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Single vs. multiple operators for chronic total occlusion percutaneous coronary interventions: From the PROGRESS-CTO Registry

Judit Karacsonyi MD, PhD[1] | Khaldoon Alaswad MD[2] | Oleg Krestyaninov MD[3] | Dimitri Karmpaliotis MD, PhD[4] | Ajay Kirtane MD[5] | Ziad Ali MD[6] | Margaret McEntegart MD[5] | Amirali Masoumi MD[4] | Paul Poomipanit MD[7] | Farouc A. Jaffer MD, PhD[8] | Jaikirshan Khatri MD[9] | James Choi MD[10] | Mitul Patel MD[11] | Michalis Koutouzis MD[12] | Ioannis Tsiafoutis MD | Sevket Gorgulu MD[13] | Abdul M. Sheikh MD[14] | Basem Elbarouni MD[15] | Wissam Jaber MD[16] | Ahmed ElGuindy MD, MSc, FRCP[17] | Robert Yeh MD[18] | Spyridon Kostantinis MD[1] | Bahadir Simsek MD[1] | Bavana Rangan BDS, MPH[1] | Olga C. Mastrodemos BA[1] | Evangelia Vemmou MD[1] | Ilias Nikolakopoulos MD[1] | Imre Ungi MD, PhD[19] | Nidal A. Rafeh MD[20] | Omer Goktekin MD[21] | M. Nicholas Burke MD[1] | Emmanouil S. Brilakis MD, PhD[1] | Yader Sandoval MD[1]

[1]Minneapolis Heart Institute, Abbott Northwestern Hospital and Minneapolis Heart Institute Foundation, Minneapolis, Minnesota, USA

[2]Henry Ford Hospital, Detroit, Michigan, USA

[3]Meshalkin Novosibirsk Research Institute, Novosibirsk, Russia

[4]Morristown Medical Center, Gagnon Cardiovascular Institute, Morristown, New Jersey, USA

[5]Columbia University, New York, New York, USA

[6]St. Francis Hospital and Heart Center, Roslyn, New York, USA

[7]Harrington Heart and Vascular Institute, University Hospitals, Case Western Reserve University, Cleveland, Ohio, USA

[8]Division of Cardiology, Massachusetts General Hospital, Boston, Massachusetts, USA

[9]Department of Cardiovascular Medicine, Cleveland Clinic, Cleveland, Ohio, USA

[10]Baylor Heart and Vascular Hospital, Baylor University Medical Center, Dallas, Texas, USA

[11]Division of Cardiovascular Medicine, University of California San Diego, La Jolla, California, USA

[12]2nd Department of Cardiology, Red Cross Hospital of Athens, Athens, Greece

[13]Department of Cardiology, Biruni University Medical School, Istanbul, Turkey

[14]Wellstar Health System, Marietta, Georgia, USA

[15]Department of Internal Medicine, Section of Cardiology, St. Boniface General Hospital, Winnipeg, Manitoba, Canada

[16]Division of Cardiology, Emory University School of Medicine, Atlanta, Georgia, USA

[17]Aswan Heart Centre, Magdi Yacoub Foundation, Aswan, Egypt

[18]Beth Israel Deaconess Medical Center, Boston, Massachusetts, USA

[19]Division of Invasive Cardiology, Department of Internal Medicine and Cardiology Center, University of Szeged, Szeged, Hungary

[20]North Oaks Health System, Hammond, Los Angeles, USA

[21]Department of Cardiology, Memorial Bahcelievler Hospital, Istanbul, Turkey

Correspondence
Yader Sandoval, MD, Minneapolis Heart Institute, Abbott Northwestern Hospital and Center for Coronary Artery Disease, Minneapolis Heart Institute Foundation 920 E 28th St #300, Minneapolis, MN 55407, USA.
Email: yader.sandoval@allina.com

Abstract

Background: There is limited data on the impact of a second attending operator on chronic total occlusion (CTO) percutaneous coronary intervention (PCI) outcomes.

Methods: We analyzed the association between multiple operators (MOs) (>1 attending operator) and procedural outcomes of 9296 CTO PCIs performed between 2012 and 2021 at 37 centers.

Results: CTO PCI was performed by a single operator (SO) in 85% of the cases and by MOs in 15%. Mean patient age was 64.4 ± 10 years and 81% were men. SO cases were more complex with higher Japan-CTO (2.38 ± 1.29 vs. 2.28 ± 1.20, $p = 0.005$) and Prospective Global Registry for the Study of Chronic Total Occlusion Intervention scores (1.13 ± 1.01 vs. 0.97 ± 0.93, $p < 0.001$) compared with MO cases. Procedural time (131 [87, 181] vs. 112 [72, 167] min, $p < 0.001$), fluoroscopy time (49 [31, 76] vs. 42 [25, 68] min, $p < 0.001$), air kerma radiation dose (2.32 vs. 2.10, $p < 0.001$), and contrast volume (230 vs. 210, $p < 0.001$) were higher in MO cases. Cases performed by MOs and SO had similar technical (86% vs. 86%, $p = 0.9$) and procedural success rates (84% vs. 85%, $p = 0.7$), as well as major adverse complication event rates (MACE 2.17% vs. 2.42%, $p = 0.6$). On multivariable analyses, MOs were not associated with higher technical success or lower MACE rates.

Conclusion: In a contemporary, multicenter registry, 15% of CTO PCI cases were performed by multiple operators. Despite being more complex, SO cases had lower procedural and fluoroscopy times, and similar technical and procedural success and risk of complications compared with MO cases.

