Retrograde CTO-PCI of Native Coronary Arteries Via Left Internal Mammary Artery Grafts: Insights From a Multicenter U.S. Registry

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ABSTRACT: Background. Retrograde percutaneous coronary intervention (PCI) of native coronary artery chronic total occlusion (CTO) via left internal mammary artery (LIMA) graft has received limited study. **Methods and Results.** We compared the clinical and procedural characteristics and outcomes of retrograde CTO-PCI through LIMA grafts vs other conduits in a contemporary multicenter CTO registry. The LIMA was used as the collateral channel in 20 of 990 retrograde CTO-PCIs (2.02%) performed at 18 United States centers. The mean age of the study patients was 69 ± 7 years and 95% were men. The most common CTO target vessel was the right coronary artery (55%). The mean J-CTO score in the LIMA group was high (3.45 ± 0.76). The technical success rates were 70% for retrograde PCI via LIMA graft vs 81.05% for retrograde via other conduits (*P*=.25), while procedural success rates were 70% for retrograde PCI via LIMA graft and 78.19% for retrograde via other conduits (*P*=.41). The incidence of major in-hospital complications was also similar between the LIMA and non-LIMA retrograde groups (5% vs 6%; *P*>.99). Use of guide-catheter extensions (40% vs 28%; *P*=.22), intravascular ultrasound (45% vs 31%; *P*=.20), and left ventricular assist devices (24% vs 10%; *P*=.08) was numerically higher in retrograde CTO-PCIs via LIMA grafts. **Conclusions.** Retrograde CTO-PCI is infrequently performed via LIMA grafts and is associated with similar success and major in-hospital complication rates as retrograde CTO-PCI performed via other conduits.

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KEY WORDS: left internal mammary artery graft, LIMA, retrograde PCI, chronic total occlusion

The retrograde approach is essential for contemporary chronic total occlusion (CTO) percutaneous coronary intervention (PCI) and involves advancement of a guidewire through a collateral vessel or a bypass graft distal to the occlusion, followed by crossing against the former direction of blood flow.[1-5] Septal collaterals are the most commonly used vessels for retrograde CTO-PCI, whereas epicardial collaterals are used less commonly, as they can be more challenging to cross and carry higher risk for tamponade in case of perforation.[6] Saphenous vein grafts (both patent and occluded) are also commonly used for retrograde CTO-PCI,[7,8] although they carry risk for perforation and other complications as well.[9-13] Left internal mammary artery (LIMA) grafts are the least preferred retrograde channels due to the large area of myocardium they supply with the concomitant risk for severe ischemia.[14-18] Moreover, LIMA grafts are often highly tortuous, and straightening with guidewires and/or microcatheters may result in pseudolesions and compromised flow.[19] We examined a contemporary multicenter registry to determine the frequency and outcomes of retrograde CTO-PCI via LIMA grafts.

Methods

We analyzed the clinical, angiographic, and procedural characteristics of retrograde CTO-PCI via LIMA grafts among 990 retrograde cases in 976 patients included in the PROGRESS CTO (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention) registry (NCT02061436) between January 2012 and April 2017 at 18 United States centers. Some centers only enrolled patients during part of the study period due to participation in other studies. The study was approved by the Institutional Review Board of each center.

Definitions. *Coronary CTOs* were defined as coronary lesions with Thrombolysis in Myocardial Infarction (TIMI) grade 0 flow of at least 3-month duration. Estimation of the duration of occlusion was clinical, based on the first onset of angina, prior history of myocardial infarction in the target-vessel territory, or comparison with a prior angiogram. *Calcification* was assessed by angiography as mild (spots), moderate (involving ≤50% of the reference lesion diameter), or severe (involving >50% of the reference lesion diameter). *Moderate proximal vessel tortuosity* was defined as the presence of at least 2 bends >70° or 1 bend >90°, while *severe tortuosity*

Table 1. Clinical characteristics, classified according to whether a LIMA graft was used as retrograde channel during chronic total occlusion percutaneous coronary intervention.

