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Guide catheter extension use are associated with higher procedural success in chronic total occlusion percutaneous coronary interventions

Evandro M. Filho MD[1] | Gustavo N. Araujo MD, PhD[2,3] | Guilherme P. Machado MD, PhD[4] | Lucio Padilla MD[5] | João E. T. de Paula MD[6] | Antonio C. Botelho MD[7] | Carlos M. Campos MD, PhD[8] | Franklin L. H. Quesada MD[9] | Marco Alcantara MD[10] | Ricardo Santiago MD[11] | Félix D. de los Santos MD[12,13] | Marcos D. Oliveira MD, MsC[14] | Marcelo H. Ribeiro MD, PhD[2,15] | Luiz Perez MD[16] | Mauro E. Pinto MD, MsC[17] | Leandro A. Côrtes MD[18] | Pedro Piccaro MD, PhD[19] | Emmanouil S. Brilakis MD, PhD[20] | Alexandre S. Quadros MD, PhD[19]

[1]Santa Casa de Misericórdia de Maceió, Maceió, Brazil

[2]Imperial Hospital de Caridade, Florianópolis, Brazil

[3]Instituto de Cardiologia de Santa Catarina, São José, Brazil

[4]Hospital de Clínicas de Porto Alegre, Porto Alegre, Brazil

[5]Instituto Cardiovascular de Buenos Aires, Buenos Aires, Argentina

[6]Instituto Cardiovascular de Linhares UNICOR, Linhares, Brazil

[7]Hospital São José do Avaí, Itaperuna, Brazil

[8]Heart Institute (InCor), University of São Paulo Medical School, São Paulo, Brazil

[9]Clinica Comfamiliar, Pereira, Colombia

[10]Centro Médico 20 de Noviembre, Mexico City, Mexico

[11]Hospital Pavia Santurce, San Juan, Puerto Rico

[12]Instituto Nacional de Cardiología Ignacio Chávez, Mexico City, Mexico

[13]Centro Medico ABC, Mexico City, Mexico

[14]Hospital São Paulo, Escola Paulista de Medicina, UNIFESP, São Paulo, Brazil

[15]Hospital SOS Cardio, Florianópolis, Brazil

Abstract

Background: Guide catheter extensions (GCEs) increase support and facilitate equipment delivery, but aggressive instrumentation may be associated with a higher risk of complications.

Aim: Our aim was to assess the impact of GCEs on procedural success and complications in patients submitted to chronic total occlusion (CTO) percutaneous coronary intervention (PCI).

Methods: We analyzed data from the multicenter LATAM CTO Registry. Procedural success was defined as <30% residual stenosis and TIMI 3 distal flow. Major adverse cardiac and cerebrovascular events (MACCE) was defined as the composite of all-cause death, myocardial infarction, target vessel revascularization, and stroke. Propensity score matching (PSM) was used to compare outcomes with and without GCE use.

Results: From August 2010 to August 2021, 3049 patients were included. GCEs were used in 438 patients (14.5%). In unadjusted analysis, patients in the GCE group were older and had more comorbidities. The median J-CTO score and its components were higher in the GCE group. After PSM, procedural success was higher with GCE use (87.7% vs. 80.5%, $p = 0.007$). The incidence of coronary perforation (odds ratio [OR]: 1.46, 95% confidence interval [CI]: 0.78–2.71, $p = 0.230$), bleeding (OR: 1.99, 95% CI: 0.41–2.41, $p = 0.986$), in-hospital death (OR: 1.39, 95% CI: 0.54–3.62, $p = 0.495$) and MACCE (OR: 1.07, 95% CI: 0.52–2.19, $p = 0.850$) were similar in both groups.

Abbreviations: CTO, chronic total occlusion; GCE, guide catheter extensions; HF, heart failure; MACCE, major adverse cardiac and cerebrovascular events; MI, myocardial infarction; PCI, percutaneous coronary intervention; PSM, propensity score matching.

[16]Hospital Clinico Regional Dr Guillermo Grant Benavente, Concepcion, Chile

[17]Hospital General ISSSTE, Mexico City, Mexico

[18]Instituto Nacional de Cardiologia, Rio de Janeiro, Brazil

[19]Instituto de Cardiologia do Rio Grande do Sul, Porto Alegre, Brazil

[20]Minneapolis Heart Institute and Minneapolis Heart Institute Foundation, Minneapolis, Minnesota, USA

Correspondence
Alexandre S. Quadros, Instituto de Cardiologia/Fundação Universitária de Cardiologia, Av. Princesa Isabel, 395, Santana, Porto Alegre, CEP 90.620.001 RS, Brazil.
Email: consult.asq@gmail.com

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Conclusion: In a contemporary, multicenter cohort of patients undergoing CTO PCI, GCEs were used in older patients, with more comorbidities and complex anatomy. After PSM, GCE use was associated with higher procedural success, and similar incidence of adverse outcomes.

