E-ISSN: 3031-8629
P-ISSN: 3032-3258
Halaman 2616-2632
Volume 3 Nomor 4 Tahun 2026

Defying Demographic Barriers: High Procedural Success of CTO-PCI in a Real-World

Irma Putri Damayanti[1,2]*, Rahageng Wida Kusuma[2], Muhammad Almanfaluthi[3], Stefani Widodo[4], Yusuf Adi Gunawan[5]

[1]Division of Medical Nutrition, Faculty of Medicine, Universitas Muhammadiyah Purwokerto, Central Java, Indonesia
[2]Cardiology Department, Goeteng Taroenadibrata General Hospital, Purbalingga, Central Java, Indonesia
[3]Department of Tropical Medicine and Parasitology, Faculty of Medicine, Universitas Muhammadiyah Purwokerto, Central Java, Indonesia
[4]Department of Public Health, Faculty of Medicine, Universitas Muhammadiyah Purwokerto, Central Java, Indonesia
[5]Division of Internal Medicine, Faculty of Medicine, Universitas Muhammadiyah Purwokerto, Central Java, Indonesia
e-mail*: dokter.irma.putri@gmail.com

Abstract

Chronic Total Occlusion (CTO) historically represented the "final frontier" in percutaneous coronary intervention, frequently resulting in surgical referral due to high failure rates. Procedural success was traditionally hypothesized to be limited by patient-specific demographic factors, such as advanced age and female gender, alongside the urgency of clinical presentation. To address this clinical gap, this study aimed to evaluate the real-world success rates of CTO interventions and determine whether these baseline demographic and clinical factors significantly predict procedural outcomes. A retrospective observational study was conducted using big data analytics on a catheterization logbook from a high-volume center, yielding a cohort of 187 patients who underwent CTO-PCI.

Procedural outcomes, age, gender, and clinical status (emergency vs. elective) were evaluated using bivariate analysis and multivariable logistic regression. The findings reveal an exceptionally high overall procedural success rate of 93.0%. Statistical modeling demonstrates that advanced age, female gender, and emergency clinical status do not significantly predict procedural failure. Operator expertise and advanced crossing techniques effectively neutralize the anatomical complexities traditionally associated with adverse demographic profiles. In conclusion, CTO-PCI is highly safe and efficacious across diverse patient demographics; thus, patients must not be denied minimally invasive revascularization based on perceived, yet statistically unproven, demographic limitations.

Keywords : *Chronic Total Occlusion, Percutaneous Coronary Intervention, Procedural Success, Gender Paradox, High-Volume Center*

INTRODUCTION

Chronic Total Occlusion (CTO), defined as the complete occlusion of a coronary artery with TIMI 0 flow persisting for at least three months, remains one of the most technically demanding challenges in interventional cardiology [1, 2]. Large multicenter studies report a prevalence of approximately 15–20% among patients undergoing diagnostic coronary angiography, with some registries citing ranges as high as 35% depending on the population studied [3]. Historically, the technical complexity of CTO lesions driven by heavy calcification, severe tortuosity, and ambiguity of the vessel course led many patients to be referred for Coronary Artery Bypass Grafting (CABG) or managed with optimal medical therapy rather than percutaneous intervention [4, 5]. However, recent advances in dedicated guidewires, microcatheters, guide-catheter extensions, and novel crossing algorithms including antegrade dissection and re-entry and retrograde approaches have substantially improved success rates and transformed CTO-PCI into an increasingly adopted therapeutic strategy [1, 6, 7].

Despite these technological advancements, real-world success rates of CTO-PCI outside highly controlled clinical trials remain variable, with reported technical success fluctuating considerably across registries and institutions [8, 9]. Procedural success is

influenced not only by operator experience where dual-operator and high-volume approaches are often reserved for complex lesions [10] but also by patient-specific demographic and clinical factors. Advanced age, for instance, has been repeatedly identified as a negative predictor of CTO-PCI success, with younger patients frequently demonstrating higher procedural success rates [11]. Furthermore, female gender has emerged as a nuanced variable. Large registries, such as the ERCTO study and Polish ORPKI-derived analyses, report that women despite being older and presenting with more comorbidities often show high procedural success rates but are simultaneously exposed to greater complication risks, including coronary perforation and periprocedural mortality [12]. Additionally, the urgency of clinical presentation (elective versus emergency) significantly impacts angiographic planning, procedural complexity, and radiation metrics during catheterization [13].

