Retrograde Chronic Total Occlusion Percutaneous Coronary Intervention Through Ipsilateral Collateral Channels

Peer-reviewed author version

Azzalini, Lorenzo; Agostoni, Pierfrancesco; Benincasa, Susanna; Knaapen, Paul; Schumacher, Stefan P.; DENS, Jo; MAEREMANS, Joren; Kraaijeveld, Adriaan O.; Timmers, Leo; Behnes, Michael; Akin, Ibrahim; Toma, Aurel; Neumann, Franz-Josef; Colombo, Antonio; Carlino, Mauro & Mashayekhi, Kambis (2017) Retrograde Chronic Total Occlusion Percutaneous Coronary Intervention Through Ipsilateral Collateral Channels. In: JACC-CARDIOVASCULAR INTERVENTIONS, 10(15), p. 1489-1497.

DOI: 10.1016/j.jcin.2017.06.002
Handle: http://hdl.handle.net/1942/24397

Retrograde chronic total occlusion percutaneous coronary intervention through ipsilateral collaterals: a multicenter registry

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Running title: Retrograde CTO PCI through ipsilateral collaterals

Relationship with industry policy: Dr. Azzalini: honoraria from Guerbet, research support from ACIST Medical Systems. Dr. Agostoni: honoraria from Aquilant, Meril, Neovasc, Genae, and Angiodynamics. Dr. Dens: consultant fees from Asahi, Boston Scientific, Medical Solutions, Orbus Neich, Terumo; and Scientific grant from Boston Scientific. Dr. Mashayekhi: consultant fee from Asahi Intecc, honoraria from Vascular Solutions. The other authors report no conflict of interest.

Funding: Mr. Maeremans is a researcher for the Limburg Clinical Research Program (LCRP) UHasselt-ZOL-Jessa, supported by the foundation Limburg Sterk Merk (LSM), Hasselt University, Ziekenhuis Oost-Limburg and Jessa Hospital.

Word count: 4281

Abstract

Objectives. To describe the procedural aspects and outcomes of retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI) through ipsilateral collaterals (ILCs).

Background. Retrograde CTO PCI via ILCs is rarely performed, usually when no other retrograde options exist, and available evidence mostly derives from case reports.

Methods. A large retrospective multinational registry was compiled including all consecutive patients undergoing retrograde CTO PCI through ILCs at six centers between September 2011 and October 2016. Success rates, as well as procedural complications and in-hospital outcomes were studied.

Results. A total of 126 patients (7.7% of all CTOs attempted) were included. Mean age was 65.7±11.2 years, and J-CTO score was 2.36±1.13. The target vessel was the circumflex in 42%, the left anterior descending in 39%, and the right coronary artery in 19%. The ILCs used were epicardial in 76% and septal in 24%. ILC anatomy was very heterogeneous. One guiding catheter was used in 80%, while the ping-pong technique was utilized in 20%. A retrograde wire could be advanced to the distal cap in 81%. Technical and procedural success was 87% and 82%, respectively. ILC perforation with need for intervention was observed in 5.6%, and tamponade due to ILC perforation in 2.4%. One patient (0.8%) died.

Conclusions. Retrograde CTO PCI through ILCs is a challenging intervention that can be performed in difficult occlusions with high success rates and reasonable rates of complications by experienced operators.

Keywords: chronic total occlusion, percutaneous coronary intervention, retrograde, collateral, epicardial, ipsilateral

Condensed abstract

We created a large multinational registry of patients undergoing retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI) through ipsilateral collaterals (ILCs). The ILCs used were epicardial in 76% and septal in 24%, and their anatomy was very heterogeneous. Most procedures were completed using one single guiding catheter, with a variety of dedicated techniques. Technical and procedural success was 87% and 82%, respectively. The most frequent complication was collateral perforation with/without tamponade. In the hands of experienced operators, retrograde CTO PCI through ILCs is a challenging intervention that can be performed with high success rates and reasonable rates of complications.

Abbreviations list

CABG, coronary artery bypass graft

CART, controlled antegrade and retrograde subintimal tracking

CTO, chronic total occlusion

ILC, ipsilateral collaterals

LAD, left anterior descending

MI, myocardial infarction

PCI, percutaneous coronary intervention

RCA, right coronary artery

Introduction

The retrograde approach has currently become an established, safe and effective technique to percutaneously recanalise coronary chronic total occlusions (CTO) [1–3], and has allowed a relevant increase in procedural success rates, as compared with an antegrade-only approach (from ~80% in selected cases to ~90% in all-comers), despite a slightly increased risk of major adverse cardiac events [2,4].