KEYWORDS
chronic total occlusion, coronary artery disease, guide extension catheter, percutaneous coronary intervention

1 | INTRODUCTION

Percutaneous coronary intervention (PCI) of chronic total occlusions (CTO) is challenging, and adjunctive devices are frequently needed to achieve satisfactory results in such procedures. Patients undergoing CTO PCI are often older, with more vessel tortuosity and calcification, and a strong guide catheter support remains key to success. Radial access lowers bleeding complications,[1] but may be associated with weaker guide catheter support, which is a frequent reason for failure during transradial approach and crossover to femoral access.[2]

Guide catheter extension (GCE) allows deep seating within the coronary artery, providing increased support for guidewire and microcatheter advancement, improve deliverability of balloons and stents, and facilitate retrograde guidewire recanalization.[3] GCE also allows selective visualization of the target vessel, improve the stability, and allow a better coaxial alignment of the guide catheter and may block blood inflow during antegrade dissection and re-entry.[4] In modern complex and CTO PCI, GCEs are often used to improve procedural success, but it could also increase the risk of procedural complications,[5,6] due to more aggressive instrumentation of the coronary artery. In contemporary scientific literature, there are still few published data addressing these aspects. The objectives of the present study were to determine the impact of GCEs on procedural success, complication rates, and in-hospital outcomes in patients undergoing CTO PCI in contemporary practice.

2 | METHODS

2.1 | Study population

We analyzed the Latin American (LATAM) CTO Registry database, an ongoing international initiative to collect data on patients undergoing CTO PCI in Latin America. The registry has already been described in detail.[7–10] Patients included in the present analysis were treated in one of 57 institutions from Brazil, Argentina, Ecuador, Mexico, Chile, Puerto Rico, Costa Rica, Peru, and Colombia. The inclusion criteria were age greater than 18 years and at least one CTO PCI attempt as indicated by the attending physician. The decision to use a GCE was at the discretion of the operator. Patients undergoing CTO PCI with adjunctive GCE were compared to those who underwent CTO PCI without them.

2.2 | Data collection

Investigators added CTO PCI data to an online platform available via Research Electronic Data Capture (REDCap).[11] All investigators received standardized instructions for data entry in REDCap, and clinical, procedural and angiographic information and postprocedural clinical outcomes were collected on the same platform. Centers and operators volunteered to participate, and there were no specific requirements regarding CTO PCI volume.

2.3 | Definitions

CTO was defined as an occlusion in a major coronary artery present for at least 3 months based on clinical or angiographic features, such as previous imaging, with no evidence of antegrade flow. Technical success of the CTO PCI was defined as successful CTO revascularization within the treated segment and restoration of TIMI 3 flow with <30% residual stenosis and without significant side branch occlusions.[12] A significant branch was defined as one supplying the left ventricle that is 1.5 mm or larger in diameter. Procedural success was the achievement of technical success without in-hospital major adverse cardiac and cerebrovascular events (MACCE). Other clinical, angiographic, procedural, and postprocedure details used standard definitions from the LATAM CTO registry[7] including the J-CTO[13] and PROGRESS-CTO[14] scores.

2.4 | Outcomes

The primary endpoint of the study was procedural success of the index CTO PCI. Secondary endpoints were in-hospital MACCE and complications. MACCE included all-cause death, myocardial infarction (MI), and stroke. MI was defined using the fourth universal definition of MI (type 4a MI).[15] Stroke was defined as a new focal neurological deficit of sudden onset of presumably cerebrovascular irreversible cause (or resulting in death) within 24 h and not caused by any other easily identifiable cause.

Procedural complications included major bleeding, coronary perforation, cardiac tamponade, and urgent revascularization with PCI or coronary artery bypass graft. Major bleeding was defined as any bleeding causing a reduction in hemoglobin >3 g/dL or bleeding requiring transfusion or surgical intervention.[16] Coronary perforation was reported and classified according to the Ellis classification.[17]

2.5 | Statistical analysis

Continuous variables were expressed as mean ± standard deviation or as the median and interquartile range and were compared using the paired *t*-test or the Wilcoxon signed-rank test, as appropriate. Categorical data were presented as frequencies and percentages and were compared using the χ^2 test. All tests were two-sided and a $p < 0.05$ was considered statistically significant. *p* Values and 95% confidence intervals presented in this report have not been adjusted for multiplicity, and therefore inferences drawn from these statistics may not be reproducible.

