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ORIGINAL ARTICLE

# Recanalisation of coronary chronic total occlusions with new techniques including the retrograde approach via collaterals

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**Abstract**
*Objective* Percutaneous treatment of coronary chronic total occlusions (CTO) remains one of the major challenges in interventional cardiology. The strategies of recanalisation in CTO have changed drastically due the development of new techniques such as the retrograde approach via collaterals. In this single-centre experience we sought to analyse the success rates with the use of different CTO techniques, the complication rates, and we evaluated predictors of failed CTO recanalisation attempts.
*Methods and Results* In this single-centre observational study we analysed the prospectively entered data of 331 consecutive patients, undergoing percutaneous coronary intervention (PCI) for CTO in 338 lesions at the Heart Center Wuppertal between June 2007 and July 2010. Nineteen lesions were attempted twice and one lesion three times (=358 procedures). The lesion-related success rates were 81.1%. Single-wire usage was the predominant strategy used in 198 antegrade cases (65.6%) followed by parallel wire technique and see-saw technique in 94 cases (31.1%). In the retrograde procedures, the reverse CART technique was predominantly used (35.7%), followed by retrograde wire passage (17.9%), marker wire (17.9%) and CART (14.3%). The in-hospital complications were low and comparable with conventional PCI data. The presence of blunt stump, severe calcification, severe tortuosity and occlusion length >30 mm were independent predictors of procedural failure.
*Conclusions* A high degree of success with low in-hospital complications comparable with conventional PCI data can be expected in the hands of experienced CTO operators. A second try with a retrograde approach after antegrade failure should be considered.

**Keywords** Coronary chronic total occlusions · Retrograde approach · New techniques · Procedural outcomes

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## Introduction

A chronic total occlusion (CTO) was recently defined by the EuroCTO Club as a lesion with a Thrombolysis in Myocardial Infarction (TIMI) grade 0 flow within the occluded segment and angiographic or clinical evidence or high likelihood of an occlusion duration ≥3 months [1]. Recent data have shown that successful recanalisations of CTO improve patients' anginal symptoms, enhance left ventricular function and reduce the need for bypass surgery (CABG) [2–8]. Importantly, data from large registries have additionally shown that successful CTO percutaneous coronary interventions (PCI) lead to a long-term survival advantage for patients compared with unsuccessful attempts [7, 9, 10], especially when the left anterior descending artery is involved [11] and a multivessel disease is present [12].

The introduction of new recanalisation techniques such as the retrograde approach are still under development, and they are applied only by some very specialised CTO operators and centres [13–15].

In this single-centre study we sought to analyse the success rates with the use of different new CTO techniques, the complication rates, the fluoroscopy time and the amount of contrast medium used, and we evaluated predictors of failed CTO recanalisation attempts.

## Methods

### Study Design and Patient Population

In our study we analysed the prospectively entered data of 331 consecutive patients, undergoing PCI for CTO in 338 lesions at the Heart Center Wuppertal between June 2007 and July 2010. The indication for PCI was the presence of angina and the demonstration of viable myocardium or silent ischaemia in the territory of the occluded vessel. All patients had given informed consent to the collection of detailed clinical data.

### Definitions

A CTO was defined as proposed by the EuroCTO Club [1]: a lesion with a TIMI grade 0 flow within the occluded segment and angiographic or clinical evidence or high likelihood of an occlusion duration ≥3 months. Angiographic success was defined as a restoration of TIMI flow grade 3 in the target vessel after stent implantation and a residual stenosis <15% by visual estimation. Myocardial infarction (MI) was defined as creatine kinase-MB (CK-MB) enzyme elevation more than three times the upper limit of the normal value. A procedure-related contrast-induced nephropathy was defined as an increase of 25% or 0.5 mg/dl in serum creatinine at 48 h after PCI comparing baseline values.

### Techniques

We used biplane angiography. Unfractionated heparin was used to maintain an activated clotting time (ACT) ≥300 s during the procedure. Dual antiplatelet therapy was prescribed for 12 months after discharge.

The access route was dependent on the individual patient situation. A bilateral transfemoral approach was preferred.