Clinical Characteristics	Overall (n = 976)	Retrograde PCI via LIMA (n = 20)	Retrograde PCI via Non-LIMA (n = 956)	*P*-Value
Age (years)	65.49 ± 10.06	69.13 ± 6.92	65.41 ± 10.11	.05
Male gender	87.05%	94.74%	84.97%	.50
Body mass index (kg/m^2)	30.68 ± 6.06	28.23 ± 4.22	30.75 ± 6.09	.03
Smoking (current)	25.00%	20.00%	25.12%	.80
Diabetes	44.00%	45.00%	43.97%	>.99
Dyslipidemia	95.95%	100.00%	95.86%	>.99
Hypertension	90.37%	95.00%	90.26%	.71
CAD presentation				.55
STEMI	1.18%	0.00%	1.21%	
NSTEMI	4.86%	5.26%	4.85%	
Unstable angina	22.34%	36.84%	21.97%	
Stable angina	62.16%	57.89%	62.26%	
No symptoms, no angina	6.83%	0.00%	7.01%	
Unlikely to be ischemic	2.63%	0.00%	2.70%	
Prior MI	49.17%	50.00%	49.15%	>.99
Congestive heart failure	31.89%	40.00%	31.69%	.47
Prior valve procedure	3.73%	10.00%	3.58%	.17
Prior PCI	72.13%	78.95%	71.99%	.61
Prior CVD	11.81%	20.00%	11.61%	.28
Prior PVD	17.83%	15.79%	17.88%	>.99
Chronic lung disease	16.38%	20.00%	16.29%	.55
Baseline creatinine (mg/dL)	1.08 (0.90-1.3)	1.05 (0.89-1.26)	1.08 (0.89-1.3)	.73
Left ventricular EF (%)	49.07 ± 13.52	48.31 ± 15.38	49.08 ± 13.48	.85

Data presented as percentage, median (interquartile range), or mean ± standard deviation.
CAD = coronary artery disease; STEMI = ST-elevation myocardial infarction; NSTEMI = non-ST elevation myocardial infarction; MI = myocardial infarction; PCI = percutaneous coronary intervention; CVD = cerebrovascular disease; PVD = peripheral vascular disease; EF = ejection fraction.

was defined as 2 bends >90° or 1 bend >120° in the CTO vessel. *Blunt or no stump* was defined as lack of tapering or lack of a funnel shape at the proximal cap. *Interventional collaterals* were defined as collaterals considered amenable to crossing by a guidewire and a microcatheter by the operator. A procedure was defined "retrograde" if an attempt was made to cross the lesion through a collateral vessel or bypass graft supplying the target vessel distal to the lesion. *Retrograde PCI via LIMA* was defined as interventions that used the LIMA as retrograde pathway, while *retrograde PCI via non-LIMA* described any retrograde interventions through other collateral vessels or saphenous vein grafts. *Antegrade dissection/re-entry* was defined as antegrade PCI during which a guidewire was intentionally introduced into the subintimal space proximal to the lesion, or re-entry into the distal true lumen was attempted following intentional or inadvertent subintimal guidewire crossing.

Technical success was defined as successful CTO revascularization with achievement of <30% residual diameter stenosis within the treated segment and restoration of TIMI grade 3 antegrade flow. *Procedural success* was defined as the achievement of technical success without any in-hospital complications. *In-hospital major adverse cardiac events (MACE)* included any of the following adverse events prior to hospital discharge: death, myocardial infarction, recurrent symptoms requiring urgent repeat target-vessel revascularization with PCI or coronary artery bypass graft (CABG) surgery, tamponade requiring either pericardiocentesis or surgery, and stroke. *Myocardial infarction* was defined using the Third Universal Definition of Myocardial Infarction (type 4 myocardial infarction).[20] *Major bleeding* was defined as bleeding causing reduction in hemoglobin >3 g/dL or bleeding requiring transfusion or surgical intervention. The *J-CTO score* was calculated as described by Morino et al,[21] the *PROGRESS-CTO score* as described by Christopoulos et al,[22] and the *PROGRESS-CTO complications score* as described by Danek et al.[23]

Statistical analysis. Categorical variables were expressed as percentages and were compared using Pearson's Chi-square test or Fisher's exact test. Continuous variables were presented as mean ± standard deviation or median with interquartile range (IQR) unless otherwise specified, and were compared using the t-test or Wilcoxon rank-sum test, as appropriate. All statistical analyses were performed with JMP 13.0 (SAS Institute). A two-sided *P*-value of .05 was considered statistically significant.

