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A Retrospective Study on the Impact of Coronary Computed Tomography Angiography on the Success of Percutaneous Coronary Intervention in Chronic Total Occlusion

Background Coronary computed tomographic angiography (CTA) provides valuable anatomical and functional information before and during chronic total occlusion (CTO) – percutaneous coronary intervention (PCI). Although several studies have suggested that pre-procedural CTA may improve procedural planning and success rates, its impact has not been consistently demonstrated, particularly in real-world settings and in patients with complex lesions. This retrospective study aims to evaluate the effect of preoperative coronary CTA on the success rates of PCI in patients with CTO.

Material and methods In this single-center retrospective study, we included CTO patients who underwent PCI from January 2020 to September 2023. Participants were divided into two groups based on whether they received preoperative coronary CTA: the CTA-guided group and a angiography-guided group. The primary endpoint was the success rate of recanalization, defined as a final TIMI flow grade ≥2 and residual stenosis ≤30%.

Results A total of 400 CTO patients were included, with 200 in the CTA-guided group and 200 in the angiography-guided group. The success rate of recanalization was significantly higher (93.5%) in the CTA-guided group compared to in the angiography-guided group (84.0%, p=0.003). In high-difficulty CTO cases (based on the Japanese CTO score system J-CTO score ≥2), the advantage of the CTA-guided group was more pronounced (82.0%, p < 0.001). Regarding perioperative complications, the incidence of myocardial infarction within 24 hrs was 2.5% in the CTA-guided group compared with 5.0% in the angiography-guided group (p=0.047), and coronary perforation occurred in 1.0% vs. 3.5% of patients, respectively (p=0.035). However, At the 1-yr follow-up, there was no significant difference in major adverse cardiac events between the two groups (CTA-guided 4.5% vs. angiography-guided 7.0%, p=0.11), including cardiac death (1.0% vs. 2.0%, p=0.10) and recurrent myocardial infarction (2.0% vs. 3.5%, p=0.15).

Conclusion The use of preoperative coronary CTA in CTO-PCI is associated with higher success rates, particularly in high-difficulty CTO cases. Additionally, CTA-guided PCI was associated with a reduction in perioperative complications such as myocardial infarction and coronary perforation. Further multicenter, randomized studies are warranted to evaluate its impact on long-term cardiovascular outcomes.

Keywords Percutaneous coronary intervention; coronary computed tomography angiography; J-CTO score; CTO-PCI success rate; CTO-PCI complications

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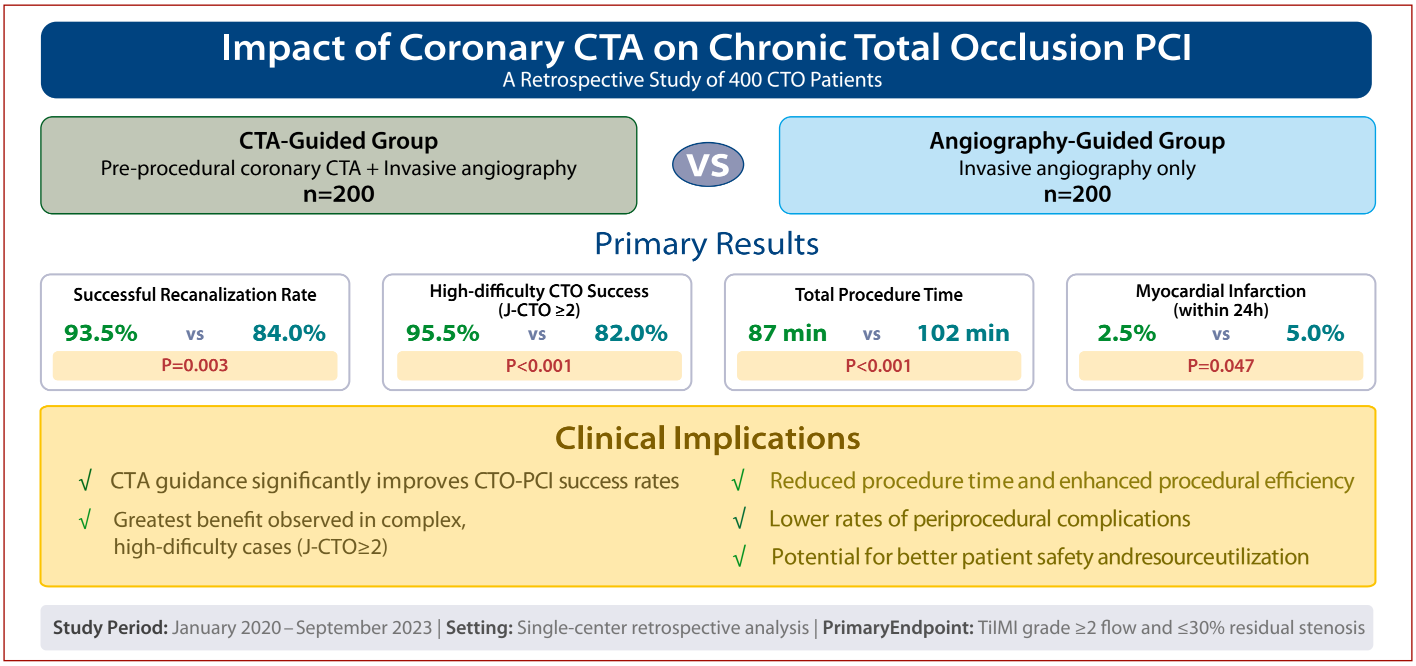
Introduction