Retrograde CTO percutaneous coronary intervention (PCI) is most frequently performed through septal collaterals [1–3], as the use of this route is associated with a lower incidence of complications (periprocedural myocardial infarction [MI] and collateral channel injury), as compared with epicardial collaterals [3]. For this reason, the retrograde approach through epicardial collaterals is currently considered one of the most challenging scenarios for the CTO PCI operator.

In this setting, a particular subgroup is represented by retrograde CTO PCI via ipsilateral collaterals (ILCs). ILCs are present in less than one third of coronary angiographies of CTO patients [5,6]. Procedures via this route are associated with unique challenges, including steeper angles to be overcome with wires and microcatheters, as well as the need for re-entry into the same or an additional guiding catheter engaging the same coronary ostium (“ping-pong” technique [7]). Additionally, most of these vessels have an epicardial course, and, as such, they are quite fragile, with a potential risk for cardiac tamponade in case of perforation. For these reasons retrograde CTO PCI via ILCs is currently rarely performed, usually when no other retrograde options

exist, and available evidence mostly derives from case reports [7–9] and the experience of two seasoned operators [6,10].

The aim of this study is to analyze the outcomes of retrograde CTO PCI via ILCs in a large retrospective multinational registry involving several operators, and to provide useful recommendations in order to promote a wider adoption of this advanced technique.

Methods

Patient population

All patients undergoing an attempt at retrograde CTO PCI through ILCs at the 6 participating centers, between September 2011 and October 2016, were retrospectively included. All procedures were indicated according to the presence of angina, ischemia or both, and were performed electively (ad hoc PCI was discouraged) [4] by experienced operators (>150 retrograde CTO PCIs overall, or >40 retrograde CTO PCIs/year). The use of the retrograde approach in our study followed the Hybrid Algorithm [11]. As such, it was chosen in case of: 1) proximal cap ambiguity, 2) poor distal target, 3) presence of interventional collaterals. Baseline, procedural and hospitalization data were recorded. All subjects gave informed consent for the procedure, and due to the retrospective nature of the registry, ethics committee approval was waived.

Definitions

CTO was defined as a 100% stenosis with Thrombolysis In Myocardial Infarction (TIMI) 0 flow for >3 months [12]. The J-CTO score [13] was

calculated for each lesion. The difficulty navigating the ILCs was graded according to the score proposed by McEntegart et al. [5], which assigns one point for each of 8 adverse collateral channel characteristics (epicardial channel, tortuous channel, small channel, long channel, adverse channel entry, adverse channel exit, multiple bifurcations, and high risk of damage or ischemia). In the original publication, mean scores for collaterals considered to be interventional vs. non-interventional were 2.18 and 4.43, respectively.

Technical success was defined as a residual stenosis <30% with antegrade TIMI 3 flow in the CTO target vessel [12]. Procedural success was defined as technical success plus the absence of in-hospital adverse events (all-cause death, Q-wave myocardial infarction [MI], stroke, recurrent angina requiring target-vessel revascularization with PCI or coronary artery bypass graft [CABG], tamponade requiring pericardiocentesis or surgery) [12].

Procedural complications and in-hospital adverse events included: procedure-related death, procedure-related stroke, periprocedural type 4a MI [14], stent thrombosis, need for urgent revascularization, major bleeding (bleeding requiring transfusion, vasopressors, surgery or percutaneous intervention), vascular complications, myocardial ischemia due to collateral injury or obstruction requiring interruption of the procedure, coronary perforation requiring intervention (coil embolization, covered stent implantation, pericardiocentesis, or surgery), and contrast-induced nephropathy (increase in serum creatinine >25% or >0.5 mg/dl at 48 h post-procedure).

Statistical analysis

Continuous variables are presented as mean±standard deviation. Categorical variables are presented as frequency (percentages). Statistical analysis was performed using SPSS 24 (IBM Corp., Armonk, NY).