Results

Clinical and angiographic characteristics. The retrograde approach was used in 990 of 2465 cases (40.16%) performed during the study period and the LIMA graft was used as retrograde channel in 20 cases (2.02% of all retrograde cases). The baseline clinical and angiographic features are summarized in Table 1 and Table 2. Mean age was higher in the LIMA group (69 ± 7 years vs 65 ± 10 years; *P*=.05) and most patients were men in both groups (94.7% vs 85.0%; *P*=.50).

Table 2. Angiographic characteristics, classified according to whether a LIMA graft was used as a retrograde channel during chronic total occlusion percutaneous coronary intervention.

Angiographic Characteristics	Overall (n = 990)	Retrograde PCI via LIMA (n = 20)	Retrograde PCI via Non-LIMA (n = 970)	P-Value
Target vessel				<.001
Right coronary	68.93%	55.00%	69.23%	
Left circumflex	16.54%	15.00%	16.58%	
Left main	0.42%	10.00%	0.22%	
Left anterior descending	14.10%	20.00%	13.98%	
CTO length (mm)	39.5 (25-60)	40 (30-60)	39 (25-60)	.68
Vessel diameter (mm)	3 (2.5-3)	3 (2.5-3.75)	3 (2.5-3)	.45
Proximal cap ambiguity	50.72%	63.16%	50.37%	.35
Side branch at proximal cap	54.39%	63.16%	54.14%	.49
Blunt stump/no stump	71.24%	84.21%	70.88%	.30
Distal cap at bifurcation	47.38%	36.84%	47.68%	.48
Moderate/severe calcification	70.06%	70.00%	70.07%	>.99
Moderate/severe tortuosity	46.65%	47.37%	46.63%	>.99
Prior failed CTO-PCI	24.79%	15.79%	24.97%	.43
Interventional collaterals	77.01%	78.95%	76.96%	>.99
In-stent restenosis	14.79%	16.67%	14.75%	.74
J-CTO score	3.15 ± 1.04	3.45 ± 0.76	3.15 ± 1.05	.10
PROGRESS CTO score	1.87 ± 0.91	2.00 ± 0.84	1.86 ± 0.91	.51
PROGRESS CTO complications score	4.26 ± 1.67	4.73 ± 1.44	4.25 ± 1.68	.22

Data presented as percentage, median (interquartile range), or mean ± standard deviation.
LIMA = left internal mammary artery; CTO = chronic total occlusion; PCI = percutaneous coronary intervention; J = Japan; PROGRESS = Prospective Global Registry of Chronic Total Occlusion Interventions.

The CTO target vessel in the LIMA group was the right coronary artery (55%), left circumflex (15%), left main (10%), and left anterior descending artery (20%). Median occlusion length was 40 mm (IQR, 30-60 mm) and median target vessel diameter was 3 mm (IQR, 2.5-3.75 mm). Patients undergoing retrograde CTO-PCI via LIMA grafts vs non-LIMA conduits were likely to have proximal cap ambiguity (63.2% vs 50.4%; *P*=.35) and blunt or no stump at the proximal cap (84.2% vs 70.9%; *P*=.30). The mean J-CTO scores (3.45 ± 0.76 vs 3.15 ± 1.05; *P*=.10), PROGRESS CTO scores (2.00 ± 0.84 vs 1.86 ± 0.91; *P*=.52), and PROGRESS CTO complications scores (4.73 ± 1.44 vs 4.25 ± 1.68; *P*=.22) were similar.

Interventional techniques. The CTO crossing techniques used in patients in whom retrograde crossing via LIMA grafts was attempted are shown in