Since the decision to use a GCE is generally driven by more complex procedures in higher-risk patients, propensity score matching (PSM) analysis was used to limit biases and create groups with similar baseline characteristics. For the multivariable model, clinical and angiographic characteristics that were both statistically different between groups and known predictors of procedural success were considered as factors or covariates. Other characteristics with unequal distribution between groups were not included to avoid overfitting of the model and collinearity. The logistic regression was performed with GCE as a dependent variable, and the following independent variables: *age, sex, diabetes, previous CTO attempt, lesion location (circumflex artery), tortuosity, calcification, lesion length, and lesion preparation*. Then, PSM was performed using nearest-neighbor methods, and two groups of 391 patients each were created. Data were analyzed using SPSS Statistics (version 23.0.0; IBM company).

3 | RESULTS

3.1 | Baseline clinical characteristics

From August 2010 to August 2021, 3136 patients were included in the LATAM CTO Registry database. Out of 3049 patients with complete information, 438 patients (14.5%) were submitted to CTO PCI with GCE use (Figure 1). Rates of GCE use among the study years are presented in Figure 2.

Patients in the GCE group were older (65.8 vs. 63.9 years, $p < 0.001$) and had higher rates of diabetes (45.5% vs. 39.0%, $p = 0.013$), dyslipidemia (77.4% vs. 70.7%, $p = 0.040$), family history of coronary artery disease (37.7% vs. 29.5%, $p = 0.001$), previous MI (51.1% vs. 46.1%, $p = 0.045$) and chronic kidney disease (11.1% vs. 7.5%, $p = 0.012$) when compared to patients submitted to PCI without GCE use (Table 1).

Table 2 shows the angiographic and procedural characteristics of the study patients. The right coronary artery was the most common target vessel in the GCE group (61.9% vs. 35.9%, $p < 0.001$), and GCE patients had more frequently moderate/severe calcification (34.4 vs. 17.3, $p < 0.001$), proximal tortuosity (10.3% vs. 4.5%, $p < 0.001$),

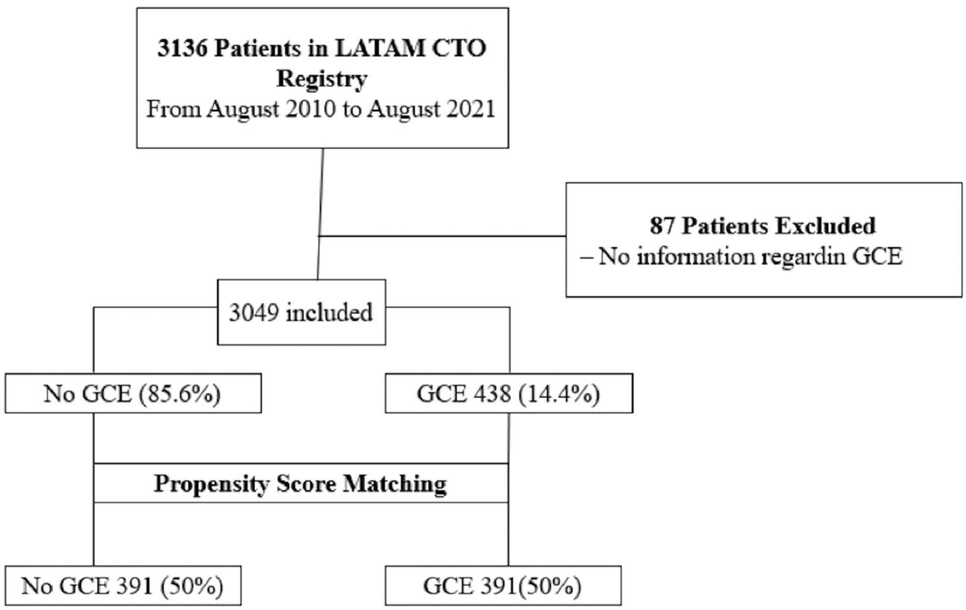


FIGURE 1 Study flowchart. CTO, chronic total occlusion; GCE, guide catheter extension.