KEYWORDS
chronic total occlusion, clinical outcomes, operator, percutaneous coronary intervention

1 | INTRODUCTION

Chronic total occlusion (CTO) percutaneous coronary interventions (PCIs) can be challenging but high success rates (85%–90%) with ~3% risk of a major periprocedural complications can be currently achieved at experienced centers.[1–4]

"Double-scrubbing," a term often used to refer to interventional procedures involving a collaborative two-operator (multiple operator [MO]) approach, is often advocated in CTO PCI to improve patient outcomes. Some programs have implemented a routine MO approach for CTO PCI.[5,6] The presumed advantages are complex procedural shared decision-making, complementary technical expertise, partnership that can facilitate maintenance and enhancement of procedural skills, and avoidance of a single operator's [SO's] mental and technical fatigue. There are also educational benefits, particularly when a more experienced operator works with a less experienced operator that can help improve the development of the junior operator, while ensuring that patient outcomes and safety are maintained. Experts have recommended a collaborative two-operator approach (one primary, one assistant), to provide technical support and augment real-time intraprocedural decision-making for high-risk cases.[5,7,8]

There is, however, limited evidence-based data to support a MO approach in CTO PCI.[9] Although an MO approach can have benefits in selected cases, routine double-scrubbing can also potentially limit operator development and independence and is subject to scheduling and administrative challenges. Further, whether an MO approach is cost-effective and associated with improved clinical outcomes is uncertain. Given paucity of evidence-based data in this area, the goal of the present study was to compare MO versus SO CTO PCIs in a large multicenter registry.

2 | METHODS

We analyzed the baseline clinical and angiographic characteristics and procedural outcomes of 9296 CTO PCIs performed between 2012 and 2021 at 37 centers in an international, multicenter registry (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention [PROGRESS-CTO]; Clinicaltrials.gov identifier: NCT02061436). Study data were collected and managed using Research Electronic Data Capture electronic data capture tools hosted at Minneapolis Heart Institute Foundation.[10,11]

The study was approved by the Institutional Review Board of each site.

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 (MI) 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 two bends >70° or one bend >90° and severe tortuosity as two bends >90° or one bend >120° in the CTO vessel. A retrograde

TABLE 1 Baseline clinical, angiographic, and technical characteristics of study patients with SO versus MOs.

Variable	SO (*n* = 7889)	MOs (*n* = 1407)	*p*
Age (years)[a]	64.6 ± 10	63.7 ± 10	0.002
Men	6023 (81.3%)	1124 (81.4%)	0.925
BMI (kg/m^2)[a]	30.5 ± 6	30.0 ± 6	0.007
Diabetes mellitus	3107 (42.9%)	567 (43.3%)	0.787
Hypertension	6638 (90.6%)	1124 (85.7%)	<0.001
Dyslipidemia	6408 (87.5%)	1063 (81.2%)	<0.001
Smoking (current)	1738 (22.0%)	364 (25.9%)	0.002
LVEF (%)[a]	50 ± 13	50 ± 12	0.173
Family history of CAD	1936 (32.0%)	354 (29.5%)	0.086
Congestive heart failure	2119 (29.9%)	308 (23.7%)	<0.001
Prior MI	3237 (46.8%)	491 (38.3%)	<0.001
Prior CABG	2205 (29.1%)	381 (28.7%)	0.750
Prior CVD	759 (10.6%)	106 (8.2%)	0.007
Prior PVD	1049 (14.7%)	154 (11.9%)	0.007
Clinical presentation			
Stable angina	4530 (65.5%)	1001 (76.2%)	<0.001
Unstable angina	1106 (16.0%)	122 (9.3%)	
NSTEMI	602 (8.7%)	59 (4.5%)	
STEMI	91 (1.3%)	24 (1.8%)	
Nonischemic symptoms	166 (2.4%)	17 (1.3%)	
No symptoms	419 (6.1%)	91 (6.7%)	
Baseline creatinine (mg/dl)[b]	1.0 (0.9, 1.2)	1.0 (0.8, 1.2)	<0.001
CTO target vessel			
RCA	4028 (52.6%)	654 (54.1%)	0.021
LAD	1971 (25.7%)	342 (28.3%)	
LCX	1501 (19.6%)	190 (15.7%)	
SVG	11 (0.1%)	0 (0%)	
LM	39 (0.5%)	6 (0.5%)	
Other	114 (1.5%)	6 (0.5%)	
Successful crossing strategy			
Antegrade wiring	4303 (55.0%)	717 (52.5%)	0.035
Retrograde	1512 (19.3%)	248 (18.1%)	
ADR	996 (12.7%)	194 (14.2%)	
None	1014 (13.0%)	208 (15.2%)	
First crossing strategy			
Antegrade wiring	6570 (83.9%)	1099 (80.5%)	0.004
Retrograde	959 (12.2%)	211 (15.5%)	
ADR	306 (3.9%)	55 (4.0%)	
Retrograde crossing strategy	2487 (31.5%)	459 (32.6%)	0.415
J-CTO score[a]	2.38 ± 1.29	2.28 ± 1.20	0.005
Progress CTO score[a]	1.13 ± 1.01	0.97 ± 0.93	<0.001
Calcification (moderate/severe)	3272 (41.5%)	550 (39.1%)	0.094
Proximal vessel tortuosity (moderate/severe)	2117 (26.8%)	261 (18.6%)	<0.001
Proximal cap ambiguity	2384 (34.4%)	440 (38.0%)	0.020
In-stent restenosis	1274 (17.2%)	179 (15.1%)	0.067
Side branch at the proximal cap	3682 (53.9%)	658 (57.4%)	0.027
Blunt/no stump, %	4473 (56.7%)	870 (61.8%)	<0.001
Vessel diameter (mm)[b]	3.0 (2.5, 3.0)	3.0 (2.5, 3.0)	<0.001
Occlusion length (mm)[b]	25 (15, 40)	23 (18, 30)	0.002
Number of stents used[a]	2.3 ± 1.1	2.4 ± 1.1	<0.001

