PAKISTAN JOURNAL OF Cardiovascular Intervention

OPEN ACCESS

ORIGINAL ARTICLE

Equipment Utilization of a Chronic Total Occlusion Percutaneous Coronary Intervention Program: An Experience from a Single Center Registry.

Muhammad Suleman[1,2], Bakht Umar Khan[1], Fahad Khalid[1], Nayyar Arif[1], Muhammad Shehram[1,3], Muhammad Jamil[4], Sohail Aziz[1], Ghulam Rasool Maken[1], Naseer Ahmed Samore[1], Shafi Ullah Khan[5]

[1]Armed Forces Institute of Cardiology & National Institute of Heart Disease, Rawalpindi-Pakistan.
[2]Peshawar Institute of Cardiology, Peshawar, Khyber Pakhtunkhwa Pakistan
[3]Mufti Mehmood Memorial Teaching Hospital, Dera Ismail khan-Pakistan.
[4]Services Hospital, Peshawar -Pakistan.
[5]District Headquarters Teaching Hospital Kohat-Pakistan.

Citation:
Suleman M, Khan BU, Khalid F, Arif N, Shehram M, Jamil M, Aziz S, Maken GR, Samore NA, Khan SU. Equipment Utilization of a Chronic Total Occlusion Percutaneous Coronary Intervention Program: An Experience from a Single Center Registry. PJCVI. 2023; 3(1): 18-25

Corresponding Author Email:
Shafiullah.hameed@gmail.com

DOI: 10.58889/PJCVI.4.18.25

Funding:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflicts of Interests:
The authors have declared that no competing interests exist.

Received 09/03/2023
Accepted 24/04/2023
First Published 01/06/2023

Abstract

Background: Chronic total occlusion (CTO) is a prevalent and challenging condition for interventional cardiologists. Recent advancements in guidewires and microcatheters have played a crucial role in improving the success rate of percutaneous coronary intervention (PCI) in CTO cases. Our study aimed to assess the utilization of equipment in CTO-PCI procedures.
Methodology: We conducted a retrospective analysis of 1483 patients with CTO who underwent PCI, including both antegrade and retrograde approaches, at a single center over a 5-year period from January 2015 to December 2019.
Results: The majority of cases (n=1473) were performed using the antegrade approach, with only a small proportion (n=10) utilizing the retrograde approach. The mean age of the patients was 59 years, and there was a higher prevalence of males (84%). Radial access was used in 933 cases, while femoral access was used in 533 cases. The right coronary artery (RCA) was the most frequently involved vessel, and the left circumflex (LCX) had the highest success rate. The overall procedural success rate was 76.1%. The mean contrast volume used was 236 ± 88 ml. The average utilization of guidewires, stents, microcatheters, and balloons was 2.7 ± 2, 1.7 ± 1, 1.6 ± 1, and 3.8 ± 3, respectively. Commonly used guidewires included Pilot 50 and Pilot 200, while OTW and Corsair were frequently utilized microcatheters in the antegrade approach. In retrograde cases, RG3 and BMW 300 cm were commonly used. JR and hockey stick guides were predominantly used in RCA vessels. The utilization of double stick procedures was limited to 10.8% of cases due to cost barriers.
Conclusion: The use of polymer jacketed guidewires, torque-producing microcatheters with varying penetration forces, and the double stick approach significantly improved the success rate of CTO-PCI procedures. However, cost-effectiveness remains a significant barrier in the context of Pakistan.

Keywords

Chronic Total Occlusion, Equipment, Guidewire, Microcatheter, Percutaneous Coronary Intervention.

Published by Pakistan Society of Interventional Cardiology

Introduction

Chronic total occlusion (CTO) is a common finding during routine coronary angiography, with a prevalence ranging from 18% to 52%[1]. Despite its high incidence, interventional cardiologists have been reluctant to perform percutaneous coronary intervention (PCI) for CTOs due to factors such as cost, lack of specialized equipment, and relatively low success rates[2].

However, recent advancements in guidewire technology, micro-catheters, hybrid techniques, and the use of various imaging modalities for procedural guidance have significantly improved the success rates of CTO PCI[3]. Specialized centers with experienced operators have achieved success rates of up to 90%[4]. It is important to note that CTO PCI should only be performed in centers equipped with the necessary tools, techniques, and comprehensive training and monitoring systems[5].