Percutaneous coronary intervention (PCI) for chronic total occlusion (CTO) is indeed a challenging procedure with significant variability in its success rate. Numerous attempts have been made to improve the success rate of CTO-PCI, and various strategies have been explored [1–4]. Coronary computed tomography angiography (CTA) offers valuable information before and during CTO-PCI, which is essential for the development of primary and secondary procedural procedural strategies, such as selecting the antegrade or retrograde approach, determining guidewire pathways, and assessing risks and benefits of revascularization techniques [5–7]. However, although several studies, including a recent systematic review and meta-analysis, have demonstrated the potential added value of pre-procedural CTA in improving CTO-PCI outcomes, randomized evidence remains limited and inconclusive, warranting further investigation [8].

Globally, the success rate of PCI for CTO has been reported to be nearly 90%, with acceptable rates of in-hospital complications, as shown in the PROGRESS-CTO regi-

Central illustration. A retrospective study on the impact of coronary computed tomographic angiography on chronic total occlusion percutaneous coronary intervention



stry data. This registry included 3 122 CTO interventions performed in 3 055 patients across 20 centers in the USA, Europe, and Russia. The study demonstrated that the overall technical and procedural success rates were 87% and 85%, respectively, with a major adverse cardiovascular event rate of 3.0%, primarily consisting of death (0.85%), acute myocardial infarction (1.08%), and stroke (0.26%) [9, 10].

Previous studies have suggested that CTA guidance may not only facilitate procedural planning but also improve success rates, particularly in complex CTO lesions. While some reports have noted fewer periprocedural complications with CTA, the clinical significance of this finding remains uncertain, and the primary question is whether CTA can meaningfully enhance recanalization success compared with conventional angiography [11]. Higher success rates were more prominently observed in patients with CTO who had a high J-CTO score than those who did not, indicating that CTA guidance may be particularly beneficial in patients with more complex CTO lesions.

This retrospective study was designed to investigate whether preoperative CTA contributes to higher PCI success rates in patients with CTO.

Material and methods

Study design

This single-center retrospective non-randomized observational study reviewed patients who underwent coronary angiography at Huzhou First People's Hospital from January 2020 to September 2023. The study included patients (age ≥19 yrs) with CTO lesions, typical angina, or positive functional tests for ischemia.

Inclusion criteria:

1. Patients with chronic total occlusions (TIMI flow 0 and estimated duration of occlusion at least 3 mos).
2. Typical symptomatic angina or positive stress test in functional studies.
3. Eligible patients were those considered suitable for both pre-procedural coronary CTA and invasive coronary angiography.

The inclusion was primarily based on the presence of typical angina symptoms or positive results from functional ischemia tests, in addition to meeting the general criteria for CTO diagnosis. A documented history of myocardial infarction was not a prerequisite for enrollment. This approach mirrors real-world clinical scenarios, where chronic total occlusions are frequently discovered during evaluations for stable angina or asymptomatic ischemia, especially in individuals with diabetes or non-classic symptom presentations.

Exclusion criteria:

1. Cardiogenic shock or left ventricular ejection fraction <25%.
2. CTO lesions at DES restenosis or graft occlusion lesion.
3. Significant left main stenosis.
4. Retry of same CTO lesion within 2 wks.
5. Acute myocardial infarction within 48 hrs.
6. Hypersensitivity to aspirin, clopidogrel, or components of drug-eluting stents (e.g., mTOR inhibitors), or contraindication to antiplatelet therapy.
7. Serum creatinine >2.0 mg/dl.
8. Severe hepatic dysfunction (defined as ALT or ≥3 times the upper limit of normal).
9. Life expectancy <1 yr.
10. Pregnancy or potential childbearing.

Definitions: Hypertension was defined as a documented history of hypertension, current use of antihypertensive medication, or repeated blood pressure measurements ≥140/90 mmHg. Diabetes mellitus was defined as a documented history of diabetes, current use of hypoglycemic agents or insulin, fasting plasma glucose ≥7.0 mmol/L, or HbA1c ≥6.5%.

Study groups

According to clinical documentation, patients were retrospectively assigned to one of two groups based on whether they had undergone coronary CTA prior to PCI. These groups comprised the CTA-guided group and the angiography-guided group. To improve the comparability between groups, we selected 200 patients for each group by aligning their baseline features and treatment periods. The decision to conduct coronary CTA was made independently by the treating interventional cardiologist as part of the standard clinical workflow. All procedures for CTO-PCI were conducted separately following diagnostic coronary angiography, in accordance with routine interventional protocols. All CTO-PCI procedures in both groups were performed separately after diagnostic angiography as non-ad hoc PCI. A single operator at each center performed the CTO-PCI. For patients in the coronary CTA-guided group, operators planned CTO-PCI based on coronary CTA images and reports analyzed in the imaging department and on displayed coronary CTA images in the catheterization laboratory during PCI to guide advancement of the wire. Three-dimensional volume rendering images corresponding to invasive coronary angiography for the direction or course of the occluded segment or cross-sectional or longitudinal images for understanding the relation of the guidewire and calcium/side branches were displayed. For the angiography-guided group, operators performed PCI without coronary CTA images. CTO-PCI followed current standard CTO intervention procedures. The initial approach to CTO and the choice of access sites and devices were left to the operators' discretion.