While these baseline patient characteristics are frequently hypothesized to increase procedural difficulty, there remains a lack of comprehensive, real-world data evaluating whether they act as definitive barriers to success in contemporary high-volume centers. Understanding the complex interaction between demographic factors and procedural outcomes is crucial for optimizing patient selection, risk stratification, and resource allocation in the cardiac catheterization laboratory. Therefore, this study aims to evaluate the procedural success rates of CTO interventions in a real-world, high-volume setting. Furthermore, we seek to determine whether demographic factors (age and gender) and clinical status (elective vs. emergency) significantly predict procedural outcomes, thereby providing empirical evidence to refine and guide modern interventional strategies.

METHOD

This research utilized a retrospective observational design, analyzing a comprehensive dataset derived from the cardiac catheterization laboratory logbook at Goeteng Taroenadibrata General Hospital, Purbalingga, Central Java, Indonesia. The data extraction encompassed consecutive procedures performed within a specified high-volume operational period. From an initial dataset of 1,404 cardiovascular procedures, we purposefully isolated cases specifically involving chronic total occlusion (CTO). The

inclusion criteria required explicit documentation of CTO in the procedural notes, diagnosis, or intervention records. This filtering process yielded a final cohort of 187 patients who underwent CTO PCI. The primary outcome variable of this study was procedural success, defined dichotomously as 'Successful' or 'Failed' based on the operator's final angiographic evaluation recorded in the clinical notes. Secondary outcomes included the occurrence of intra-procedural or post-procedural mortality (categorized as 'Deathcase+' and 'Deathcase-'). The independent variables analyzed included patient demographics (Age and Gender) and the clinical urgency of the procedure (categorized as 'Cito' for emergency interventions and 'Elective' for scheduled interventions). Data processing and statistical analyses were conducted using R-Studio (R version 4.5.1). Descriptive statistics, including median and interquartile range (IQR) for continuous variables and frequencies for categorical variables, were utilized to establish the baseline characteristics of the cohort. Bivariate analyses were performed to assess the association between the independent variables and the procedural outcomes. The Mann-Whitney U Test was applied for continuous variables (e.g., age), while Fisher's Exact Test and Pearson's Chi-Squared Test were employed for categorical variables. Finally, a multivariable logistic regression model was constructed to evaluate the predictive trajectory of the combined demographic and clinical factors on the likelihood of a successful operation. The results of the regression were visualized using a forest plot to report the Odds Ratios (OR) and 95% Confidence Intervals (CI). Statistical significance for all tests was defined as a p-value of <0.05 [14].

RESULT AND DISCUSSION

Baseline Demographic and Clinical Characteristics

Based on the analysis of patient characteristics stratified by gender (Table 1), this study evaluated a cohort of 187 patients who underwent percutaneous coronary intervention for Chronic Total Occlusion (CTO). The cohort was predominantly male compare to female. A statistically significant difference in age was observed between

genders, with female patients presenting at an older median age compared to males. Despite this demographic variance, the clinical setting of the procedures (Cito vs. Elective) was evenly distributed across genders, with the majority of procedures performed electively. Importantly, the occurrence of intra-procedural or post-procedural death was exceedingly rare and demonstrated no gender bias. These baseline findings confirm that while females present at an older age, the overall clinical complexity upon admission does not disproportionately skew between genders.

Table 1 Patients characteristics stratified by Gender

Variables	Level / Metric	Female (N=31)	Male (N=156)	Statistical Tests
AGE	Median [IQR]	62 [59-67]	58 [52-65]	Mann-Whitney U Test (p=0.032*)
OPERATION	Cito	6 (19.4%)	35 (22.4%)	Pearson's Chi-Squared Test (p=0.888)
	Elective	25 (80.6%)	121 (77.6%)	
OUTCOME	Failed	4 (12.9%)	9 (5.8%)	Fisher's Exact Test (p=0.235)
	Succesfull	27 (87.1%)	147 (94.2%)	
DEATH_CASE	Deathcase-	29 (93.5%)	153 (98.1%)	Fisher's Exact Test (p=0.193)
	Deathcase+	2 (6.5%)	3 (1.9%)	

Procedural Outcomes and Influencing Variables

A categorical analysis was conducted to determine the extent to which baseline clinical and demographic factors were associated with procedural failure or success (Table 2). The overall procedural success rate was exceptionally high. Statistical analysis revealed that none of the evaluated variables significantly determined the procedural outcome. The median age of patients in the failed group was identical to that in the successful group. Furthermore, procedural success was not significantly influenced by gender or the clinical urgency of the operation. This lack of statistical significance

indicates that the high success rate of CTO interventions is uniformly maintained across diverse patient profiles.