Abbreviations: BMI, body mass index; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CTO, chronic total occlusion; CVD, cerebrovascular disease; J-CTO, Japanese CTO score; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; LM, left main coronary artery; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MO, multiple operator; PROGRESS-CTO score, Prospective Global Registry for the Study of Chronic Total Occlusion Intervention score; PVD, peripheral vascular disease; RCA, right coronary artery; SVG, saphenous vein graft; SP, single operator.

[a]Mean ± SD.

[b]Median (interquartile ranges).

procedure was an attempt to cross the lesion through a collateral vessel or bypass graft supplying the target vessel distal to the lesion; otherwise, the intervention was classified as an antegrade-only procedure. 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 after 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 achievement of technical success without any in-hospital major adverse cardiac event (MACE), which were defined as any of the following events before hospital discharge: death, MI, recurrent symptoms requiring urgent repeat target-vessel revascularization with PCI or coronary artery bypass graft surgery, tamponade requiring either pericardiocentesis or surgery, and stroke. MI was defined using the Third Universal Definition of Myocardial Infarction (Type 4a MI).[12] The Japanese CTO (J-CTO) score was calculated as described by Morino et al.[13] and the PROGRESS-CTO score as described by Christopoulos et al.[14] SOs were defined as a single attending operator and MOs were defined as >1 attending operators. Participation of a fellow was not considered as MOs. Proctored cases were not included in this analysis.

2.1 | Statistical analyses

Categorical variables were expressed as percentages and compared using Pearson's χ^2 test. Continuous variables were presented as mean ± SD or median (interquartile range [IQR]), unless otherwise specified, and were compared using the Student's *t* test for normally distributed variables and the Kruskal–Wallis test for nonparametric variables, as appropriate. The effect of multiple operators on technical success and periprocedural major cardiac adverse events was examined using univariable logistic regression; thereafter, multivariable adjustment was performed by entering variables exhibiting significant univariable association ($p < 0.10$) in the models. Two-sided $p < 0.05$ was considered statistically significant. All statistical analyses were performed using JMP, version 13.0 (SAS Institute).

3 | RESULTS

CTO PCIs were performed by a SO in 85% and by MO in 15% of the cases. Temporal trends are illustrated in **Supporting Information: Figure** 1. Of the 37 institutions included in this analysis, 29 (78%) had CTO PCIs performed by more than one operator. Fellows were present in 23% of CTO PCI cases. Mean patient age was 64.4 ± 10 years, 81% were men, 29% had a history of congestive heart failure, and 46% had a history of MI. The baseline clinical characteristics of the study patients classified according to SO versus MOs are shown in Table 1. Patients in the SO group were older and more likely to have comorbidities than those in the MO group.

The angiographic characteristics of the study lesions are summarized in Table 1. The most common target vessel was the right coronary artery (53%), followed by the left anterior descending coronary artery (26%) and left circumflex (19%). There was no difference between the SO and MO cases in use of the retrograde approach (32% vs. 33%, $p = 0.415$) and antegrade dissection and re-entry (22% vs. 22%, $p = 0.987$). SO cases were more complex with higher Japan-CTO (2.38 ± 1.29 vs. 2.28 ± 1.20, $p = 0.005$) and Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO) (1.13 ± 1.01 vs. 0.97 ± 0.93, $p < 0.001$) scores compared with cases performed by MO. Moderate/severe proximal vessel tortuosity (27% vs. 19%, $p < 0.001$) was more common and the occlusion length longer in the SO compared with the MO group.

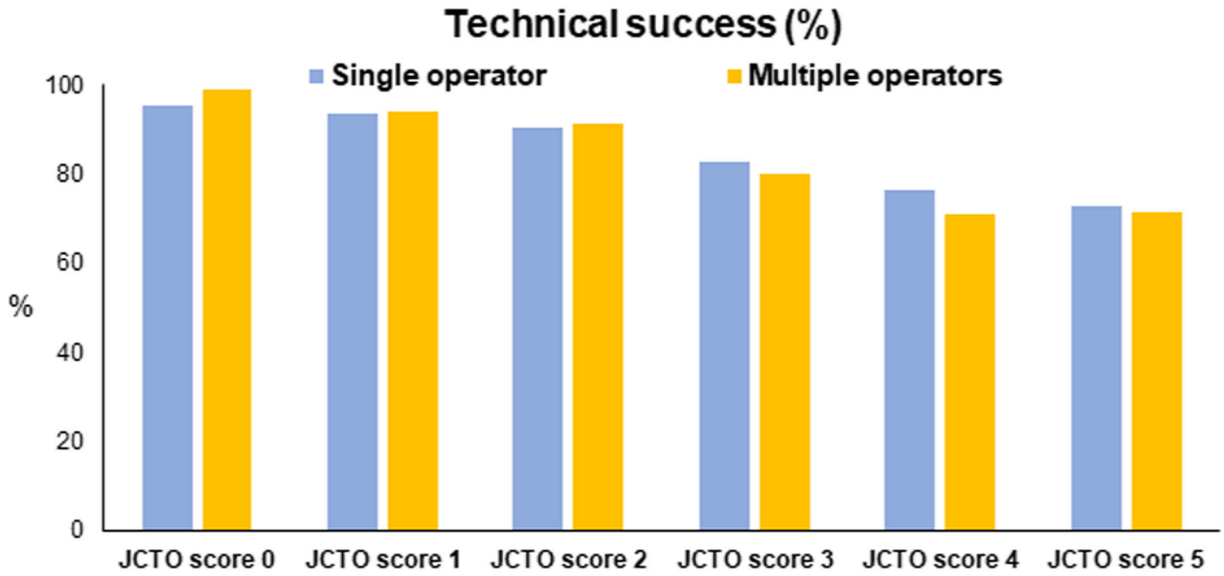
The procedural outcomes are shown in Table 2. Overall technical and procedural success were 86% and 84%, respectively, and the incidence of in-hospital MACE was 2.21%. Cases performed by MO and SO had similar technical (86% vs. 86%, $p = 0.9$) and procedural