Pre-procedural coronary CTA image acquisition and analysis

All image acquisition and post-processing of coronary CTA were performed following the Society of Cardiovascular Computed Tomography guidelines. Coronary CTA used at least 64-slice scanners. When clinically applicable, radiologists at each site decided upon the use of radiation dose reduction strategies, such as electrocardiographically gated tube-current modulation, tube voltage reduction, or prospective electrocardiographically gated axial acquisition. For the coronary CTA-guided group, invasive coronary angiography and coronary CTA results were transferred to the imaging department in the Digital Imaging and Communications in Medicine format, and experienced imaging cardiologists analyzed the coronary CTA images. CTO on coronary CTA was defined by the complete absence of luminal contrast enhancement. Tortuosity was defined as a >45-degree bend within the CTO segment [12–14]. Post-processed images, including thin-slab maximum intensity projection and multiplanar reconstruction, were used to visualize the side branches from the CTO segment. The following parameters were used to quantify the degrees of calcification in the CTO segment and within 5 mm of its proximal and distal ends in the cross-sectional and longitudinal views:

1) Maximal extent of cross-sectional calcification (presence of cross-sections with extents of maximal calcification ≥50% or <50%).
2) Circular involvement (cross-sectional calcification arc <180 degrees [semicircular], ≥180 degrees [circular], 360 degrees [full moon], or none).
3) Longitudinal involvement (length of the calcification with the maximal extent of cross-sectional calcification >50%).

Locations and morphologies of the proximal and distal CTO caps were identified and categorized as a blunted or tapered stump. Reference vessel diameters were measured on the cross-sectional images. Calcium arcs on the cross-sectional views were quantified at the proximal, mid, and distal CTO segments.

Study endpoints

The primary endpoint was the successful recanalization rate, defined as a final TIMI grade flow ≥2 and ≤30% residual stenosis after stent implantation on the final angiogram, without the occurrence of death or severe complications requiring emergency operations during the procedure. Device success was defined as residual stenosis ≤30% on the final angiogram after stent implantation. Procedure success was defined as a final TIMI grade flow ≥2. All quantitative and qualitative analyses for the final coronary angiogram to assess the primary endpoint were independently performed in the core laboratory blinded to the randomization process [15–17].

The total procedure time was defined as the interval between local anesthesia administration for vascular access and removal of the last catheter. Crossing time was defined as the time from local anesthesia administration until:

4) Successful wire entry into the distal true lumen for antegrade crossing.
5) Externalization for retrograde crossing.
6) Procedure abortion.

Antegrade-only crossing time was defined as the interval between local anesthesia administration and/or:

1) Successful wire entry into the distal true lumen or procedure abortion for antegrade crossing.
2) Start of retrograde wiring for retrograde crossing.

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Major adverse cardiac event occurrence was defined as cardiac death, target vessel related myocardial infarction, or ischemia-driven target-vessel revascularization at 12 mos. All PCI procedures in this study were elective, and patients with acute MI within 48 hrs prior to intervention were excluded. All data were collected using a web-based system, and clinical follow-up was performed at 3, 9, and 12 mos after the index procedure either by clinic visit or telephonically. A clinical events committee, which was blinded to patient group assignment and procedural details, independently monitored and assessed all clinical events.

Statistical analysis

All analyses were performed using SAS version 9.1.3. Continuous variables are presented as mean±SD if normally distributed, or otherwise as median (interquartile range). Normal distribution was assessed using the Shapiro-Wilk test. Continuous data were compared using the Student's t-test or Mann-Whitney U test, as appropriate. Categorical variables are presented as frequencies and percentages. Frequencies were compared using the Pearson's chi-square test or Fisher exact test. The primary endpoint was compared between the two groups using unadjusted Pearson's chi-square test, and also reported as absolute risk differences with 95% confidence intervals. All analyses were performed using the intention-to-treat principle. Operator effect was assessed by a mixed-effects logistic regression model that included a random intercept for study center. An interaction between the operator volume of CTO-PCI and treatment group for the primary endpoint was also assessed; ≥50 CTO-PCI cases/year was defined as an experienced operator. As for clinical and lesion characteristics, pre-specified subgroup analyses for the primary endpoint were performed using interaction tests. Cumulative incidences of clinical outcomes at 1 yr were calculated using the Kaplan-Meier estimates and compared using the log-rank test. The 2-tailed p values were used, and $p<0.05$ was considered statistically significant.