Results

Clinical characteristics

During the study period, a total of n=1670 CTO PCIs were performed at the six participating centers. In n=721 (43%) of these, the retrograde approach was used. Among retrograde cases, an ILC was used in n=126 patients (17%), who represented the study population. Table 1 shows the clinical characteristics of this cohort. Mean age was 65.7±11.2 years, and 90% of patients were male. Cardiovascular risk factors and comorbities were highly prevalent. In particular, the prevalence of diabetes was 37%, 48% of patients had suffered prior MI, and 21% had previously undergone CABG. Moderate-to-severe angina was present in 45%. Left ventricular ejection fraction was mostly normal (52.3±12.7%). The most frequent indication for CTO PCI was angina.

Angiographic characteristics

Angiographic data are shown in Table 2. The most frequent target CTO vessel was the circumflex (42%), followed by the left anterior descending (LAD, 39%) and the right coronary artery (RCA, 19%). Importantly, a left-dominant coronary circulation was observed in 22 out of 53 circumflex CTO cases (42%), ischemia in the circumflex territory was proven in 13 subjects (25%), and refractory angina despite optimal medical therapy was diagnosed

in all of these patients. Occlusion complexity was very pronounced (J-CTO score 2.36±1.13). In particular, the angiographic characteristics that usually dictate the utilization of a retrograde approach were highly prevalent in our cohort: proximal cap ambiguity (68%), distal cap at bifurcation (37%), and distal vessel of suboptimal quality (40%).

The majority of collateral channels were classified as CC1 (69%) and CC2 (27%). Seventy-six percent of ILCs were epicardial, while 24% were septal. Collateral tortuosity was mild-to-moderate in the great majority of patients, with only 6% being classified as “corkscrew”. The mean McEntegart collateral channel score was 3.71±1.30, which indicates considerable difficulty navigating these ILCs. The anatomic distribution of the ILCs in our study was very varied (Figure 1). The most frequent ILCs for the left coronary artery were from the circumflex system to the diagonal/LAD system or vice versa (22%), diagonal-to-diagonal/LAD (20%), from the apical LAD to the circumflex system or vice versa (19%), and from the LAD via septals to the circumflex system or vice versa (17%). All five types of RCA ILCs according to the Mashayekhi’s classification [6] were encountered and utilized, with type A (acute marginal to posterolateral/posterior descending artery) being the most frequent (38%).

Procedural data

The retrograde approach was chosen as first intention in 18 (14%) patients and as bailout following failed antegrade techniques in 108 (86%) subjects. Table 3 displays the procedural data of our cohort. At least one femoral access was utilized in the majority of cases (87%). In 80% one single

guiding catheter was used, while in 20% the ping-pong technique with two catheters was employed. Large guiding catheters (≥7 Fr) were used in 90% of cases as initial approach. When the ping-pong technique was performed, a 6-Fr guiding catheter was used in 7 cases (28%), a 7-Fr guiding in 16 (64%), and an 8-Fr catheter in 2 (8%). The Corsair microcatheter (64%) and the Sion family of guidewires (90%; both by Asahi Intecc, Nagoya, Japan) were most frequently used to navigate the ILCs. There were no differences with regard to wire or microcatheter utilization between epicardial and septal collaterals. The operators could advance a retrograde wire to the distal cap through an ILC in 81%.

Externalization was most commonly performed with the conventional technique (e.g., using a RG3 guidewire, Asahi). The most common final crossing techniques were retrograde true-to-true (36%), followed by reverse controlled antegrade and retrograde subintimal tracking (reverse CART, 32%), while bailout antegrade techniques were successful in 11% after retrograde failure. Technical success was achieved in 87% and procedural success in 82%. There were no differences with regard to the McEntegart score in cases with procedural success vs. failure (3.66±1.25 vs. 3.91±1.54, p=0.40). However, we observed a direct relationship between operator volume of retrograde CTO PCI through ILCs and success rates (technical success: ≤10 procedures 72% vs. 11-20 procedures 81% vs. >20 procedures 93%, p=0.04; procedural success: 61% vs. 78% vs. 88%, p=0.03). Procedural metrics reflected the high complexity of these occlusions and the retrograde approach through ILCs.

