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A Practical Technique to Advance Stent Through Uncrossable Coronary Lesions: A Prospective Cohort Study

Geçilemeyen Koroner Lezyonlarda Stenti İlerletmenin Pratik Tekniği: Prospektif Kohort Çalışması

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This study was presented as an oral presentation 18th International Congress of Update in Cardiology and Cardiovascular Surgery, December 1-4, 2022, Antalya, Türkiye.

ABSTRACT Objective: Uncrossable coronary lesions are still challenging to treat. Several devices and techniques are introduced, including rotational atherectomy, or anchor balloon. However, these methods are expensive, not always available, and associated with lower procedural success and higher major adverse cardiac events. Our study describes a simple, effective method [patience technique (PT)] to advance a stent through uncrossable lesions that has not been described in the literature. **Material and Methods:** In a prospective study with 24 patients undergoing uncrossable lesion percutaneous coronary intervention with stent advancement failures, we identify PT and describe our experience with PT. The PT is the process of pushing the uncrossed same stent for a prolonged time under an optimum constant force to overcome the intraluminal friction. **Results:** Twenty-three (95.8%) patients had modified American College of Cardiology/ American Heart Association classification Type C, 22 (91.70%) diffuse [median length: 38 mm (quartiles 31.25-52.25)], 22 (91.70%) eccentric and 20 (83.30%) moderate-extensive calcified lesions. Respectively, 8 (27.59%) of 29 stenosis was in left anterior descending, and right coronary artery, 6 (20.69%) left circumflex coronary artery, 3 (10.35%) D1, 2 (6.90%) left main coronary artery-Cx, 1 (3.45%) LCxOM2 and saphenous vein graft-LCxOM2. The median stent advancement time was 134.00 seconds (quartiles 95.25-178.50). All procedures progressed after using the PT and finally resulted successfully without complications. **Conclusion:** The PT is feasible, and safe for facilitating the passage of stents through uncrossable lesions. Before advancing percutaneous cardiac intervention techniques, this method could be used advantageously in calcified, diffuse, and eccentric lesions.

Keywords: Coronary artery disease;
percutaneous coronary intervention

ÖZET Amaç: Geçilemeyen koroner lezyonların tedavisi hâlen zorlayıcıdır. Bunun için rotasyonel aterektomi veya çapa balonu gibi çeşitli cihaz ve teknikler tanımlanmıştır. Ancak bu ve benzeri cihaz ve yöntemler pahalıdır, her zaman mevcut değildir, başarı oranları düşüktür, komplikasyon oranları yüksektir ve belirli koşullar altında uygulanabilmektedirler. Çalışmamızda, karmaşık yöntemlerden önce zorlayıcı geçilemeyen lezyonlarda stenti ilerletmek için basit, etkili, maliyetsiz, güvenli ve literatürde daha önce tanımlanmamış bir tekniği [sabır tekniği (ST)] açıklıyoruz. **Gereç ve Yöntemler:** Geçilmesi zor koroner lezyonların girişimi esnasında stent ilerletme işlemi başarısızlığa uğrayan 24 hasta üzerinde ileriye dönük çalışma ile yeni bir teknik tanımladık. ST, koroner arter ile stent arasındaki lümen içi sürtünme kuvvetinin üstesinden gelmek için optimum sabit bir kuvvet altında, periyodu uzatarak, uzun süre stenti itme işlemidir. **Bulgular:** Hastaların 23'ünde (%95,8) modifiye Amerikan Kardiyoloji Koleji/Amerikan Kalp Birliği sınıflandırması Tip C, 22'sinde (%91,70) yaygın [medyan lezyon uzunluğu: 38 mm (çeyrekler 31,25-52,25)], 22'sinde (%91,70) eksantrik ve 20'sinde (%83,30) orta-ileri düzeyde kalsifiye lezyonlar mevcuttu. Yirmi dokuz lezyonun 8'inde (%27,59) sağ koroner arter ve sol ön inen koroner arter, 6'sında (%20,69) sol sirkumfleks koroner arter, 3'ünde (%10,35) D1, 2'sinde (%6,90) sol ana koroner arter-Cx, 1'inde (%3,45) LCxOM2 ve safen ven greft lezyonları izlendi. Ortanca stent ilerletme süresi 134,00 sn (çeyrekler 95,25-178,50) saptandı. ST kullandıktan sonra tüm koroner girişimsel işlemleri komplikasyonsuz olarak başarıyla sonuçlandırıldı. **Sonuç:** Stentin geçirilmesi zor, eksantrik, diffüz ve ileri kalsifik koroner lezyonlarda, stent geçişini kolaylaştırmak için karmaşık yöntemlere geçmeden önce başarılı ve güvenilir bir yöntem olan ST kullanılabilir.

Anahtar Kelimeler: Koroner arter hastalığı;
perkütan koroner girişim

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For the video/videos of the article:

Video 1: Illustration of the Patience Technique. The guiding catheter showed good coaxial engagement into the left main coronary artery. A stent was used to cover the left anterior descending lesion with the support of Patience Technique for 70.0 seconds.