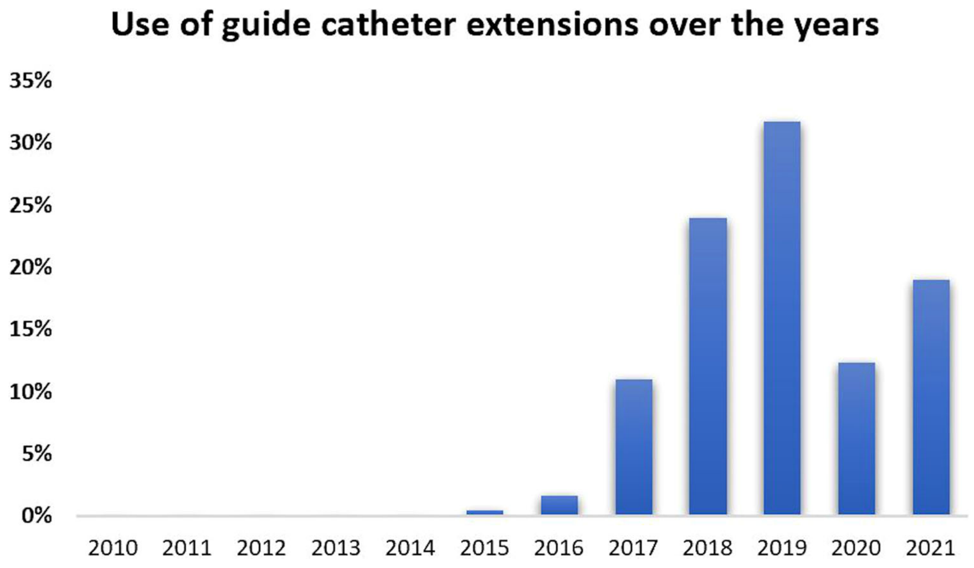


FIGURE 2 Rates of guide catheter extension use according to study year. [Color figure can be viewed at wileyonlinelibrary.com]

previous CTO PCI attempt (18.5% vs. 11.6%, $p < 0.001$) and ostial lesions (23.9% vs. 17.0%, $p < 0.001$). The J-CTO score was higher in the GCE group (median of 3 vs. 2, $p < 0.001$). Antegrade wire escalation was less often the initial crossing strategy (52.7% vs. 86.5%, $p < 0.001$), while an initial retrograde approach was more common (31.1% vs. 5.4%, $p < 0.001$) in the GCE group.

3.2 | PSM

After PSM, the study sample was comprised of 782 patients (391 patients in each group). Most differences in baseline clinical characteristics did not remain statistically different between the two paired groups, as shown in Table 1. Right coronary artery was more frequent in the GCE group (61.4% vs. 40.2%, $p < 0.001$), while anterior descendent coronary was more frequent in the control group (40.9% vs. 21.2%, $p < 0.001$). Absence of moderate/severe calcification was less common in the GCE group (9.7% vs. 13.6%, $p = 0.028$). Microcatheter use (96.9% vs. 84.1%, $p < 0.001$), intravascular ultrasound (36.8% vs. 27.4%, $p = 0.006$) and an initial retrograde strategy (31.9% vs. 8.3%, $p < 0.001$) were more frequent in the GCE group (Table 2).

3.3 | Procedural and in-hospital outcomes

In unadjusted analysis, PCI success was similar between groups (86.5% vs. 86.1%, $p = 0.818$). In-hospital death was numerically higher in the GCE group without a statistical difference (2.6% vs. 1.9%, $p = 0.493$), but there was a trend toward higher MACCE rates in the GCE group (3.9% vs. 2.5%, $p = 0.084$). The incidences of major bleeding, perforation and cardiogenic shock were similar between groups. Minor bleeding was borderline higher in the GCE group (2.5% vs. 1.4%, $p = 0.058$), and heart failure (HF) after the procedure was more common in the GCE group (3.2% vs. 1.3%, $p = 0.003$). The need for a temporary pacemaker during the procedure was higher in the GCE group (1.7% vs. 0.2%, $p < 0.001$).

After PSM, procedural success was significantly higher in the GCE group (87.7% vs. 80.5%, $p = 0.006$). Among retrograde only procedures, success rates with and without GCE were 79.5% and 40%, respectively ($p > 0.001$). There were no statistically significant differences between groups regarding in-hospital death and MACCE. The incidences of major bleeding, perforation, cardiogenic shock, minor bleeding (2.3% vs. 1.8%, $p = 0.535$), and postprocedure HF after (2.8% vs. 3.1%, $p = 0.818$) were similar in the two groups but there was still a trend toward higher use of temporary pacemaker in GCE group (1.5% vs. 0.3%, $p = 0.059$). Table 3 summarizes procedural and in-hospital outcomes in the unselected cohort and after PSM.

