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Radial access for chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO registry

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Abstract

Use of radial access for chronic total occlusion (CTO) percutaneous coronary intervention (PCI) has been increasing. We examined the clinical characteristics and procedural outcomes of patients who underwent CTO PCI with radial versus femoral access in the Prospective Global Registry for the Study of CTO Intervention (PROGRESS-CTO, NCT02061436). Of 10,954 patients who underwent CTO PCI at 55 centers in 7 countries between 2012 and 2022, 2578 (24%) had a radial only approach. Patients who underwent radial only access were younger (63 ± 10 vs. 65 ± 10, years, $p < 0.001$), more likely to be men (84% vs. 81%, $p = 0.001$), and had significantly lower prevalence of comorbidities compared with the femoral access group including diabetes mellitus (39% vs. 45%, $p < 0.001$) and coronary artery bypass graft surgery (57% vs. 64%, $p < 0.001$). In addition, radial only cases had lower angiographic complexity with lower J-CTO and PROGRESS-CTO scores. After adjusting for potential confounders, radial only access was associated with lower risk of access site complications (odds ratio [OR]: 0.45, 95% confidence interval [CI]: 0.22–0.91), similar technical success (OR: 0.87, 95% CI: 0.74–1.04) and major adverse cardiovascular events (MACE) (OR: 0.65, 95% CI: 0.40–1.07), compared with the femoral access group. Radial only access was used in 24% of CTO PCIs and was associated with lower access site complications, and similar technical success and MACE as compared with the femoral access group.

KEYWORDS

chronic total occlusion, complications, femoral access, percutaneous coronary intervention, radial access

1 | INTRODUCTION

Complex percutaneous coronary interventions (PCI) have traditionally been performed via femoral access that allows use of large guide catheters and often provides strong support. Radial access has been increasingly used in complex PCI, such as in chronic total occlusion (CTO) PCI, with encouraging outcomes.[1–5] We examined the temporal trends, prevalence, and clinical outcomes of radial versus femoral access in CTO PCI in a large multinational CTO PCI registry.

2 | METHODS

We examined the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO, NCT02061436) database after stratifying patients based on access site into 3 groups: radial only, radial/femoral, and femoral only.

PROGRESS-CTO includes patient level data for CTO PCI procedures performed between 2012 and 2022 at experienced CTO PCI centers from the United States, Canada, Greece, Turkey, Egypt, Russia, and Lebanon.[6] Study data were collected and managed using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at the Minneapolis Heart Institute Foundation.[7,8]

2.1 | Definitions

The radial only group was defined as the absence of femoral access (includes single or biradial access). The radial/femoral (femoral) group was defined as access via the right and/or left femoral artery, regardless of radial access. The femoral only group was defined as femoral access without radial access (includes single or bifemoral access).

CTOs were defined according to the definition of CTO Academic Research Consortium, as absence of antegrade flow through the lesion with a presumed or documented duration of ≥3 months.[9]

Technical success was defined as the successful canalization of the CTO vessel with <30% residual stenosis and final Thrombolysis in Myocardial Infarction (TIMI) 3 flow. 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).

The Multicenter CTO Registry of Japan (J-CTO) score was calculated as described by Morino et al.,[10] the PROGRESS-CTO score as described by Christopoulos et al.,[11] and the PROGRESS-CTO complications score as described by Danek et al.[12]

Myocardial infarction (MI) was defined using the Third Universal Definition of Myocardial Infarction.[13]

In-hospital major adverse cardiovascular events (MACE) were defined as the composite of in-hospital all-cause mortality, MI, stroke, urgent repeat revascularization (re-PCI or surgery), or pericardiocentesis.

Vascular access site complications included small hematoma (<5 cm), large hematoma (≥5 cm), arteriovenous fistula, pseudoaneurysm, or acute arterial closure.

The study was approved by the institutional review board of each site.