For the video/videos of the article:

Video 2: The stent was unable to advance through the left anterior descending lesion. The use of the Patience Technique resulted in an improvement in the advancement of the same stent. All procedure progresses after the use of the technique. The stent smoothly crossed the left anterior descending lesion.

For the video/videos of the article:

Video 3: AL 1 guide catheter adjustment is required due to stent advancement failure. The operator tried deep seating guiding catheter maneuver to facilitate stent delivery, but its backup support was inadequate for stent advancement. The right lateral projections showed the passage of the same stent from the beginning to the end. 46.0 seconds of steady force provided stent delivery.

In recent years, percutaneous coronary intervention (PCI) techniques for complex coronary anatomy have evolved significantly.[1] Despite that, specific lesion characteristics such as tortuous vessels, diffuse stenosis, and calcified and angulated lesions continue to be challenging.[2-5] These typical lesions are associated with lower procedural success and higher major adverse cardiac events.[6] Various devices and techniques are introduced to facilitate the stent, including the mother-in-child technique, rotational atherectomy, and anchor balloon technique.[7,8] However, these devices and methods are expensive, associated with an increased risk of complications (acute vessel closure, perforation, and equipment loss or entrapment), not always available, and may not be feasible for specific situations. Therefore, a relatively simple, reproducible, and inexpensive technique is needed to overcome this problem. Here, we describe a simple technique, the patience technique (PT), to advance a stent through long, angulated, complex, and uncrossable coronary lesions based on the impulse-momentum relationship and static friction forces.

THE PT

Scientific Basis

The advancement of a stent into a narrow vessel with severe stenosis is sometimes a very challenging task. The difficulty varies, especially with the shape, length, and height. The intraluminal frictional forces between the blood vessel and the stent hinder the movement of the stent through the vessel. The intraluminal impedance (resistance) is one of the main flow characteristics that impede a stent's movement inside the vessel with stenosis. Intraluminal impedance is defined as the friction resistance per unit length or simply as the resistance to flow. It is affected by the shape, length, and height of the stenosis.[9] As the length and height of the stenosis increase, so does the intraluminal impedance. Impulse-momentum-change theorem (analogous to the work-energy theorem) can explain this phenomenon.[10] The impulse created by an object (in this case, the stent or balloon) always equals the change in its momentum. The force multiplied by the time is known as the impulse. Mass multiplied by the velocity change is known as the change in momentum. These are expressed as $J=F.\Delta t=m\ \Delta v=\Delta P=m\ \Delta x/\Delta t$. [F, force; J, impulse; Δt, changing in time; m, mass; v, the velocity defined as the rate of change of displacement of a stent (displacement over elapsed time); Δx, the displacement]. The change in momentum, ΔP, is the integral of the forces applied to the stent over time. The momentum may be expressed in a simpler form: ΔP=. (F, force; J, impulse; m, the object's mass; Δv, the object's velocity; ΔP, momentum; t1 and t2, times when the impulse begins and ends, respectively).[11] Since force and time are inversely proportional in this relationship, instead of increasing the applied contact force, increasing the duration of interaction results in the same or greater (depending on the magnitude of the application time) momentum change, and therefore the magnitude of displacement of the stent through the vessel (Figure 1a). As seen in Figure 1a, reducing the magnitude of the force exerted on the stent and increasing the application time results in a larger displacement of the stent into the vessel. The greater the time over which the interaction between the stent and stenotic region occurs, the fixed smaller the force is applied to the stent. Thus, to minimize the effect of the force on a vessel, the time must be increased to obtain a greater amount of momentum and thus displacement of the stent.

When the object is standstill, the thing experiences static friction force, which initially prevents the entity from sliding along a surface. However, as the application force continues eventually, the object begins to move instantly. This is because static friction reaches its maximum value before it allows an object to begin to move (statistical kinetic friction versus time graph) (Figure 1b).[12] After the object moves, it experiences kinetic friction force, lower than the maximum static friction. Therefore, after the static friction force, stent migration is facilitated.

From An İnterventionist Perspective

Before using advanced techniques, PT, working with the impulse-momentum relationship can advance a stent through complex lesions. To increase the impulse, either the force is increased or the time is extended. If pressure suddenly increases too much, the catheter backup is lost due to an action reaction, and the advancement of the stent becomes impossible.