In the antegrade approach, different techniques were used as previously described [1, 16]: contralateral injection during guidewire advancement, single wire technique, parallel wire method, see-saw wiring, side-branch technique and intravascular ultrasound (IVUS) guided wiring technique. We used several anchor techniques [17], the child-in-mother catheter (Heart Rail®) [18] and the Tornus® device [19] to either improve guiding catheter support or facilitate balloon and stent passage.

Dedicated guidewires were used in order to perform these techniques such as soft or moderate polymeric wires, including tapered Fielder XT® and stiff flat spring ones such as Miracle® 3–12 and stiff tapered Confienza® Family 9–12. The selection of the guidewire was completely dependent on the operator's judgement.

The techniques in retrograde approach were purely retrograde wire crossing, kissing wire technique, controlled antegrade and retrograde subintimal tracking (CART), reverse CART technique and knuckle wire technique as previously described [20–22].

All patients were checked for any post-procedural events such as chest pain, heart failure, bleeding, or any ischaemic events. CK-MB and Troponin T were measured at 6–8 and 12–24 h post-procedure, serum creatinine at 24 and 48 h after the procedure.

### Statistical Analyses

Categorical variables were expressed as counts and percentages. Continuous variables were presented as mean±standard deviation. Fisher's exact test was used to test the independence of two categorical variables and the Mann–Whitney two-sample statistic to test the hypothesis that two groups are from populations with the same distribution with regard to a continuous variable. Odds ratios, 95% confidence intervals and Mantel-Haenszel test were calculated to compare the chance of procedural success of two groups or in dependence of a continuous variable. Stepwise logistic regression (forward selection) was used to select the independent predictors of procedural success. All variables were included in a stepwise logistic regression model to detect the independent predictors for procedural success (forward selection).

A $p$ value of <0.05 was considered significant.

## Results

### Patient Population

Between June 2007 and July 2010, 324 patients underwent CTO recanalisation for one CTO lesion and seven patients for two CTO lesions (=338 lesions). Nineteen lesions were attempted twice and one lesion three times (=358 procedures). Of the 331 patients, 72 (21.8%) underwent an unsuccessful CTO attempt before admission to our institution.

Baseline patients' demographics and vessel characteristics for both antegrade and retrograde procedures are shown in Table 1. The right coronary artery (RCA) was predominantly treated (51.1%), followed by the left anterior

**Table 1** Baseline patient demographics and vessel characteristics for antegrade and retrograde approaches

| | Antegrade $n=302$ | Retrograde $n=56$ | $P$ |
|---|---|---|---|
| Age, years | 63.1+10.1 | 62.6+11.8 | 0.994 |
| Male | 84.7% | 76.8% | 0.168 |
| Diabetes mellitus | 30.1% | 29.6% | 1.000 |
| Smoking | 29.3% | 25.9% | 0.690 |
| Family history of CAD | 24.0% | 22.2% | 0.863 |
| Hyperlipidaemia | 29.1% | 30.3% | 0.935 |
| Previous CABG | 12.9% | 12.5% | 0.984 |
| One-vessel disease | 63 (20.9%) | 11 (19.4%) | 0.876 |
| Three-vessel disease | 126 (41.7%) | 15 (26.8%) | 0.056 |
| LAD | 97 (31.1%) | 18 (32.1%) | |
| RCA | 145 (48.0%) | 38 (67.9%) | |
| LCX | 56 (18.5%) | 0 (0.0%) | |
| Bypass | 3 (0.9%) | 0 (0.0%) | |
| Main stem | 1 (0.3%) | 0 (0.0%) | |

*CAD* coronary artery disease, *CABG* coronary artery bypass surgery, *LAD* left anterior descending artery, *RCA* right coronary artery, *LCX* left circumflex artery

descending (LAD) (32.1%) and the left circumflex artery (LCX) (15.6%).

The mean occlusion duration of the angiographically confirmed lesions was 35.3 months (3 to 168 months). The mean ejection fraction was 56.9%±12 (10 to 85%).

## Angiographic and Anatomical Lesion Characteristics

Table 2 summarises the angiographic and anatomical characteristics. The incidence of moderate to severe calcification in the CTO was significantly higher and the occluded segments were longer in the retrograde group compared with the antegrade group. Ostial location, severe tortuosity of the vessel and blunt stump at the occlusion were seen more frequently in the retrograde group.