3 | STATISTICAL ANALYSIS

Continuous variables were presented as mean ± standard deviation or median (interquartile range) and compared using the independent *t* test or Mann–Whitney *U* test, as appropriate. Categorical variables were presented as absolute numbers and percentages and were compared using Chi-square or Fisher's exact test, as appropriate. Multivariable logistic regression for technical success, MACE, and vascular access complications was performed separately to adjust for potential confounders using variables with $p < 0.10$ on univariable analysis and clinical plausibility in the multivariable model. Statistical analyses were performed using Stata v17.0 (StataCorp).

4 | RESULTS

4.1 | Clinical and angiographic characteristics

Of 10,954 patients that underwent CTO PCI, 2578 (24%) had radial only access, (12% had single radial access, 12% had biradial access), 29% had femoral-radial access, 15% had single femoral access, and 33% had bifemoral access (Figure 1). Compared with the femoral group, patients who had radial only access were younger, more likely to be men, and had significantly lower prevalence of comorbidities: diabetes mellitus, prior heart failure, prior PCI, and/or prior coronary artery bypass graft surgery (Table 1). In addition, patients who had radial only access had more favorable angiographic characteristics including lower incidence of proximal cap ambiguity, moderate-severe proximal tortuosity, moderate-severe calcification, and significantly lower J-CTO and PROGRESS-CTO scores compared with the femoral group (Table 1). Moreover, balloon undilatable or uncrossable lesions were more prevalent in the femoral group.

Ad hoc PCI rates were higher with radial only access (12.2% vs. 8%, $p < 0.001$), but equipment use was significantly higher in the femoral group (Table 1). The CTO vessel was more often the left

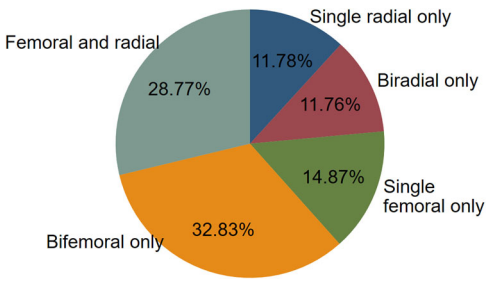

FIGURE 1 Distribution of access sites used for CTO PCI in the PROGRESS-CTO registry. CTO, chronic total occlusion; PCI, percutaneous coronary intervention [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Characteristics and procedural outcomes of patients stratified by chronic total occlusion percutaneous coronary intervention access site