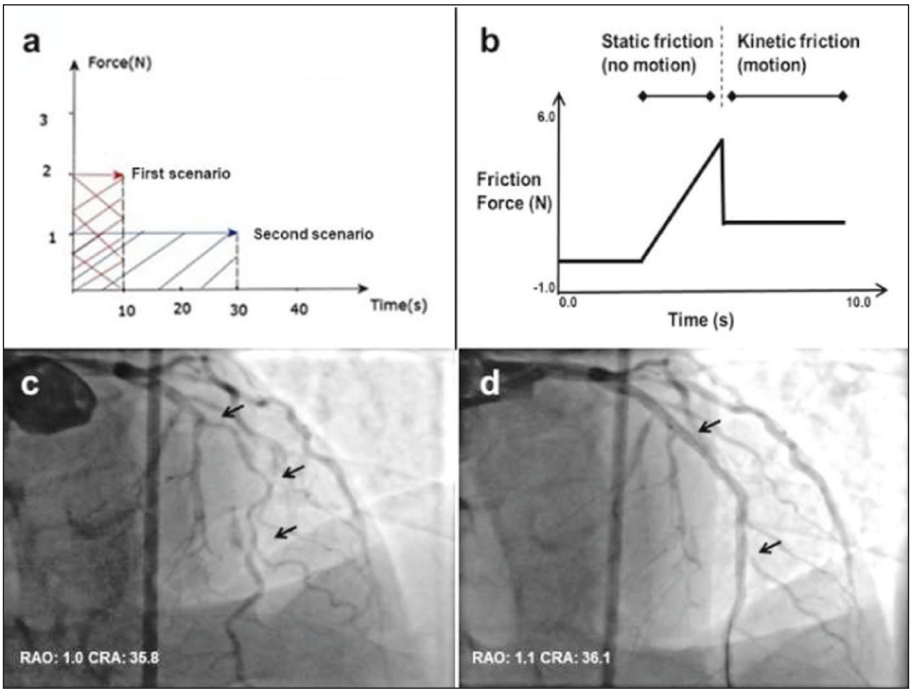

FIGURE 1: a) Force-time graph. In the first scenario, a considerable force is applied for a short period; in the second scenario, constant and sufficient pressure is used for an extended period. The magnitude of the impulse, the area under the graph, is more significant in the second scenario. (F: Force; s: Seconds). **b)** Static and kinetic friction force versus time graph. (F: Force; s: Seconds). **c)** Coronary angiogram RAO cranial projection; LAD: severe, long, 80% mid stenosis (arrows). d) Right cranial projection; LAD: At the end of the procedure, an optimal anatomical result and distal TIMI 3 flow were achieved.
RAO: Right anterior oblique; LAD: Left anterior descending.

Additionally, a sudden increase in external force can cause trauma to the vessel. The second option is to increase the impulse by extending the time under fixed power. An optimum fixed external pressure with an extended time and patient wait can lead to successful delivery.

In addition, stent delivery is effortless after the static friction force is over. As a result, we describe a simple technique to advance stents through uncrossable lesions based on the impulse-momentum relationship theorem and static-kinetic friction forces.

MATERIAL AND METHODS

The study was conducted on twenty-four subjects with uncrossable complex coronary lesions between February 2020 and May 2022. Patients were excluded if data was missing. We have evaluated 30 patients with the PT method. Six patients were excluded due to insufficient evidence of outcome events [stent advancement was performed improperly with intermittent pause, inadequate angiographic stent visualization, or stent advancement time (SAT) was not measured correctly]. A cohort of 24 patients in whom the PT procedure yielded successful outcomes was selected as the study sample. In the study, we expounded upon the intricacies of the PT procedure and elucidated our comprehensive experiences.

ANGIOGRAPHIC ANALYSIS

Cardiologists (at least a post-fellowship experience of 10 years) reviewed the diagnostic and procedural angiograms to determine suitability for study entry and to code for lesion-specific characteristics. Fifteen variables characterizing the severity and morphology of each coronary stenosis were assessed based on angiographic definitions used in recent scientific reports and modified The American College of Cardiology/American Heart Association (ACC/AHA) systematized coronary stenosis-specific classification.[5,13-16] The pa-

tient was excluded from the study if insufficient information was available to apply the defined criteria. All confirmers, reviewers, and abstracters were blinded to the study.

PERCUTANEOUS INTERVENTION AND FOLLOW-UP

The coronary angiogram was performed using a Siemens Artis Zee angiography machine (Erlangen, Germany). Coronary angiogram views decided on the therapeutic approach. The PCI procedure was executed in accordance with the recommended protocols.[17] Interventional cardiologists had advanced techniques for high-risk patients. Every patient was administered an initial dose of dual antiplatelet therapy [acetylsalicylic acid and a P2Y12 receptor inhibitor (clopidogrel, prasugrel, or ticagrelor)] and unfractionated heparin (weight adjusted) before or during PCI. After the procedure, ASA was continued indefinitely, and a P2Y12 receptor inhibitor was prescribed for at least 12 months. Regular follow-up was conducted at 30 days, three months, six months, 12 months, and every six months. The patient's clinical status, interventions, and outcome events were recorded at each polyclinic control.

