrop's classification (17).

Statistical analysis. Statistical analysis was performed with SPSS version 10.0 software (SPSS Inc., Chicago, Illinois). Continuous variables (mean ± 1 SD) were compared with unpaired Student *t* test or Mann-Whitney *U* test. Categorical variables (frequencies) were compared with chi-square statistics or the Fisher exact test. Logistic regression analysis was employed to determine predictors of subintimal guidewire passage and of the composite end point of subintimal wiring, angiographic extravasation, coronary hematoma (intramural or extramural), or IVUS-detected coronary perforation. Significant variables ($p < 0.05$ in the univariate analysis) were entered into multivariate analysis. A p value <0.05 was considered significant.

Results

Patient characteristics. Patients in both groups had advanced atherosclerosis with multiple coronary risk factors (Table 1). Right coronary artery CTOs were treated more frequently retrograde, and left circumflex coronary artery CTOs were treated more frequently antegrade ($p = 0.04$). The rate of multivessel disease was significantly higher in the Retro group. Eight of the 25 Retro patients (32%) had a failed previous CTO-PCI. The CART technique was used in 11 of 25 Retro patients (44%).

Pre-procedural angiographic findings. The CTO lesion and occlusion length were longer in the Retro group than in the Ante group (Table 2). In the Retro group, well-developed collaterals to the distal vessel were via a bypass graft in 2 of 25 (8%), an epicardial channel in 4 of 25 (16%), or an intraseptal channel in 19 of 25 patients (76%). A non-tapered proximal stump or origin of a side branch at the proximal occlusion was more common in the Retro group.

Post-procedure IVUS and angiographic findings and acute results. As shown by IVUS (Table 3), there were no significant differences in maximum arc of calcium within the CTO length between Retro and Ante groups (137 ± 99° vs. 115 ± 72°, $p = 0.78$). The guidewire was more often subintimal in the Retro group (40% vs. 9%, $p = 0.02$). Once the guidewire entered the subintimal space, the guidewire stayed in the subintimal space over a longer length in the Retro group. However, the subintimal course of the guidewire was limited to the CTO, and the guidewire re-entered the distal true lumen beyond the distal end of the CTO in all cases. In the univariate analysis retrograde approach (odds ratio [OR]: 7.0, 95% confidence interval [CI]: 1.3 to 36.7, $p = 0.02$), CART technique (OR: 6.2, 95% CI: 1.4 to 27.1, $p = 0.02$) and long CTO length (OR: 1.3, 95% CI: 1.0 to 1.7, $p = 0.049$) correlated with subintimal wiring; in the multivariate analysis, only retrograde approach tended to be a predictor of subintimal guidewire course (OR: 5.1, 95% CI: 0.8 to 33.4, $p = 0.09$). However, there was not a sufficient number of subintimal wiring cases to evaluate independent predictors with multivariate analysis. Candi-

Table 1. Clinical Demographic Data

Variable	Ante Group (n = 23)	Retro Group (n = 25)	p Value
Male	20 (87%)	23 (92%)	0.66
Age, yrs	62 ± 10	60 ± 11	0.60
Body mass index ≥25 kg/m^2	13 (57%)	9 (36%)	0.15
Hypertension	14 (61%)	16 (64%)	0.82
Hyperlipidemia	9 (39%)	16 (64%)	0.08
Diabetes mellitus	12 (52%)	9 (36%)	0.26
Cigarette smoking	14 (61%)	14 (56%)	0.73
History of coronary artery bypass grafting	2 (9%)	4 (16%)	0.67
Family history of coronary artery disease	6 (26%)	4 (16%)	0.39
Location of CTO			0.04
Right	10 (44%)	19 (76%)	
Left anterior descending	7 (30%)	5 (20%)	
Left circumflex	6 (26%)	1 (4%)	
Multivessel disease	8 (35%)	20 (80%)	0.002
Reattempt after previous CTO intervention failure	0	8 (32%)	0.004

Values are n (%) or mean ± SD.
Ante = antegrade approach; CTO = chronic total (coronary) occlusion; Retro = retrograde approach.