## Approach Strategy and Guidewire Techniques

Single-wire technique was the predominant strategy used in 198 antegrade cases (65.6%) followed by parallel wire technique and see-saw technique in 94 cases (31.1%) while IVUS guided approach was used less frequently (10 cases). Contralateral injection by a second catheter was necessary in 68.5% of the antegrade cases.

The final guidewires used were most often Confienza Pro® (40.3%) and Fielder XT® (34.9%).

In the retrograde procedures reverse CART technique was predominantly used (35.7%) followed by retrograde wire passage (17.9%), marker wire (17.9%) and CART (14.3%). Further procedural characteristics are shown in Table 3. In the majority of cases the wires which finally reached the distal true lumen were Confienza Pro® (50.0%) and Fielder XT® (35.7%). The Corsair® Channel dilator was used in 39 cases (69.6%).

The procedures in which the retrograde approach was employed were longer for both procedural (135.3±39.7 min vs. 88.5±30.3 min, $p<0.0001$) and fluoroscopy times (58.2±18.4 min vs. 28.9±13.1 min, $p<0.001$), respectively (Fig. 1). Moreover, in patients treated by retrograde approach, more contrast medium was administered (271±125 ml vs. 418±160 ml, $p=0.0001$).

In order to facilitate balloon and stent passage, we used several anchor techniques such as anchor wire in 6.4% or anchor balloon in 5.9% of the cases. The child-in-mother catheter system was used in two cases and the Tornus® device in 40 cases (11.2%).

**Table 2** Angiographic and anatomical lesion characteristics

| | Antegrade $n=302$ | Retrograde $n=56$ | $P$ |
|---|---|---|---|
| Calcification: mild | 119 (39.4%) | 9 (16.1%) | 0.003 |
| Calcification: moderate to severe | 183 (60.6%) | 47 (83.9%) | 0.001 |
| Osial location | 20 (6.6%) | 8 (14.3%) | 0.059 |
| Tortuosity: severe (>90°) | 48 (15.9%) | 21 (37.5%) | 0.001 |
| Blunt stump at occlusion | 116 (38.4%) | 48 (85.7%) | 0.0001 |
| Sidebranch at occlusion | 101 (33.4%) | 26 (46.4%) | 0.069 |
| Length of occlusion (mm) | 41+15 | 53+14 | 0.0001 |

**Table 3** Procedural characteristics

| | Procedures |
|---|---|
| Antegrade approach ($n$=302) | |
| Contralateral injection | 207 (68.5%) |
| Single wire | 198 (31.1%) |
| Parallel wire | 94 (31.1%) |
| IVUS guided | 10 (3.3%) |
| Microcatheter | 281 (93.0%) |
| Over the wire balloon | 21 (7.0%) |
| 6 F guiding catheter | 116 (38.4%) |
| 7 F guiding catheter | 171 (56.6%) |
| 8 F guiding catheter | 15 (5.0%) |
| Procedural time (min) | 88.5+30.3 |
| Fluoroscopy time (min) | 28.9+31.1 |
| Contrast medium (ml) | 271+125 |
| Retrograde approach ($n$=56) | |
| Septal collaterals | 51 (91.1%) |
| Epicardial collaterals | 5 (8.9%) |
| Reverse CART | 20 (35.7%) |
| Retrograde wire passage | 10 (17.9%) |
| Marker wire | 10 (17.9%) |
| Kissing wire | 6 (10.7%) |
| CART | 8 (14.3%) |
| Knuckle wire | 2 (3.6%) |
| 8 F+7 F guiding catheter | 20 (35.7%) |
| 7 F+7 F guiding catheter | 27 (48.2%) |
| 6 F+7 F guiding catheter | 9 (16.1%) |
| Procedural time (min) | 135+39.7 |
| Fluoroscopy time (min) | 58.2+18.4 |
| Contrast medium (ml) | 418+160 |

## Factors of Procedural Success or Failure

The overall lesion-related success was achieved in 274 lesions (81.1%). Nineteen lesions were attacked twice and one lesion three times. The rate of success among the retry cases, after a previous failure attempt was lower (70.0%, $p$=0.001). A total of 49 patients (14.5%) were treated conservatively and 15 patients (4.4%) were sent to bypass surgery.

Of the procedures, 302 (84.4%) were performed antegradely and 56 (15.6%) retrogradely.