Table 2 Influencial outcome procedures

Variable	Level / Metric	Failed (N=13)	Succesfull (N=174)	Statistical Tests
AGE	Median [IQR]	59 [57-64]	59 [52-65]	Mann-Whitney U Test (p=0.396)
GENDER	Female	4 (30.8%)	27 (15.5%)	Fisher's Exact Test (p=0.235)
	Male	9 (69.2%)	147 (84.5%)	
OPERATION	Cito	4 (30.8%)	37 (21.3%)	Fisher's Exact Test (p=0.486)
	Elective	9 (69.2%)	137 (78.7%)	

Success Rate Stratification by Clinical Status and Gender

Figure 1 illustrates the robust procedural success rates stratified by sex and the urgency of the clinical procedure. The bar chart demonstrates a consistently high success rate across all categories, reflecting the overall efficacy of the interventions. Notably, male patients undergoing elective procedures achieved the highest success rate. Conversely, female patients undergoing emergency (Cito) procedures recorded the lowest comparative success rate. While these proportional differences did not reach statistical significance (as established in Table 2), this visual stratification provides clinical insight into the compounded challenges of treating female patients in emergency settings

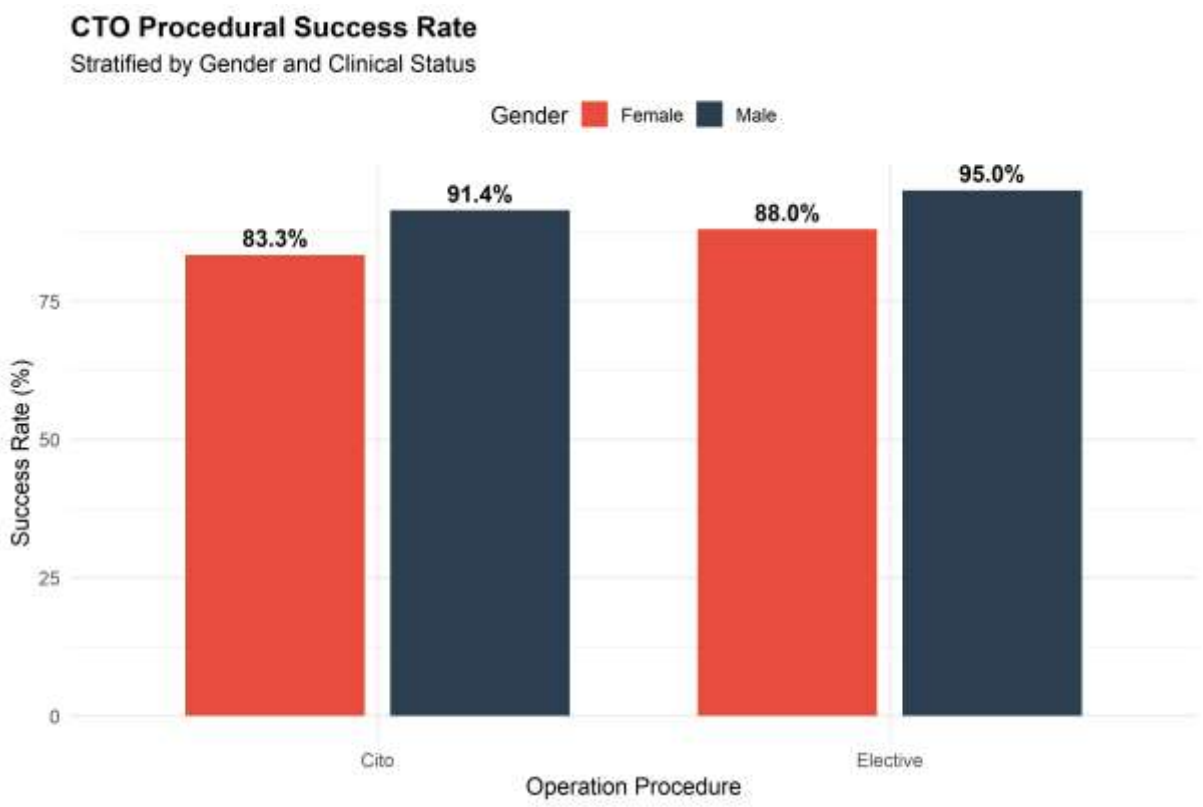

Figure 1 Operation Success Rate Stratified by Procedures and Gender

Statistical Modeling of Procedural Success Predictors

To evaluate the predictive trajectory of demographic and clinical factors on procedural success, a logistic regression model was constructed (Figure 2). The forest plot corroborates the bivariate analysis, showing that Age, Gender, and Clinical Status are not statistically significant independent predictors of procedural success (all confidence intervals cross the line of no effect, OR=1). However, the trend of the Odds Ratios provides valuable clinical context. Increasing age marginally trends toward reduced success. Being male indicates a trend toward a higher likelihood of success, while emergency (Cito) procedures trend toward reducing the odds of success. Although statistically non-