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Table 2. Angiographic Findings

Variable	Ante Group (n = 23)	Retro Group (n = 25)	p Value
Preprocedural findings			
Lesion length, mm	37.4 ± 18.8	61.2 ± 22.3	0.0002
Occlusion length, mm	17.6 ± 8.6	45.0 ± 26.0	<0.0001
Rentrop's classification >2	7 (30%)	19 (76%)	0.002
Angiographic morphology of CTO segment			
Abrupt morphology of stump	3 (13%)	11 (44%)	0.02
Side branch arising from stump	4 (17%)	17 (68%)	0.0004
Angiographic calcification	3 (13%)	9 (36%)	0.07
Bridging collateral	4 (17%)	5 (20%)	>0.99
Postprocedural findings			
Reference diameter, mm	3.24 ± 0.47	3.16 ± 0.32	0.78
Minimum lumen diameter, mm	2.61 ± 0.41	2.55 ± 0.28	0.79
Diameter stenosis, %	19.5 ± 5.9	19.0 ± 6.5	0.57

Values are mean ± SD or n (%).
Abbreviations as in Table 1.

date variables entered into the model included angiographic features (CTO length, right coronary artery CTO, abrupt occlusion site morphology, side branch at occlusion site, and angiographic calcification) and procedural details (retrograde approach, CART technique, and pre-IVUS balloon use). The CART technique was excluded from the multivariate analysis because CART was part of the retrograde approach. Although the procedural concept of the CART technique involves deliberate subintimal wiring, subintimal guidewire passage was not observed in 5 of 11 CART technique cases (45%).

The influence of CTO length on subintimal wiring is shown in Figure 3. Patients were divided into CTO length quartiles (<14.8 mm, 14.8 to 21.9 mm, 21.9 to 40.1 mm, >40.1 mm). With increasing CTO length, the frequency of subintimal wiring also tended to increase; in the longest CTO quartile subintimal wiring was observed in 50%.

The IVUS and angiographic findings are summarized in Figure 4. We defined a composite end point as the combination of subintimal wiring, angiographic extravasation, coronary hematoma (intramural or extramural), or IVUS-detected coronary perforation. This composite end point was more common in the Retro group (68% vs. 30% in the Ante group, p = 0.01). However, no additional therapy was needed in the 24 patients who had 1 of these findings, including 2 Retro group patients with angiographic contrast extravasation who were managed conservatively without additional intervention. None of the IVUS-detected coronary perforations was recognized angiographically. Table 4

Table 3. IVUS Findings

Variable	Ante Group (n = 23)	Retro Group (n = 25)	p Value
"Baseline" IVUS measurements*			
Maximum arc of calcium, °	115 ± 72	137 ± 99	0.78
Subintimal wiring			
Prevalence of subintimal wiring	2 (9%)	10 (40%)	0.02
Length of subintimal wiring, mm	1.1 ± 0.3	28.9 ± 16.8	0.04
Proximal reference-segment EEM CSA, mm^2	16.1 ± 3.8	18.5 ± 4.9	0.21
Proximal reference-segment lumen CSA, mm^2	8.1 ± 2.3	9.4 ± 2.8	0.35
Distal reference-segment EEM CSA, mm^2	11.4 ± 4.9	6.9 ± 2.6	<0.005
Distal reference-segment lumen CSA, mm^2	5.9 ± 2.3	4.2 ± 1.4	0.04
Post-stenting IVUS measurements			
Minimum stent CSA, mm^2	5.8 ± 2.3	5.0 ± 1.3	0.54
Stent expansion	0.84 ± 0.25	0.79 ± 0.21	0.68
Stent symmetry index	0.85 ± 0.08	0.89 ± 0.06	0.06

Values are mean ± SD or n (%). *Immediately after wiring or after pre-dilation with a 1.5- to 2.0-mm balloon.
CSA = cross-sectional area; EEM = external elastic membrane; IVUS = intravascular ultrasound; other abbreviations as in Table 1.