Results

Patient demographics and baseline characteristics

The demographic and baseline characteristics of patients in the CTA guided and the contrast guided groups are summarized in Table 1. Patients in both groups were well matched in terms of age, sex distribution, and major cardiovascular risk factors such as hypertension, diabetes, and smoking history. Left ventricular ejection fraction and renal function were also comparable. Overall, there were no statistically significant differences in baseline characteristics, ensuring good comparability between the CTA-guided and angiography-guided groups.

Table 1. Patient demographics and baseline characteristics

Characteristic	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
Average Age (yrs)	62.5±8.4	62.5±8.1	0.95
Gender (Male %)	140 (70.0%)	140 (70.0%)	1.00
Hypertension (%)	90 (45.0%)	90 (45.0%)	0.99
Diabetes (%)	60 (30.0%)	60 (30.0%)	1.00
Hyperlipidemia (%)	50 (25.0%)	50 (25.0%)	0.98
Smoking History (%)	80 (40.0%)	84 (42.0%)	0.65
Family History of CAD (%)	40 (20.0%)	36 (18.0%)	0.41
Body Mass Index (BMI kg/m^2)	27.5±3.3	27.8±3.6	0.31
Renal Function (eGFR ml/min)	85.0±15.7	83.0±16.2	0.09
Left Ventricular Ejection Fraction (%)	60.0±6.4	59.0±6.8	0.23
Prior PCI (%)	30 (15.0%)	34 (17.0%)	0.39
Prior CABG (%)	10 (5.0%)	12 (6.0%)	0.68
History of MI (%)	24 (12.0%)	28 (14.0%)	0.25
CCS Angina Class	2.5±0.6	2.6±0.5	0.57
Heart Rate (bpm)	72.0±8.3	73.0±8.9	0.46
Systolic Blood Pressure (mmHg)	135.0±12.4	137.0±13.1	0.19
Diastolic Blood Pressure (mmHg)	80.0±8.2	82.0±9.1	0.11

Data are value or percentage. Abbreviations: CAD – coronary artery disease; BMI – body mass index; eGFR – estimated glomerular filtration rate; PCI – percutaneous coronary intervention; CABG – coronary artery bypass grafting; MI – myocardial infarction; CCS – Canadian Cardiovascular Society.

Procedural success rates and related indicators

The results presented in Table 2 demonstrate a higher procedural success rate in the CTA-guided group compared to the angiography-guided group, with significant differences in successful recanalization, device success, and procedural success rates. The CTA-guided group also exhibited shorter total procedure and crossing times, indicating a more efficient intervention process. Although the myocardial infarction rate within 24 hrs and the coronary perforation rate were lower in the CTA-guided group, these differences were not statistically significant. However, there was a significant reduction in contrast agent usage and a lower injection rate in the CTA-guided group, suggesting potential benefits in terms of patient safety and resource efficiency. The surgical complication rate was lower in the CTA-guided group, though not significantly so, and the hospital stay was shorter for this group, which may indicate faster recovery times. The 30-day readmission rate was similar between the two groups, and the 1-yr MACE rate, while higher in the angiography-guided group, did not reach statistical significance. Overall, these findings suggest that CTA guidance may offer advantages in procedural efficiency and patient outcomes, although further study is needed to confirm the long-term benefits.

Table 2. Indicators related to procedural success rates

Indicators	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
Successful Recanalization, n (%)	187 (93.5%)	168 (84.0%)	0.003
Device Success, n (%)	190 (95.0%)	173 (86.5%)	0.001
Procedural Success, n (%)	188 (94.0%)	170 (85.0%)	0.002
Total Procedure Time (min)	87.0±15.2	102.0±17.4	<0.001
Crossing Time (min)	45.0±10.3	58.0±11.5	<0.001
Myocardial Infarction within 24 hrs, n (%)	5 (2.5%)	10 (5.0%)	0.047
Coronary Perforation, n (%)	2 (1.0%)	7 (3.5%)	0.035
Contrast Agent Usage (ml)	70.0±12.4	75.0±13.1	0.040
Contrast Injection Rate (ml/s)	3.5±0.6	4.0±0.7	0.020
Surgical Complications, n (%)	10 (5.0%)	16 (8.0%)	0.060
Hospital Stay (days)	3.0±0.8	4.0±0.9	0.030
30-Day Readmission, n (%)	4 (2.0%)	6 (3.0%)	0.200
1-Yr Major Adverse Cardiac Events (MACE), n (%)	9 (4.5%)	14 (7.0%)	–

Data are value or percentage. Abbreviations: MACE – major adverse cardiac events; PCI – percutaneous coronary intervention.

Indicators related to complexity and difficulty

The results presented in Table 3 highlight the effectiveness of CTA-guided PCI in managing complex and challenging cases of chronic total occlusions (CTO). The CTA-guided group demonstrated superior success rates in high-difficulty CTO cases as defined by the J-CTO score, as well as in scenarios involving severe calcification, tortuous vessels, and multiple lesions, suggesting that CTA guidance can navigate these complexities more effectively. Additionally, the CTA-guided group had a higher success rate in collateral circulation assessment, which is pivotal for strategic planning in CTO PCI. The rate of underexpansion after stenting was lower in the CTA-guided group, potentially leading to better long-term outcomes. Moreover, the increased use of advanced imaging techniques like IVUS or OCT in the CTA-guided group indicates a more comprehensive approach to understanding and addressing the intricacies of the vascular anatomy during PCI. These findings underscore the potential advantages of CTA guidance in improving procedural success and possibly patient outcomes in complex PCI cases.