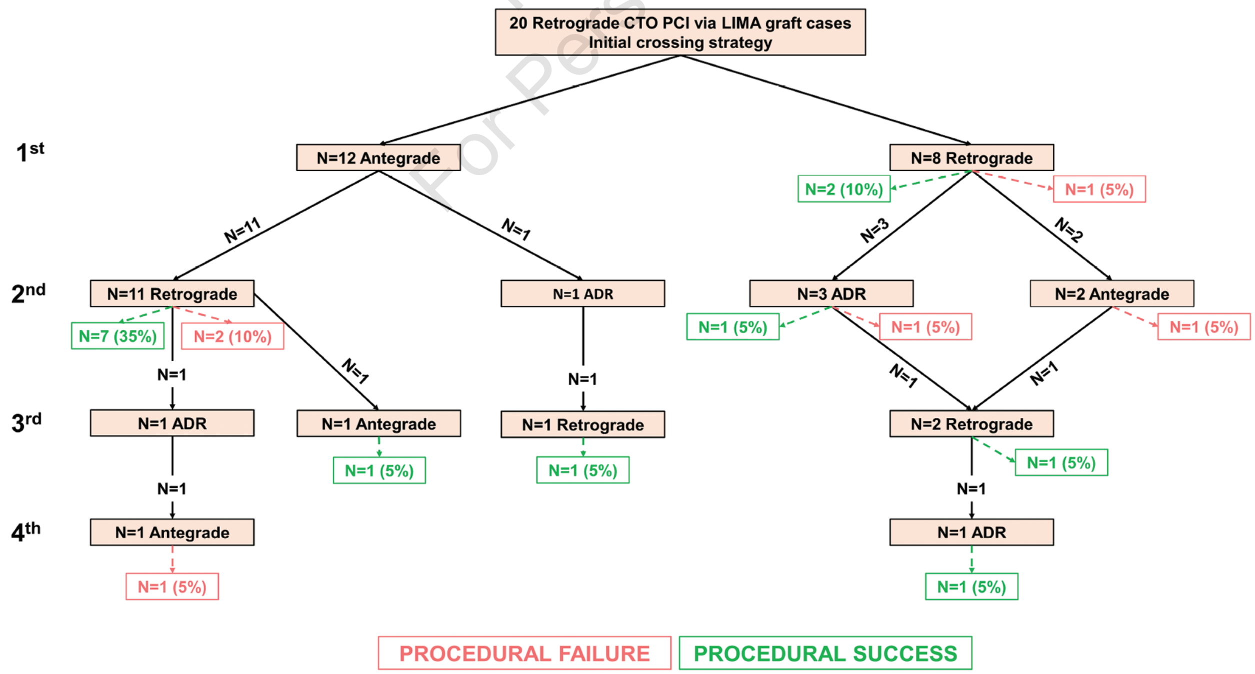

FIGURE 1. Application of hybrid approach during retrograde chronic total occlusion percutaneous coronary intervention via left internal mammary artery grafts.