Characteristic/procedural outcomes	Radial only (*n* = 2578)	Femoral (*n* = 8376)	*p* value
Age in years, mean ± *SD*, (*n*)	63 ± 10 (*n* = 2336)	65 ± 10	<0.001
Men, *n*, (%)	2015 (84)	6115 (81)	0.001
Hypertension, *n*, (%)	2093 (88)	6701 (90)	0.021
Dyslipidemia, *n*, (%)	1847 (78)	6685 (89)	<0.001
Atrial fibrillation, *n*, (%)	214 (11)	668 (13)	0.004
Dyspnea, *n*, (%)	1519 (66)	4689 (71)	<0.001
Fatigue, *n*, (%)	1025 (45)	3195 (52)	<0.001
Diabetes mellitus, *n*, (%)	908 (39)	3289 (45)	<0.001
Peripheral arterial disease, *n*, (%)	272 (12)	1068 (15)	<0.001
Family history of premature coronary artery disease, *n*, (%)	694 (32)	1934 (33)	0.371
Prior myocardial infarction, *n*, (%)	1025 (44)	3134 (45)	0.714
Prior heart failure, *n*, (%)	601 (26)	2095 (29)	0.003
Prior percutaneous coronary intervention, *n*, (%)	1368 (57)	4801 (64)	<0.001
Prior coronary artery bypass graft surgery, *n*, (%)	406 (17)	2546 (33)	<0.001
Left ventricular ejection fraction, mean ± *SD*, (*n*)	51 ± 12	50 ± 13	<0.001
Proximal cap ambiguity, *n*, (%)	668 (27)	2681 (38)	<0.001
Moderate/severe proximal tortuosity, *n*, (%)	563 (25)	1892 (30)	<0.001
Moderate/severe calcification, *n*, (%)	891 (35)	3790 (50)	<0.001
CTO length in mm, mean ± *SD*, (*n*)	24 ± 17 (2470)	33 ± 22 (7581)	<0.001
J-CTO score, mean ± *SD*, (n)	2.0 ± 1.3 (2530)	2.5 ± 1.2 (7859)	<0.001
PROGRESS-CTO score, mean ± *SD*, (*n*)	1.2 ± 1.0 (2281)	1.3 ± 1.0 (6293)	<0.001
PROGRESS-CTO complications score, mean ± *SD*, (*n*)	2.3 ± 1.9 (2215)	3.1 ± 1.9 (5492)	<0.001
Balloon uncrossable, *n*, (%)	180 (8.2)	645 (10.5)	0.002
Balloon undilatable, *n*, (%)	116 (5.8)	483 (9.3)	<0.001
CTO target vessel, *n*, (%)			
LAD	724 (28)	1996 (25)	0.001
LCx	528 (21)	1495 (19)	0.031
RCA	1245 (49)	4288 (54)	<0.001
Left main	3 (0.1)	49 (0.6)	0.002
Ad hoc CTO PCI, *n*, (%)	289 (12.2)	554 (8)	<0.001
Total number of guidewires, mean ± *SD*, (*n*)	4.4 ± 3.2 (2140)	6.1 ± 4.4 (4925)	<0.001
Total number of balloons, mean ± *SD*, (*n*)	3.4 ± 2.3 (2123)	4.3 ± 4.2 (4886)	<0.001
Total number of microcatheters, mean ± *SD*, (*n*)	1.0 ± 0.9 (2121)	1.6 ± 1.0 (4909)	<0.001
Total number of support catheters, mean ± *SD*, (*n*)	0.3 ± 0.5 (1898)	0.5 ± 1.0 (4130)	<0.001
Crossing strategy, *n*, (%)			
Antegrade wiring	2415 (94)	7107 (85)	<0.001
Retrograde	474 (18)	3009 (36)	<0.001
Procedure time, mean ± *SD*, (*n*)	100 ± 57 (2304)	140 ± 82 (6628)	<0.001

(Continues)

TABLE 1 (Continued)

Characteristic/procedural outcomes	Radial only (*n* = 2578)	Femoral (*n* = 8376)	*p* value
Contrast volume (ml), mean ± *SD*, (*n*)	216 ± 114 (2423)	246 ± 127 (7549)	<0.001
AK Fluoroscopy Dose (Gray), mean ± *SD*, (*n*)	2.6 ± 2.3 (1535)	2.8 ± 2.1 (5954)	<0.001
Fluoroscopy Time (min), mean ± *SD*, (*n*)	42 ± 31 (2418)	54 ± 34 (7525)	<0.001
Technical success, *n*, (%)	2281 (88.5)	7171 (85.5)	<0.001

Abbreviations: AK, Air kerma; CTO, chronic total occlusion; J-CTO, Multicenter CTO Registry of Japan; LAD, left anterior descending; LCX, left circumflex; PCI, percutaneous coronary intervention; PROGRESS-CTO, Prospective Global Registry for the Study of Chronic Total Occlusion Intervention; RCA, right coronary artery; SD: Standard deviation.

anterior descending (28% vs. 25%, $p = 0.001$) or left circumflex (21% vs. 19%, $p = 0.031$) in the radial only approach, and less often the right coronary artery (49% vs. 54%, $p < 0.001$) or the left main (0.1% vs. 0.6%, $p = 0.002$) (Table 1).

Antegrade wiring (94% vs. 85%, $p < 0.001$) was used more often in the radial only group, whereas retrograde crossing was used more often in the femoral group (18% vs. 36%, $p < 0.001$) (Table 1).