Indicators of perioperative complications

The data in Table 4 reveal a comprehensive view of perioperative complications associated with CTA-guided and angiography-guided PCI procedures. As shown in Table 2, the incidence of perioperative myocardial infarction within 24 hrs was 2.5% in the CTA-guided group compared with 5.0% in the angiography-guided group (p=0.047). Coronary perforation occurred in 1.0% vs. 3.5% of patients, respectively (p=0.035). These findings suggest a more favorable short-term safety profile with CTA guidance. Additionally, the CTA-guided group has a reduced rate of contrast-induced nephropathy, which is crucial for protecting kidney function, especially in patients with pre-existing renal impairment. While the rates of coronary spasm and puncture site complications are slightly higher in the angiography-guided group, they were not statistically significant. The CTA-guided group also exhibits a lower unplanned return to the operating room rate and intraoperative hypothermia rate, suggesting better postoperative management and patient care. Prophylactic antibiotics were not routinely used prior to PCI. A minority of patients received antibiotics based on individual clinical indications, such as suspected infection, indwelling vascular devices, or high-risk

Table 3. Indicators related to complexity and difficulty

Indicators	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
Success rate for high-difficulty CTO (J-CTO ≥2), n (%)	191 (95.5%)	164 (82.0%)	<0.001
Success rate with severe calcification, n (%)	176 (88.0%)	150 (75.0%)	0.010
Success rate for tortuous vessels, n (%)	180 (90.0%)	156 (78.0%)	0.002
Success rate for multiple lesions, n (%)	170 (85.0%)	140 (70.0%)	0.005
Collateral circulation assessment, n (%)	184 (92.0%)	160 (80.0%)	0.001
Rate of stent underexpansion, n (%)	10 (5.0%)	20 (10.0%)	0.030
Use of IVUS or OCT, n (%)	60 (30.0%)	30 (15.0%)	0.020

CTO – chronic total occlusion; J-CTO – Japanese CTO score; IVUS – intravascular ultrasound; OCT – optical coherence tomography.

Table 4. Indicators related to perioperative complications

Indicators	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
Myocardial infarction within 24 hrs, n (%)	5 (2.5%)	10 (5.0%)	0.047
Coronary perforation, n (%)	2 (1.0%)	7 (3.5%)	0.035
Contrast-induced nephropathy, n (%)	4 (2.0%)	12 (6.0%)	0.028
Coronary spasm, n (%)	3 (1.5%)	5 (2.5%)	0.420
Puncture site complications, n (%)	6 (3.0%)	9 (4.5%)	0.380
Unplanned return to operating room, n (%)	2 (1.0%)	5 (2.5%)	0.250
Intraoperative hypothermia (<36.0 °C), n (%)	4 (2.0%)	7 (3.5%)	0.310
Prophylactic antibiotic use, n (%)	8 (4.0%)	10 (5.0%)	0.650
Perioperative arrhythmia, n (%)	5 (2.5%)	8 (4.0%)	0.410

°C – degrees Celsius; PCI – percutaneous coronary intervention.

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comorbidities. Although the difference in prophylactic antibiotic use and perioperative arrhythmia rate is not significant, the overall trend suggests that CTA guidance may contribute to a more controlled and safer perioperative environment, which could lead to improved patient outcomes and reduced complications.

Indicators related to procedural time

The results in Table 5 provide a detailed account of the procedural timings and related indicators for both CTA-guided and angiography-guided PCI procedures. The CTA-guided group exhibited shorter total procedure times and crossing times, suggesting a more efficient surgical process. Additionally, patients in the CTA-guided group spent less time in the operating room, indicating better utilization of resources and potentially faster patient turnover. The time from admission to surgery was also shorter for the CTA-guided group, reflecting a more streamlined preoperative workflow. The surgery preparation time and anesthesia preparation and induction time were both reduced in the CTA-guided group, which could contribute to reduced patient anxiety and quicker access to surgery. The time from incision to skin closure was quicker in the CTA-guided group, indicating a more rapid surgical execution. The intraoperative transfusion rate was lower in the CTA-guided group, suggesting less blood loss and potentially better surgical hemostasis. The rate of intraoperative hypothermia was also lower in the CTA-guided group, which is important for maintaining patient comfort and outcomes. Lastly, a higher proportion of patients in the CTA-guided group received pre-warmed fluids, which can help prevent hypothermia and its associated complications. Overall, these findings suggest that CTA guidance may lead to improved procedural efficiency, reduced complications, and better patient outcomes.