4 | DISCUSSION

The main findings of our study are that patients undergoing CTO PCI with adjunctive use of GCEs had more adverse baseline clinical and angiographic characteristics when compared to patients in whom GCEs were not used. After PSM, GCE use was associated with a higher procedural success and similar incidence of complications.

CTO PCI can be a challenging procedure, especially in older patients and those with multiple comorbidities and complex anatomies. The success rates of a CTO PCI have significantly increased in the last decade, reaching 90% at highly experienced centers.[18–20] To achieve higher CTO recanalization success rates in increasingly more challenging lesions, more complex techniques are often required, potentially increasing procedural risk. The incidence of CTO PCI complications ranges from 0.5% to 9% depending on the strategy used, clinical scenario, and operator's expertise.[21] Periprocedural MI

TABLE 1 Baseline clinical characteristics of the study patients before and after propensity score matching.

	Unselected cohort			Propensity matched cohort		
	No GCE (*n* = 2611)	GCE (*n* = 438)	*p*-Value	No GCE (*n* = 391)	GCE (*N* = 391)	*p*-Value
Clinical characteristics						
Age (SD)	63.9 (±10.7)	65.8 (±9.8)	<0.0001	65.6 (±10.4)	65.8 (±9.9)	0.784
Male sex	196 (77.4)	352 (80.4)	0.163	324 (82.9)	317 (81.1)	0.515
Caucasian	1415 (58.3)	217 (52.0)	0.046	221 (58.6)	201 (52.9)	0.276
BMI	27.5 (25.1–30.0)	27.6 (25.1–29.7)	0.942	27.4 (25.1–29.6)	27.5 (24.9–29.7)	0.890
Hypertension	2102 (85.2)	372 (88.6)	0.069	336 (85.9)	346 (88.7)	0.242
Diabetes	960 (39.0)	191 (45.5)	0.013	177 (45.3)	182 (46.5)	0.720
Dyslipidemia	1739 (70.7)	326 (77.4)	0.04	284 (72.8)	304 (77.7)	0.110
PVD	205 (8.8)	69 (17.1)	<0.0001	43 (11.7)	64 (17.2)	0.035
Family history	675 (29.5)	14 8 (37.7)	0.001	103 (28.8)	138 (37.8)	0.010
Smoking (current)	515 (21.1)	93 (22.4)	0.571	73 (18.8)	87 (22.4)	0.214
Previous AMI	1087 (46.1)	209 (51.5)	0.045	172 (46.2)	198 (52.4)	0.092
Previous PCI	1094 (46.0)	229 (55.2)	0.001	209 (56.2)	215 (55.8)	0.925
Previous CABG	302 (12.7)	87 (21.0)	<0.0001	72 (19.4)	77 (20.0)	0.838
Previous stroke	78 (3.3)	17 (4.1)	0.400	9 (2.4)	15 (3.9)	0.246
Heart failure	369 (15.6)	69 (16.7)	0.565	71 (19.1)	66 (17.2)	0.487
Chronic kidney disease	177 (7.5)	46 (11.1)	0.012	39 (10.5)	43 (11.2)	0.772
Angina class			0.089			0.085
I	216 (12.7)	41 (12.7)		41 (14.9)	35 (11.9)	
II	825 (48.4)	148 (45.7)		136 (49.3)	135 (46.1)	
III	589 (34.5)	110 (34.0)		90 (32.6)	100 (34.1)	
IV	75 (4.4)	25 (7.7)		9 (3.3)	23 (7.8)	
NYHA class			0.297			0.159
Asymptomatic—No HF	1404 (57.5)	233 (54.1)		199 (52.8)	205 (53.1)	
I	320 (13.1)	58 (13.5)		56 (14.6)	51 (13.2)	
II	439 (18.0)	96 (22.3)		567 (17.8)	91 (23.6)	
III	229 (9.4)	36 (8.4)		44 (11.7)	31 (8.0)	
IV	50 (2.0)	8 (1.9)		11 (2.9)	8 (2.1)	

Note: Values are expressed as mean (SD), median [IQR], or *n* (%).

The variables used in propensity score matching were age, sex, diabetes, previous chronic total occlusion attempt, lesion location (circumflex artery), tortuosity, calcification, lesion length, and lesion preparation. No corrections for multiple testing were applied.