Procedure time, contrast volume, fluoroscopy time and air kerma fluoroscopy dose were higher in the femoral group (Table 1). In radial access, access size was either 6F or 7F in over 90% of cases. The most commonly used guides for antegrade attempts were EBU 3.5 (22%), JR4 (16%), AL 1.0 (13%), AL 0.75 (9%), EBU 3.75 (8%), EBU 4.0 (8%), XB 3.5 (4%), and AL 2.0 (4%); and for retrograde attempts EBU 3.5 (19%), EBU 4.0 (18%), AL 1.0 (14%), JR4 (9%), EBU 3.75 (9%), XB 3.5 (5%), AL 0.75 (4%).

The use of bifemoral access in CTO PCI decreased over time (from 80% in 2012 to 31% in 2021) and was replaced by increasing use of radial access and combined femoral/radial access (Figure 2).

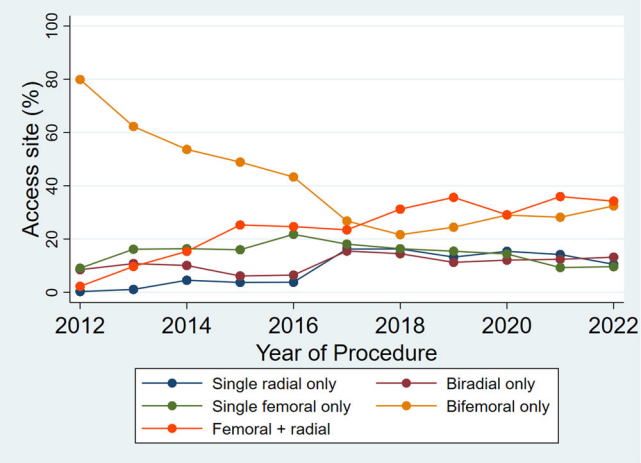

FIGURE 2 Temporal trends of access site utilization in the PROGRESS-CTO registry. CTO, chronic total occlusion [Color figure can be viewed at wileyonlinelibrary.com]

4.2 | Procedural and in-hospital outcomes

Technical success was significantly higher (88.5% vs. 85.5%, $p < 0.001$) (Table 1) and in-hospital complications including all-cause mortality (0.2% vs. 0.5%, $p = 0.037$), MACE (1.5% vs. 2.2%, $p = 0.023$), coronary perforation (3.5% vs. 5.3%, $p < 0.001$), and vascular access complications (0.5% vs. 1.2%, $p = 0.001$), were all significantly lower in the radial only group (Table 2).

4.3 | Femoral/radial versus femoral only access

Baseline characteristics including demographics, comorbidities, and angiographic characteristics were comparable between the femoral only and the femoral group (femoral/radial). Technical success, MACE, and vascular access site complications were also similar (Tables 1 and 2).

4.4 | Multivariable logistic regression

After adjusting for age, sex, dyslipidemia, atrial fibrillation, diabetes mellitus, peripheral artery disease, prior heart failure, prior PCI, prior CABG, proximal cap ambiguity, moderate-severe tortuosity, moderate-severe calcification, and CTO length, radial only access continued to be associated with lower vascular access complications (odds ratio [OR]: 0.45, 95% confidence intervals [CI]: 0.22–0.91, $p = 0.026$) compared with femoral access.

After adjusting for the same variables, radial only access was no longer associated with higher technical success (OR: 0.87, 95% CI: 0.74–1.04, $p = 0.126$) compared with femoral access.

Radial only access continued to have a significant association with lower MACE (OR: 0.60, 95% CI: 0.37–0.97, $p = 0.038$) after adjusting for the same variables; however, when retrograde crossing strategy was added to the adjustment, radial only access was no longer associated with lower MACE (OR: 0.65, 95% CI: 0.40–1.07, $p = 0.087$) compared with femoral access.