significant, these directional trends closely match real-world clinical intuitions regarding case complexity.

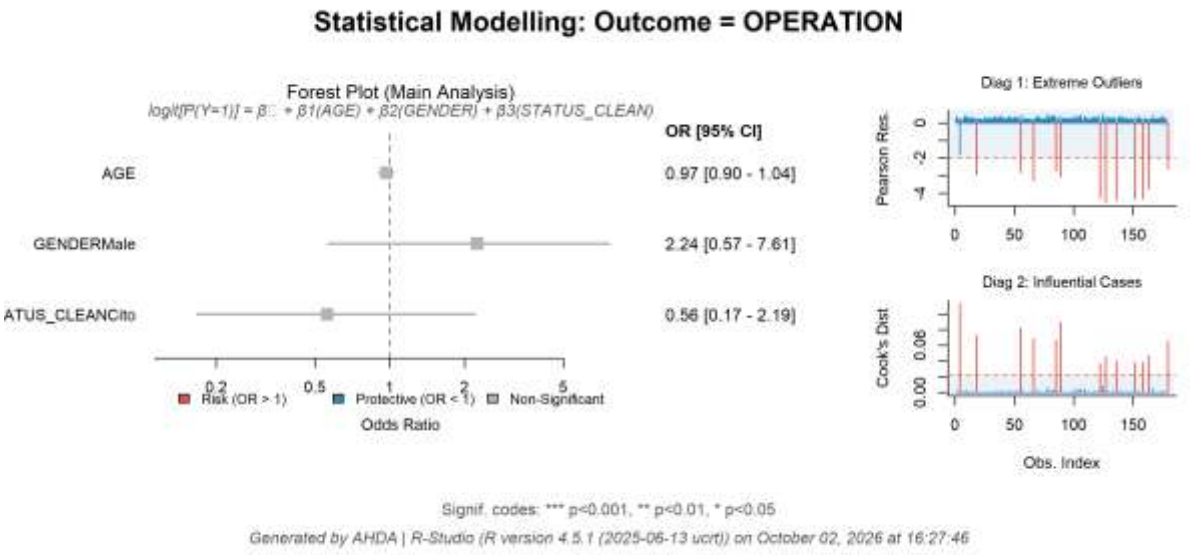

Figure 2 Logistic regression for factors associated with Succesfull Operation

A. DISCUSSION

The Uniformity of High Procedural Success

This study reveals a compelling finding within a high-volume interventional cardiology center: the procedural success rate for addressing Chronic Total Occlusion (CTO) is remarkably high and uniform, irrespective of the patient's baseline demographic or clinical presentation. The lack of statistical significance among variables such as age, gender, and clinical urgency (Table 2) in predicting procedural failure is, paradoxically, a strong indicator of clinical excellence. It demonstrates that the inherent anatomical or physiological complexities brought by older age or emergent conditions do not act as insurmountable barriers. Instead, this uniformity suggests that procedural success in modern CTO interventions is primarily driven by operator expertise, advanced wire

escalation techniques, and the availability of sophisticated microcatheters, which collectively override historical limitations posed by patient-specific factors.

This observation strongly aligns with a growing body of literature emphasizing operator- and center-volume effects as the primary determinants of CTO-PCI outcomes. Multiple large registries have demonstrated that success is intrinsically linked to procedural volume, with high-volume operators consistently achieving success rates substantially higher than their low-volume counterparts, often independent of baseline lesion complexity [1, 9, 15]. For example, direct comparisons have shown technical success rates of 83.3% for high-volume operators versus 64.1% for low-volume operators, reinforcing that accumulated procedural expertise effectively mitigates anatomical complexity [9]. Furthermore, single-center experiences employing dedicated CTO operators have reported procedural success rates comparable to major international registries (e.g., OPEN-CTO, PROGRESS-CTO, and EURO-CTO) with low associated short-term major adverse cardiac events, despite treating broad, unselected patient populations [16].