Abbreviations: ACS, acute coronary syndrome; AMI, acute myocardial infarction; BMI, body mass index; CABG coronary artery bypass graft; GCE, guide catheter extension; HF, heart failure; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; PVD, peripheral vessel disease.

and MACCE rates are higher in patients with unsuccessful CTO PCI.[22]

Among the devices available for treating complex lesions, GCEs are widely present in interventional practice, due to their ease of use, improvement in equipment delivery, and relatively low rate of complications. GCEs are considered a key device in the catheterization laboratory armamentarium for the management of uncrossable lesions, to facilitate wire externalization in retrograde CTO PCI, thrombus aspiration, intracoronary thrombolysis and to retrieve entrapped and/or loss of intracoronary devices.[5] The frequency of GCE use in the daily practice of PCIs is around 5%,[6] but it is not generally described in CTO registries. Kinnaird et al.[23] have shown a progressive use of GCEs in CTO PCI throughout the years, from 1.8% in 2009 to 7% in 2014. In the LATAM CTO registry, GCEs were used

TABLE 2 Angiographic and procedural characteristics of the study patients before and after propensity score matching.

	Unselected cohort			Propensity matched cohort		
	No GCE (*n* = 2611)	GCE (*n* = 438)	*p*-Value	No GCE (*n* = 391)	GCE (*N* = 391)	*p*-Value
Procedural characteristics						
Lesion preparation	159 (6.1)	74 (16.9)	<0.0001	55 (14.1)	62 (15.9)	0.483
Left main	12 (0.5)	5 (1.1)	0.086	4 (1.0)	3 (0.8)	0.704
Anterior descending	989 (37.9)	92 (21.0)	<0.0001	160 (40.9)	83 (21.2)	<0.0001
Circumflex	575 (22.0)	69 (15.8)	0.003	64 (16.4)	64 (16.6)	1.000
Right coronary	938 (35.9)	269 (61.4)	<0.0001	157 (40.2)	240 (61.4)	<0.0001
Successful crossing strategy			<0.0001			<0.0001
AWE	1867 (86.5)	198 (52.7)		257 (82.1)	180 (52.6)	
ADR	174 (8.1)	61 (16.2)		30 (9.6)	53 (15.5)	
RWE	70 (3.2)	45 (12.0)		15 (4.8)	39 (11.4)	
RDR	48 (2.2)	72 (19.1)		11 (3.5)	70 (20.5)	
Calcification			<0.0001			0.028
Absent	660 (26.5)	40 (9.3)		53 (13.6)	38 (9.7)	
Mild	733(29.4)	112 (26.0)		76 (19.4)	108 (27.6)	
Moderate	669 (26.8)	130 (30.2)		121 (30.9)	121 (30.9)	
Important	430 (17.3)	148 (34.4)		141 (36.1)	124 (31.7)	
Proximal tortuosity			<0.0001			0.766
No	1343 (54.0)	174 (40.6)		167 (42.7)	1365 (42.2)	
Mild	738 (29.7)	136 (31.7)		125 (32.0)	124 (31.7)	
Moderate	294 (11.8)	75 (17.5)		69 (17.6)	64 (16.4)	
Important	111 (4.5)	44 (10.3)		30 (7.7)	38 (9.7)	
Previous attempt	290 (11.6)	80 (18.5)	<0.0001	84 (21.5)	74 (18.9)	0.373
IVUS	468 (20.4)	162 (37.0)	<0.0001	97 (27.4)	144 (36.8)	0.006
Ostial lesion	424 (17.0)	103 (23.9)	0.001	85 (21.7)	89 (22.8)	0.731
Fluoroscopy	30 (20–48)	63.5 (42–90)	<0.0001	38 (25–57)	63 (42–89)	<0.0001
Time to cross the CTO	19 (10–35.5)	45 (21–80)	<0.0001	20 (12–46.5)	45 (23–80)	<0.0001
No. of balloons	3 (2–4)	4 (3–6)	<0.0001	3 (2–4)	4 (3–6)	<0.0001
No. of DES	2 (1–3)	3 (2–3)	<0.0001	2 (1–3)	3 (2–3)	<0.0001
Lesion length	20 (15–30)	25 (20–34.7)	<0.0001	25 (15–35)	25 (20–34)	0.117
Diameter < 2.5 mm	231 (10.8)	36 (9.3)	0.563	40 (11.8)	34 (9.2)	0.272
J-CTO score	2 [1–3]	3 [2–4]	<0.0001	3 [2–3]	3 [2–3]	0.167
Contrast volume	220 (150–300)	280 (200–350)	<0.0001	250 (180–312)	270 (200–350)	0.003
Microcatheter use	2020 (77.4)	425 (97.0)	<0.0001	329 (84.1)	379 (96.9)	<0.0001

Note: Values are expressed as mean (SD), median [IQR], or *n* (%).

