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Research

# The Relationship Between Chronic Total Occlusion Morphology and Procedure Success in Percutaneous Endovascular Treatment of Left Subclavian Artery

## Sol Subklavyen Arterin Perkütan Endovasküler Tedavisinde Kronik Total Oklüzyon Morfolojisi ile İşlem Başarısı Arasındaki İlişki

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## ABSTRACT

**Objective:** In this study, we aimed to investigate results of percutaneous endovascular interventions (PEI) in symptomatic proximal left subclavian artery (LSA) chronic total occlusions (CTOs) and its relationship with angiographic and morphological typing.

**Methods:** This study enrolled retrospectively evaluated 60 patients (41 males 68.3%, mean age 61.2±7.727 years) treated by PEI symptomatic proximal LSA CTOs between April 2010 and December 2021. Technical success was defined as residual stenosis of <30%, the absence of major complications (any access side complications, flow-limiting dissection, rupture). CTOs were classified mainly into 4 types according to their angiographic appearance [rat-tail n=12 (20%), plain n=18 (30%), hilly n=18 (30%) and peak n=10 (16.7%) types, also n=2 (3,3%) in-stent CTOs].

**Results:** The study cohort was divided into 2 groups as technically successful (n=49) and technical unsuccessful (n=11). Symptoms were due to 15 (25%) vertebrobasilar insufficiency 17 (28.3%) coronary ischemia had a left internal mammary artery by-pass graft and 28 (46.7%) arm claudications. Plain type CTO of LSA (81.8 vs. 18.4%, p<0.001), dual approach (femoral and radial) (100 vs. 65.3%, p=0.017) and lesion crossing-retrograde (90.9 vs. 44.9%, p=0.022) were notably higher in the technical successful group than in the technical unsuccessful group. In the logistic regression analysis, the presence of plain-type CTO lesions (odds ratio: 14.85, 95% confidence interval: 2.498-88.334, p=0.003) was found to be the independent predictor of technical failure.

**Conclusion:** PEI is a safe and effective treatment for LSA CTOs; the antegrade approach is the preferred initial method, although this choice may necessitate a retrograde approach depending on certain anatomical and clinical characteristics.

**Keywords:** Chronic proximal left subclavian artery, chronic total occlusions, endovascular therapy

## ÖZ

**Amaç:** Bu çalışmada, semptomatik proksimal sol subklavyen arter (LSA) kronik total oklüzyonlarında (KTO) perkütan endovasküler girişimlerin (PEG) sonuçlarını ve bunların anjiyografik ve morfolojik sınıflama ile ilişkisini araştırmayı amaçladık.

**Gereç ve Yöntem:** Bu çalışmaya, Nisan 2010 ile Aralık 2021 tarihleri arasında semptomatik proksimal LSA KTO'su nedeniyle PEI ile tedavi edilen ve geriye dönük olarak değerlendirilen 60 hasta (41 erkek %68,3, ortalama yaş 61,2±7,727 yıl) dahil edildi. Teknik başarı; %30'un altında rezidüel stenoz varlığı ve majör komplikasyonların (herhangi bir giriş yeri komplikasyonu, akımı kısıtlayan diseksiyon veya rüptür) yokluğu olarak tanımlandı. KTO'lar, anjiyografik görünümlerine göre temelde 4 tipe ayrıldı: *rat-tail* (n=12; %20), *plain* (n=18; %30), *hilly* (n=18; %30), *peak* (n=10; %16,7). Ayrıca 2 olguda (%3,3) stent içi total oklüzyon saptandı.

**Bulgular:** Çalışma grubu, teknik başarı olan (n=49) ve teknik başarı olmayan (n=11) olmak üzere iki gruba ayrıldı. Semptomlar; 15 hastada (%25) vertebrobaziler yetmezlik, 17 hastada (%28,3) koroner iskemi (sol iç meme atardamarı bypass grefti mevcut) ve 28 hastada (%46,7) kol kladikasyosu kaynaklıydı. Teknik başarı olmayan grupta LSA'da *plain* tip KTO (%81,8'e karşı %18,4; p<0,001), ikili yaklaşım (femoral ve radial) (%100'e karşı %65,3; p=0,017) ve retrograd lezyon geçişi (%90,9'a karşı %44,9; p=0,022) oranları, teknik başarı olan gruba kıyasla belirgin şekilde daha yüksekti.