This pattern supports the interpretation that modern technological sophistication and strategic adaptability in the contemporary device era have fundamentally altered procedural risk profiles [8]. Notably, gender-based analyses offer further support for the assertion that demographic variables do not straightforwardly predict failure. Despite often presenting at an older age and with more comorbidities, women undergoing CTO-PCI have paradoxically shown equal or even higher procedural success rates than men in several large registries [12, 17]. This evidence is inconsistent with a simple paradigm where older or frailer demographic profiles equate to lower success. Ultimately, this body of evidence corroborates the conclusion that in dedicated, high-volume centers, procedural success in CTO-PCI is predominantly driven by operator skill and technological capability rather than baseline patient demographic or clinical presentation variables [18-20].

The Age and Urgency Complexity Trend

While patient demographics and clinical factors did not reach statistical significance in dictating final outcomes, the logistic regression model (Figure 2) reveals directional trends that align closely with established clinical intuition and mechanistic understanding of CTO complexity. The marginal trend indicating that increasing age lowers the odds of procedural success (OR = 0.97) is biologically plausible. Advancing age is strongly associated with a higher prevalence of severe coronary calcification and vessel tortuosity, which mechanically impedes guidewire crossing and device delivery. Severe calcification independently predicts wire-crossing failure and is formally incorporated into major CTO complexity scoring systems precisely because of its interference with lesion penetration [21-23]. Similarly, proximal vessel tortuosity often exacerbated in older populations has been independently linked to lower technical success in large multicenter registries such as PROGRESS-CTO, reinforcing the connection between age-related anatomical complexity and procedural difficulty [24].

Likewise, the trend indicating that emergency (Cito) procedures reduce the likelihood of success (OR = 0.56) highlights the extreme operational constraints imposed by unstable clinical presentations. In a Cito setting, operators frequently contend with hemodynamically unstable patients, active thrombosis, and significantly compressed decision-making windows [13]. These high-stress parameters prioritize rapid revascularization, thereby inherently restricting the time available to employ prolonged, meticulous, and time-intensive stepwise crossing strategies such as antegrade wire escalation, dissection re-entry, or retrograde collateral traversal that typically underpin high CTO success rates in elective settings [21, 25]. Consequently, the operational environment of an emergency intervention naturally limits the technical repertoire that can be safely deployed, contributing to the observed trend of lower success.

The Gender Paradox in CTO Interventions

The data highlighted a subtle but persistent sex disparity in interventional cardiology. Although not statistically significant regarding the final outcome, females in our cohort presented at a significantly older median age (62 years vs. 58 years) and exhibited

the lowest comparative success rate when operated on emergently (83.3%, Figure 1). This finding aligns with the broader " sex paradox" in cardiovascular disease, wherein women tend to present with ischemic heart disease later in life. Due to more atypical initial symptoms and delayed diagnoses, women are frequently older and carry a heavier burden of comorbidities such as hypertension, diabetes, and renal failure by the time they undergo CTO-PCI [12, 26]. Multiple large registries, including the European Registry of CTOs (ERCTO) and PROGRESS-CTO, consistently corroborate this delayed and highly comorbid presentation among female patients.

In our cohort, the trend indicating that males have higher odds of procedural success (OR = 2.24) intuitively underscores the anatomical reality that smaller coronary vessel diameters in older females may inherently increase procedural difficulty during complex revascularization. However, the broader literature presents a significant nuance: despite their adverse clinical risk profiles, several large registries have reported that women paradoxically achieve equal or even higher technical success rates than men. For example, the ERCTO study reported an adjusted odds ratio favoring women, and the PROGRESS-CTO registry similarly found higher technical success among females (89% vs. 86%) [12, 26].

This paradox is widely attributed to selection bias. The literature suggests that women are frequently referred for CTO-PCI only when they possess lower J-CTO anatomical complexity scores than men, effectively offsetting the procedural risks posed by their advanced age and comorbidities [12, 26]. Furthermore, evidence from diverse international cohorts remains mixed; a Chinese registry found sex to be a non-significant independent predictor, whereas an Indian cohort associated male sex with poorer outcomes [27, 28]. Ultimately, these discrepancies suggest that the intersection of gender, age, and anatomical complexity in CTO-PCI is highly multifaceted. Rather than representing a uniform anatomical disadvantage for women, gender-based outcomes are likely heavily modulated by institutional referral patterns, operator case selection, and specific population dynamics.