Indicators related to 12-mo major adverse cardiac events

The results outlined in Table 6 offer a detailed perspective on the 12-mo major adverse cardiac events (MACE) and associated indicators for patients undergoing CTA-guided and angiography-guided PCI. The 1-yr MACE rate is notably lower in the CTA-guided group, suggesting a more favorable long-term outcome. Additionally, the CTA-guided group shows a reduced incidence of recurrent angina, recurrent myocardial infarction, and acute heart failure, indicating better cardiac health maintenance post-surgery. The lower rate of malignant arrhythmias in the CTA-guided group may imply a decreased risk of sudden cardiac events. The cardiogenic mortality rate is also lower, although not significantly so, and the reduction in left ventricular ejection fraction is less pronounced, indicating better preservation of heart function. The CTA-guided group also exhibits a lower median increase in NT-proBNP concentrations and cardiac troponin I, suggesting less cardiac stress and injury. Furthermore, the group has a higher hemoglobin level and lower blood urea nitrogen level, which may reflect better overall health and renal function, respectively. At the 12-month follow-up, the incidence of MACE was 4.5% in the CTA-guided group versus 7.0% in the angiography-guided group (p=0.11). Specifically, recurrent myocardial infarction occurred in 2.0% vs. 3.5% (p=0.15), and cardiogenic mortality in 1.0% vs. 2.0% (p=0.10). These differences were not statistically significant. Collectively, these findings indicate that CTA guidance may contribute to a lower

Table 5. Indicators related to procedural time

Indicators	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
Total procedure time (min)	87.0±15.2	102.0±17.4	<0.001
Crossing time (min)	45.0±10.3	58.0±11.5	<0.001
Time spent in the operating room (min)	50.0±9.8	65.0±11.6	0.002
Time from admission to surgery (hr)	8.0±2.1	10.0±2.4	0.040
Surgery preparation time (min)	30.0±6.4	40.0±7.2	0.030
Anesthesia preparation and induction time (min)	20.0±4.6	25.0±5.2	0.080
Time from incision to skin closure (min)	60.0±8.7	70.0±9.5	0.010
Intraoperative transfusion, n (%)	4 (2.0%)	8 (4.0%)	0.060
Intraoperative hypothermia (<36.0 °C), n (%)	4 (2.0%)	7 (3.5%)	0.100
Patients receiving pre-warmed fluids, n (%)	140 (70.0%)	100 (50.0%)	0.001

Table 6. Indicators related to 12-major adverse cardiac events

Indicators	CTA-guided Group (n=200)	Angiography-guided Group (n=200)	p-value
1-yr MACE, n (%)	9 (4.5%)	14 (7.0%)	0.110
Recurrent angina, n (%)	6 (3.0%)	10 (5.0%)	0.080
Recurrent myocardial infarction, n (%)	4 (2.0%)	7 (3.5%)	0.150
Malignant arrhythmia, n (%)	3 (1.5%)	5 (2.5%)	0.200
Acute heart failure, n (%)	5 (2.5%)	8 (4.0%)	0.060
Cardiogenic mortality, n (%)	2 (1.0%)	4 (2.0%)	0.100
Reduction in LVEF (%)	5.0±2.1	8.0±2.6	0.040
NT-proBNP concentration (pg/mL), median (IQR)	360 (290–450)	430 (330–560)	0.030
Cardiac troponin I (ng/L)	50.0±12.3	60.0±13.5	0.020
Hemoglobin (g/L)	130.0±9.5	125.0±10.2	–

Continuous variables are presented as mean ± SD if normally distributed, or as median (IQR) otherwise; categorical variables as n (%). Abbreviations: MACE – major adverse cardiac events; LVEF – left ventricular ejection fraction; NT-proBNP – N-terminal pro-B-type natriuretic peptide; IQR – interquartile range; SD – standard deviation.

risk of adverse cardiac events and complications within the first year after PCI, emphasizing the potential benefits of CTA-guided procedures for long-term cardiac health.

Discussion

The present study, aligning with the global trend of nearly 90% success rates in PCI for chronic total occlusion (CTO) as reported by the PROGRESS-CTO registry, sought to elucidate the impact of pre-procedural coronary computed tomography angiography (CTA) on the success rates of PCI in patients with CTO. The registry's data, encompassing a diverse patient population across continents, underscored the technical and procedural success rates of 87% and 85%, respectively, with a major adverse cardiovascular event rate of 3.0% [18–20]. These outcomes provide a benchmark for evaluating new strategies. Recent evidence has suggested that pre-procedural coronary computed tomography angiography (CTA) may further improve success by providing detailed anatomical information on lesion characteristics, vessel course, and collateral circulation. A systematic review and meta-analysis by Liang et al. demonstrated that CTA guidance was associated with higher procedural success and shorter crossing times compared with angiography alone [8]. Consistent with these findings, our study shows that CTA-guided PCI achieved higher recanalization and device success rates, particularly in high J-CTO lesions, thereby reinforcing the growing body of evidence that CTA can enhance both planning and execution of complex CTO interventions.

Several prior studies have highlighted the incremental value of coronary CTA in the management of CTO. Beyond conventional angiography, CTA provides information on lesion length, calcification, vessel tortuosity, and the course of collateral channels, all of which are critical factors influencing procedural strategy and outcomes. For instance, observational analyses and meta-analyses have consistently demonstrated that CTA guidance improves operator preparation, shortens crossing time, and increases procedural efficiency compared with angiography alone [21]. These findings suggest that CTA serves not only as a diagnostic tool but also as a procedural roadmap that can guide wire escalation strategies and device selection in complex cases.