Procedural-related success according to the approaches employed was 239/302 (79.1%) and 35/56 (62.5%) for antegrade and retrograde (OR 0.44 [0.24–0.81], $p$=0.007), respectively.

Results of the logistic regression model are shown in Table 4. Only occlusion length >30 mm, presence of blunt stump, severe tortuosity, moderate to severe calcification and ostial occlusion were recognised as univariate predictors of procedural failure.

After multivariate analysis the presence of blunt stump (OR 0.15 [0.07–0.31], $p$=0001), severe calcification (OR 0.16 [0.08–0.37], $p$=0001), severe tortuosity (OR 0.49 [0.25–1.00], $p$=0.041 and occlusion length >30 mm (OR 0.07 [0.01–0.55], $p$=011) were independent predictors of procedural failure.

In 254 (92.7%) of the 274 successful cases, drug-eluting stents (DES) were implanted. The mean stent length was 60.2±27 mm.

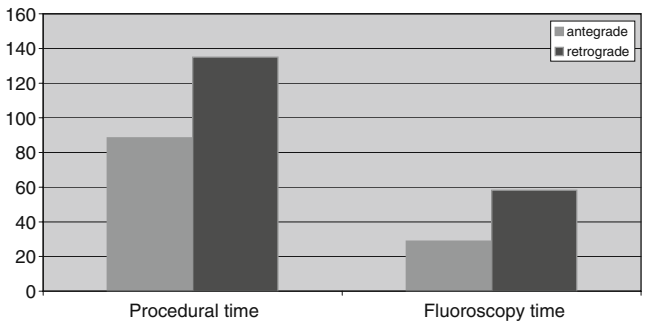


**Fig. 1** Procedural and fluoroscopy times of antegrade and retrograde approaches in minutes

**Table 4** Logistic regression results for unsuccessful procedures

| | Odds ratio | 95% CI | *P* value |
|---|---|---|---|
| Female | 0.80 | 0.40–1.60 | 0.536 |
| Age | 1.00 | 0.97–1.02 | 0.761 |
| BMI | 1.00 | 0.97–1.02 | 0.761 |
| Diabetes | 1.07 | 0.61–1.87 | 0.821 |
| Smoking | 0.80 | 0.46–1.39 | 0.427 |
| Hypertension | 1.69 | 0.90–3.17 | 0.096 |
| Hyperlipidaemia | 0.93 | 0.67–1.30 | 0.695 |
| Previous CABG | 0.75 | 0.37–1.50 | 0.411 |
| Occlusion duration | 0.40 | 0.13–1.22 | 0.096 |
| LAD | 0.68 | 0.39–1.19 | 0.176 |
| RCA | 1.58 | 0.66–3.81 | 0.302 |
| LCX | 2.32 | 1.02–5.29 | 0.040 |
| 3-vessel-disease | 0.94 | 0.55–1.63 | 0.837 |
| Bridging collaterals | 0.86 | 0.53–1.41 | 0.558 |
| Occlusion length >30 mm | 0.04 | 0.01–0.35 | 0.0001 |
| Blunt stump | 0.10 | 0.05–0.21 | 0.0001 |
| Side branch at occlusion | 0.62 | 0.38–1.03 | 0.061 |
| In-stent occlusion | 2.04 | 0.45–9.27 | 0.345 |
| Severe tortuosity | 0.30 | 0.17–0.53 | 0.0001 |
| Severe calcification | 0.09 | 0.04–0.22 | 0.0001 |
| Moderate calcification | 0.38 | 0.19–0.75 | 0.0004 |
| Ostial occlusion | 0.44 | 0.20–0.98 | 0.040 |

*CI* confidence index, *BMI* body mass index, *CABG* coronary artery bypass surgery, *LAD* left anterior descending artery, *RCA* right coronary artery, *LCX* left circumflex artery

### Complications and In-Hospital Outcome

No in-hospital death or stroke occurred. One patient needed acute cardiac surgery due to a trapped anchoring balloon, which was overstented. Two myocardial infarctions were seen. An aortic dissection happened in one patient needing only conservative treatment. Coronary perforations (including septal perforation during retrograde approach) occurred in six cases, needing conservative treatment in three cases. In three cases cardiac tamponade was treated with pericardiocentesis.