TABLE 2 Procedural characteristics and outcomes of study patients with single versus multiple operators.

Variable	SO (*n* = 7889)	MOs (*n* = 1407)	*p*
Technical success	6803 (86.2%)	1212 (86.1%)	0.926
Procedural success	6652 (84.3%)	1192 (84.7%)	0.704
Procedural time (min)[a]	112 (72, 167)	131 (87, 181)	<0.001
Fluoroscopy time (min)[a]	42 (25, 68)	49 (31, 76)	<0.001
Air kerma radiation dose (Gray)[a]	2.10 (1.17, 3.55)	2.32 (1.35, 4.14)	<0.001
Contrast volume (ml)[a]	210 (150, 300)	230 (170, 325)	<0.001
MACE	171 (2.17%)	34 (2.42%)	0.558
Death	35 (0.44%)	10 (0.71%)	0.184
Acute MI	53 (0.67%)	12 (0.85%)	0.453
Re-PCI	22 (0.28%)	2 (0.14%)	0.352
Stroke	16 (0.20%)	2 (0.14%)	0.634
Emergency CABG	8 (0.10%)	2 (0.14%)	0.668
Pericardiocentesis	65 (0.82%)	15 (1.07%)	0.365
Perforation	405 (5.13%)	65 (4.62%)	0.418
Dissection/Thrombus of donor artery	62 (0.79%)	7 (0.50%)	0.246
Vascular access site complication	89 (1.13%)	18 (1.28%)	0.624

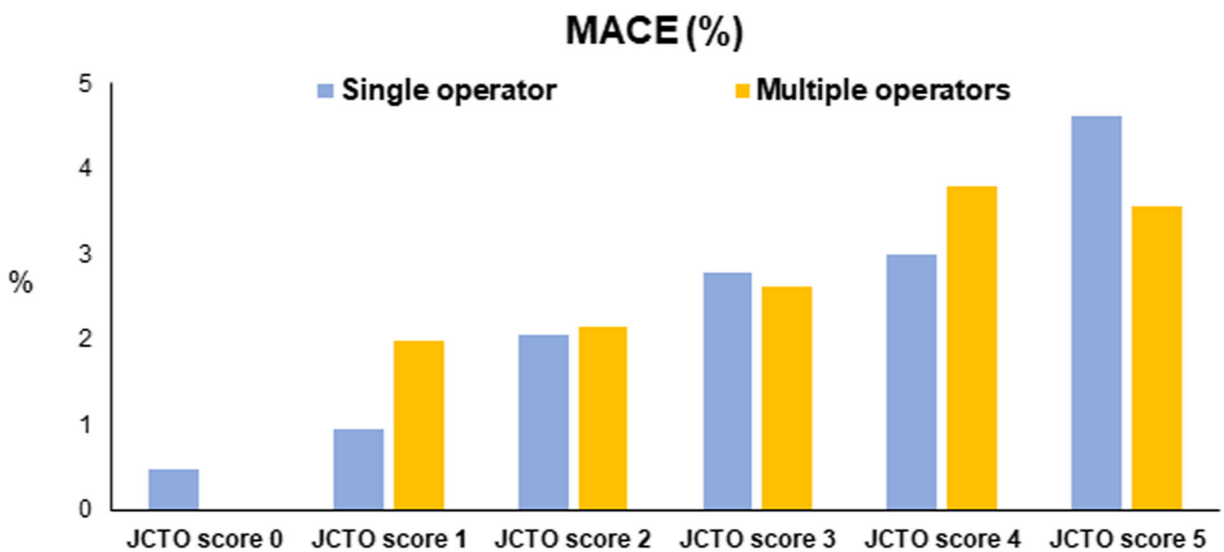
Abbreviations: CABG, coronary artery bypass grafting; MACE, major cardiac adverse events; MI, myocardial infarction; MO, multiple operator; PCI, percutaneous coronary intervention; SO, single operator.
[a]Median (interquartile ranges).

