Angiography and Percutaneous Coronary Intervention for Chronic Total Coronary Occlusion in Daily Practice (from a Large French Registry [CARDIO-ARSIF])

Madjid Boukantar, MD[a,*], Aurélie Loyeau, PhD[b], Romain Gallet, MD[a], Sophie Bataille, MD[b], Hakim Benamer, MD[c], Christophe Caussin, MD[d], Philippe Garot, MD[c], Bernard Livarek, MD[e], Olivier Varenne, MD, PhD[f], Christian Spaulding, MD, PhD[g], Gaëtan Karrillon, MD[h], and Emmanuel Teiger, MD, PhD[a]

The aim of this study was to provide contemporary data on chronic total occlusion (CTO) prevalence and management in a large unselected population representing the daily activity of cathlabs, in the greater Paris area, and to compare percutaneous coronary intervention (PCI) features in patients with and without CTO. Procedures were collected from the CARDIO-ARSIF (Agence Régionale de Santé Ile de France) registry from 2012 to 2015. Patients with acute coronary syndrome or previous coronary artery bypass grafting were excluded. CTO features were assessed and PCIs with and without CTO were compared. Among 128,739 included patients, 10,468 (8.1%) had at least 1 CTO. Cardiovascular risk-factor burden was higher in the CTO group, which had more patients with multivessel disease (74% vs 24%) and with referral for interventional management (59% vs 33%). Of all PCIs during the study period, 5.7% involved a CTO; this proportion increased significantly over the study period. PCI success rate was 75.9% in the CTO group. CTO-PCI volume per center did not correlate with CTO-PCI success rate. In conclusion, CTO is common in patients who underwent scheduled coronary angiography. Invasive management is done more often in patients with than without CTO. The success rate of PCI in CTO is not associated with case volume per center. **(Am J Cardiol 2019;124:688−695)**

The true prevalence of coronary chronic total occlusions (CTO) is unclear. Among patients with coronary artery disease (CAD) referred for coronary angiography (CA), 16% to 52% have CTO.[1−4] The prevalence of CTO in unselected populations in 3 recent multicenter retrospective studies was 11.5% to 14.7%.[2,5,6] Limitations of these studies include the small number of participating centers, short study period, and absence of data collected after 2013. To date, only few studies have assessed the prevalence, and management of CTO in a large unselected population of patients who underwent scheduled heart catheterization in daily practice. Our first objective was to assess the prevalence, clinical characteristics, and management of CTO in stable unselected patients who underwent nonemergent CA. Our secondary objective was to compare percutaneous coronary intervention (PCI) features in patients with and without CTO. To achieve these objectives, we used data from CARDIO-ARSIF (*Agence Régionale de Santé Ile de France*), an ongoing prospective regional registry of all patients who underwent CA with or without PCI in the greater Paris area.

Methods

The CARDIO-ARSIF registry was initiated in 2001 by the Regional Health Agency of the Greater Paris Area, a governmental agency, to record and monitor all coronary diagnostic and therapeutic procedures performed in 36 catheterization laboratories (7 university, 12 general, 5 nonprofit private, and 12 for-profit private hospitals) of the greater Paris area, which has a population of about 12 million (19% of the population in France). Each procedure is entered prospectively into a computer database by the physician who performed the procedure. Multiple procedures in the same patient are entered separately. Recorded variables include demographics, preprocedural clinical status and extensive procedural information. Participation in the registry is mandatory to obtain PCI certification. Internal audits are performed on 10% of cases twice a year at each center. In addition, an independent external random audit of 3% of cases is performed every 6 months to check data completeness and accuracy. In accordance with French ethical requirements, the CARDIO-ARSIF registry was approved by the French data protection

[a]Interventional Cardiology, University Hospital Henri Mondor, Assistance Publique-Hôpitaux de Paris, France; [b]Agence Régionale de Santé d'Ile-de-France (ARSIF), Paris, France; [c]Hôpital Privé Jacques Cartier, Institut Cardiovasculaire Paris Sud (ICPS), Massy, France; [d]Cardiology Department, Institut Mutualiste Montsouris, Paris, France; [e]Cardiology Department, Versailles Hospital (André Mignot), Le Chesnay, France; [f]Cardiology Department, University Hospital Cochin, Assistance Publique-Hôpitaux de Paris, France; [g]Cardiology Department, European Georges Pompidou Hospital, Assistance Publique-Hôpitaux de Paris, France; and [h]Cardiology Department, Simone Veil Hospital, Eaubonne, France. Manuscript received February 5, 2019; revised manuscript received and accepted May 21, 2019.

Funding: None.

See page 694 for disclosure information.

*Corresponding author: Tel: +33149812111; fax: +33181942111.

E-mail address: madjid.boukantar@aphp.fr (M. Boukantar).

0002-9149/
https://doi.org/10.1016/j.amjcard.2019.05.062

authority (*Commission Nationale de l'Informatique et des Libertés*, CNIL).