Our findings from the CT-CTO trial suggest a significant advantage of CTA in enhancing the success rate of recanalization. The definition of successful recanalization, adhering to a final TIMI grade ≥2 and ≤30% residual stenosis, was met more frequently in the CTA-guided group. This supports the hypothesis that CTA provides invaluable anatomical insights prior to PCI, facilitating better procedural planning and execution. The ability to visualize the occlusion and its surrounding anatomy in three dimensions with CTA likely contributes to the selection of more effective revascularization strategies and reduces the reliance on two-dimensional angiography.

An additional observation was that the incidence of periprocedural complications, such as myocardial infarction and coronary perforation, was numerically lower in the CTA-guided group; however, these differences did not reach statistical significance. While this trend may indicate a potential safety benefit, it requires confirmation in larger, prospective studies. In this study, CTA guidance was associated with fewer perioperative complications, including a lower incidence of coronary perforation (1.0% vs. 3.5%, p=0.035) and periprocedural myocardial infarction within 24 hrs (2.5% vs. 5.0%, p=0.047), suggesting a potentially safer short-term procedural profile.

Furthermore, the study highlights the pronounced benefits of CTA guidance in patients with high J-CTO scores, indicating that complex lesions may particularly benefit from the detailed anatomical assessment provided by CTA. This is a crucial finding, as it identifies a subset of patients who stand to gain the most from this additional imaging modality, potentially leading to more tailored and effective treatment strategies for complex CTO cases.

While the findings of this study are encouraging, several limitations should be acknowledged. First, the retrospective, single-center, and non-randomized design may introduce inherent selection bias, as group allocation was determined retrospectively rather than through randomization. Second, although the two groups were comparable in size and baseline characteristics, residual confounding cannot be entirely excluded. Third, the study did not provide sufficient power to evaluate the long-term impact of CTA guidance on hard cardiovascular outcomes such as cardiac death, target vessel-related myocardial infarction, or target vessel revascularization. Therefore, larger multicenter randomized controlled trials with extended follow-up are warranted to validate our findings and to clarify the role of CTA in improving long-term outcomes in patients undergoing CTO-PCI.

In conclusion, this CT-CTO study provides compelling evidence that pre-procedural CTA is associated with higher success rates in CTO-PCI and may reduce the incidence of periprocedural complications. The study's findings, particularly in patients with high J-CTO scores, demonstrate that CTA guidance can improve the success rates of complex CTO-PCI and reduce perioperative complications, supporting its role as a valuable adjunct to conventional angiography.

No conflict of interest is reported.