Clinical outcomes

Procedural complications and in-hospital adverse events are outlined in Table 4. Tamponade was diagnosed and treated in 5 patients overall: in 3 patients (2.4%) this was due to ILC perforation, while in 2 cases (1.6%) it was related to target CTO vessel perforation. Major perforation requiring intervention was observed in 7 ILC patients (5.6%), and in 3 other patients (2.4%) it involved the target CTO vessel. No case of ischemia causing ST-segment elevation due to collateral damage/obstruction was observed during the procedure. Biochemical evidence of periprocedural MI was diagnosed in 7%: in all but one case, this was an asymptomatic event with no clinical consequences. One patient presented with symptomatic periprocedural ST-elevation MI and urgent need for reintervention due to acute occlusion of the LAD following retrograde extension of a dissection 1 hour after successful proximal circumflex CTO recanalization with reverse CART via a diagonal-to-marginal ILC. The patient underwent successful additional stenting of the left main and LAD. One patient died because of presumed aortic dissection. This 27-year-old man had been diagnosed with an unspecified connective tissue disease before CTO PCI. During the index procedure, he suffered multiple coronary dissections. These dissections were observed following non-traumatic guiding catheter engagement in both the RCA and the LAD (target CTO vessel), and required the implantation of a total of 11 stents. After successful LAD recanalization via a marginal-to-diagonal ILC, the patient was admitted to the coronary care unit, where a few hours later he suffered chest pain with subsequent cardiac arrest. No echocardiographic signs of tamponade were observed. Electrocardiographic monitoring before cardiac

arrest did not show ST-segment changes. Resuscitation efforts proved unsuccessful and consent to performing an autopsy was denied by the family. Therefore, the most likely cause of death was judged to be subacute aortic dissection in the context of connective tissue disease. Others complications included contrast-induced nephropathy (n=2), vascular complications (n=3), and major bleeding (n=3).

Discussion

We report the angiographic and procedural data as well as the in-hospital outcomes of the first large multicenter registry of retrograde CTO PCI performed via ILCs. Despite complex occlusions, the operators were able to reach technical and procedural success rates in line with the figures reported by large all-comer CTO PCI registries [4], and which compared favorably with the retrograde cohorts of the European CTO Registry (75% and 71%), the Multicenter US Registry (85% and 82%), and the Japanese Multicenter Registry (84%) [1–3] (Figure 2). In our experience, retrograde CTO PCI via ILCs is a challenging procedure (as reflected by high J-CTO and McEntegart scores, as well as procedural metrics) that was associated with non-negligible rates of collateral damage with need for intervention and tamponade. It must be underlined that 76% of ILCs in our study were epicardial channels, which are known to be at higher risk of complications than septal collaterals, which contributes explaining our findings. Perforation-related events were also reported, albeit to a lower extent, in the aforementioned multicenter registries on retrograde CTO PCI (perforation 2.0-11.7%, tamponade 0.5-1.3%) [1–3]. However, such cohorts included retrograde procedures performed through the

full spectrum of collaterals (not limited to ILCs), and epicardial channels were used in a minority of cases (13%-34%) [1–3]. With the exception of tamponade, in-hospital outcomes of our cohort compared favorably with those from the aforementioned reports [1–3] (Figure 2).

Retrograde CTO PCI through ILCs shows distinctive characteristics. First, the prevalence of circumflex CTO is highest, and that of RCA CTO is lowest, which is opposite to vessel distribution in CTO PCI in general and overall retrograde CTO PCI. This is due to the fact that the RCA and LAD most frequently receive collaterals from the contralateral system [5], and the RCA presents very few branches proximal to the crux cordis (which could potentially give origin to ILCs). Therefore, the RCA has the lowest prevalence of ILCs, while the circumflex shows the highest representation of such connections [5]. Additionally, retrograde CTO PCI via ILCs is technically more challenging due to steep angles to overcome and the need for re-entry into the same or an additional guiding catheter. Finally, circumflex CTO PCI has been identified as an independent predictor of technical failure [15]. As such, retrograde CTO PCI via ILCs is considered one of the most challenging procedure in interventional cardiology, and thus requires specific skills.

Figure 3 outlines key factors for an optimal approach to retrograde CTO PCI through ILCs. The introduction of dedicated low-profile microcatheters with improved crossing performance [16] has allowed using the retrograde approach through epicardial collaterals (which represent the majority of ILCs), since over-the-wire balloons are contraindicated in such setting due to their high crossing profile and stiffness, as well as poor trackability, which would expose the patient to an unacceptably high rate of

collateral injury. In parallel, the development of novel guidewires with atraumatic tip, flexible shaft, high lubricity, and improved torque response has allowed safely tracking very tortuous and fragile collateral channels. As a consequence, such microcatheters and guidewires represent must-haves for the operator willing to tackle retrograde CTO PCI through ILCs.