CTO was included among the variables recorded in the CARDIO-ARSIF registry in January 2012. For the purpose of this study, we included all patients who underwent nonemergent CA between January 1, 2012, and December 31, 2015. Among them, we identified those with CTO, defined as 100% luminal diameter stenosis and absence of antegrade flow, known or assumed to have been present for more than 3 months. To ensure that only chronic lesions were included, we excluded patients receiving emergency care for cardiac arrest, ST-elevation myocardial infarction (STEMI), or non-STEMI. We also excluded patients with a history of coronary artery bypass grafting (CABG). In the second part of the study, we identified all PCIs performed during the same period, excluding emergent PCIs performed for cardiac arrest, STEMI, or non-STEMI. For each patient in the CTO and non-CTO groups, we recorded demographic data, CA findings and treatment strategies. Features of CTO-PCI and non-CTO-PCI were compared, including demographic and procedural data.

Continuous variables are presented as mean ± SD or median and quartiles, and categorical variables were reported as percentages. The baseline characteristics were compared between patients with CTO versus without CTO. Treatment strategies were compared between coronary angiograms with CTO versus without CTO. A second set of comparison was performed between PCIs of CTO versus non-CTO PCIs. Differences in baseline characteristics between the groups were tested using the chi-square test or Fisher's exact test for categorical variables and Student's *t* test or Wilcoxon rank-sum test for continuous variables, as appropriate. Nonparametrics Mann-Whitney U test and Kruskal-Wallis test were used for comparison of continuous non-normally distributed variables in 2 or more independent groups. Tests for trends were made using the Armitage-Cochrane trend test for categorical data. We used logistic regression with test for linear trend to evaluate whether CTO-PCI procedural success was correlated to CTO volume activity per center. p values < 0.05 were taken to indicate statistically significant differences. Statistical analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC).

Results

During the study period, 258,526 coronary procedures were performed in the greater Paris area, including 143,294 nonemergent CAs in 128 739 patients, which form the basis for this study. The flowchart is shown in Figure 1. Of these 128,739 patients, 10,468 (8.1%) had CTO. CTO was more common in the right coronary artery and branches (n = 6782, 47.63%) than in the left anterior descending artery and branches (n = 3668, 25.76%) and circumflex artery and branches (n = 3789, 26.61%).

Compared with the non-CTO group, the CTO group had a greater burden of cardiovascular risk factors with higher prevalence of hypertension, dyslipidemia, current smoking, and diabetes. Patients with CTO more often had a history of myocardial infarction, chronic kidney disease, stroke, and/or peripheral vascular disease. Multivessel disease was more common in the CTO group (Table 1). In-hospital mortality was not different between CTO patients and non-CTO patients (n = 80, 0.6% vs n = 764, 0.8%, p = 0.15).

PCI to either CTO or non-CTO arteries was undertaken more frequently in the CTO group (49% vs 33%, $p < 0.0001$). Among CAs with CTO, 31% were extended by ad hoc PCI and 18% by staged PCI on CTO or non-CTO lesions, compared with 23% and 10%, respectively, in the non-CTO group. Referral to a heart team was more common in the CTO group than in the non-CTO group (18% vs 7%, $p < 0.0001$). Referral for CABG was twice as common in the CTO group compared with the non-CTO group (n = 1101, 10% vs n = 6058, 5%; $p < 0.0001$) (Table 2).

Of the 61,469 nonemergent PCIs performed during the study period, 8,976 (14.6%) staged PCIs could not be linked to a previous diagnostic CA and were excluded from our analysis, as were the 2,514 (4%) procedures with missing data on lesion severity and the 56 PCIs performed more than 1 year after the diagnostic CA. The flowchart is shown in Figure 2. Of the 49 923 remaining PCIs, in 43,768 patients, 2,829 (5.7%) were for CTO lesions and 47,094 for non-CTO lesions. In 72 cases, at least 2 CTOs were treated during the same procedure. Table 3 lists the indications for PCI. Multiple accesses were more common in the CTO-PCI group, which had a longer fluoroscopy time and a higher dose-area product (DAP). Figure 3 shows that the DAP was high for most CTO-PCIs. Mean number of stents implanted was higher, total stented length greater, and mean stent diameter lower in the CTO-PCI group (Table 4). In-hospital mortality was not different between CTO-PCIs and non-CTO PCIs (n=7, 0.25% vs n=194, 0.41%, p=0.18).

The proportion of CTO-PCIs among all PCIs increased from 2.6% in 2012 to 7.2% in 2015 ($P<0.0001$). Fluoroscopy time decreased significantly from 2012 to 2014 and remained stable thereafter, whereas the DAP continued to decrease ($p < 0.0001$) (Table 5). The procedural success rate was lower for CTO-PCI than for non-CTO-PCI (Table 4). Procedural CTO-PCI success rates improved nonsignificantly during the study period from 74 to 76% (p = 0.19). In the center-by-center analysis, CTO-PCI volume did not correlate with procedural success overall (Figure 4). Even after excluding very low-volume centers (<25 CTO procedures/year), CTO-PCI success rates showed no correlation with CTO-PCI volume (p = 0.17) (Figure 5).