(A)



	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO
Technical success	95.4%	98.8%	93.8%	94.0%	90.3%	91.1%	82.9%	80.0%	76.2%	70.9%	72.9%	71.4%
p value	0.150		0.883		0.673		0.183		0.141		0.864	
Number of cases	696		1634		2270		2397		1424		331	

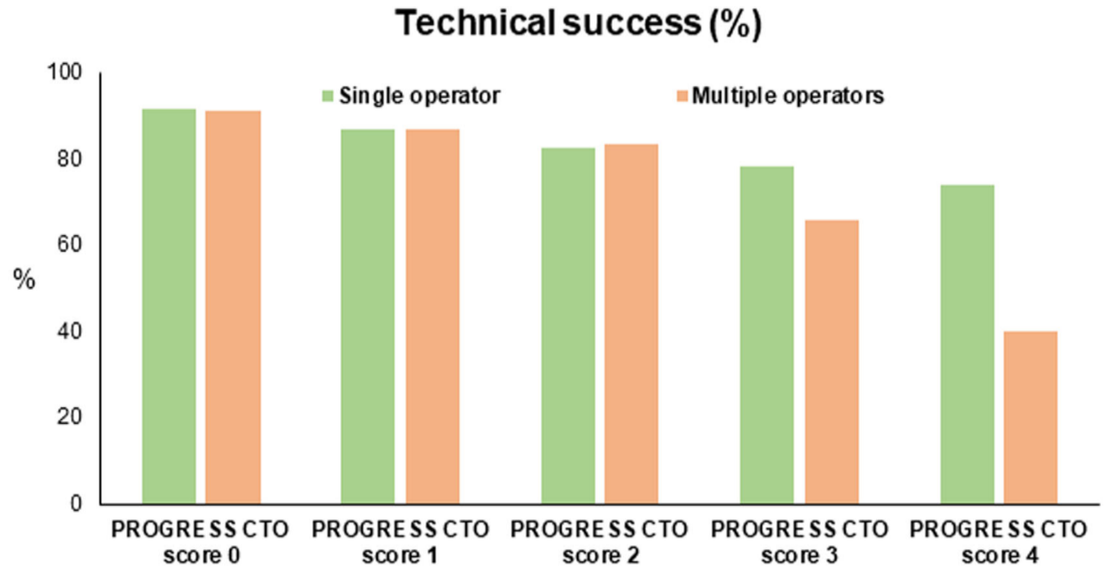
(B)



	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO
MACE	0.49%	0%	0.94%	1.99%	2.06%	2.15%	2.78%	2.61%	3.00%	3.80%	4.62%	3.57%
p value	0.523		0.142		0.909		0.859		0.586		0.799	
Number of cases	696		1634		2270		2397		1424		331	

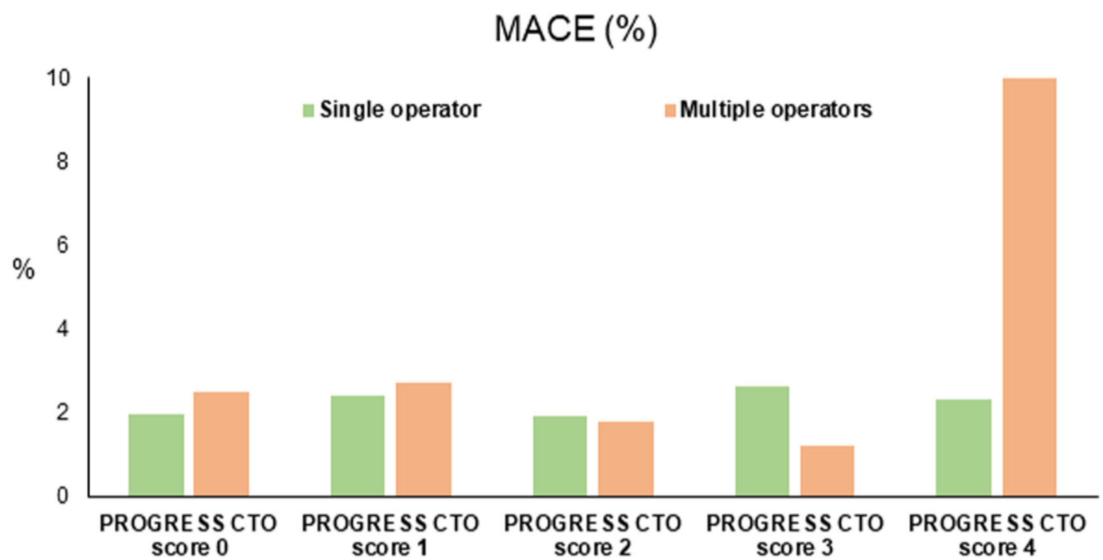
FIGURE 1 Periprocedural outcomes according to Japanese chronic total occlusion (Japan-CTO) scores in single operator (SO) versus multiple operator cases (MOs). (A) Technical success. (B) Major cardiac adverse events (MACEs). [Color figure can be viewed at wileyonlinelibrary.com]

(A)



	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO
Technical success	91.3%	91.1%	86.6%	86.8%	82.5%	83.3%	78.1%	65.9%	73.9%	40.0%
p value	0.913		0.923		0.748		0.013		0.022	
Number of cases	3032		3314		2040		770		140	

(B)



	SO	MO	SO	MO	SO	MO	SO	MO	SO	MO
MACE	1.95%	2.50%	2.39%	2.72%	1.93%	1.78%	2.62%	1.22%	2.31%	10.0%
p value	0.416		0.661		0.861		0.441		0.159	
Number of cases	3032		3314		2040		770		140	

FIGURE 2 Periprocedural outcomes according to Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO) scores in single operator (SO) versus multiple operator (MO) cases. (A) Technical success. (B) Major cardiac adverse events (MACEs). [Color figure can be viewed at wileyonlinelibrary.com]

(84% vs. 85%, $p = 0.7$) success rates, as well as periprocedural MACE 2.17% versus 2.42%, $p = 0.6$). Procedural time (131 [87, 181] vs. 112 [72, 167] min, $p < 0.001$), fluoroscopy time (49 [31, 76] vs. 42 [25, 68] min, $p < 0.001$), air kerma radiation dose (2.32 vs. 2.10 Gray, $p < 0.001$), and contrast volume (230 vs. 210 ml, $p < 0.001$) were higher in MO cases. Technical success and MACE according to J-CTO scores were similar in the two groups (Figure 1). Based on PROGRESS-CTO scores, SO cases had higher technical success rates compared with MO cases in lesions with PROGRESS-CTO scores of 3 (78% vs. 66%, $p = 0.013$) and 4 (74% vs. 40%, $p = 0.022$, Figure 2). On multivariable analyses, MO was not associated with higher technical success or lower MACE rates (Figure 3).