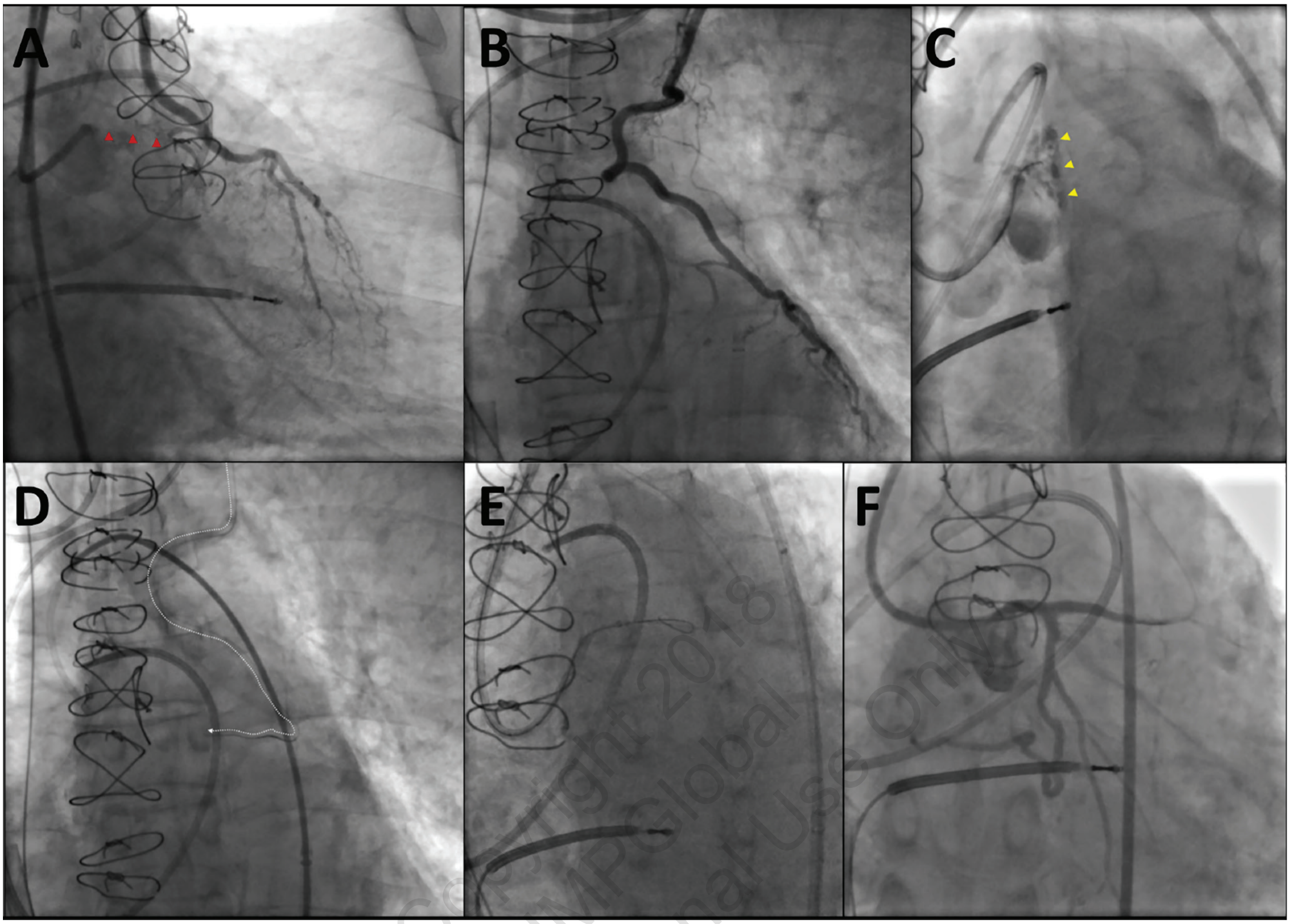

FIGURE 2. Left-main chronic total occlusion (CTO) percutaneous coronary intervention (PCI) using a left internal mammary artery (LIMA) graft as a retrograde channel, with prophylactic use of veno-arterial extracorporeal membrane oxygenator (VA-ECMO). (A) Dual injection demonstrating flush occlusion of the left main coronary artery (arrowheads). (B) LIMA graft supplying the mid left anterior descending (LAD) coronary artery, which was occluded proximal and distal to the anastomosis. (C) Failed antegrade attempt for CTO crossing (arrowheads). (D) Retrograde wiring through the LIMA in the proximal LAD and the left main, using a SuperCross microcatheter and a Pilot 200 guidewire. (E) GuideLiner reverse controlled antegrade and retrograde tracking (CART) technique for lesion crossing. (F) After stent implantation, TIMI 3 flow was restored in the left main and circumflex arteries.

Figure 1, and the overall technical characteristics are listed in Table 3. An initial antegrade crossing attempt was used in 12 patients (60%) and a primary retrograde approach was used in the remaining 8 cases (40%). The success rate of the initially applied crossing technique was low (only 2 cases in the primary retrograde group). After failure of antegrade-wire escalation, retrograde crossing was attempted in all cases except 1 case in which antegrade dissection/re-entry was used. In 5 cases, three or more crossing strategies were used, with success in 4 cases.

Overall, antegrade-wire escalation was attempted in 14 cases (70%), but was only successful in 1 case, after multiple failed retrograde or antegrade dissection re-entry crossing attempts. Antegrade dissection re-entry was used in 5 cases (25%) – in most cases after a failed retrograde crossing attempt – and was successful in 2 cases (10%) using Stingray-based re-entry (Boston Scientific) in 1 case and wire-based re-entry in the other. Retrograde crossing through a LIMA graft was attempted in every case and the CTO was successfully crossed in 12 patients (60%). In 11 cases, the lesion crossings were carried out via the LIMA graft, while 1 of them was crossed through a saphenous vein graft and an epicardial collateral. Among the successful retrograde cases, the following crossing techniques were applied: reverse controlled antegrade and retrograde tracking (CART) in 6 cases, GuideLiner reverse CART in 1 case (Figure 2), and true retrograde lumen puncture in 5 cases. Intravascular ultrasound tended to be used more commonly in the LIMA group (45.0% vs 31.4%; P=.20), as were guide-catheter extensions (40.0% vs 27.9%; P=.22).