TABLE 2 In-hospital clinical events stratified by chronic total occlusion percutaneous coronary intervention access site

In-hospital events	Radial only (n = 2578)	Femoral (n = 8376)	p value
All-cause mortality, *n*, (%)	5 (0.2)	42 (0.5)	0.037
Major adverse cardiovascular events, *n*, (%)	38 (1.5)	184 (2.2)	0.023
Acute myocardial infarction, *n*, (%)	9 (0.4)	57 (0.7)	0.057
Stroke, *n*, (%)	3 (0.1)	16 (0.2)	0.591
Re-PCI, *n*, (%)	6 (0.2)	19 (0.2)	0.956
Emergency coronary artery bypass graft surgery, *n*, (%)	1 (0.04)	9 (0.1)	0.469
Tamponade, *n*, (%)	21 (0.8)	71 (0.8)	1.0
Pericardiocentesis, *n*, (%)	21 (0.8)	71 (0.8)	1.0
Equipment loss, *n*, (%)	3 (0.1)	39 (0.5)	0.010
Perforation, *n*, (%)	90 (3.5)	441 (5.3)	<0.001
Vascular access site complication, *n*, (%)	12 (0.5)	103 (1.2)	0.001
Small hematoma (<5 cm)	7 (0.27)	20 (0.24)	0.769
Large hematoma (≥5 cm)	5 (0.19)	25 (0.30)	0.375
Arteriovenous fistula	0 (0.0)	0 (0.0)	N/A
Pseudoaneurysm	0 (0.0)	5 (0.06)	0.598
Acute arterial closure	0 (0.0)	10 (0.12)	0.130
Dissection, *n*, (%)	14 (0.5)	60 (0.7)	0.348

Abbreviation: PCI, percutaneous coronary intervention.

5 | DISCUSSION

The main findings of our study are that radial only access: (a) is increasingly being used for CTO PCI, as it was utilized in 24% of all CTO PCI procedures with increased use over time; (b) is used more often in lesions with lower angiographic complexity; and (c) is associated with lower vascular access site complications and similar technical success and MACE compared with femoral access, after adjusting for potential confounders (Tables 1 and 2) (Figure 3—Central Illustration).

Similar to our study, a recent meta-analysis investigating the outcomes of radial versus femoral access showed that radial access was used in CTO lesions of lower complexity with J-CTO score (2.3 ± 1.2 vs. 2.5 ± 1.3; $p < 0.001$), with similar technical success (78.7% vs. 78.5%, $p = 0.24$), risk of pericardial tamponade (OR: 0.85, 95% CI: 0.24–3.02, $p = 0.8$), and rate of emergency CABG (OR: 0.79, 95% CI: 0.29–2.11, $p = 0.63$), but with significantly lower incidence of major bleeding (OR: 0.22, 95% CI: 0.10–0.45) and access site complications (OR: 0.34, 95% CI: 0.22–0.51).[14]