The variables used in propensity score matching were age, sex, diabetes, previous CTO attempt, lesion location (circumflex artery), tortuosity, calcification, lesion length, and lesion preparation. No corrections for multiple testing were applied.

Abbreviations: ADR, antegrade dissection and re-entry; AWE, antegrade wire escalation; CTO, chronic total occlusion; DES, drug eluting stent; GCE, guide catheter extension; IVUS, intravascular ultrasound; RDR, retrograde dissection and re-entry; RWE, retrograde wire escalation.

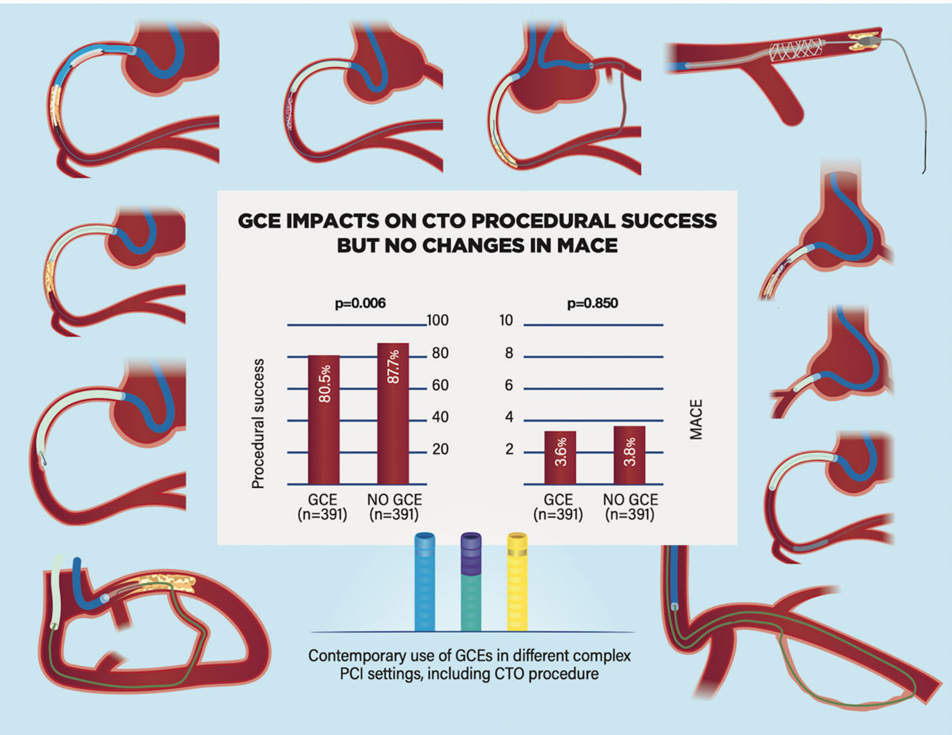
TABLE 3 Procedural results, complications, and in-hospital clinical outcomes of the study patients before and after propensity score matching.

	Unselected cohort			Propensity matched cohort		
	No GCE (*n* = 2611)	GCE (*n* = 438)	*p*-Value	No GCE (*n* = 391)	GCE (*N* = 391)	*p*-Value
Slow flow	118 (4.7)	24 (5.5)	0.466	26 (6.8)	23 (5.9)	0.611
PCI success	2172 (86.1)	378 (86.5)	0.818	314 (80.5)	343 (87.7)	0.006
HF after procedure	34 (1.3)	14 (3.2)	0.003	12 (3.1)	11 (2.8)	0.818
Temporary pacemaker	4 (0.2)	7 (1.7)	<0.0001	1 (0.3)	6 (1.5)	0.059
Cardiogenic shock	37 (1.5)	10 (2.3)	0.204	6 (1.5)	9 (2.3)	0.433
Bleeding			0.058			0.535
No	2470 (97.6)	426 (97.3)		378 (97.4)	381 (97.4)	
Minor	35 (1.4)	11 (2.5)		7 (1.8)	9 (2.3)	
Major	26 (1.0)	1 (0.2)		3 (0.8)	1 (0.3)	
Death	37 (1.5)	11 (2.6)	0.118	7 (1.9)	10 (2.6)	0.493
Stroke	7 (0.3)	1 (0.2)	0.844	1 (0.3)	1 (0.3)	0.983
MI	26 (1.1)	6 (1.5)	0.548	6 (1.6)	5 (1.3)	0.714
MACCE	64 (2.5)	17 (3.9)	0.084	14 (3.6)	15 (3.8)	0.850

Note: Values are expressed as mean (SD), median [IQR], or *n* (%).