Bifemoral approach was used in 9 cases (45%) and biradial approach was used in 2 cases. Use of left radial access was significantly higher in the LIMA group (55.0% vs 22.2%; P=.02).

Table 3. Technical characteristics, classified according to whether a LIMA graft was used as retrograde channel during chronic total occlusion percutaneous coronary intervention.

Technical Characteristics	Overall (n = 990)	Retrograde PCI via LIMA (n = 20)	Retrograde PCI via Non-LIMA (n = 970)	P-Value
Dual injection	86.22%	85.00%	86.26%	.75
Right femoral access	86.46%	85.00%	86.49%	.74
Left femoral access	72.22%	60.00%	72.47%	.22
Right radial access	27.47%	25.00%	27.53%	>.99
Left radial access	22.83%	55.00%	22.16%	<.01
Right brachial access	0.20%	0.00%	0.21%	>.99
Left brachial access	0.10%	5.00%	0.00%	.20
Crossing strategies used				
Antegrade wire escalation	61.31%	70.00%	61.13%	.49
Antegrade dissection/re-entry	38.69%	25.00%	38.97%	.25
Retrograde	100%	100%	100%	–
First crossing strategy				.35
Antegrade wire escalation	48.88%	60.00%	48.65%	
Antegrade dissection/re-entry	7.42%	0.00%	7.57%	
Retrograde	43.70%	40.00%	43.78%	
Final crossing strategy				.75
Antegrade wire escalation	7.42%	5.00%	7.46%	
Antegrade dissection/re-entry	15.14%	10.00%	15.23%	
Retrograde	60.04%	60.00%	59.98%	
None	17.40%	25.00%	17.39%	
Guide-catheter extensions	27.88%	40.00%	27.63%	.22
Intravascular ultrasound use	31.72%	45.00%	31.44%	.20
Stents used (n)	2.88 ± 1.17	3.39 ± 1.61	2.88 ± 1.16	.28

Data presented as percentage or mean ± standard deviation.

In 6 cases, triple arterial access was used, including the left radial approach in 5 cases (in 1 patient, brachial access was attempted for providing appropriate IMA guide-catheter support).

Procedural outcomes and complications. The procedural outcomes are shown in Table 4. Technical and procedural success in the retrograde via LIMA grafts was 70% and 70%, respectively, and was similar with other retrograde cases (81% and 78%; *P*=.25 and *P*=.41, respectively). Median contrast volumes (300 mL [IQR, 250-346 mL] vs 300 mL [IQR, 222.5-420 mL]; *P*=.70), patient air-kerma doses (3.54 Gy [IQR, 2.91-5.23 Gy] vs 3.85 Gy [IQR, 1.50-5.78 Gy]; *P*=.92), and fluoroscopy times (89.4 min [IQR, 61-126 min] vs 76.9 min [IQR, 54.9-103 min]; *P*=.14) were also similar in the two study groups, whereas procedural time (222.5 min [IQR, 174-311.5 min] vs 189 min [IQR, 134-245 min]; *P*=.03) was longer in the LIMA group.

Use of mechanical circulatory support was numerically higher in the LIMA vs non-LIMA group (23.5% vs 9.5%; *P*=.08). Mechanical circulatory support was used in 4 retrograde via LIMA cases (prophylactic in 3 and elective in 1); both Impella (Abiomed) and veno-arterial extracorporeal membrane oxygenator (VA-ECMO) were used. One patient initially had an Impella device that was changed to VA-ECMO due to progressive cardiogenic shock.

The incidence of in-hospital MACE was similar in the LIMA and control retrograde groups (5.0% vs 5.5%; *P*>.99). One patient in the LIMA group had a complication; the CTO was successfully crossed using the reverse-CART technique. The CTO was balloon uncrossable, requiring laser atherectomy that led to coronary perforation of the target vessel (left main), which necessitated placement of a covered stent that jailed the circumflex and led to periprocedural myocardial infarction.