Additionally, the operator willing to venture into retrograde CTO PCI through ILCs should possess advanced skills that arise from years of dedicated training, attendance at CTO meetings, and networking with peers. We advocate that such operator must be already confident performing retrograde CTO PCI through septal collaterals and bypass grafts. Also, he or she must have some experience utilizing contralateral epicardial collaterals, since most ILCs are epicardial. We observed a direct relationship between operator volume of retrograde CTO PCI through ILCs and success rates, which had also been reported by others in overall CTO PCI [18]. This emphasizes the importance of achieving and maintaining adequate skills with this complex intervention. Importantly, the ILC operator must be skilled at complication troubleshooting. Perforation management include mastering pericardiocentesis, the ping-pong technique [7], implantation of covered stents (which are challenging to deliver due to their high crossing profile), coil or fat embolization, and use of hemodynamic support devices [17]. Safer navigation through collaterals might be achieved by the use of a gentle tip injection through the microcatheter, when collateral course is not completely understood. Additionally, ischemia and subsequent hemodynamic compromise might arise when a dominant ILC is accessed. This is secondary to the shear stress induced by manipulating guidewires and microcatheters

making a tight loop in a very localized region of the heart [17]. However, we did not observe any of such cases in our cohort. This risk can be reduced by using alternative externalization techniques, such as tip-in [19] or rendez-vous [20] (for one-guiding-catheter procedures), or conventional externalization using the ping-pong technique [7]. Also, the operator must pay attention to avoid an ostial dissection, which is expected to be more common in retrograde procedures, due to the friction created advancing the microcatheter back into the guiding catheter after retrograde crossing. Finally, we observed a non-negligible rate of periprocedural MI (7.1%), which was also reported in other cohorts treated with the retrograde approach, indicating a higher risk of myocardial injury secondary to collateral manipulation [21–23].

Our article has several limitations. First, modelling the clinical reasoning that brought the operator to choose an ILC (instead of a contralateral collateral) or a specific ILC is somehow complex, and was therefore not captured by our database. Second, our follow-up is limited to the hospitalization when CTO PCI through ILCs was performed. However, since all complications related to ILC utilization are diagnosed during the immediate periprocedural period, it is unlikely that the availability of such information would have added significantly to our manuscript. Finally, the procedures described in this report were performed by experienced CTO operators and our study findings might therefore not be generalizable to other clinical practices.

Conclusions

Retrograde CTO PCI through ILCs is a challenging intervention that can be performed with high success rates and reasonable complication rates in the hands of experienced operators. Dedicated material as well as specific continuous learning and training are fundamental to achieve such results.

CLINICAL PERSPECTIVES

WHAT IS KNOWN?

Ipsilateral collaterals (ILCs) are frequently encountered in chronic total occlusion (CTO) percutaneous coronary intervention (PCI). However, their utilization involves several challenges and a higher risk of complications. As such, retrograde CTO PCI through ILCs is rarely performed.

WHAT IS NEW?

This multinational registry of patients undergoing retrograde CTO PCI through ILCs included 126 patients from 6 institutions. The ILCs used were epicardial in 76% and septal in 24%, and their anatomy was very heterogeneous. Technical and procedural success was 87% and 82%, respectively. The most frequent complication was collateral perforation with/without tamponade.

WHAT IS NEXT?

The development of newer-generation microcatheters and guidewires, as well as dedicated training initiatives for CTO PCI operators, will likely improve the outcomes of this challenging procedure. Further data are needed to ascertain the comparative effectiveness and safety of CTO PCI through ILC versus contralateral collaterals.

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Figure legends

Figure 1. Anatomy of the ipsilateral collaterals. For right coronary artery (RCA) collaterals, the classification by Mashayekhi et al. was used [6]: type A: acute marginal to posterolateral (PL)/posterior descending artery (PDA); type B: proximal to distal RCA; type C: proximal RCA to distal RCA or crux; type D: proximal RCA to PL; type E: septals from right superior descending to PL or PDA. Abbreviations: LAD, left anterior descending; LCx, circumflex.

Figure 2. Procedural and in-hospital outcomes in the present study and comparison with other large multicenter registries [1–3].

Figure 3. Suggested approach to optimal retrograde CTO PCI through ipsilateral collaterals.