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## ÖZ

Lojistik regresyon analizinde, *plain* tip KTO lezyonlarının varlığı (olasılık oranı: 14,85; %95 güven aralığı: 2,498-88,334; p=0,003], teknik başarısızlığın bağımsız bir öngördürücüsü olarak saptandı.

**Sonuç:** PEI, LSA KTO'ları için güvenli ve etkili bir tedavi yöntemidir; antegrad yaklaşım tercih edilen ilk yöntem olmakla birlikte, belirli anatomik ve klinik özelliklere bağlı olarak bu tercih retrograd bir yaklaşımı gerektirebilir.


**Anahtar Kelimeler:** Proksimal sol subklavyen arter, kronik total oklüzyonlar, endovasküler tedavi

## INTRODUCTION

Some of symptomatic extracranial cerebrovascular diseases consist of chronic total occlusions (CTOs) of the subclavian artery (SA) (1). SA CTOs are usually atherosclerotic. Inflammatory arteritis and other rare causes are less common. The prevalence of SA stenosis in the general population is estimated at approximately 2% (2). They occur 1.5 to 2 times more frequently in men and are more common in the population over the age of 50 (3). The most affected part of left SA (LSA) by atherosclerosis is proximal first 2 centimeter from aorta origin (Figure 1) (4). CTOs were classified into 4 types according to their angiographic appearance (rat-tail, plain, hilly and peak type) (Figure 2) (5). CTO of the proximal LSA occurred four times more frequently than right side even when imnominate artery include two main branch originated (6). LSA stenosis or CTOs require treatment when symptomatic (7). The main three reasons for endovascular treatmant are vertigo caused by subclavian steel syndrome, arm claudication and ischemia in coronary vascular system due to patent left internal mammarian artey-left anterior descending artery (LIMA-LAD) bypass greft (8). CTO of the proximal LSA occurred four times more frequently than right side even when imnominate artery include two main branch originated (6). Since first successful percutoneus transluminal angioplasty (PTA) was done by Bachman and Kim (9) in 1980 PTA and stenting is becoming first treatment strategy in left subclavian atherosclerotic disease. Stenting after PTA is superior to PTA alone strategy for long term patency rate (10). However the success of percutaneous therapy is hıgh in high-grade stenozis of the LSA, the percutaneous success rate is lower in CTOs (11) . Standart open surgical carotid-subclavian bypass (CSB) surgery operation is required when PTA is failed . They are few report and case series including endovasculer treatment (ET) of left subclavian CTO lesions (12-14). With advances in stent technology and increased usage rates, short- and long-term success rates have increased, and it has become the first-choice treatment compared with bypass surgery (15). Here we aim to report our ET of isolated proximal left subclavian CTOs results and its relationship with angiographic and morphological features.

## METHODS

Our retrospective cohort study included percutaneous interventions for symptomatic, isolated CTO of the left proximal SA in 60 patients between April 2010 and December 2021. Approval was obtained from the

**Figure 1.** Computed tomography angiography image of left subclavian artery chronic total occlusion

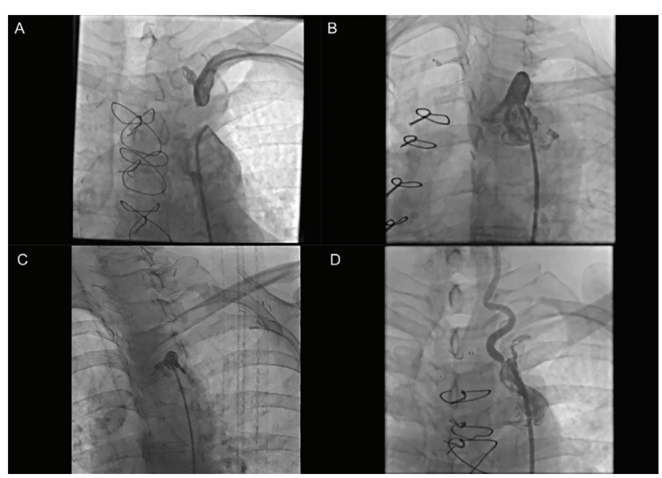


**Figure 2.** Conventional angiography depicts 4 different morphological types of chronic total occlusion of the proximal left subclavian artery. A: Plain type, B: Hilly type, C: Peak type, D: Rat-tail type