Other complications were common in both the LIMA and non-LIMA retrograde groups (25.0% vs 16.7%; *P*=.36). Five complications occurred in the LIMA group. LIMA dissection occurred in 1 patient, but did not compromise flow and no additional treatment was required. Three patients had a vascular access complication (1 patient who was supported by ECMO required surgical correction of a pseudoaneurysm and 2 patients developed groin hematoma without need for surgical correction). One patient developed acute kidney failure requiring hemodialysis.

Procedural outcomes among patients with prior CABG. The procedural outcomes of patients with prior CABG who underwent retrograde CTO intervention are listed in Table 5. Prior CABG was common among retrograde CTO-PCI (46.0%) and the overall technical and procedural success rates were 79.4% and 77.6%, respectively, which was comparable with the retrograde LIMA group (*P*=.27). The overall procedural complications were high in CABG patients (19.7%), as they were in retrograde PCIs via LIMA (25.0% vs 19.4%; *P*=.56), and in-hospital major complications remained similarly low (5.0% vs 5.1%; *P*>.99).

Discussion

To the best of our knowledge, this is the first systematic study of retrograde CTO-PCI via LIMA grafts. LIMA grafts were infrequently used for retrograde CTO-PCI, but

Table 4. Procedural outcomes among patients undergoing retrograde chronic total occlusion percutaneous coronary intervention (CTO-PCI), classified according to whether a LIMA graft was used as retrograde channel during CTO-PCI.

Procedural Outcomes	Overall (n = 976)	Retrograde PCI via LIMA (n = 20)	Retrograde PCI via Non-LIMA (n = 956)	*P*-Value
Technical success	80.81%	70.00%	81.03%	.25
Procedural success	78.00%	70.00%	78.19%	.41
Procedural complications	16.93%	25.00%	16.74%	.36
Procedure time (min)	190 (134.75-246)	222.5 (174-311.5)	189 (134-245)	.03
Contrast volume (mL)	300 (225-419.5)	300 (250-346)	300 (222.5-420)	.70
Fluoroscopy time (min)	76.9 (55-103)	89.4 (61-126)	76.9 (54.9-103)	.14
Patient air-kerma dose (Gray)	3.85 (2.4-5.75)	3.54 (2.91-5.23)	3.85 (1.50-5.78)	.92
In-hospital MACE	5.53%	5.00%	5.54%	>.99
Death	1.43%	0.00%	1.46%	>.99
Acute MI	2.25%	5.00%	2.20%	.37
Stroke	0.31%	0.00%	0.31%	>.99
Re-PCI	0.72%	0.00%	0.73%	>.99
Re-CABG	0.10%	0.00%	0.10%	>.99
Pericardial tamponade	1.64%	0.00%	1.67%	>.99
Vascular access complication	1.84%	15.00%	1.57%	<.01
Acute kidney injury	0.41%	5.00%	0.31%	.08
Donor vessel dissection/ thrombosis	2.22%	5.00%	2.16%	.36
LVAD use	9.87%	23.53%	9.52%	.08

Data presented as percentage or median (interquartile range).
MACE = major adverse cardiovascular events; MI = myocardial infarction; PCI = percutaneous coronary intervention; CABG = coronary artery bypass graft; LVAD = left ventricular assist device.

were associated with similar technical and procedural success rates. Use of LIMA grafts was associated with higher risk for vascular access complications and a trend for more frequent use of mechanical circulatory support devices.

The retrograde approach is critical to the success of CTO PCI, as demonstrated in several studies from around the world.[3,24,25] However, it carries higher risk for complications as compared with antegrade-only crossing strategies, especially in older patients, longer lesions,[23] and prior CABG patients.[26,27] The availability of "interventional" collaterals, ie, collaterals that appear amenable to retrograde crossing with guidewires and microcatheters, is necessary to perform retrograde CTO-PCI. Several patterns of septal and epicardial collaterals were recently described,[28] along with a collateral scoring system for predicting their crossability. Septal collaterals are preferred over epicardial collaterals for retrograde CTO-PCI, as they carry low risk for complications.[29,30] Saphenous vein grafts are also appealing for retrograde CTO-PCI, even when they are occluded.[7,8] LIMA grafts are rarely used for retrograde CTO-PCI, because they carry higher intrinsic risk for complications for several reasons. First, LIMA grafts are often tortuous and advancing guidewires and microcatheters may result in straightening of the graft and an "accordion" effect, leading to compromised flow and ischemia. Second, dissection of the LIMA graft origin can occur; hence, large guide catheters (such as 7 Fr or 8 Fr) are not usually used in these cases. Third, LIMA grafts are usually anastomosed to the left anterior descending artery, and compromising their flow can lead to severe ischemia. Fourth, LIMA grafts have excellent long-term patency, so attempts to prevent vessel injury are critical.