To contribute to the understanding of CTO PCI and its equipment utilization, we conducted a retrospective analysis of 5-year data from a single-center CTO PCI registry in a developing country. The purpose of this study is to provide insights and guidance for other centers considering the establishment of a CTO PCI program by analyzing the equipment used during these procedures. We believe that our findings will not only help improve the success rates of CTO PCI but also encourage more centers to offer this crucial intervention for patients with CTO.

Methodology

This descriptive case series study was conducted at the Cardiac Catheterization Lab of the Armed Forces Institute of Cardiology & National Institute of Heart Diseases in Pakistan. The study aimed to investigate patients of both genders aged 35 years or older who underwent either antegrade or retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI) at the cath-lab during the study period. Patients who had a myocardial infarction in the target vessel within the last three months were excluded from the study.

All patients who underwent CTO-PCI between January 2015 and December 2019 were included in the study if they met the inclusion criteria. Patients who met the exclusion criteria were excluded from the analysis to control for confounding bias. A total of 1483 patients were included in the study after excluding 130 patients.

The study utilized descriptive statistics to present the data. Categorical variables, such as gender, diabetes, hypertension, angina class, target vessel, and history of myocardial infarction, were reported as frequencies. Continuous variables, including age, ejection fraction, number of vessels, number of stents, number of wires, and number of balloons used, were presented as means with standard deviation.

To control for effect modifiers and potential confounding variables, stratification was employed. Post-stratification chi-square analysis was then applied to compare means, with a p-value of less than 0.05 considered statistically significant.

Results

A total of 1483 patients underwent chronic total occlusion (CTO) percutaneous coronary intervention (PCI), with a male predominance of 84% (n=1245). Among the patients, 1129 (75.8%) had successful procedures, while 354 (24%) experienced procedure failure. The mean age of the patients was 59 years, and there was a high burden of risk factors for coronary artery disease. Radial access was utilized in 933 patients, resulting in a success rate of 78%, while femoral access was used in 533 patients, with a success rate of 72%. The right coronary artery (RCA) was the most frequently involved vessel, with a success rate of 70%, while the left circumflex (LCX) had the highest success rate at 83%. For a detailed analysis of all baseline characteristics, please refer to Table 1.

Table 1: Basic Characteristics

		Total		Success		Failed	
		Mean ± SD	Count (%)	Mean ± SD	Count (%)	Mean ± SD	Count (%)
Age		59±10	-	59±10	-	59±9	-
EF (%)		50±10	-	50±10	-	50±11	-
Gender	Male	-	1245 (84.0%)	-	935 (82.8%)	-	310 (87.6%)
	Female	-	238 (16.0%)	-	194 (17.2%)	-	44 (12.4%)
Access	Femoral	-	509 (34.3%)	-	367 (32.5%)	-	142 (40.1%)
	Radial	-	933 (62.9%)	-	730 (64.7%)	-	203 (57.3%)
Hypertension		-	178 (12.0%)	-	141 (12.5%)	-	37 (10.5%)
Diabetes		-	114 (7.7%)	-	94 (8.3%)	-	20 (5.6%)
Smoker		-	97 (6.5%)	-	78 (6.9%)	-	19 (5.4%)
PCI		-	92 (6.2%)	-	73 (6.5%)	-	19 (5.4%)
CABG		-	18 (1.2%)	-	14 (1.2%)	-	4 (1.1%)
NSTEMI		-	73 (4.9%)	-	54 (4.8%)	-	19 (5.4%)
Inferior Wall MI		-	51 (3.4%)	-	41 (3.6%)	-	10 (2.8%)
Anterior Wall MI		-	58 (3.9%)	-	49 (4.3%)	-	9 (2.5%)
Target Artery	LAD	-	508 (34.3%)	-	401 (35.5%)	-	107 (30.2%)
	LCX	-	315 (21.2%)	-	263 (23.3%)	-	52 (14.7%)
	RCA	-	634 (42.8%)	-	444 (39.3%)	-	190 (53.7%)
	Trifurcation	-	13 (0.9%)	-	12 (1.1%)	-	1 (0.3%)

EF=Ejection Fraction, MI=Myocardial Infarction, PCI=Percutnaous Intervention, CABG=Coronary Artery Bypass, NSTEMI=Non ST Elevation MI, LAD=Left Anterior Descening Artery, LCX=Left Circumflex, RCA=Right Coronary Artery

Overall procedural success was reported at 76.1%, with the highest success rate observed in 2018 (80.1%) and the lowest in 2017 (69.5%). Further information on procedural success can be found in Table 2.