The Evolving Paradigm of CTO Revascularization

The findings of this study reinforce a profound paradigm shift in the management of complex coronary artery disease. Historically characterized as the "final frontier" of percutaneous coronary intervention, CTO lesions were frequently bypassed in favor of Coronary Artery Bypass Grafting (CABG) or conservative medical therapy due to presumed high failure rates [19, 29]. However, the >90% procedural success rate documented in our cohort, coupled with a remarkably low mortality rate, proves that CTO-PCI is highly efficacious and safe in a real-world high-volume setting. This performance mirrors outcomes from dedicated CTO programs internationally, which consistently demonstrate success rates exceeding 90% along with low in-hospital complication rates, even in centers lacking traditional on-site surgical backup [29, 30]. Recent evidence forcefully underscores that specific operator expertise, rather than institutional surgical capacity, drives safety and efficacy, with dedicated CTO operators drastically outperforming general interventional cardiologists [30].

Furthermore, our data, corroborated by large multicenter analyses, confirm that demographic factors such as female gender or advanced age do not act as independent biological barriers to successful revascularization or increased major adverse cardiac events [12, 31]. This collective evidence strongly supports a modern clinical framework in which well-resourced, experienced CTO programs can extend the life-saving benefits of minimally invasive revascularization broadly, without demographic restrictions.

To optimize patient safety and clinical outcomes, healthcare systems are encouraged to align with contemporary consensus statements that advocate for the extensive training of dedicated CTO operators and mandate the referral of complex cases from lower-volume hospitals to specialized, high-volume centers [30, 32]. Ultimately, this big data-driven insight delivers a clear clinical directive: patients, regardless of their age, gender, or the urgency of their clinical status, must not be denied the transformative benefits of CTO-PCI due to perceived, yet statistically unproven, demographic limitations.

CONCLUSION

This study demonstrates that percutaneous coronary intervention (PCI) for chronic total occlusion (CTO) is highly efficacious and safe when performed in a contemporary, high-volume interventional center, achieving an overall procedural success rate exceeding 90% with minimal mortality. Crucially, baseline demographic characteristics (such as advanced age and female gender) and clinical urgency (emergency versus elective settings) do not serve as statistically significant barriers to procedural success. While directional trends suggest inherent anatomical and operational complexities associated with older age and emergency presentations, these challenges are effectively overcome by advanced operator expertise and modern technological capabilities. Clinical decision-making regarding CTO revascularization should not be prejudiced by patient age or gender. Lower-volume centers are strongly encouraged to refer complex CTO cases to dedicated, high-volume operators to ensure equitable access to minimally invasive revascularization. Institutions must prioritize the development of dedicated CTO programs and the continuous training of interventional operators, as institutional commitment to specialized expertise is the primary driver of patient safety and procedural success in complex coronary interventions.

ACKNOWLEDGEMENT

The authors express their deepest gratitude to the Goeteng Taroenadibrata General Hospital, Purbalingga, Central Java, Indonesia.

Ary, D., Jacobs, L.C. & Razavieh, A. 1976. *Pengantar Penelitian Pendidikan.* Terjemahan oleh Arief Furchan. 1982. Surabaya: Usaha nasional

REFERENCES

1. Cilia L, Megaly M, Davies R, Tehrani BN, Batchelor WB, Truesdell AG. A non-interventional cardiologist's guide to coronary chronic total occlusions. Front Cardiovasc Med. 2024;11:1350549. https://doi.org/10.3389/fcvm.2024.1350549

2. Xu W, Ma J, Chen Y, Zhou F, Zhou C, Zhang LJ. Coronary chronic total occlusion on coronary CT angiography: what radiologists should know? Insights Imaging. 2024;15(1):55. https://doi.org/10.1186/s13244-024-01621-y

3. Wang C, Liu S, Kamronbek R, Ni S, Cheng Y, Yan H, et al. Percutaneous Coronary Intervention versus Coronary Artery Bypass Grafting for Chronic Total Occlusion of Coronary Arteries: A Systematic Review and Meta-Analysis. J Interv Cardiol. 2023;2023:9928347. https://doi.org/10.1155/2023/9928347

4. Abdulah DM, Miro SS. Prevalence and correlated factors for chronic total occlusion in patients with coronary artery disease in Iraqi Kurdistan. Annals of Clinical and Biomedical Research. 2022;3(1). https://doi.org/10.4081/acbr.2022.170