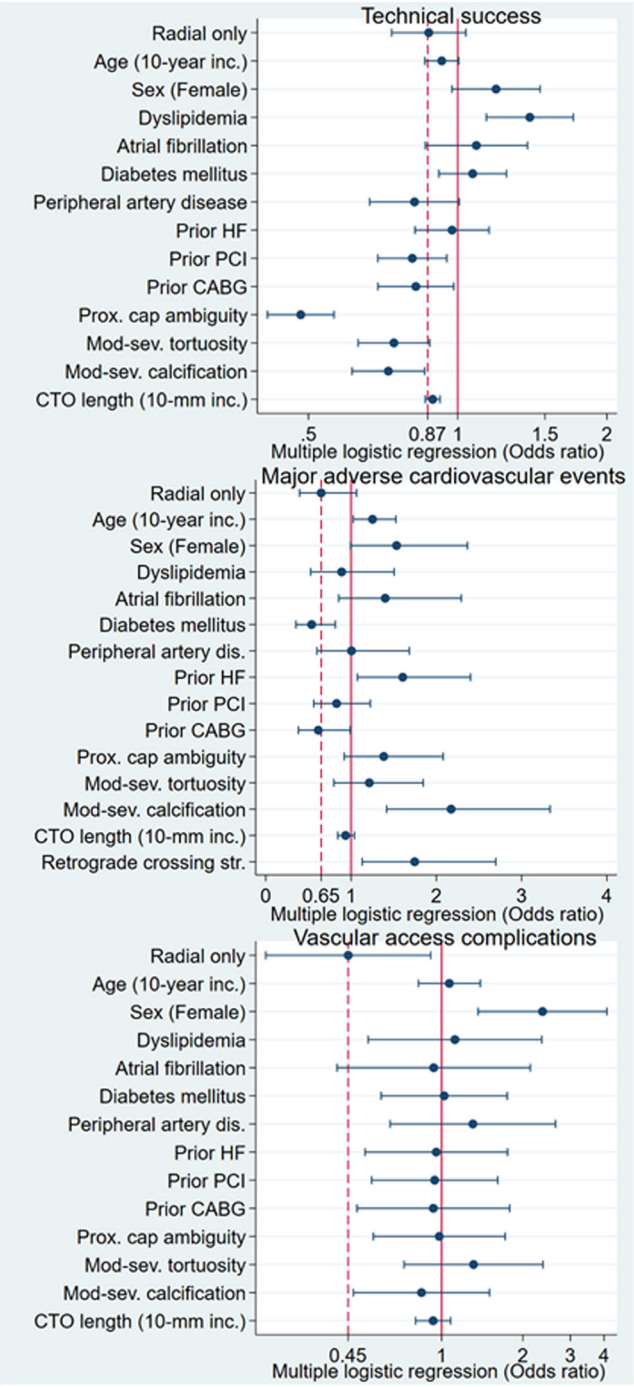

FIGURE 3 (Central illustration): Multiple logistic regression analyses of technical success, major adverse cardiovascular events, and vascular access complications [Color figure can be viewed at wileyonlinelibrary.com]

To determine whether the difference in complications were attributable to femoral access, we created a third comparison group (femoral only), which had similar clinical and angiographic characteristics and outcomes as the "any femoral" group.

In the COLOR (Complex Large-Bore Radial Percutaneous Coronary Intervention) trial, radial versus femoral access in complex

PCI was compared by randomizing 388 patients with complex lesions including LM (14%), CTOs (58%), heavy calcification (19%), or bifurcations (9%) to either 7-French radial ($n = 194$) or 7-French femoral ($n = 194$) access. While overall procedural success was 86% and 89.2% ($p = 0.29$) in the femoral and radial arms, respectively, procedural success in CTO lesions ($n = 223$) was 78.9% and 85.3% ($p = 0.22$) in the femoral and radial groups, respectively.[15] The primary composite outcome of access-site related clinically significant bleeding or vascular complications requiring intervention at discharge was 3.6% for radial and 19.1% for femoral access groups ($p < 0.001$), which was driven by less frequent Bleeding Academic Research Consortium (BARC) type 2 bleeding (16.5% vs. 3.6% for femoral vs. radial access) ($p < 0.001$).[15] However, ultrasound guided puncture was used only in only 40% of femoral and 7% of radial access cases; consistent use of ultrasound-guided puncture might have decreased access site complications.[16]

In the FORT CTO (Femoral or Radial Approach in the Treatment of Coronary Chronic Total Occlusion) trial, the only dedicated randomized controlled trial comparing radial versus femoral access in CTO PCI, 610 patients were randomized to radial ($n = 305$) or femoral ($n = 305$) access.[1] In this trial, technical success (88% vs. 89%, $p = 0.616$) and in-hospital MACE (2.6% vs. 2.4%) were similar between the groups; however, the secondary outcome of access site complications was lower in the radial access group (2.0% vs. 5.6%, $p = 0.019$).[1] No difference was observed in procedure time, contrast volume, or fluoroscopy time between the groups.[1] However, in this study access (femoral or radial) was obtained without the use of ultrasound or fluoroscopic guidance, and arterial closure devices were not used in the femoral group.[17,18] While femoral access might provide better equipment support and facilitate CTO PCI, the FORT CTO trial demonstrated that similarly high success rates can be achieved in CTO PCI independent of access site, highlighting the importance of operator experience. Operators early in the learning curve in CTO PCI might prefer state-of-the-art femoral access in the beginning and gradually transition to radial access.