Table 2: Procedure Success

		Total	2015	2016	2017	2018	2019
		Count (%)	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)
Outcome	Success	1129 (76.1%)	145 (76.7%)	151 (75.1%)	191 (69.5%)	265 (80.1%)	377 (77.4%)
	Failed	354 (23.9%)	44 (23.3%)	50 (24.9%)	84 30.5%)	66 (19.9%)	110 (22.6%)
		Chi-Square=10.146 , P value (0.038)					

The mean contrast volume increased over time from 2015 to 2017. Detailed usage and utilization of inventory are provided in Table 3 and Table 4, respectively.

Table 3: Basic Inventory usage

	Total		Success		Failed		
	Mean (SD)	Median	Mean (SD)	Median	Mean (SD)	Median	P-value
Stents	1.7±1	2	2.1±1	2	0.3±1	0	<0.001
Balloons	3.8±3	3	4.4±2	4	2.0±2	1	<0.001
Wires	2.7±2	2	2.6±2	2	2.9±2	3	0.007
Catheter	1.6±1	1	1.6±1	1	1.8±1	2	<0.001
Contrast (ml)	236.5±88	200	243.7±86	200	213.3±87	200	<0.001

Table 4: Basic inventory utilization

	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Years	**2015**	**2016**	**2017**	**2018**	**2019**
Stents	1.7±1.2	1.6±1.1	1.4±1.1	1.7±1.1	1.9±1.3
Balloons	3.1±1.7	2.9±1.8	3.3±2.4	3.9±2.5	4.6±3.0
Wires	2.2±1.5	1.8±1.0	2.2±1.3	2.4±1.3	3.8±2.5
Catheter	1.5±1.1	1.3±0.7	1.5±0.7	1.5±0.7	2.1±1.2
Contrast	192.4±53.9	229.1±57.1	212.9±55.3	231.5±72.5	273.8±114.8

Pilot wires were the most utilized wire followed by Gaia family as shown in figure 1 and table 5.