Appropriate guide catheter selected for lesions with optimum size variations (6 to 7 French). To overcome complex lesions, we requested additional backup catheters. To engage in left main coronary artery (LMCA) lesions, JL 4.0, Ebu 3.5-3.75-4.0 (Launcher, Medtronic, MN, USA) or CLS 3.5-4.0 (Mach 1, Boston Scientific, MA; USA) coronary guiding catheters were selected. Judkins Right 4.0 or Amplatz Left 1.0 (Launcher, Medtronic, MN, USA) coronary guiding catheters were chosen to engage in the right coronary artery (RCA) lesions. Pre-dilation using a semi-compliant or non-compliant balloon was performed for pre-lesion modification-post-dilatation performed by a non-compliant balloon. All lesions are treated by drug-eluting stent (DES) systems [BioMime aura® sirolimus-eluting (Meril, Gujarat, India), Cre8® amphilimus-eluting (Alvimedica, Saluggia, Italy), Evermime50® everolimus-eluting (Meril, Gujarat, India), Resolute Integrity® zotarolimus-eluting (Medtronic, Medtronic, MN, USA), or Xience® Pro^{A} everolimus-eluting (Abbott Vascular, CA, USA)], or bare-metal stents [Commander® (Alvimedica, IDF, France), EphesosII® (Alvimedica, IDF, France), or Nexgen® (Meril, Gurajat, India)]. The stents' dimensional geometry had an axial diameter of 2.25 to 4.0 mm and a length of 15 to 48 mm. After the stents could not be advanced with conventional methods, the same stents crossed the lesions with the PT.

In PT, the operator applies the feasible, constant, and maximal force upon the uncrossed stent's catheter, adhering to the limits of the system's capacity and waiting an extended time. The application of force, maintained consistently for up to approximately 15 seconds, results in gradual stent migration. When the stent fails to advance or exhibit recoil, applying stent catheter force is maintained consistently for up to approximately 15 seconds. Even on the brink of system failure, the steady pressure on the stent catheter must be sustained. As feasible, constant, and maximal pressure continues steadily, ultimately, the stent slides slightly and crosses the lesion, as exemplified in Video 1, Video 2, and Video 3. Throughout the procedure, diligent vigilance was exercised over the backup catheter and stent to detect potential complications such as system loss or stent dislodgement. The pivotal aspect of this technique lies in the endurance of the prolonged force application with unwavering constancy. Because, despite the thrust applied to the stent catheter with the force allowed by the system limits, the response of the stents progresses at a considerably slower rate when juxtaposed with stent advancement in traditional coronary interventions. Our study has elucidated the significant effectiveness of PT in facilitating the passage of longer stents.

Consequently, PT may be preferred for interventions involving extended stent configurations. If the method proves unsuccessful, it can be reiterated. Nevertheless, in the event of several unsuccessful attempts, it would be prudent to contemplate a transition to alternative methods.

Based on the patient's presentation, we performed primary PCI or elective stenting for coronary artery diseases.

The SAT was taken as the time elapsed between the beginning and end of the stent push forward. It

was calculated in seconds. If two vessels needed stents or a coronary required more than one stent, the advancement time was added for each stent, and the sum of time was defined as the SAT of the lesion.

The radiation exposure is higher since the PT's SAT is much longer than conventional PCI methods. Therefore, the low-dose pulsed progressive fluoroscopy coronary imaging technique was utilized to reduce exposure to X-ray doses. This approach consists of fluoroscopic coronary imaging, taking only a few seconds at a time, long enough to view the current stent position (approximately every 1-5 seconds).[18] High-dose fluoroscopy or cine-mode imaging is not used if not necessary. Also, consider the other X-ray dose reduction techniques.

Research ethics standards compliance:

This study was performed in line with the principles of the Declaration of Helsinki. The approval was granted by the Ethics Committee of the Şişli Hamidiye Etfal Hospital (date: September 06, 2022, no: 2130). Informed consent was obtained from each participant.

STATISTICAL ANALYSIS

SPSS (17.0, Chicago, IL, USA) was used for statistical analysis. The Shapiro-Wilk test determined normally distributed data. The ANOVA test (one-way analysis of variance) determined the homogeneity of the data. Medians with 25th and 75th percentiles reported continuous variables, and percentages expressed categorical variables.

RESULTS

In this study, we experienced and presented successful PCI of 24 patients with uncrossable coronary lesions treated by the PT that have not been described before in the literature.

The median age was 63.00 years (quartiles 58.25-69.25). The electrocardiogram exhibited normal sinus rhythm without early beats or rhythm disturbances in all cases. Left ventricular function was generally well preserved (median ejection fraction, 52.5%; quartiles, 40.00-60.00).

Of importance, 23 (95.8%) of the patients had modified ACC/AHA classification Type C, and 22 (91.70%) patients had diffused (>20 mm) lesions. The lesions had long stenosis with a median length of 38 mm (quartiles 31.25-52.25). Also, 22 (91.70%) patients had eccentric lesions. Additionally, moderate-extensive calcification was observed in 20 (83.30%) patients.

Six (25.00%) patients had bifurcation lesions. Three (12.50%) patients had instent lesions. Only one (4.20%) patient had an extremely (>90 degrees) angulated segment in the lesion and extensive tortuosity. And, one (4.20%) patient had a chronic total occlusion lesion.