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REFERENCES

1. Khandaker MAH, Kumar JS, Panduranga P. Acute Aortic Dissection Masquerading as Acute Coronary Syndrome: Is Echocardiogram Mandatory before Primary Percutaneous Coronary Intervention? Mymensingh Medical Journal. 2025;34(1):295–9. PMID: 39739505
2. Li J, Wang X, Chen R, Zhou P, Liu C, Song L et al. Outcomes of Optical Coherence Tomography-Guided and Angiography-Guided Primary Percutaneous Coronary Intervention in Patients with ST-Segment Elevation Myocardial Infarction. Reviews in Cardiovascular Medicine. 2024;25(12):444. DOI: 10.31083/j.rcm2512444
3. Liu Y, Wang S, Peng H, Liu J. Early improvement of left ventricular dyssynchrony after percutaneous coronary intervention in patients with single chronic total occlusion vessel. Heart and Vessels. 2025;40(7):570–6. DOI: 10.1007/s00380-024-02507-1
4. Zhou D, Wu J, Wang Q, Liu Y, Wang S, Zhang W et al. Miniature Mass Spectrometry for Point-of-Care Testing the GPIIb/IIIa Inhibitor Tirofiban during Perioperative Period of Percutaneous Coronary Intervention. ACS Omega. 2024;9(51):50326–33. DOI: 10.1021/acsomega.4c06581
5. Naeem H, Khan U, Mohsin M, Niazi K, Malik J, Satti DI et al. Comparison of Invasive Coronary Angiography Versus Computed Tomography Angiography to Assess Mehran Classification of In-Stent Restenosis in Bifurcation Percutaneous Coronary Intervention. The American Journal of Cardiology. 2022;172:11–7. DOI: 10.1016/j.amjcard.2022.02.014
6. Simsek B, Jaffer FA, Kostantinis S, Karacsonyi J, Koike H, Doshi D et al. Preprocedural coronary computed tomography angiography in chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO registry. International Journal of Cardiology. 2022;367:20–5. DOI: 10.1016/j.ijcard.2022.08.027
7. Xing H, Zhang L, Zhang D, Wang R, Tian J, Le Y et al. Quantitative coronary computed tomography angiography assessment of chronic total occlusion percutaneous coronary intervention. Quantitative Imaging in Medicine and Surgery. 2022;12(7):3625–39. DOI: 10.21037/qims-21-1050
8. Liang S, Bai Y, Zhang J, Wang A, Li J, Diao K et al. The added value of coronary CTA in chronic total occlusion percutaneous coronary intervention: a systematic review and meta-analysis. European Radiology. 2023;34(6):4041–52. DOI: 10.1007/s00330-023-10341-8
9. Kostantinis S, Simsek B, Karacsonyi J, Rempakos A, Alaswad K, Megaly M et al. Impact of proximal cap ambiguity on the procedural techniques and outcomes of chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO Registry. Catheterization and Cardiovascular Interventions. 2023;101(4):737–46. DOI: 10.1002/ccd.30580
10. Rempakos A, Simsek B, Kostantinis S, Karacsonyi J, Choi JW, Poommipanit P et al. Impact of lesion length on the outcomes of chronic total occlusion percutaneous coronary intervention: Insights from the PROGRESS-CTO registry. Catheterization and Cardiovascular Interventions. 2023;101(4):747–55. DOI: 10.1002/ccd.30581
11. Roller F, Harth S, Rixe J, Krombach G, Schneider C. Development and Suggestion of a Cardiac CTA Scoring System for the Prediction of Revascularization Success in Chronic Total Occlusions (CTO) of the Coronary Arteries. RöFo - Fortschritte auf dem Gebiet der Röntgenstrahlen und der bildgebenden Verfahren. 2015;188(2):172–8. DOI: 10.1055/s-0041-108199
12. Carvalho PEP, Rempakos A, Mutlu D, Alexandrou M, Strepkos D, Rangan BV et al. External validation of the JR-CTO score in retrograde chronic total occlusion intervention: from the PROGRESS-CTO registry. The Journal of Invasive Cardiology. 2025;37(2). DOI: 10.25270/jic/24.00208
13. Gorgulu S, Kostantinis S, ElGuindy AM, Abi Rafeh N, Simsek B, Rempakos A et al. Contemporary In-Hospital Outcomes of Chronic Total Occlusion Percutaneous Coronary Interventions: Insights from the MENATA (Middle East, North Africa, Turkey, and Asia) Chapter of the PROGRESS-CTO Registry. The American Journal of Cardiology. 2023;206:221–9. DOI: 10.1016/j.amjcard.2023.08.103
14. Hirata GM, Rempakos A, Walker Boyd A, Alexandrou M, Mutlu D, Choi JW et al. Chronic total occlusion percutaneous coronary intervention of anomalous coronary arteries: insights from the PROGRESS CTO registry. Catheterization and Cardiovascular Interventions. 2024;104(6):1148–58. DOI: 10.1002/ccd.31248
15. Higuma T, Soeda T, Yamada M, Yokota T, Yokoyama H, Nishizaki F et al. Coronary Plaque Characteristics Associated With Reduced TIMI (Thrombolysis in Myocardial Infarction) Flow Grade in Patients With ST-Segment-Elevation Myocardial Infarction: A Combined Optical Coherence Tomography and Intravascular Ultrasound Study. Circulation. Cardiovascular Interventions. 2016;9(9):e003913. DOI: 10.1161/CIRCINTERVENTIONS.116.003913
16. Jia R, Nie X, Li H, Zhu H, Pu L, Li X et al. Impact of attenuated plaques on TIMI grade flow and clinical outcomes of coronary artery disease patients: a systematic review and meta analysis. Journal of Thoracic Disease. 2016;8(3):527–36. DOI: 10.21037/jtd.2016.02.51
17. Karwowski J, Poloński L, Gierlotka M, Gąsior M, Bęćkowski M, Kowalik I et al. Post-procedural TIMI flow grade 2 is not associated with improved prognosis in patients with non-ST-segment elevation myocardial infarction undergoing percutaneous coronary revascularization (PL-ACS registry). Cardiology Journal. 2016;23(4):402–10. DOI: 10.5603/CJ.a2016.0025
18. Allana S, Kostantinis S, Simsek B, Karacsonyi J, Rempakos A, Alaswad K et al. Lesion Complexity and Procedural Outcomes Associated With Ostial Chronic Total Occlusions: Insights From the PROGRESS-CTO Registry. Journal of Invasive Cardiology. 2023;35(12). DOI: 10.25270/jic/23.00034
19. Mutlu D, Rempakos A, Alexandrou M, Al-Ogaili A, Khatri J, Alaswad K et al. Validation of the J-Channel Score for Retrograde Channel Crossing in the PROGRESS-CTO Registry. Journal of Invasive Cardiology. 2024;36(5). DOI: 10.25270/jic/24.00006
20. Mutlu D, Rempakos A, Alexandrou M, Al-Ogaili A, Rangan B, Mastrodemos O et al. Radiation Dose During Contemporary Percutaneous Coronary Interventions for Chronic Total Occlusion: Insights From the PROGRESS-CTO Registry. Journal of Invasive Cardiology. 2024;36(4). DOI: 10.25270/jic/23.00281
21. Hong S-J, Kim B-K, Cho I, Kim H-Y, Rha S-W, Lee S-H et al. Effect of Coronary CTA on Chronic Total Occlusion Percutaneous Coronary Intervention: A Randomized Trial. JACC: Cardiovascular Imaging. 2021;14(10):1993–2004. DOI: 10.1016/j.jcmg.2021.04.013