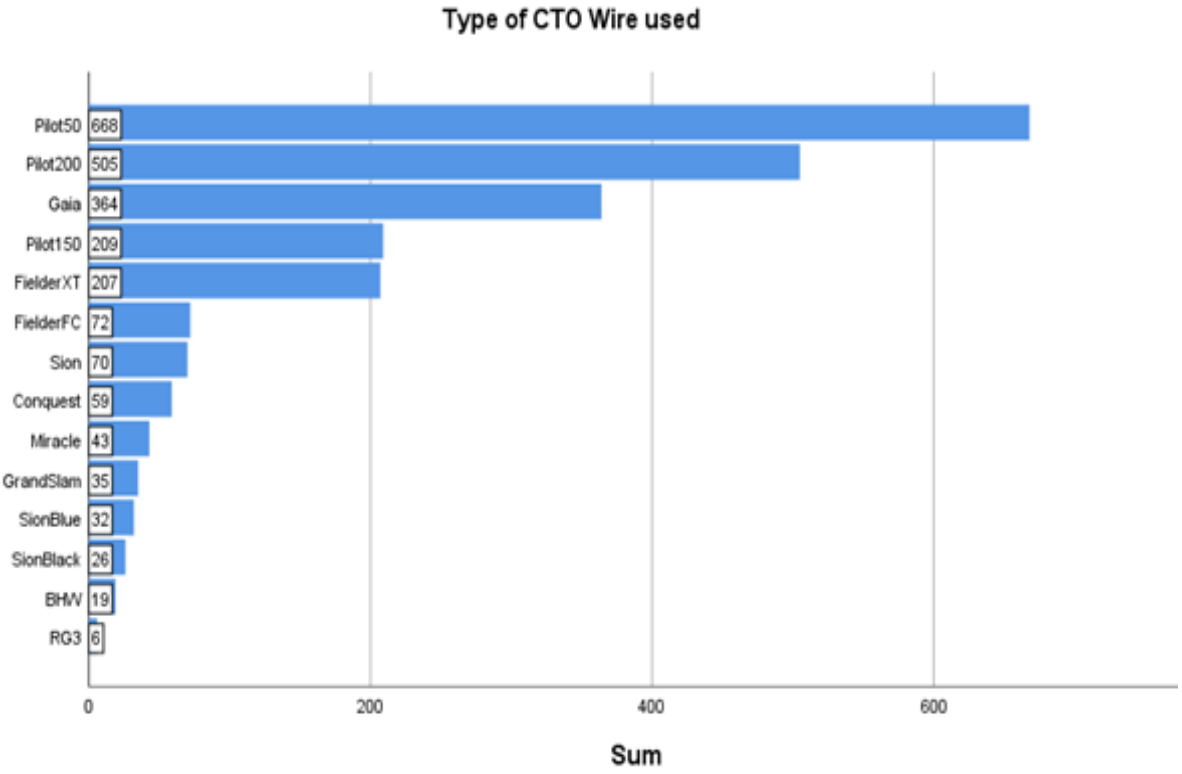

Figure 1: Types of CTO wires used.

The use of the double-stick procedure increased over the years, with the highest utilization observed in 2019. This also led to an increase in contrast usage. For a comprehensive analysis of the double-stick procedure across the years, please see Table 5.

Table 5: Double Stick Over the Year

		Total	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)
		Years	**2015**	**2016**	**2017**	**2018**	**2019**
Double Stick	**No**	1323(89.2)	176(93.1%)	188(93.5%)	246(89.5%)	288(87.0%)	425(87.3%)
	Yes	160(10.8)	13(6.9%)	13(6.5%)	29(10.5%)	43(13.0%)	62(12.7%)
				Chi square=10.49, P-value=0.33			

Among the guides used for RCA CTO, JR was the most commonly employed, while the hockey stick guide was initially preferred but later replaced by the AL guide. For a detailed analysis of the RCA guide, please refer to Table 6.

Table 6: Choice of RCA guide over the years

	Count (%)	Count (%)	Count (%)	Count (%)	Count (%)
Years	**2015**	**2016**	**2017**	**2018**	**2019**
JR	59 (31.2%)	68 (33.8%)	129 (46.9%)	165 (49.8%)	247 (50.7%)
MPA	5 (2.6%)	4 (2.0%)	1 (0.4%)	1 (0.3%)	7 (1.4%)
AL	22 (11.6%)	17 (8.5%)	44 (16.0%)	38 (11.5%)	88 (18.1%)
AR	9 (4.8%)	4 (2.0%)	5 (1.8%)	8 (2.4%)	11 (2.3%)
HS	36 (19.0%)	44 (21.9%)	36 (13.1%)	35 (10.6%)	42 (8.6%)

3DRC	2 (1.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

JR=Judkin Right, MPA=Multipurpose, AL-Amplatrz Left, AR-Amplatz Right, HS=Hocket Stick, 3DRC=3D Right Curve

Over-the-wire balloon (OTW) was frequently used in the study, while the utilization of microcatheters remained low due to financial barriers. A comprehensive analysis of all microcatheter utilization is provided in Table 7.

Table 7: Microcatheter utilization over the year

	Count (%)	**Count (%)**	**Count (%)**	**Count (%)**	**Count (%)**
Years	2015	2016	2017	2018	2019
OTW	27 (14.3%)	22 (10.9%)	50 (18.2%)	78 (23.6%)	84 (17.2%)
Caravel	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (1.2%)
Corsair	12 (6.3%)	3 (1.5%)	12 (4.4%)	15 (4.5%)	22 (4.5%)

OTW = Over the wire balloon catheter

Discussion

The results of our study provide important insights into the equipment utilization and procedural characteristics of chronic total occlusion (CTO) percutaneous coronary intervention (PCI). The observed contrast volume of 250 ml during the CTO procedure aligns with findings from a US multicenter registry[6]. This consistency suggests that our data is in line with international trends.

The median number of wires required for CTO PCI was 3, and 4 balloons were used per procedure. This reflects the need for multiple wires in antegrade wire escalation, where a workhorse wire is used to reach the proximal cap of the lesion, and a special CTO wire is used for further advancement[7]. The use of multiple balloons is necessary for effective pre-dilatation of the CTO lesion, as smaller balloons are often required to navigate the tightly stenotic segment[7].

Interestingly, our study revealed that more catheters were utilized in failed CTO PCI procedures (2 vs. 1), possibly indicating the need for increased support to successfully cross the lesion with a wire. This finding suggests that improved equipment, advanced techniques, and operator expertise contribute to better outcomes in CTO-PCI procedures[8].