According to angiography findings, the left anterior descending (LAD) branch artery and RCA were the most commonly demonstrated culprit lesions [respectively, 8 of 29 total lesions (27.59%)]. Six (20.69%) lesions had left circumflex coronary artery (LCx), 3 (10.35%) the first diagonal branch artery (D1), 2 (6.90%) LMCA-Cx, one (3.45%) left circumflex coronary artery obtuse marginal branch artery (LCxOM2), and one (3.45%) saphenous vein graft-LCxOM2 stenosis.

In addition, two patients were needed for other complex stenting techniques. The eighth case presented with stable angina pectoris and 70% proximal LAD stenosis at the bifurcation point of the first sizeable D1, and D1 had long 80-90% proximal to mid stenosis (Table 1, Table 2, and Table 3). Stents were deployed across LAD and D1 stenosis with the double kissing crush technique. The thirteenth case had two vessel diseases with occluded RCA after the right ventricle branch. The chronic total occlusion procedure was successfully ended with a 3.0x40 mm DES implantation (Table 1, Table 2, and Table 3).

The median SAT was 134.00 seconds (quartiles 95.25-178.50). Finally, all procedures resulted successfully with the utilization of the PT.

We presented angiographic views of three patients in whom we used the PT to treat lesions in LAD (2 cases) and RCA.

The first case was presented with Canadian Cardiovascular Society (CCS) Class II angina (Table 1, Table 2, and Table 3). The results of the physical examination were unremarkable. A coronary angiogram

TABLE 1: Baseline demographic and clinical characteristics of patients.

Case	Gender	Age (years)	Current smoker	HT	DM	HL	Previous PCI	Previous CABG	CRD	HR (bpm)	SBP (mmHg)	LVEF (%)
1	M	62	-	-	-	-	-	-	-	65	120	60
2	F	55	+	+	+	+	+	-	-	88	142	50
3	M	61	+	+	+	-	+	-	+	77	136	40
4	M	65	-	-	+	-	+	+	-	68	120	40
5	M	71	-	+	+	-	-	+	-	82	170	60
6	M	60	-	-	-	-	-	+	-	74	130	N/A
7	F	67	-	+	+	+	+	+	-	64	130	60
8	F	50	-	+	+	+	+	+	-	68	125	60
9	M	59	+	-	-	-	+	-	-	88	126	50
10	F	84	-	+	+	+	+	+	-	92	130	40
11	M	72	-	+	-	-	+	-	-	98	140	27
12	F	67	-	+	+	-	-	-	-	88	135	60
13	M	62	-	+	-	-	-	-	-	74	130	50
14	F	82	-	+	-	-	-	+	-	68	120	60
15	M	63	-	+	+	-	-	-	-	72	132	N/A
16	M	76	-	+	+	-	+	-	-	74	136	60
17	M	64	-	-	+	-	-	-	-	88	110	27
18	M	50	-	-	-	-	-	-	-	98	135	60
19	M	55	-	+	+	+	-	-	-	62	130	60
20	M	64	-	+	+	-	-	-	-	72	130	40
21	M	63	-	+	-	-	-	+	-	72	130	55
22	M	70	+	-	-	-	-	-	-	65	125	47
23	F	56	-	+	+	-	+	+	-	75	120	60
24	M	58	-	+	+	-	-	+	-	92	132	22

HT: Hypertension; DM: Diabetes mellitus; HL: Hyperlipidemia; PCI: Percutaneous coronary intervention; CABG: Coronary artery bypass graft; CRD: Chronic kidney disease-creatinine >2.0 mg/dL, hemodialysis or renal transplantation; HR: Heart rate; bpm: Beats per minute; SBP: Systolic blood pressure; LVEF: Left ventricle ejection fraction; M: Male; F: Female.

revealed a complex 80-90% LAD stenosis proximal to the mid-portion (Figure 1c). The decision was to perform PCI on the LAD. The LAD lesion body was predilatated with a 2.0x15 mm semi-compliant balloon. Stent push-forward attempts failed, so we proceeded with PT with successful advancement of the stents followed by straightforward delivery. The SAT was 70.00 seconds (Video 1). The procedure ended with the implantation of two sirolimus-eluting overlapping stents (Figure 1d).

The second case was a 55-year-old female admitted with unstable angina pectoris (Table 1, Table 2, and Table 3). The patient had coronary artery disease (stent implantation history in the LCxOM after an inferior myocardial infarction on 11/June/2018). Electrocardiography showed normal sinus rhythm and poor R wave from V1 to V3 leads. Echocardiography showed mild hypokinesis of the basal segment of the inferior wall. Coronary angiography revealed subocclusive diffuse, calcified stenosis in the proximal, distal segment of the LAD and severe stenosis (80%) in the proximal part of LCxOM2 (Figure 2a). The PCI to LAD lesion was performed in the first stage, and PCI to LCxOM2 was planned in a staged procedure for complete revascularization. An Ebu 3.75 coronary guiding catheter was used to engage in LMCA. After sequential predilatation of the LAD lesion body with semi-compliant balloons of 1.2x15 mm Mini trek® (Abbott Vascular, CA, USA) and 2.0x12 mm Invader® (Alvimedica, IDF, France), the case was complicated by diffuse, calcified anatomy, which hindered the cross of the stent through the lesion. Therefore, the same stent was forced by PT, after which the advancement improved (Video 2).