Discussion

This large multicenter registry study provides data on CTO in unselected patients who underwent scheduled diagnostic CA in daily clinical practice in a large urban area. The prevalence of CTO was 8.1%. Both ad hoc and staged PCIs were more common in the presence of a CTO. Of all PCIs performed in these patients managed in the nonemergency setting, 5.7% were done to treat CTO. CTO-PCI had a lower procedural success rate compared to non-CTO-PCI, as well as greater radiation exposure, a larger number of stents used, a greater stented length, and a lower mean stent diameter. The CTO-PCI procedural success rate was not

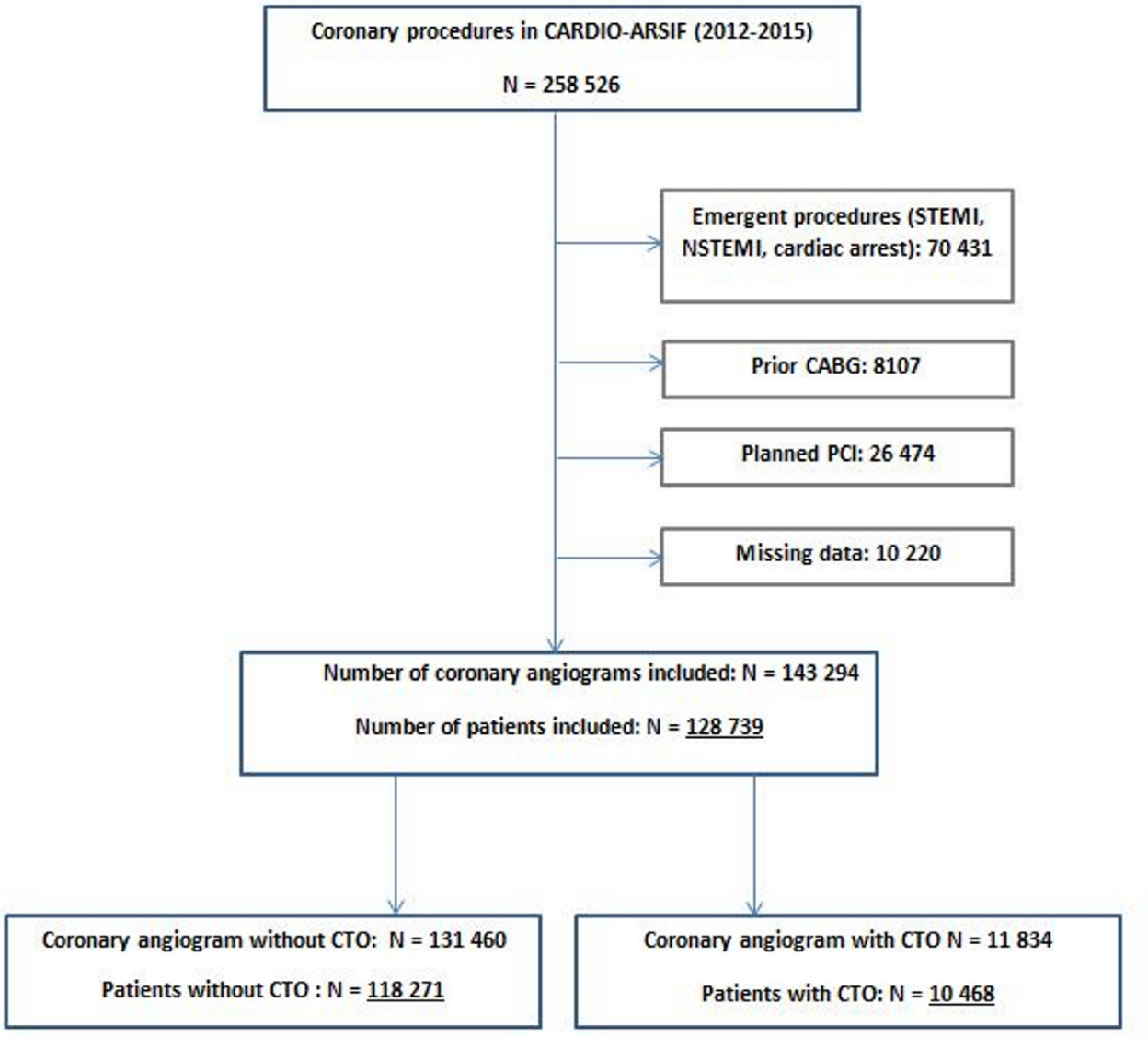

Figure 1. Patient flowchart. NSTEMI = non-ST-segment elevation myocardial infarction.

associated with case volume and showed no significant variation across study centers.

Reported prevalence of CTO varies across populations.[1–3,5,7] Of 6,581 patients with at least 1 >70% stenosis, 52% had CTO.[1] In a population-based sample entered into the Swedish SCAAR registry in 2005 to 2012, the prevalence of CTO was 11.5% overall and 16% among patients with coronary artery stenosis >50%.[5] Coronary emergencies were excluded from these analyses, as they were from ours. In the Italian Registry of Chronic Total Occlusions (IRCO), CTO was noted in 13.3% of 13 423 patients screened in 2007.[6] The lower prevalence of 8.1% in our study compared with earlier reports may be ascribable to several factors. Of the cases in our registry, 27% were emergency procedures and were therefore excluded. In the SCAAR registry, 41.8% of patients with unstable CAD had CTO.[5] Among patients with STEMI, 10% to 15% had CTO, regardless of the culprit artery.[8,9] In the IRCO, however, only 16.7% of patients with CTO presented with STEMI or non-STEMI.[6] In our study, including patients with non-STEMI in the analysis would not substantially change the prevalence of CTO. Recent data suggest that the prevalence of CTO may be declining in western countries, although variations in local practices and populations may act as a confounding factor. A decline in CTO may reflect improved cardiovascular risk management and/or the increasing rate of primary PCI in patients with STEMI and non-STEMI. The latter hypothesis is supported by data from the French Registry of Acute ST-Elevation or Non-ST-elevation Myocardial Infarction. In France, the rate of primary PCI increased from 12% to 75% in STEMI and the rate of PCI in non-STEMI patients from 9% to 60% between 1995 and 2015.[10]