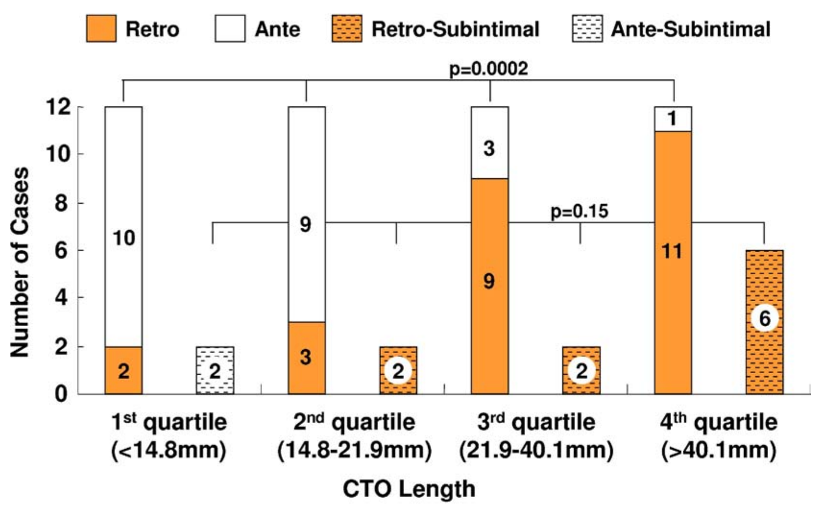

Figure 3. Influence of CTO Length on Technique Selection and Subintimal Wiring

The retrograde technique was selected more frequently with increasing chronic total occlusion (CTO) length. The frequency of subintimal wiring also tended to increase with increasing CTO length. In the longest CTO quartile, the subintimal wiring was observed in 50% of the CTO lesions. Ante = antegrade approach; Retro = retrograde approach.

shows univariate and multivariate predictors of this composite end point. Candidate variables were the same as analysis of subintimal wiring (see the preceding text). In the univariate analysis retrograde approach, CART technique and right coronary artery CTO correlated with the composite end point similar to predictors of subintimal wiring; in the multivariate analysis only right coronary artery CTO was a significant predictor of the composite end point, although the retrograde approach just missed statistical significance.

As shown in Tables 2 and 3, angiographic and IVUS findings were favorable at the end of the procedure in both groups with TIMI flow grade 3 in all patients regardless of the approach. Although total stent length was significantly longer in the Retro group (84 ± 21 mm vs. 42 ± 24 mm, $p < 0.0001$), reflecting longer CTO and lesion lengths,