TABLE 2: Clinical and angiographic characteristics.

Case	Clinical presentation	Peak Troponin T (ng/L)	SAT (seconds)	IS lesion	CTO	Calcification (≥ moderate)	Extensive tortuosity	ACC/AHA modified lesion classification
1	SAP	4.90	70.0	-	-	+	-	C
2	USAP	15.00	70.7	-	-	-	-	C
3	SAP	N/A	46.0	+	-	+	-	C
4	USAP	8.61	192.0	-	-	+	-	C
5	USAP	13.98	174.0	-	-	+	+	C
6	SAP	N/A	114.0	-	-	+	-	C
7	NSTEMI	368.20	95.0	-	-	-	-	C
8	SAP	N/A	168.0	-	-	+	-	C
9	SAP	N/A	96.0	-	-	+	-	C
10	NSTEMI	507.60	667.80	-	-	+	-	C
11	USAP	32.36	247.8	-	-	+	-	C
12	NSTEMI	174.50	62.0	-		+	-	C
13	NSTEMI	299.30	102.0	-	-	+	-	C
14	USAP	10.19	180.0	-	-	+	-	C
15	SAP	N/A	156.0	-	-	+	-	C
16	NSTEMI	280.00	186.0	-	-	+	-	B2
17	USAP	11.62	258.0	-	-	+	-	C
18	STEMI	1550.00	150.0	-	-	+	-	C
19	NSTEMI	68.62	96.0	-	-	-	-	C
20	NSTEMI	22.50	40.0	-	+	+	-	C
21	USAP	23.46	160.0	+	-	-	-	C
22	STEMI	987.00	130.0	-	-	+	-	C
23	USAP	13.71	108.0	+	-	+	-	C
24	SAP	4.90	138.0	-	-	+	-	C

SAT: Stent advancement time; IS: In-stent; CTO: Chronic total occlusion; ACC/AHA: The American College of Cardiology/American Heart Association; SAP: Stable angina pectoris; USAP: Unstable angina pectoris; NSTEMI: Non-ST elevation myocardial infarction; STEMI: ST-segment elevation myocardial infarction.

The LAD lesion is stented with a 2.5x38 mm Xience at 12 atm. Finally, the stent was post-dilated with a 2.75x12 mm Simpass® (Simteks Medical, IST, Türkiye) non-compliant balloon at 17 atm (final diameter: 2.81 mm). After adequate post-dilation, the final angiogram showed satisfactory results with sufficient stent expansion, and distal TIMI 3 flow was achieved. (Figure 2b).

The third case was presented with CCS Class II angina. The patient's medical history included stent implantation history in the RCA in 2007 and the LAD on 22/April/2022 (Table 1, Table 2, and Table 3). Laboratory findings were normal, and vital signs were stable. Electrocardiogram exhibited sinus rhythm with left bundle branch block. On echocardiography, the left ventricular wall motion showed inferior hypokinesis. We decided to perform coronary angiography to determine the underlying cause, even though he had chronic renal failure (glomerular filtration rate: 43.03 mL/min). Normal saline was infused at 40 ml/hour for 24 hours before and after the PCI procedure. Coronary angiograms revealed 70% calcified stenosis before and after the mid-portion RCA stent (Figure 2b). A 6 Fr Amplatz Left 1.0 guiding catheter was used to cannulate RCA (Figure 2c). The lesion is dilatated with 2.0x20 mm semi-compliant Invader® (Alvimedica, IDF, France) and 2.5x18 mm non-compliant Apollo® (Brosmed, Dongguan, China). It was difficult to cross the coronary lesion. After PT is used to advance the stent, the procedure results in a successful delivery (Video 3). We covered the mid-portion RCA lesion with a 2.5x37

TABLE 3: Angiographic characteristics.