Treatment strategies differed depending on the presence or not of CTO. Coronary revascularization was performed more often in the CTO group, due to the high proportion of

Table 1
Baseline characteristics of patients with coronary chronic total occlusion

Variable	Chronic total occlusion		Missing data	p Value
	Yes n = 10468	No n = 118 271	n	
Age (years)	67.4 ± 11.4	66.7 ± 12.3	212 (0%)	0.0008
Men	8757 (84%)	81 220 (69%)	307 (0%)	<0.0001
Family history of coronary artery disease	1458 (15%)	14 736 (13%)	8600 (7%)	0.0004
Hypertension	6516 (63%)	63 508 (56%)	4130 (3%)	<0.0001
Dyslipidemia	6310 (61%)	55 110 (49%)	4917 (4%)	<0.0001
Overweight*	3683 (67%)	27 550 (64%)	5389 (10%)	<0.0001
Smoker (ever)	5363 (61%)	47 223 (49%)	24 380 (19%)	<0.0001
Diabetes mellitus	3636 (35%)	29 712 (26%)	3562 (3%)	<0.0001
Prior percutaneous coronary intervention	3479 (34%)	22 725 (20%)	4770 (4%)	<0.0001
Prior myocardial infarction	1551 (15%)	6499 (6%)	3129 (2%)	<0.0001
Prior stroke	460 (5%)	3335 (3%)	7700 (6%)	<0.0001
Chronic kidney disease	676 (7%)	5778 (5%)	7797 (6%)	<0.0001
Peripheral vascular disease	1421 (14%)	8714 (8%)	7525 (6%)	<0.0001
Left ventricle ejection fraction <50 %	3753 (38%)	49 254 (45%)	9418 (7%)	<0.0001
1-vessel coronary artery disease	2700 (26%)	29 245 (25%)	2023 (2%)	0.1401
2-vessel coronary artery disease	3678 (35%)	17 352 (15%)	2023 (2%)	<0.0001
3-vessel coronary artery disease	4051 (39%)	10 037 (9%)	2023 (2%)	<0.0001

Values are mean ± SD or n (%).

Hypertension = systolic blood pressure >140 mm Hg, diastolic blood pressure >90 mm Hg, or the use of antihypertensive medications; Dyslipidemia = low-density lipoprotein cholesterol ≥140 mg/dl, high-density lipoprotein cholesterol ≤40 mg/dl, triglyceride ≥150 mg/dl, or current treatment with statins and/or lipid-lowering agents; Overweight = body mass index > 25kg/m^2.

* Data available since 2014.

CA without severe coronary stenosis in the non-CTO group. However, the CTO group had a high rate of revascularization by either PCI (49%) or CABG (10%). Heart team referral, which usually leads to CABG or PCI, was 18%. Pharmacological therapy alone was used in only 21% of CTO patients. These results are in contradiction with previous studies. Of our CTO cases, 49% were managed with staged or ad hoc PCI, compared with 11% of 1,612 cases of CTO in an earlier study.[1] Similarly, in the Canadian CTO registry, only 30% of patients with CTO underwent PCI, and 40% received pharmacological therapy only.[2] Another recent US study showed that 50% of patients with CTO and no previous CABG underwent PCI.[3] Similarly, in the IRCO, 43.7% of CTOs were managed by PCI.[6] These results confirm that the presence of a CTO is no longer an obstacle to treat coronary stenosis by PCI.

Table 2
Therapeutic strategies according to the presence or absence of coronary chronic total occlusion at diagnostic coronary angiography

Variable	Chronic total occlusion		p Value
	Yes	No	
Coronary angiogram (n)	11 834	131 460	
Missing data	556	6407	
Medical treatment	2381 (21%)	50 712 (41%)	<0.0001
Coronary bypass	1101 (10%)	6058 (5%)	<0.0001
Ad hoc percutaneous coronary intervention	3530* (31%)	29 367 (23%)	<0.0001
Planned percutaneous coronary intervention	2012* (18%)	12 458 (10%)	<0.0001
Heart team referral	2009 (18%)	9073 (7%)	<0.0001
No treatment	35 (0%)	10 359 (8%)	<0.0001
Valve surgery	128 (1%)	5008 (4%)	<0.0001
Other	82 (1%)	2018 (2%)	<0.0001
Total	11278	125053	

Values are n (%).

* PCI could involve CTO or non-CTO lesion.