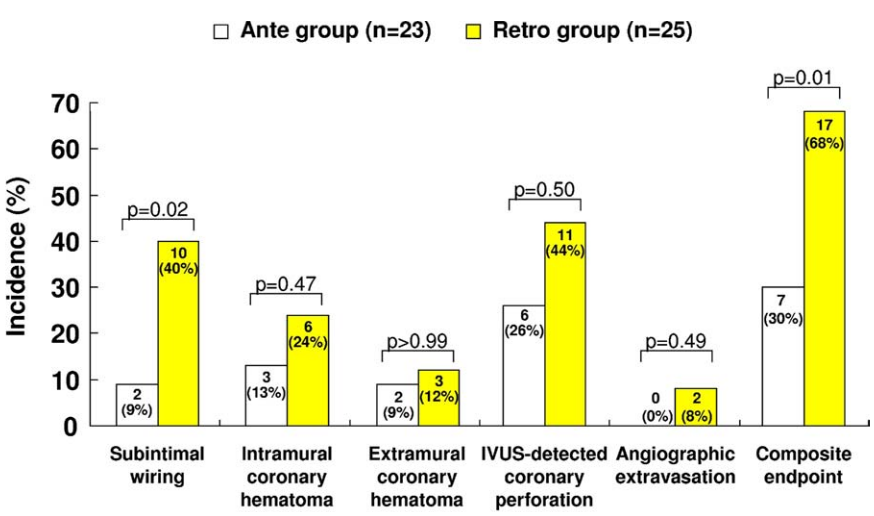

Figure 4. Comparison of Ante Versus Retro

The retrograde approach (Retro) group had significantly higher incidence of composite end point—defined as a combination of subintimal wiring, angiographic extravasation, coronary hematoma (intramural or extramural), or intravascular ultrasound (IVUS)-detected coronary perforation (68% vs. 30%, p = 0.01). Ante = antegrade approach.

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Table 4. Predictors for Composite End Point

	Univariate Analysis		Multivariate Analysis	
Variable	OR (95% CI)	p Value	OR (95% CI)	p Value
Retrograde approach	4.85 (1.43–16.48)	0.01	3.56 (0.98–13.00)	0.054
CART technique	6.58 (1.25–34.95)	0.03	—	—
CTO length, cm	1.22 (0.94–1.58)	0.14	—	—
Side branch arising from stump	1.67 (0.53–5.26)	0.38	—	—
Abrupt morphology of stump	2.28 (0.63–8.26)	0.21	—	—
Right coronary artery CTO	5.32 (1.48–19.07)	0.01	3.92 (1.02–15.03)	0.046
Angiographic calcification	4.20 (0.97–18.18)	0.06	—	—
Pre-IVUS balloon use	4.61(0.47–44.60)	0.19	—	—

CART = controlled antegrade and retrograde subintimal tracking; CI = confidence interval; CTO = chronic total coronary occlusion; OR = odds ratio.

post-procedural angiographic minimum lumen diameter, IVUS MSA, and stent expansion were comparable between the 2 groups.

There were no post-procedural adverse events such as death, myocardial infarction, urgent bypass graft surgery, or repeated PCI.

Discussion

Older occlusions, greater CTO length, a nontapered stump, origin of a side branch at the occlusion site, and calcification negatively affect the ability to successfully cross a CTO (18–20). A consensus document reported that procedural success rates dropped to <60% to 70% in the presence of 1 or more these unfavorable predictors (15).

Katsuragawa et al. (21) reported a small recanalized lumen surrounded by loose fibrous tissue within the CTO segment in tapering-origin, but not in abrupt-origin occlusions that were also frequently located just distal to a side branch. Fujii et al. (22) demonstrated that CTO calcium was mainly located opposite the side branch take-off. This explained the difficulty with the antegrade guidewire approach in abrupt-origin type CTO origins; the guidewire often preferentially entered the side branch.

Autopsy studies (21,23) demonstrated neovascular microchannels within CTO lesions—some extending from the proximal to the distal lumen, but others leading to small side branches or vasa vasorum in the vessel wall. When the antegrade guidewire entered a channel that extended to vasa vasorum, a subintimal false lumen was formed. It is unlikely that a retrograde guidewire will enter a microchannel originating from the proximal lumen.

With the antegrade approach the proximal and distal fibrous caps act as barriers forcing the guidewire to enter the subintimal space (24). The proximal cap of CTO lesions is believed to be harder than the distal cap (25,26). Although the present study showed that subintimal guidewire passage was associated with the retrograde technique (10 of 25 patients, 40%), the retrograde guidewire did not necessarily enter the subintimal space at the distal cap but more often at the site of hard plaque and/or calcification in longer CTO segments (6 of 10 patients, 60%).