In line with international data, our study showed a higher usage of guidewires in both the antegrade and retrograde approaches for more complex CTO cases[9,10]. The selection of guidewires is influenced by the characteristics of the proximal cap. For tapered lesions, low-penetration forced, polymer-jacketed wires like Fielder X are typically used, while composite core wires with higher penetration forces are employed for blunt proximal caps in the antegrade approach[11-13]. In our study, Pilot 50, Pilot 200, Gaia, Pilot 150, and Fielder XT were the most commonly used guidewires.

Due to limitations in relevant catheterization labs and operator dexterity, our study had a limited focus on the retrograde approach. However, Pilot 50 was the most frequently used guidewire in the retrograde cases we performed.

Microcatheters demonstrated advantages over conventional over-the-wire balloons in CTO PCI, such as flexible tips, better penetration power, easy guidewire switching, wider lumens, torque transmission, and precise lesion localization[14]. The use of microcatheters has been associated with higher success rates in CTO PCI, as demonstrated by the Progress CTO registry[15,16]. In our study, frequently used microcatheters included OTW, Caravel, and Corsair.

Notably, the mean utilization of contrast volume over the years 2015-2019 in our study (227.96 ml) was significantly lower compared to registries from the same period[17]. This could be attributed to factors such as the lower utilization of the retrograde approach, the incorporation of new guidewires and microcatheters in CTO PCI, and the relatively lower usage of double stick procedures with simultaneous catheters[10,18,19]. However, there was an overall increase in contrast volume from 2015 to 2019, primarily driven by the increased usage of the double stick procedure with two simultaneous catheters.

Conclusion

In conclusion, our study provides valuable insights into the equipment utilization and procedural characteristics of chronic total occlusion percutaneous coronary intervention (CTO-PCI). We observed a high success rate in CTO-PCI procedures, with variations depending on access site and the involved coronary artery. The utilization of wires, balloons, and microcatheters demonstrated the evolving techniques and advancements in CTO-PCI. The findings emphasize the importance of appropriate equipment selection, operator expertise, and the potential benefits of microcatheters in improving procedural success rates. However, further research and advancements are needed to optimize the utilization of the retrograde approach, enhance operator skills, and overcome financial barriers that limit the utilization of certain equipment.

Limitation

Our study has certain limitations that need to be acknowledged. Firstly, it was a retrospective analysis conducted in a single-center, which may limit the generalizability of the findings. Secondly, the lack of relevant catheterization labs and procedural expertise limited the exploration of the retrograde approach in CTO-PCI procedures. Additionally, financial barriers hindered the utilization of certain equipment, such as microcatheters. These limitations underscore the need for multicenter studies, specialized training programs, and adequate resources to overcome these challenges and improve CTO-PCI outcomes.

Recommendation

Based on our findings, we recommend several areas for future research and practice. Firstly, efforts should be made to establish and expand specialized catheterization labs to facilitate the utilization of the retrograde approach in CTO-PCI procedures. This would require training programs and collaboration among interventional cardiologists. Secondly, addressing financial barriers and promoting the availability of advanced equipment, such as microcatheters, would enhance procedural success rates. Moreover, multicenter studies are warranted to validate our findings and further explore the impact of equipment utilization on long-term clinical outcomes in CTO-PCI. Finally, continuous professional development programs and knowledge-sharing platforms should be established to keep operators updated with the latest techniques and advancements in CTO-PCI. By implementing these recommendations, we can improve the overall success rates of CTO-PCI and expand its availability to more patients in need.

Acknowledgment

We would like to express our sincere gratitude to the patients who participated in this study and the healthcare professionals involved in their care. We also acknowledge the support and cooperation of the staff at the Cardiac Catheterization Lab of Armed Forces Institute of Cardiology & National Institute of Heart Diseases, Pakistan, for their assistance in data collection and analysis.

References

1) Fefer P, Knudtson ML, Cheema AN, Galbraith PD, Osherov AB, Yalonetsky S, Gannot S, Samuel M, Weisbrod M, Bierstone D, Sparkes JD. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. J Am Coll Cardiol. 2012;59(11):991-997.
2) Grantham JA, Marso SP, Spertus J, House J, Holmes DR, Rutherford BD. Chronic total occlusion angioplasty in the United States. JACC: Circ Cardiovasc Interv. 2009;2(6):479-486.
3) Rinfret S, editor. Percutaneous Coronary Intervention for Chronic Total Occlusion: The Hybrid Approach. Springer Nature; 2022.