Dual access is essential in most CTO PCIs. In our registry, overall ad hoc CTO PCI rate was 9%. However, rate of ad hoc CTO PCI was higher in cases with uniradial access (21% vs. 7%, $p < 0.001$) or unifemoral access (25% vs. 5%, $p < 0.001$) compared with other access combinations. In addition, cases with uniradial or unifemoral access (combined) were less complex compared with dual access (J-CTO score: 1.9 ± 1.3 vs. 2.5 ± 1.2, $p < 0.001$), demonstrating that single access cases were more often performed ad hoc and were less complex.

In light of recent data from the FORT CTO trial, and the class 1A recommendation for radial access PCI in acute coronary syndrome and stable ischemic heart disease,[19] use of radial access will likely increase. However, the most common access site in our registry (despite high operator experience) was femoral access (76%) and we believe that femoral access will continue to be useful, not only when radial access is not feasible but also in highly complex cases.

The ongoing REBIRTH (Radial vs. State-Of-The-Art Femoral Access for Bleeding and Access Site Complication Reduction in Cardiac Catheterization, NCT04077762) trial, which is randomizing 3266 patients without ST-segment elevation MI undergoing coronary angiogram with possible PCI (non-CTO) to either radial or state-of-the-art femoral access (18 gauge or 21 gauge, ultrasound-guided puncture, routine femoral angiography, and use of closure devices in femoral access) has the composite primary outcome of BARC type 2-3-5 bleeding at up to 30 days, and will help determine the comparative effectiveness of radial versus femoral access.

6 | LIMITATIONS

Our study has important limitations. First, the PROGRESS-CTO registry is observational with all inherent limitations. Second, we did not adjust for multiple statistical comparisons, which could lead to false positive findings. Third, events were not adjudicated by an independent adjudication committee. Fourth, the postprocedure patency of the radial artery was not routinely assessed. Fifth, the crossover rate from radial to femoral access (or vice versa) was not available. Sixth, the PROGRESS-CTO operators are highly experienced in CTO PCI, which could limit the external validity of the study.

7 | CONCLUSION

In a large multinational CTO PCI registry, radial only access was used in 24% of CTO PCIs with increasing use over time, especially in lower complexity CTOs, and was associated with fewer access site complications, but similar technical success and MACE compared with femoral access after adjusting for potential confounders.

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CONFLICTS OF INTEREST

Dr. Alaswad: consultant and speaker for Boston Scientific, Abbott Cardiovascular, Teleflex, and CSI

Dr. Jaffer: Sponsored research: Canon, Siemens, Shockwave, Teleflex, Mercator, Boston Scientific; Consultant: Boston Scientific, Siemens, Magenta Medical, IMDS, Asahi Intecc, Biotronik, Philips, Intravascular Imaging. Equity interest—Intravascular Imaging Inc, DurVena. Massachusetts General Hospital—licensing arrangements: Terumo, Canon, Spectrawave, for which FAJ has right to receive royalties.

Dr. Doshi: speaker's bureau for Abbott Vascular, Boston Scientific, and Medtronic and research support from Biotronik

Dr. Patel: Consulting Honoraria from Abbott, Medtronic, Terumo, Cardiovascular Systems, Inc.

Dr. Abi Rafeh: Proctor and consultant for Boston Scientific, Abbott, and Shockwave Medical.

Dr. Brilakis: consulting/speaker honoraria from Abbott Vascular, American Heart Association (associate editor Circulation), Amgen, Asahi Intecc, Biotronik, Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), ControlRad, CSI, Elsevier, GE Healthcare, IMDS, InfraRedx, Medicure, Medtronic, Opsens, Siemens, and Teleflex; research support: Boston Scientific, GE Healthcare; owner, Hippocrates LLC; shareholder: MHI Ventures, Cleerly Health, Stallion Medical.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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