5. Kirov H, Fischer J, Caldonazo T, Tasoudis P, Runkel A, Soletti GJ, et al. Coronary Artery Bypass Grafting versus Percutaneous Coronary Intervention in Patients with Chronic Total Occlusion. Thorac Cardiovasc Surg. 2025;73(8):609–17. https://doi.org/10.1055/s-0044-1787014

6. Cosgrove C, Mahadevan K, Spratt JC, McEntegart M. The Impact of Calcium on Chronic Total Occlusion Management. Interv Cardiol. 2021;16:e30. https://doi.org/10.15420/icr.2021.01

7. Almanfaluthi M, Dewi A. Evolution of Artificial Intelligence in Patient Safety across Southeast Asia: A Bibliometric Analysis. International Archives of Medical Sciences and Public Health. 2026;7(1):28–40. https://doi.org/10.53806/iamsph.v7i1.1447

8. Mandour KMM, El Menshawy MD, El Zaiat AM, Salama AEM. Effect of Lesion Age on Short Term Outcomes of Chronic Total Occlusion Percutaneous Coronary Intervention. The Egyptian Journal of Hospital Medicine. 2022;88(1):3692–8. https://doi.org/10.21608/ejhm.2022.251209

9. Mohebbi B, Sadeghipour P, Zolfaghari R, Vadala G, Khalilipur E, Zahedmehr A, et al. Outcomes of chronic total occlusion percutaneous coronary intervention from the RAIAN (RAjaie - Iran) registry. Indian Heart J. 2023;75(6):429–35. https://doi.org/10.1016/j.ihj.2023.10.002

10. Januszek R, De Luca G, Silka W, Bryniarski L, Malinowski KP, Surdacki A, et al. Single versus Dual-Operator Approaches for Percutaneous Coronary Interventions within

Chronic Total Occlusion-An Analysis of 27,788 Patients. J Clin Med. 2023;12(14):4684. https://doi.org/10.3390/jcm12144684

11. Li QY, Lin XL, Li FQ, Cheng ZC, Tian JY, Zhao DH, et al. A Chinese scoring system for predicting successful retrograde collateral traverse in patients with chronic total coronary occlusion. BMC Cardiovasc Disord. 2023;23(1):380. https://doi.org/10.1186/s12872-023-03405-6

12. Avran A, Zuffi A, Gobbi C, Gasperetti A, Schiavone M, Werner GS, et al. Gender differences in percutaneous coronary intervention for chronic total occlusions from the ERCTO study. Catheter Cardiovasc Interv. 2023;101(5):918–31. https://doi.org/10.1002/ccd.30616

13. Abu Khadija H, Alnees M, George J, Bakry M, Abasi D, Abu Hamdeh N, et al. Shedding light on radiation exposure: Emergency vs. elective catheterization procedures in a prospective cohort study. Am Heart J Plus. 2025;53:100530. https://doi.org/10.1016/j.ahjo.2025.100530

14. Almanfaluthi M, Effendy K, Yuniarsih S, Widodo S, Ulya Z, Maulidi S, et al. Menyusun Penelitian Kesehatan dan Kedokteran Seri: Konsep Dasar Penelitian dan Statistik. Sleman, Indonesia: Deepublish; 2025. 180 p.

15. Mohandes M, Moreno C, Fuertes M, Rojas S, Pernigotti A, Zambrano D, et al. New scoring system for predicting percutaneous coronary intervention of chronic total occlusion success: Impact of operator's experience. Cardiol J. 2023;30(4):506–15. https://doi.org/10.5603/CJ.a2021.0109

16. Etriby KAE, Okasha NK, Zahran ME, Mohamed TR. Impact of successful antegrade and retrograde CTO PCI on short-term prognosis. Egypt Heart J. 2024;76(1):66. https://doi.org/10.1186/s43044-024-00501-6

17. Siudak Z, Bryniarski L, Malinowski KP, Wanha W, Wojakowski W, Surowiec S, et al. Procedural Outcomes in Patients Treated with Percutaneous Coronary Interventions within Chronic Total Occlusions Stratified by Gender. J Clin Med. 2022;11(5):1419. https://doi.org/10.3390/jcm11051419

18. Kotev S, Sami F, Malangu B. A Review of Indications and Guidelines of Chronic Total Occlusion Revascularization. Int J Angiol. 2025;34(4):354–9. https://doi.org/10.1055/a-2655-2536

19. Sahu AK, Kazmi DH, Kaushik A. Is it Worthy Enough to Revascularize Chronically Occluded Coronaries? Cardiol Rev. 2024;32(4):338–47. https://doi.org/10.1097/CRD.0000000000000509