The variables used in propensity score matching were age, sex, diabetes, previous chronic total occlusion attempt, lesion location (circumflex artery), tortuosity, calcification, lesion length, and lesion preparation. No corrections for multiple testing were applied.

Abbreviations: GCE, guide catheter extension; HF, heart failure; MACCE, major cardiac and cerebrovascular outcomes; MI, myocardial infarction; PCI, percutaneous coronary intervention.



CENTRAL ILLUSTRATION 1 Contemporary use of GCEs in different complex PCI settings, including CTO procedures. CTO, chronic total occlusion; GCE, guide catheter extension; MACE, major adverse cardiac and cerebrovascular event; PCI, percutaneous coronary intervention. [Color figure can be viewed at wileyonlinelibrary.com] in 14.5% of cases but mostly used after the second half of the registry period.

A GCE is of particular importance when CTO PCI is performed by radial access, as it often provides less support than femoral access. Complication rates with GCE use in general PCI are <2%,[24] and a small registry of CTO PCI has shown one coronary perforation (4.3%) without hemodynamic compromise in a small series of 23 patients with balloon uncrossable CTOs.[25] Other possible complications are proximal dissections due to deep intubation, ischemia due to pressure damping, and gear damage (smaller lumen than a regular guide catheter). Procedural complications may be associated with but not caused by GCE use, as more complex lesions require adjunctive devices and aggressive approaches. Unfortunately, there are no randomized controlled data comparing success rates, overall complications and clinical outcomes of patients undergoing CTO PCI with and without GCE.

GCEs can be also especially useful in retrograde CTO PCI. While such techniques increase success rates,[26] procedural complexity also becomes higher, as dissection and reentry techniques are often required to overcome long and calcified occluded segments. Guide catheter support is crucial in these settings, and GCEs facilitate reentry with both antegrade and retrograde dissection techniques. One of the new commonly used techniques is the "Guide Extension Catheter Facilitated Reverse Controlled Antegrade and Retrograde Tracking" where a GCE is advanced over the antegrade guidewire, creating a new "target" for the retrograde guidewire.[27–29] In our registry, GCEs were used in 10% of procedures with antegrade crossing versus 39% of retrograde cases ($p < 0.001$). Antegrade wire escalation as the initial strategy was commonly used in the non-GCE group that included less complex CTOs. Retrograde wire escalation, antegrade and retrograde dissection and re-entry techniques were more often the initial crossing strategy in the GCE group, and among retrograde only procedures, success rates with GCE were significantly higher (79.5% vs. 40%, $p < 0.001$).

Our study has limitations. First, the data included were reported by centers, with no on-site auditing or monitoring. To minimize such bias, all centers received data-input training, and databank administrators periodically checked the database for outliers, spurious values, and asymmetries to improve gathered data quality. Second, the inclusion of patients by each center was not necessarily consecutive, which could have introduced a selection bias. Third, this analysis is from LATAM countries that included procedures from operators and centers of all levels of expertise and equipment availability, and it may not apply to other regions with different operator's profile and equipment availability. Fourth, the observational nature of this analysis may be subject to bias. Some variables were different between groups even after PSM, which may have influenced the study results. As an example, there were significant differences between groups in anterior descendent and right coronary artery intervention rates. However, most previous studies have not shown significantly different CTO PCI success rates between these vessels, while circumflex artery interventions are consistently associated with lower success rates.[30,31] For that reason, we felt that this variable must had to be included in PSM. Unfortunately, we cannot include all variables we want because of collinearity and overfitting of the model.

In conclusion, in this multicenter registry of patients undergoing CTO PCI, GCEs were used in older patients, with more comorbidities and more complex anatomy. After adjustment for baseline differences by PSM, their use was associated with higher rates of procedural success, and similar procedural complications and adverse clinical outcomes (Central Illustration 1).

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in LATAM at https://www.latamctoregistry.com.

ORCID

Evandro M. Filho http://orcid.org/0000-0001-9926-5081
Gustavo N. Araujo http://orcid.org/0000-0002-1989-1670
Guilherme P. Machado http://orcid.org/0000-0002-5514-2562
Carlos M. Campos http://orcid.org/0000-0003-1734-6924
Marcos D. Oliveira https://orcid.org/0000-0001-6953-8544
Emmanouil S. Brilakis http://orcid.org/0000-0001-9416-9701
Alexandre S. Quadros http://orcid.org/0000-0002-1733-6665

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