The presence and tortuosity of collaterals are key issues in selecting a retrograde interventional strategy when treating CTOs. Nontortuous septal collaterals are preferentially used for the retrograde approach, whereas epicardial and/or tortuous collaterals are at higher risk for procedure-related vessel trauma. As a CTO lesion grows older, collateral vessels develop and become less tortuous. In the present study, visible, continuous collaterals were more common in the Retro group than in the Ante group. Rathore et al. (27) recently showed that conventional unfavorable predictors for successful antegrade CTO recanalization such as greater occlusion length did not have any significant impact on procedural success of retrograde CTO recanalization. Thus, indications for the retrograde approach would include longer lesion length, developed collaterals with a healthy donor vessel, and reattempt at recanalization. Conversely, a relatively short CTO with tortuous and discontinuous or epicardial collaterals would be preferentially managed with the antegrade approach.

An IVUS can be used to insure that the guidewire is in the distal true lumen, to optimize acute results (MSA and stent expansion) and to help to direct guidewire manipulation by identifying the optimal entry point in an abrupt-type occlusion with an adjacent side branch or the true distal vessel from a false lumen (28). The IVUS is superior to angiography in the detection of vessel wall damage during PCI of nonocclusive lesions (29,30). In the current study most intramural/extramural hematomas and/or perforations were not detected angiographically, partly because angiographic dissections precluded accurate evaluation of other complication morphologies. Intravascular ultrasound–detected coronary hematomas have been shown to be associated with an increased rate of non–Q-wave myocardial infarction and need for repeat revascularization if appropriate treatment (e.g., coverage by stenting) was not performed

(30). Some of these injuries (e.g., IVUS-detected extramural coronary hematoma or perforation) can evolve to angiographic free perforation either directly from guidewire manipulation or from subsequent ballooning or stenting (31,32). One recent IVUS report indicated that subintimal drug-eluting stent implantation during a CTO-PCI caused multiple late-acquired malappositions due to coronary aneurysm formation (33). Furthermore, Erlich et al. (34) have reported a case of acute stent thrombosis after multiple subintimal stenting. Thus, when these arterial wall injuries or subintimal stenting are detected by IVUS during the procedure, careful short- and long-term clinical follow-up and strict dual antiplatelet therapy should be recommended.

Strong correlations exist between post-procedural IVUS MSA and restenosis (35,36). Although these studies have been performed in nonocclusive lesions, we believe that optimal stent expansion also will improve long-term outcomes in CTO lesions.

Finally, in the current study TIMI flow grade 3 was obtained in all patients; and similar IVUS MSA and angiographic minimum lumen diameter were observed between the Ante and Retro group even though the Retro group had much longer CTO lengths and more unfavorable angiographic factors.

Study limitations. There was probably selection bias in opting for the Ante versus the Retro approach. In such a small group it might be difficult to separate technique from lesion complexity. The IVUS was performed after predilation with a 1.5- to 2.0-mm balloon in 90% of the lesions, although the rate of predilation was identical between the 2 groups, and the area of these small balloons (1.5 or 2.0 mm) measured only 1.8 to 3.1 mm^2, the minimum needed to advance the IVUS catheter into the distal true lumen through CTO lesions with hard plaque and/or calcification. Finally, this study comprised a relatively modest number of patients treated by only 1 highly experienced operator; therefore, interpretation of our findings must be cautious and might not be applicable for less-experienced operators.

Conclusions

Retro is a promising option for complex CTO lesions, especially long right coronary artery CTOs. Although there was a higher incidence of subintimal guidewire passage and/or procedure-related vessel injury and more complex lesion morphology in the Retro group, the final results (IVUS MSA and angiographic minimum lumen diameter) were similar to the "simpler" lesions treated with the Ante technique. The IVUS can be performed (antegrade) once the CTO is crossed. Use of IVUS might enhance the efficacy, safety, and acute results of the Retro in CTO PCI.

Acknowledgments

The authors thank Celia Castellanos, MD, Jian Liu, MD, Junqing Yang, MD, and Carlos Oviedo, MD, for their assistance with IVUS image analysis.

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Key Words: chronic total coronary occlusion ■ imaging ■ retrograde approach ■ ultrasonics.