20. Sliman H, Kasem Ali Sliman R, Knaapen P, Nap A, Sobieszek G, Opolski MP. The Role of Intravascular Imaging in Coronary Chronic Total Occlusion PCI: Enhancing Procedural Success Through Real-Time Visualization. J Pers Med. 2025;15(7):318. https://doi.org/10.3390/jpm15070318

21. Dabrowski EJ, Swieczkowski M, Dudzik JM, Grunwald O, Januszko T, Muszynski P, et al. Percutaneous Coronary Intervention for Chronic Total Occlusion-Contemporary Approach and Future Directions. J Clin Med. 2023;12(11):3762. https://doi.org/10.3390/jcm12113762

22. Mashayekhi KA, Pyxaras SA, Werner GS, Galassi AR, Garbo R, Boudou N, et al. Contemporary issues of percutaneous coronary intervention in heavily calcified chronic total occlusions: an expert review from the European CTO Club. EuroIntervention. 2023;19(2):e113–e22. https://doi.org/10.4244/EIJ-D-22-01096

23. Sakuma M, Oikawa Y, Kishi K, Ito Y, Okada H, Sumitsuji S, et al. Percutaneous Coronary Intervention Outcomes for Chronic Total Occlusion in Patients on Dialysis: Analysis of the Japanese CTO-PCI Expert Registry. Catheter Cardiovasc Interv. 2025;106(2):908–17. https://doi.org/10.1002/ccd.31622

24. Strepkos D, Rempakos A, Alexandrou M, Mutlu D, Carvalho PEP, Bahbah A, et al. Association of Proximal Vessel Tortuosity with Technical Success and Clinical Outcomes: Analysis From the Progress-CTO Registry. Catheter Cardiovasc Interv. 2025;105(1):1–10. https://doi.org/10.1002/ccd.31338

25. Di Mario C, Mashayekhi KA, Garbo R, Pyxaras SA, Ciardetti N, Werner GS. Recanalisation of coronary chronic total occlusions. EuroIntervention. 2022;18(7):535–61. https://doi.org/10.4244/EIJ-D-21-01117

26. Kostantinis S, Simsek B, Karacsonyi J, Alaswad K, Basir MB, Megaly M, et al. Gender differences in chronic total occlusion percutaneous coronary interventions: Insights from the PROGRESS-CTO registry. Catheter Cardiovasc Interv. 2022;100(6):1010–8. https://doi.org/10.1002/ccd.30425

27. Gong X, Zhou L, Ding X, Li H, Chen H. A sex-stratified long-term clinical outcome analysis in coronary chronic total occlusion patients. Biol Sex Differ. 2021;12(1):9. https://doi.org/10.1186/s13293-020-00354-z

28. Vemuri KS, Sihag BK, Sharma Y, Nevali KP, Vijayvergiya R, Kumar RM, et al. Real world perspective of coronary chronic total occlusion in third world countries: A tertiary care centre study from northern India. Indian Heart J. 2021;73(2):156–60. https://doi.org/10.1016/j.ihj.2021.03.001

29. Bryniarski L, Opolski MP, Wojcik J, Lesiak M, Pawlowski T, Drozd J, et al. Chronic total occlusion percutaneous coronary intervention in everyday clinical practice - an expert opinion of the Association of Cardiovascular Interventions of the Polish Cardiac Society. Postepy Kardiol Interwencyjnej. 2021;17(1):6–20. https://doi.org/10.5114/aic.2021.104763

30. Gilpin TR, Maznyczka A, Anantharam B, Dana A. Procedural Results and Long-term Outcome of Chronic Total Occlusion Percutaneous Coronary Intervention in a UK Non-surgical Centre. Interv Cardiol. 2024;19:e05. https://doi.org/10.15420/icr.2023.23

31. Lansky A, Baron SJ, Grines CL, Tremmel JA, Al-Lamee R, Angiolillo DJ, et al. SCAI Expert Consensus Statement on Sex-Specific Considerations in Myocardial Revascularization. J Soc Cardiovasc Angiogr Interv. 2022;1(2):100016. https://doi.org/10.1016/j.jscai.2021.100016

32. Curzen N, Routledge H, McGrath S, Abouelasaad M, Mamas M, Kinnaird T, et al. Percutaneous Coronary Intervention in the UK: Recommendations of the British Cardiovascular Intervention Society. Interv Cardiol. 2025;20:e01. https://doi.org/10.15420/icr.2024.43