4) 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: Circ Cardiovasc Interv. 2015;8(2):245-253.
5) Karmpaliotis D, Lembo N, Kalynych A, Carlson H, Lombardi WL, Anderson CN, Rinehart S, Kirkland B, Shemwell KC, Kandzari DE. Development of a high - volume, multiple - operator program for percutaneous chronic total coronary occlusion revascularization: procedural, clinical, and cost - utilization outcomes. Catheter Cardiovasc Interv. 2013;82(1):1-8.
6) Sapontis J, Christopoulos G, Grantham JA, Wyman RM, Alaswad K, Karmpaliotis D, Lombardi WL, McCabe JM, Marso SP, Kotsia AP, Rangan BV. Procedural failure of chronic total occlusion percutaneous coronary intervention: insights from a multicenter US registry. Catheter Cardiovasc Interv. 2015;85(7):1115-1122.
7) Alaswad K. Toolbox and Inventory Requirements for Chronic Total Occlusion Percutaneous Coronary Interventions. Interv Cardiol Clin. 2012;1(3):281-297.
8) Kostantinis S, Simsek B, Karacsonyi J, Alaswad K, Krestyaninov O, Khelimskii D, Karmpaliotis D, Jaffer FA, Khatri JJ, Poommipanit P, Choi JW. In-hospital outcomes and temporal trends of percutaneous coronary interventions for chronic total occlusion. EuroIntervention. 2022;18(11):e929-e932.
9) Tajti P, Karmpaliotis D, Alaswad K, Jaffer FA, Yeh RW, Patel M, Mahmud E, Choi JW, Burke MN, Doing AH, Dattilo P. The hybrid approach to chronic total occlusion percutaneous coronary intervention: update from the PROGRESS CTO registry. JACC: Circ Cardiovasc Interv. 2018;11(14):1325-1335.
10) Nikolakopoulos I, Choi JW, Alaswad K, Khatri JJ, Krestyaninov O, Khelimskii D, Yeh RW, Jaffer FA, Toma C, Patel M, Mahmud E. Equipment utilization in chronic total occlusion percutaneous coronary interventions: Insights from the PROGRESS - CTO registry. Catheter Cardiovasc Interv. 2021;97(4):658-667.
11) Wu EB, Brilakis ES, Mashayekhi K, Tsuchikane E, Alaswad K, Araya M, Avran A, Azzalini L, Babunashvili AM, Bayani B, Behnes M. Global chronic total occlusion crossing algorithm: JACC state-of-the-art review. J Am Coll Cardiol. 2021;78(8):840-853.
12) Brilakis E. Manual of percutaneous coronary interventions: a step-by-step approach. Academic Press; 2020.
13) Olivecrona GK, Consensus GE. Guiding Principles for Chronic Total Occlusion Percutaneous Coronary Intervention: A Global Expert Consensus Document. Circulation. 2019;140(5):420-433.
14) Simsek B, Kostantinis S, Karacsonyi J, Alaswad K, Karmpaliotis D, Masoumi A, Jaffer FA, Doshi D, Khatri J, Poommipanit P, Gorgulu S. Predictors of success in primary retrograde strategy in chronic total occlusion percutaneous coronary intervention: insights from the PROGRESS - chronic total occlusion registry. Catheter Cardiovasc Interv. 2022;100(1):19-27.
15) Vemmou E, Nikolakopoulos I, Xenogiannis I, Megaly M, Hall A, Wang Y, Chavez I, Garcia S, Burke MN, Brilakis ES. Recent advances in microcatheter technology for the treatment of chronic total occlusions. Expert Rev Med Devices. 2019;16(4):267-273.
16) Salim L. Community awareness on Coronary Heart Disease in northern areas of Pakistan (Process evaluation of healthy heart program). IJEHSR. 2013;1(1):43-46
17) Iosif Xenogiannis MD, Fotios Gkargkoulas MD, Karmpaliotis D, Khaldoon Alaswad MD, Jaffer FA, Yeh RW, Mitul Patel MD, Ehtisham Mahmud MD, Choi JW, M Nicholas Burke MD, Santiago Garcia MD. Temporal trends in chronic total occlusion percutaneous coronary interventions: insights from the PROGRESS-CTO Registry. J Invasive Cardiol. 2020;32(4).
18) Brilakis ES, Grantham JA, Rinfret S, Wyman RM, Burke MN, Karmpaliotis D, Lembo N, Pershad A, Kandzari DE, Buller CE, DeMartini T. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. JACC: Circ Cardiovasc Interv. 2012;5(4):367-379.