The 75.7% CTO-PCI procedural success rate in our study is higher than the 53% and 59% rates in recent studies and remained stable over the 4-year study period.[11,12] Our data are from 2012 to 2015 and therefore reflect recent improvements in equipment and techniques. This procedural success rate is in keeping with the 79.7% and 74% rates reported previously.[6,13] However, patient selection may also have contributed to our procedural success rate. Few centers had high CTO-PCI volumes. Interventional cardiologists with limited experience in CTO-PCI may reserve PCI for cases of limited complexity, thus increasing their success rate. During the study period, the CTO-PCI volume increased almost 3-fold. This finding probably reflects growing confidence in CTO-PCI and its benefits for patients.[6,14] Radiation exposure measured by the DAP and air Kerma decreased over the study period. These data are consistent with Cardio-ARSIF registry results in the overall population of PCI patients in the same geographic area.[15] Overall, CTO-PCI volume did not correlate with the CTO-PCI procedural success rate, even after excluding centers performing less than 25 CTO-PCI procedures per year. The overall CTO-PCI procedural success rate was high in our population. As suggested above, this may reflect selection of relatively simple CTO cases for PCI. Thus, a double approach is generally required to treat complex CTO cases

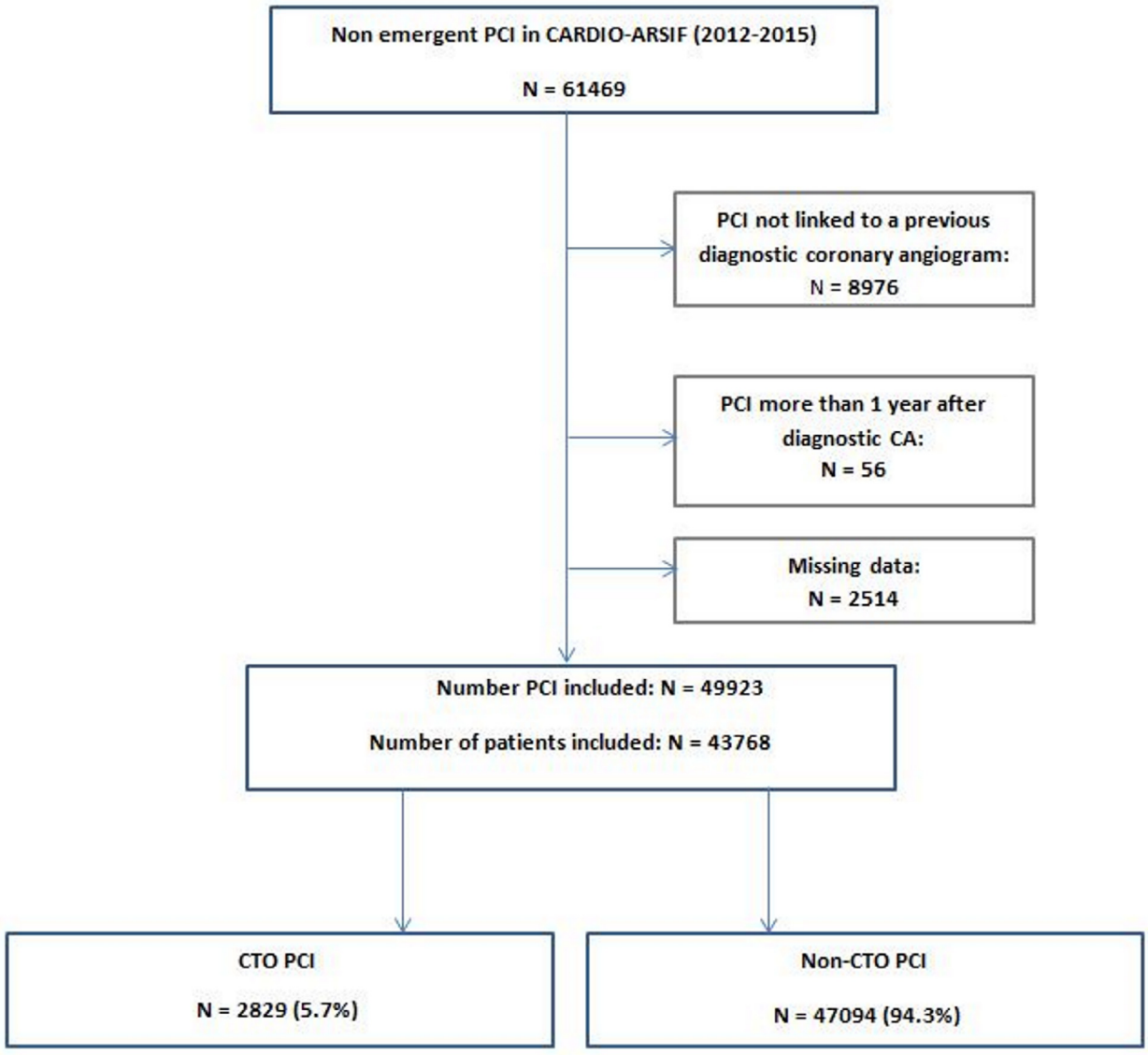

Figure 2. Flowchart of patients with CTO-PCI.