The median (IQR) annual volume for first operators (including SO and MO cases, $n = 9296$ cases) was 45 (21, 81) cases and stratification according to CTO PCI volumes as follows: low-volume operators (<30 cases/year) 37%; medium-volume operators (30–60 cases/year) 30%; and high-volume operators (>60 cases/year) 32%. In cases with MO, the annual volume for second operators was 23 (10, 34). The study population with MO (1407 cases) was also divided into three groups based on annual second operator CTO PCI volume: low-volume operators 57% of the cases; medium-volume operators 41%; and high-volume operators 2.3%. The association of operator volume with first and second operators is shown in Figure 4 ($p < 0.001$). MO cases were performed by a high-volume operator

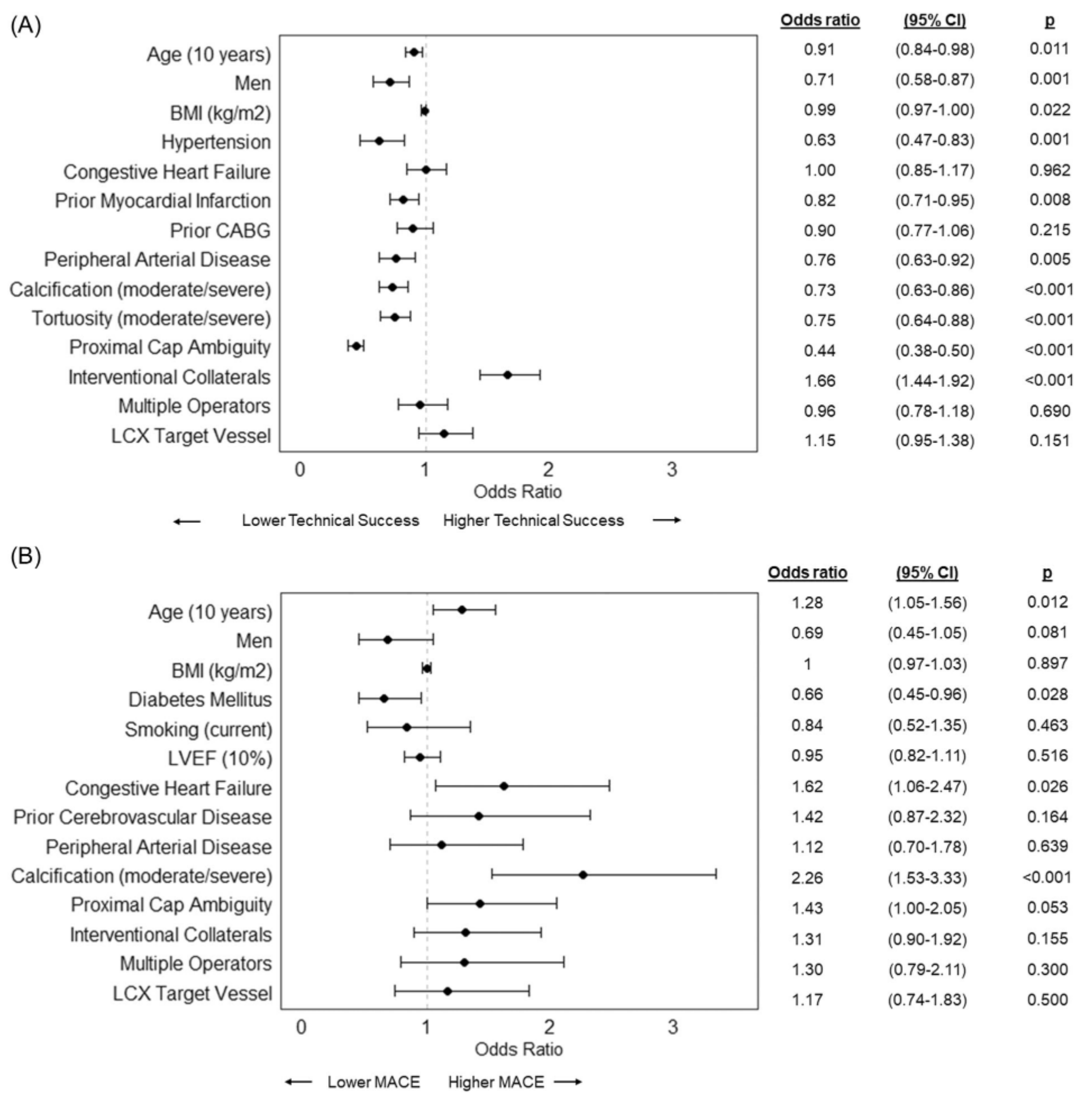


FIGURE 3 Forest plot representing the results of the multivariable analyses technical success (A) and on major cardiac adverse events (MACE; B). BMI, body mass index; CABG, coronary artery bypass grafting; CVD, cerebrovascular disease; LCX, left circumflex coronary artery; LVEF, left ventricular ejection fraction; MACE, major cardiac adverse event.