Case	Lesion length (mm)	Lesion diameter (mm)	Eccentricity	Bifurcation lesion	Angulation (>90)	Balloon diameter used for pre-dilation (mm)	Lesion locations and stent diameter (mm)	NC balloon diameter used for post-dilation (mm)
1	50	2.4	C	-	-	2.0x15	LAD: 2.25x37, 2.5x16 Biomime	2.5x15
2	35	2.5	E	-	-	1.2x15, 2.0x12	LAD: 2.5x38 Xience	2.75x12
3	53	2.75	E	-	-	2.0x20, 2.5x18	RCA: 2.5x37 Evermine, 2.75x19 Biomime	2.75x28
4	38	4.0	E	-	-	3.0x15	RCA: 3.0x38 Resolute	4.0x15
5	25	4.0	E	-	-	2.5x12	LMCA-LCx: 3.0x28 Xience	4.0x15
6	45	3.0	E	-	+	D1: 2.0x15, LCxOM: 2.0x15	D1: 2.75x33 Xience, LCxOM: 2.75x15 Xience	D1: 3.0x9, LCxOM: 3.0x9
7	13	3.2	C	-	-	1.5x12, 2.0x12	SVG-LCxOM2: 3.0x15 EphesosII	3.0x9
8	110	2.5	E	-	-	1.5x12, 2.0x12	RCA: 2.25x18, 2.25x28, 2.5x18, 2.5x38, 2.75x15 Xience	2.5x9, 2.75x9
9	73	3.0	E	+	-	1.25x10, 1.5x12,	LAD: 3.0x29 Biomime, D1: 2.5x48 Biomime	LAD: 3.0x12, 3.5x9, D1: 2.5x12
10	36	3.25	E	-	-	2.5x12	RCA: 3.0x38 Xience	3.5x15
11	50	2.75	E	-	-	1.5x15, 1.5x20, 2.0x15, 2.0x20	LCx: 2.5x28 Xience, 2.5x28 Xience	2.75x9
12	46	3.0	E	+	-	2.0x12	LAD: 2.75x48 Biomime	3.0x15
13	38	3.5	E	-	-	2.5x15, 3.0x9	RCA: 3.0x40 Biomime	3.5x15
14	68	2.75	E	-	-	Cx: 2.5x15, RCA: 2.0x15	LCx: 2.75x18 Commander, RCA: 2.75x32, 4.0x18 EphesosII	
15	88	3.5	E	-	-	PDA: 2.5x15, 2.5x20, RCA:	PDA: 2.5x31 Cre8, RCA: 3.0x48 Biomime, 3.5x9 Ephesos II	PDA: 2.5x15, RCA: 3.5x9, 3.5x15
16	17	3.0	E	-	-	2.0x15	LAD: 2.75x18 Xience	
17	29	3.0	E	+	-	2.5x15	LAD: 3.0x32 Biomime	3.5x15, 3.5x9
18	36	3.0	E	-	-	2.0x15	LCx: 3.0x38 Xience	3.0x9
19	38	3.0	E	+	-	2.0x12	LCx: 2.5x40 Biomime	3.0x9
20	36	3.5	E	-	-	2.0x12, 2.5x12	LAD: 2.75x38 Xience	3.5x15
21	30	2.5	E	+	-	2.0x12, 2.0x15	LCxOM2: 2.5x33 Xience	3.0x12
22	28	2.5	E	-	-	2.0x12	LAD: 2.75x16 Biomime, D1: 2.25x16 Nexgen	D1: 2.5x9, LAD: 3.25x15
23	62	3.0	E	+	-	LCx: 2.5x9, 3.0x12	LCx: 2.5x24 Biomime, LMCA-LCx: 3.0x28 Xience	LMCA: 4.5x9, Cx: 3.0x9
24	88	3.0	E	-	-	LCxOM1: 2.0x15, RCA: 2.0x15	LCxOM1: 2.5x48 Xience, RCA: 3.0x48 Xience	CxOM1:3.0x15, RCA: 3.5x15

C: Concentric lesion; D: Diagonal branch artery; E: Eccentric lesion; LAD: Left anterior descending branch artery; LCx: Left circumflex coronary artery; LCxOM: Left circumflex coronary artery obtuse marginal branch; LMCA: Left main coronary artery; NC: Non-compliant; PDA: Posterior descending artery; RCA: Right coronary artery; SVG: Saphenous vein graft.