Table 3
Comparison of percutaneous coronary intervention indications and vascular access between patients treated for coronary chronic total occlusion or not

Indication	CTO-PCI (N = 2829)	Non-CTO-PCI (N = 47 094)	Missing data	p Value
Angina pectoris	1433 (52%)	22 639 (50%)	3%	0.0936
Silent myocardial ischemia	918 (36%)	11 811 (31%)	18%	<0.0001
Documented myocardial ischemia	2440 (87%)	37 424 (81%)	2%	<0.0001
Vascular access				
Radial	1788 (64%)	40 230 (87%)	1%	<0.0001
Femoral	250 (9%)	4374 (9%)	1%	0.4406
Multiple	733 (26%)	1682 (4%)	1%	<0.0001

Values are n (%).
CTO = chronic total occlusion; PCI = percutaneous coronary intervention.

but was rarely used in our population. These data suggest that volume of the center is not a good reflection of the good management of CTOs. Previous studies showed that CTO-PCI volume per interventional cardiologist correlated more closely with the procedural success rate than did the CTO-PCI volume per center.[11,12,16]

This study has substantial limitations. First of all, our choice to compare data from an unselected population

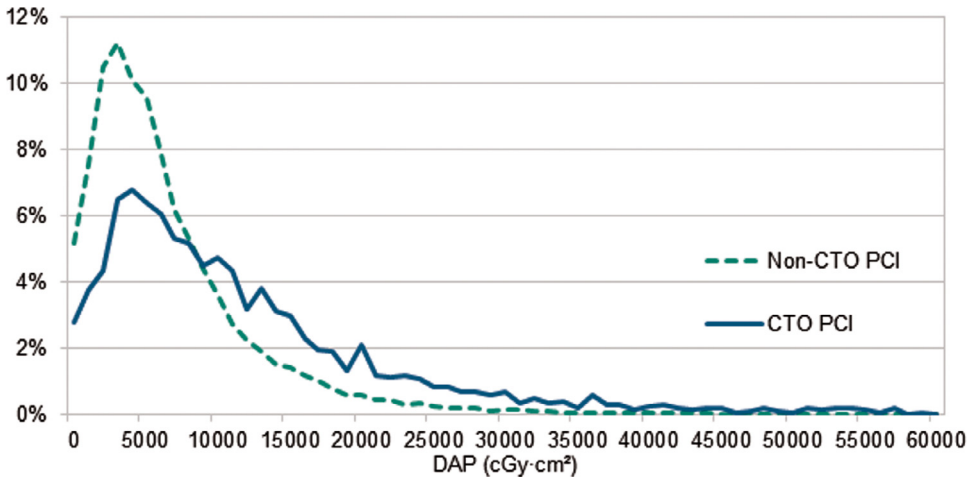

Figure 3. Dose-area product (cGy·cm^2) distribution of CTO-PCIs and non CTO-PCIs.

Table 4
Procedural characteristics of percutaneous coronary interventions performed to treat coronary chronic total occlusion or not

Procedural characteristics	CTO-PCI N = 2829 (5.7%)	Non CTO-PCI N = 47 094 (94.3%)	p Value
Fluoroscopy time (minutes)	20:49 (12:46-34:37)	10:19 (6:33-16:30)	<0.0001
Dose area product, c·Gy cm^2, 75th percentile	9011(4640-15769)	5122(2754-8854)	<0.0001
Number of stents per percutaneous coronary intervention	1.93 ± 0.92	1.50 ± 0.79	<0.0001
Stent length per percutaneous coronary intervention (mm)	46.94 ± 26.42	28.11 ± 17.64	<0.0001
Stent diameter (mm)	2.76 ± 0.40	2.92 ± 0.47	<0.0001
Procedural success	75.7 %	97.1%	

Values are median (Q1 to Q3) or mean ± SD unless stated otherwise.

Table 5
Changes in procedural parameters of coronary chronic total occlusion percutaneous coronary interventions over the study period

	2012	2013	2014	2015	2012-2013 p value*	2013-2014 p value*	2014-2015 p value*	TOTAL p value†
Fluoroscopy time (min) median	25:04	21:21	19:10	20:16	0.0009	0.0155	0.2451	<0.0001
Dose area product, c·Gy cm^2 (75th percentile)	24 152	16 541	15 104	14 000	<0.0001	0.011	0.0037	<0.0001
Bare metal stent per percutaneous coronary intervention (mean)	0.17	0.19	0.16	0.08	0.5274	0.4277	0.0006	0.0005
Drug eluting stent per percutaneous coronary intervention (mean)	1.89	1.77	1.72	1.81	0.1128	0.5665	0.1645	0.1576
Stents per percutaneous coronary intervention (mean)	2.06	1.96	1.88	1.90	0.2735	0.1362	0.8531	0.0696
Stent length (mm)	52.28	48.1	44.74	46.31	0.0592	0.1407	0.3575	0.0157
Stent diameter (mm)	2.75	2.73	2.78	2.78	0.4774	0.0618	0.7107	0.2803

Values are median (Q1 to Q3) or mean ± SD unless stated otherwise.
* Mann-Whitney U test was used to compare distribution between 2 different years (2012 to 2013, 2013 to 2014, 2014 to 2015).
† Kruskal-Wallis test was used to compare distribution of all years (p Total).