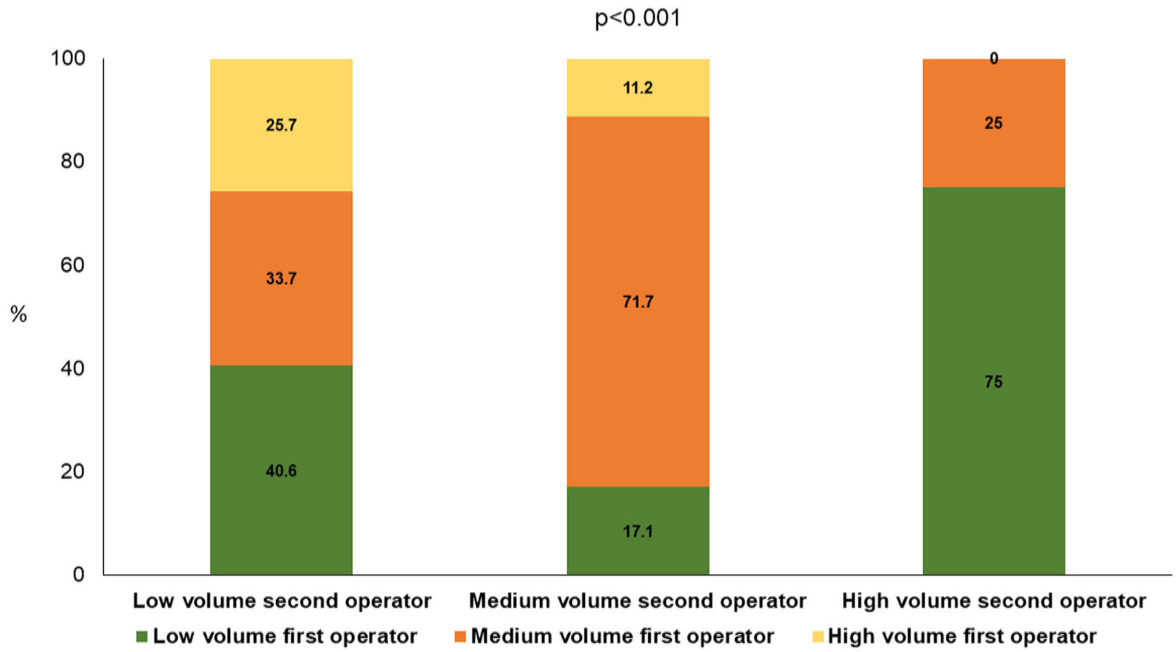


FIGURE 4 The association of operator volume with first and second operators. Low-volume operators (<30 cases/year); medium-volume operators (30–60 cases/year) 30%; high-volume operators (>60 cases/year). [Color figure can be viewed at wileyonlinelibrary.com]

in 19% versus 35% for SO cases. Among MO cases ($n = 1407$), the first and second operator annual CTO PCI volume was 34 (median, IQR 22, 54) and 23 (10, 34), respectively. Among SO cases ($n = 7889$), the annual first operator CTO PCI volume was 45 (21, 81).

4 | DISCUSSION

To the best of our knowledge, this is the first multicenter, international study providing insights on the impact of multiple operators on the outcomes of CTO. First, a MO approach is infrequent (15%). Second, despite the anticipated benefits of double scrubbing, a MO approach was not associated with higher procedural success or lower complications rates as compared with a SO approach. Third, CTO PCIs in the MO group had longer procedural times and were associated with a higher use of radiation and contrast. Fourth, SO cases were more often performed by a high-volume operator as compared with MO cases.

Our study has multiple strengths. First, we utilized data from a large multicenter, international registry with 37 sites and 9296 CTO PCI procedures, providing high power. Second, our registry systematically collects detailed information on the operators performing each procedure, allowing us to compare outcomes of CTO PCI performed by SO versus MOs. Third, we incorporated objective measures of CTO complexity such as the J-CTO and PROGRESS-CTO scores.

Although a MO approach is recommended for high-risk procedures,[5] the impact of a second operator on clinical outcomes is unknown. Kovach et al.[9] identified 6672 patients who underwent high-risk-PCI within the Veterans Affairs Healthcare System and reported similar 12-month incidence of major adverse cardiovascular events after high-risk PCI performed by a SO (6211 cases—93%) versus MO (461 cases—7%). A higher proportion of patients treated by MO underwent left main (10% vs. 7%, $p = 0.045$) or CTO PCI (11% vs. 5%, $p < 0.001$).[9] Operators performing multiple-operator high risk PCI had fewer years of experience and lower annual PCI (and high risk PCI) volumes than those involved in SO procedures.[9,15] Similarly, in our study, operators performing SO CTO PCIs had higher annual CTO PCI volume compared with operators performing MO procedures.