## Discussion

The present study evaluated consecutive patients undergoing a recanalisation of a CTO with an occlusion duration ≥3 months according to EuroCTO Club definition 2007 [1]. Major findings of the present study are as follows: 1) The lesion-related success rates will be high around 81% if novel guidewire techniques including the retrograde approach via collaterals are used; 2) The in-hospital complications are rare and comparable with conventional PCI data; 3) The presence of blunt stump, severe calcification, severe tortuosity and occlusion length >30 mm were independent predictors of procedural failure; 4) A second session with a retrograde approach after antegrade failure should be considered.

### Procedural Strategy and Success Rates

PCI for CTO are associated with lower procedural success rates predominantly related to the inability to cross the lesion [23, 24]. Hoye et al. [25] reported success rates of 65.1% in 885 CTO lesions in their cohort during the period of 1992–2002. Olivari et al. [6] reported success rates of 73.3% in the TOAST-GISE trial. In a German PCI registry [26] from 2006, 35 centres contributed 8882 PCIs, 674 of which were CTO (7.6%) with a success rates of 60.1%. Prasad et al. [24] published the 25-year Mayo Clinic experience with a CTO recanalisation success rate of 70% with little improvement over time. Rathore et al. [27] reported an 87.5% procedural success rate in 665 consecutive lesions, treated at Toyohashi Heart Center from 2002 to 2008 with a steadily increasing use of IVUS guided and retrograde wiring techniques. Kimura et al. [13] recently published data from the CART registry: in 224 cases, 145 patients (64.7%) had undergone previous failure in antegrade recanalisation. The overall success rates were 90.6%. Very recently Rathore and Katoh [22] introduced a novel modification of the retrograde approach by using an IVUS guided reverse CART technique with a 100% success rate in the first series of 31 patients. This indicates that the modified retrograde approach can improve success rates in very complex cases. In our study the success in retrograde approach was 62.5%. In almost all of these cases, a prior antegrade approach was unsuccessful.

Interestingly, Thompson et al. [28] presented the US experience of the influence of expert operators in the procedural outcome. They reported overall success rates of about 69% among 636 consecutive CTO treated. There was a significantly lower success rate in operators who were not able to perform the retrograde approach in comparison with retrograde operators (58.9 vs. 75.2%, respectively, $p<0.0001$).

Due to the length of the procedures and the amount of contrast medium used, we think the retrograde approach should rather be chosen in a second session after previous antegrade failure. This strategy is confirmed by the EuroCTO Club data [15] on retrograde approach: The success rates were 89% for primary retrograde approach and 66% for retrograde immediately after antegrade failure and 88% for repeat procedure after previous antegrade failure. After any antegrade failure, the success rate was 78%.

### Predictors of Procedural Failure

In our study a multivariate analysis showed that the presence of a blunt stump, severe calcification of the CTO, severe tortuosity and occlusion length >30 mm were independent predictors of procedural failure. Similar results are shown by Rathore et al. [27]. In their study severe tortuosity and moderate to severe calcification were the only predictors of failure. Presence of multivessel disease, CTO length >15 mm, and moderate to severe calcifications were shown to be independent predictors of unsuccessful procedures in a study by Olivari [6].

In our opinion the presence of a blunt stump can be a good indication for retrograde approach.

### Complications and In-Hospital Outcomes

In our study the in-hospital complication rate was low. Neither in-hospital death nor any stroke occurred. Two MIs were seen. Despite frequent use of very stiff wires and aggressive guidewire strategies a coronary perforation was only seen in six cases and pericardiocentesis was needed in three cases. These data are concurrent with conventional PCI data [26, 29, 30].

### Limitations

First, this is a retrospective study although we did include all consecutive patients who were planned for CTO recanalisation. Second, the cases are from a single centre and were performed by two experienced CTO operators and may not be generally applicable. Third, the results of the study could be influenced by different selection criteria and technique variation among the operators.

## Conclusion

The techniques of PCI in chronic occlusions have changed dramatically due to the development of new techniques such as the retrograde approach.

A high degree of success with low in-hospital complications comparable with conventional PCI can be expected in antegrade and retrograde approach in the hands of experienced CTO operators. If this is provided we recommend that PCI should be considered as the preferred treatment strategy for patients who are symptomatic with a CTO of the coronary arteries.

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