overestimates the differences between the CTO and non-CTO groups since a number of included patients in the non-CTO group have no significant coronary lesions but only coronary atheroma. However, the aim of the study was not to be limited to population with severe coronary lesions, this subject has been studied extensively in the literature, but to assess the importance of the CTO field in the daily activity of cathlabs in a stable unselected population. Second, the observational design can produce information on associations but cannot obtain evidence of causality. Third, the CARDIO-ARSIF registry is limited to the greater Paris area where the density of physicians is higher than most areas in France. Fourth, angiographic information about CTO (e.g., J-CTO score) are not recorded in the registry nor are procedure technique and clinical outcomes. Fifth, numbers of PCIs and of CTO-PCIs per interventional cardiologist were not available. Finally, follow-up is

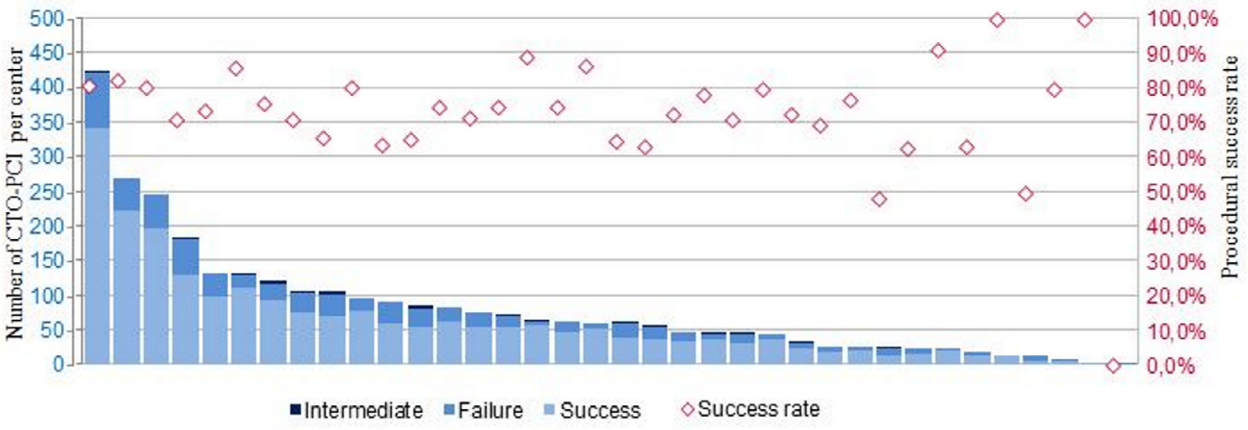

Figure 4. Volume and success rates of CTO-PCI in the centers contributing to the CARDIO-ARSIF registry over the study period.

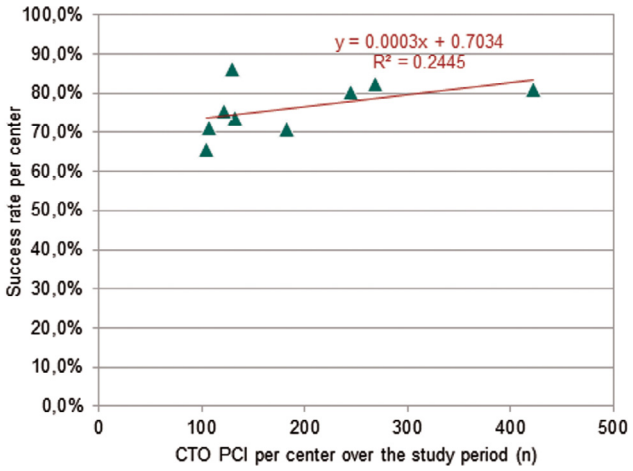

Figure 5. Correlation between volume and success rate of PCIs in patients with CTO (p = 0.15).

limited to the hospital mortality and long-term data are not recorded in the registry.

Disclosures

None of the authors have conflicts of interest to declare.