CTO PCIs can be complex, can last multiple hours and involve intraprocedural multitasking, and operators are often required to focus on the details of the patient's clinical status and hemodynamics, while at the same time performing technically challenging tasks. Although not supported by our findings, a second experienced operator could potentially improve the success and safety of CTO PCI.[15] In the study by Kovach et al.[9,15] patients with the highest complexity underwent MO intervention. In contrast, in our study SO cases were more complex with higher J-CTO and PROGRESS-CTO scores compared with MO cases. Moreover, technical success and MACE according to J-CTO scores in SO versus MO cases demonstrated no difference between the groups. However, SO had higher technical success rates compared with MO in PROGRESS-CTO score 3 and 4 cases. Although our study findings do not support a MO approach for CTO PCIs, an MO approach may be beneficial in some cases. A MO approach could help improve individual volumes and facilitate maintenance and growth in PCI skills, as well as allow more exposure to complex cases.[5,7] It may also enhance referral of appropriately selected patients for complex procedures. It could also facilitate on-the-job training of interventionists with an interest in CTO PCI, including an environment for supervised autonomy and growth and development of junior operators. Proctoring differs from double scrubbing in that proctorship does not involve "hands-on" participation of the proctor, whereas a MO approach involves active participation and alternating primary operator roles. Similar to proctoring, however, participation of a highly experienced operator is likely critical in MO cases to prevent "blind leading the blind".[16] Some CTO techniques, such as the DRAFT (Deflate, Retract and Advance into the Fenestration Technique), require two operators.[17,18]

4.1 | Study limitations

Limitations of our study are the observational design, the lack of clinical event adjudication, and core laboratory analyses, and performance of all procedures at experienced PCI centers, limiting the generalizability of our findings to centers with limited CTO PCI experience. Moreover, SO cases were more often performed by high-volume operators compared with MO cases.

4.2 | Conclusion

In a contemporary, multicenter registry, 15% of CTO PCI cases were performed by multiple operators. Despite being more complex, SO cases had lower procedural and fluoroscopy times, and similar technical and procedural success and risk of complications compared with MO cases.

ACKNOWLEDGMENTS

Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at the Minneapolis Heart Institute Foundation (MHIF), Minneapolis, Minnesota. 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. The authors are grateful for the generosity of our many philanthropy partners, including our anonymous donors, Drs. Mary Ann and Donald A. Sens, Ms. Dianne and Dr. Cline Hickok, Ms. Charlotte and Mr. Jerry Golinvaux Family Fund, the Roehl Family Foundation, and the Joseph Durda Foundation, Ms. Wilma and Mr. Dale Johnson, for making this work possible at the Minneapolis Heart Institute Foundation's Science Center for Coronary Artery Disease (CCAD).

CONFLICT OF INTEREST STATEMENT

Khaldoon Alaswad: consultant and speaker for Boston Scientific, Abbott Cardiovascular, Teleflex, and CSI. Dimitri Karmpaliotis: Honoraria: Boston Scientific, Abbot Vascular; Equity: Saranas, Soundbite, Traverse Vascular. Ajay Kirtane: Consulting from IMDS; Travel Expenses/Meals from Medtronic, Boston Scientific, Abbott Vascular, Abiomed, CSI, Siemens, Philips, ReCor Medical, Chiesi, OpSens, Zoll, and Regeneron. Ziad Ali: received institutional grants from Abbott, Philips, Boston Scientific, Acist Medical, Opsens Medical, Medtronic, Abiomed, and Cardiovascular Systems Inc.; consulting fees from AstraZeneca, Amgen, and Boston Scientific; honoraria from AstraZeneca; and stock from Shockwave Medical. Paul Poomipanit: CTO proctor - Abbott Vascular, Asahi Intecc, Boston Scientific. Farouc A. Jaffer: sponsored research from Canon USA, Siemens, Shockwave, Teleflex; Institutional grants: Abbott vascular, Boston Scientific, CSI, Philips, Asahi Intecc, and Biotronik; Consultant for Boston Scientific, Siemens, Biotronik, Magenta Medical, IMDS, and Asahi Intecc; Equity interest, Intravascular Imaging Inc.; DurVena; Massachusetts General Hospital has a patent licensing arrangement with Terumo, Canon USA, and Spectrawave; Farouc A. Jaffer has the right to receive royalties. Jaikirshan Khatri: Personal Honoria for proctoring and speaking: Abbott Vascular, Asahi Intecc, Terumo, Boston Scientific. Mitul Patel: Abbott: Consulting Honoraria, Medtronic: Consulting Honoraria, Terumo: Consulting Honoraria, Cardiovascular Systems, Inc.: Consulting Honoraria. Wissam Jaber: Medtronic and proctoring fees from Abbott. Dr. ElGuindy: received consultancy and proctorship fees from Medtronic, Asahi Intecc, Boston Scientific, and Terumo. Robert Yeh: grants and personal fees from Abbott Vascular, AstraZeneca, Medtronic, and Boston Scientific. Nidal A. Rafeh: proctor and speaker honoraria from Boston Scientific and Abbott Vascular. M. Nicholas Burke: reports being a shareholder in Egg Medical and MHI Ventures. Emmanouil S. 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. All other authors: nothing to disclose.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ORCID

Ziad Ali http://orcid.org/0000-0002-2482-3197
Farouc A. Jaffer http://orcid.org/0000-0001-7980-384X
Jaikirshan Khatri http://orcid.org/0000-0002-0315-3219
James Choi http://orcid.org/0000-0002-2884-7778
Ioannis Tsiafoutis http://orcid.org/0000-0001-7835-793X
Sevket Gorgulu http://orcid.org/0000-0003-4775-1402
Spyridon Kostantinis http://orcid.org/0000-0003-1099-681X
Bahadir Simsek http://orcid.org/0000-0001-6198-8006
Evangelia Vemmou http://orcid.org/0000-0003-3286-6610
Ilias Nikolakopoulos http://orcid.org/0000-0002-7408-8653
Emmanouil S. Brilakis http://orcid.org/0000-0001-9416-9701
Yader Sandoval http://orcid.org/0000-0003-4800-2972

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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