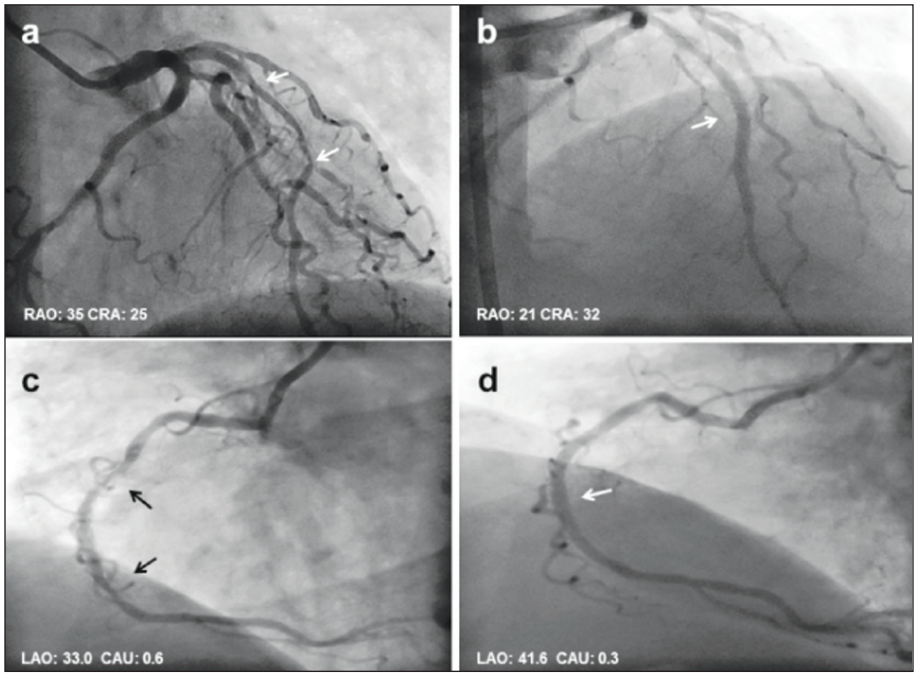

FIGURE 2: a) Coronary angiography showed LAD in RAO cranial view with severe, long proximal stenosis and sub-occlusive mid-section stenosis (arrows). b) The final post-procedure angiogram showed adequate stent with TIMI-3 distal flow. Representative coronary angiograms (left anterior oblique) of the third case: before c) Severe stenosis of the mid-segment of the right coronary artery (arrows), and after d) The patience technique supported percutaneous cardiac intervention.
LAD: Left anterior descending; RAO: Right anterior oblique.

Evemine50 DES stent and the proximal lesion with a 2.75x19 Biomime aura DES stent. Eventually, the stents were post-dilatated by a 2.75x28 NC balloon (Meril, Gujarat, India) to 14 atm. Finally, the TIMI-3 flow resumed (Figure 2d).

DISCUSSION

Long lesions comprise 20% of all PCI procedures, and long stents are continuously needed.[19] Furthermore, in most cases, these types of long severe lesions are referred to as bypass surgery due to the challenges and complications involved in the PCI of complex lesions. In time, complex lesion techniques will be required more frequently. The fact that majority our study population consisted of long lesions resisted to stent passage, and PT was effective in crossing stents in these lesions. PCI procedures with PT were performed safely without the risk of complications from complex methods such as rotational atherectomy, microcatheter support, or deep catheter intubation.

The delivery of stents to complex coronary lesions involves technical difficulties due to various anatomies, the lesions' complexities, and the vessel's morphology. Coronary interventions are influenced by the characteristics of the stent, the selection of the technique, and the procedural steps.[20] Each complex coronary artery lesion has a unique set of features. Diabetes mellitus and advanced age are independent predictors of complex coronary lesions.[21] Coronary calcification is a nonspecific term, and the amount of calcification can vary widely.[22] Gender and age are significant risk factors for calcification.[23] Our model may be too simple to explain the actual mechanism because there are many effects on stent advancement than we used in our theory. Coronary lesion calcification remains associated with adverse outcomes even with newer-generation DES and modern devices.[24-27] On the other hand, as found in our study, the PT technique was especially successful in calcific lesions.

In this study, according to a successfully treated study population with eccentric, diffuse, calcified but

without extensive angulation, and highly tortuosity lesions, we evaluated especially support for crossability and pushability with the PT.

Our study unveiled a noteworthy efficacy of PT in diffuse, eccentric, extensively calcified Type C stenosis. This technique may favor interventions involving long, eccentric, severely calcified Type C uncrossable coronary lesions. In addition, our study reveals a reference for identifying the difficulty of crossing the complex lesions in PCI.

Although we used the low-dose pulsed progressive fluoroscopy coronary imaging technique, the longer procedure times have raised concerns about the increased radiation exposure of patients, interventional cardiologists, and catheterization laboratory staff during procedures. Other complex lesion techniques (such as intravascular ultrasound catheters, rotational atherectomy systems, or shock wave lithotripsy) are also time-consuming concerning radiation exposure.

LIMITATIONS OF STUDY

Our study is only a single-center study and has the intrinsic limitations of such a design.

Since we did not have a control group, we could not give the PT success rate. The findings require randomized controlled multicenter trials, which permit a homogeneous and adequately defined study cohort.

Different types of stents have different lesion-crossing abilities.[28] Accordingly, standardization of the characteristics of the stents, in our study, we were unable to restrict the types of stents and used different types and sizes of stents. Thus, stent homogeneity could not be achieved.

CONCLUSION

PT is a feasible, thriving, safe method for facilitating the passage of stents through uncrossable complex coronary lesions and has been mentioned for the first time in literature. As a result of this, this method can be used for calcified, long, eccentric, Type C coronary lesions before ascending to advanced PCI techniques.

In conclusion, with this technique, we propose that the stent passes through uncrossable coronary lesions more easily by prolonging the time under fixed force. In other words, the operator should increase the duration of power and not force it to overcome the intraluminal friction between the vessel and the stent.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Mutlu Çağan Sümerkan;* ***Design:*** *Ömer Alyan;* ***Control/Supervision:*** *Hilal Acar Demir;* ***Data Collection and/or Processing:*** *Kudret Keskin;* ***Analysis and/or Interpretation:*** *Hilal Acar Demir;* ***Literature Review:*** *Mutlu Çağan Sümerkan;* ***Writing the Article:*** *Kudret Keskin;* ***Critical Review:*** *Ömer Alyan;* ***Materials:*** *Mutlu Çağan Sümerkan.*

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