1. Christofferson RD, Lehmann KG, Martin GV, Every N, Caldwell JH, Kapadia SR. Effect of chronic total coronary occlusion on treatment strategy. *Am J Cardiol* 2005;95:1088–1091.
2. Fefer P, Knudtson ML, Cheema AN, Galbraith PD, Osherov AB, Yalonetsky S, Gannot S, Samuel M, Weisbrod M, Bierstone D, Sparkes JD, Wright GA, Strauss BH. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. *J Am Coll Cardiol* 2012;59:991–997.
3. Jeroudi OM, Alomar ME, Michael TT, Sabbagh AE, Patel VG, Mogabgab O, Fuh E, Sherbet D, Lo N, Roesle M, Rangan BV, Abdullah SM, Hastings JL, Grodin J, Banerjee S, Brilakis ES. Prevalence and management of coronary chronic total occlusions in a tertiary veterans affairs hospital. *Catheter Cardiovasc Interv* 2014;84:637–643.
4. Råmunddal T, Hoebers LP, Henriques JPS, Dworeck C, Angerås O, Odenstedt J, Ioanes D, Olivecrona G, Harnek J, Jensen U, Aasa M, Albertsson P, Wedel H, Omerovic E. Prognostic impact of chronic total occlusions: a report from SCAAR (Swedish Coronary Angiography and Angioplasty Registry). *JACC Cardiovasc Interv* 2016;9:1535–1544.
5. Råmunddal T, Hoebers LP, Henriques JPS, Dworeck C, Angerås O, Odenstedt J, Ioanes D, Olivecrona G, Harnek J, Jensen U, Aasa M, Jussila R, James S, Lagerqvist B, Matejka G, Albertsson P, Omerovic E. Chronic total occlusions in Sweden—a report from the Swedish Coronary Angiography and Angioplasty Registry (SCAAR). *PloS One* 2014;9:e103850.
6. Tomasello SD, Boukhris M, Giubilato S, Marzà F, Garbo R, Contegiacomo G, Marzocchi A, Niccoli G, Gagnor A, Varbella F, Desideri A, Rubartelli P, Cioppa A, Baralis G, Galassi AR. Management strategies in patients affected by chronic total occlusions: results from the Italian Registry of Chronic Total Occlusions. *Eur Heart J* 2015;36:3189–3198.
7. Werner GS, Gitt AK, Zeymer U, Juenger C, Towae F, Wienbergen H, Senges J. Chronic total coronary occlusions in patients with stable angina pectoris: impact on therapy and outcome in present day clinical practice. *Clin Res Cardiol* 2009;98:435–441.
8. Claessen BE, Dangas GD, Weisz G, Witzenbichler B, Guagliumi G, Möckel M, Brener SJ, Xu K, Henriques JPS, Mehran R, Stone GW. Prognostic impact of a chronic total occlusion in a non-infarct-related artery in patients with ST-segment elevation myocardial infarction: 3-year results from the HORIZONS-AMI trial. *Eur Heart J* 2012;33:768–775.
9. Claessen BEPM, van der Schaaf RJ, Verouden NJ, Stegenga NK, Engstrom AE, Sjauw KD, Kikkert WJ, Vis MM, Baan J, Koch KT, de Winter RJ, Tijssen JGP, Piek JJ, Henriques JPS. Evaluation of the effect of a concurrent chronic total occlusion on long-term mortality and left ventricular function in patients after primary percutaneous coronary intervention. *JACC Cardiovasc Interv* 2009;2:1128–1134.
10. Puymirat E, Simon T, Cayla G, Cottin Y, Elbaz M, Coste P, Lemesle G, Motreff P, Popovic B, Khalife K, Labèque J-N, Perret T, Le Ray C, Orion L, Jouve B, Blanchard D, Peycher P, Silvain J, Steg PG, Goldstein P, Guéret P, Belle L, Aissaoui N, Ferrières J, Schiele F, Danchin N, USIK, USIC 2000, and FAST-MI investigators. Acute myocardial infarction: changes in patient characteristics, management, and 6-month outcomes over a period of 20 years in the FAST-MI Program (French Registry of Acute ST-Elevation or Non-ST-Elevation Myocardial Infarction) 1995 to 2015. *Circulation* 2017;136:1908–1919.
11. Hannan EL, Zhong Y, Jacobs AK, Stamato NJ, Berger PB, Walford G, Sharma S, Venditti FJ, King SB. Patients with chronic total occlusions undergoing percutaneous coronary interventions: characteristics, success, and outcomes. *Circ Cardiovasc Interv* 2016;9:e003586.
12. Brilakis ES, Banerjee S, Karmpaliotis D, Lombardi WL, Tsai TT, Shunk KA, Kennedy KF, Spertus JA, Holmes DR, Grantham JA. Procedural outcomes of chronic total occlusion percutaneous coronary intervention: a report from the NCDR (National Cardiovascular Data Registry). *JACC Cardiovasc Interv* 2015;8:245–253.
13. Tsai TT, Stanislawski MA, Shunk KA, Armstrong EJ, Grunwald GK, Schob AH, Valle JA, Alfonso CE, Nallamothu BK, Ho PM, Rumsfeld JS, Brilakis ES. Contemporary incidence, management, and long-term

outcomes of percutaneous coronary interventions for chronic coronary artery total occlusions: insights from the VA CART Program. *JACC Cardiovasc Interv* 2017;10:866–875.

14. Galassi AR, Brilakis ES, Boukhris M, Tomasello SD, Sianos G, Karmpaliotis D, Di Mario C, Strauss BH, Rinfret S, Yamane M, Katoh O, Werner GS, Reifart N. Appropriateness of percutaneous revascularization of coronary chronic total occlusions: an overview. *Eur Heart J* 2016;37:2692–2700.
15. Georges J-L, Karam N, Tafflet M, Livarek B, Bataille S, Loyeau A, Mapouata M, Benamer H, Caussin C, Garot P, Varenne O, Barbou F, Teiger E, Funck F, Karrillon G, Lambert Y, Spaulding C, Jouven X, CARDIO-ARSIF Registry Investigators*. Time-course reduction in patient exposure to radiation from coronary interventional procedures: the greater paris area percutaneous coronary intervention registry. *Circ Cardiovasc Interv* 2017;10:e005268.
16. Thompson CA, Jayne JE, Robb JF, Friedman BJ, Kaplan AV, Hettleman BD, Niles NW, Lombardi WL. Retrograde techniques and the impact of operator volume on percutaneous intervention for coronary chronic total occlusions an early U.S. experience. *JACC Cardiovasc Interv* 2009;2:834–842.