Given the potentially catastrophic risks associated with their use, LIMA grafts should only be used for retrograde CTO-PCI when no other options exist and the potential benefits of the procedure are substantial. Our study demonstrates that LIMA grafts can be successfully used in such cases with good success and acceptable complication rates. Donor-vessel dissection occurred in just 1 case; there was no flow limitation, and the procedure was carried out uneventfully without any additional treatment of the LIMA. To prevent LIMA graft injury, guide catheters should be selected carefully, with softer tips and small diameters (usually 6 Fr or smaller) to avoid pressure dampening. Guide-catheter extensions should be used infrequently, as they may predispose to LIMA dissection.[31] Given the potential for severe ischemia with retrograde CTO-PCI via LIMA grafts, such procedures may more often need to be performed using hemodynamic support devices, which at least in part explains the higher rate of vascular access complications. An alternative to using LIMA grafts and septal collaterals for retrograde PCI or right coronary artery CTOs is to perform left main and/or left anterior descending CTO intervention as a first step, followed by retrograde CTO-PCI via septal collaterals.

Study limitations. Our study has several limitations. The number of patients included was relatively small and we did not have long-term follow-up. The power of the study is low given the small number of cases with PCI via the LIMA graft, and further evaluation is needed with large patient cohorts. There was no core laboratory assessment of the study angiograms or clinical events committee adjudication. The procedures were performed by experienced CTO operators in dedicated, high-volume centers, limiting extrapolation to less experienced operators and centers.

Conclusion

LIMA grafts are infrequently used for retrograde CTO-PCI; however, their use is associated with similar technical and procedural success when compared with other retrograde procedures. In the hands of experienced operators and when performed with great caution, retrograde CTO-PCI via LIMA graft can be a valuable tool for highly complex CTO-PCI cases.

Acknowledgments. Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at the University of Texas Southwestern Medical Center. REDCap is a secure, web-based application designed to support data capture for research studies, providing: (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.

Table 5. Procedural outcomes of retrograde chronic total occlusion percutaneous coronary intervention in patients with prior coronary artery bypass graft, classified according to whether a LIMA graft was used as a retrograde channel.

Procedural Outcomes	Overall (n = 452)	Retrograde PCI via LIMA (n = 20)	Retrograde PCI in Prior CABG Patients (n = 432)	*P*-Value
Technical success	79.35%	70.00%	79.77%	.27
Procedural success	77.6%	70.00%	77.97%	.41
Procedural complications	19.68%	25.00%	19.42%	.56
Procedure time (min)	200 (142-265)	222.5 (174-311.5)	199 (141-264)	.09
Contrast volume (mL)	300 (220-400)	300 (250-346)	300 (220-400)	.96
Fluoroscopy time (min)	79.7 (57.12-105.75)	89.4 (61-126)	79 (56.71-104.7)	.30
Patient air-kerma dose (Gray)	3.95 (2.5-6)	3.54 (2.91-5.23)	3.96 (2.50-6.01)	.72
In-hospital MACE	5.09%	5.00%	5.09%	>.99
Death	1.99%	0.00%	2.08%	>.99
Acute myocardial infarction	2.43%	5.00%	2.31%	.40
Stroke	0.22%	0.00%	0.23%	>.99
Re-PCI	0.44%	0.00%	0.46%	>.99
Re-CABG	0.22%	0.00%	0.23%	>.99
Pericardial tamponade	–	–	–	–
LVAD use	13.35%	23.53%	12.81%	.26

Data presented as percentage or median (interquartile range).
MACE = major adverse cardiovascular events; MI = myocardial infarction; PCI = percutaneous coronary intervention; CABG = coronary artery bypass graft; LVAD = left ventricular assist device.

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