**Table 1.** Baseline clinical and demographical variables of the study population

| Parameters | All (n=60) | Successful (n=49) | Unsuccessful (n=11) | p-value |
|---|---|---|---|---|
| Age (years) | 61.2±7.727 | 60.6±7.1 | 64.0±9.8 | 0.191 |
| Gender (man), n (%) | 41 (68.3) | 34 (69.4) | 7 (63.6) | 0.484 |
| Weight (kg) | 79 (70-84) | 75 (70-84) | 80 (76-85) | 0.237 |
| Height (cm) | 168 (163-173) | 169 (163-173) | 165 (159-173) | 0.315 |
| BMI (kg/m$^2$) | 27.2±3.71 | 26.8±3.75 | 29.0±3.01 | 0.074 |
| Smoking n(%) | 32 (53.3) | 26 (53.1) | 6 (54.4) | 0.929 |
| HTN n (%) | 50 (83.3) | 40 (81.6) | 10 (90.9) | 0.409 |
| DM n (%) | 23 (38.3) | 21 (42.9) | 2 (18.2) | 0.118 |
| HPL n (%) | 55 (91.7) | 44 (89.8) | 11 (100) | 0.349 |
| CAD n (%) | 35 (58.3) | 28 (57.1) | 7 (63.6) | 0.483 |
| CABG n (%) | 21 (35) | 15 (30.6) | 6 (54.5) | 0.125 |
| CKD n (%) | 10 (16.7) | 8 (16.3) | 2 (18.2) | 0.591 |
| COPD n (%) | 10 (16.7) | 9 (18.4) | 1 (9.1) | 0.409 |
| CVD n (%) | 2 (3.3) | 2 (4.1) | 0 | 0.664 |
| CHF n (%) | 9 (15) | 6 (12.2) | 3 (27.3) | 0.206 |
| AF n (%) | 9 (15) | 7 (14.3) | 2 (18.2) | 0.525 |
| HB (g/dL) | 13.8 (12.2-14.6) | 13.9 (12.9-14.8) | 11.5 (10.3-13.8) | 0.015 |
| HTC (%) | 41.1 (36.1-43.5) | 41.2 (39.1-43.7) | 35.6 (32.4-42.8) | 0.045 |
| PLT (10$^9$/L) | 256 (221-302) | 255 (221-299) | 266 (223-329) | 0.586 |
| WBC (10$^9$/L) | 9 (7.4-10.7) | 9.1 (7.4-10.8) | 8.3 (7.5-10.5) | 0.871 |
| MPV (fL) | 9.8 (9.1-10.8) | 9.9 (9.2-10.8) | 9.6 (9.1-11.1) | 0.939 |
| Neutrophil (10$^9$/L) | 5.5 (4.5-7) | 5.4 (4.51-7.04) | 5.87 (4.72-8.5) | 0.325 |
| Lymphocyte (10$^9$/L) | 2.2 (1.8-2.7) | 2.25 (1.87-2.79) | 2.15 (1.46-2.28) | 0.172 |
| ALT (U/L) | 15 (11.2-20.7) | 16 (13-22) | 14 (10-16) | 0.083 |
| AST (U/L) | 17 (14-21.7) | 17 (14-22) | 15 (12-21) | 0.416 |
| Creatinin (mg/dL) | 1.0±0.75 | 1.05±0.81 | 1.08±0.44 | 0.906 |
| Bun (mg/dL) | 16 (13-23) | 16 (14-23) | 19 (12-27) | 0.863 |
| Sodium (mmol/L) | 138 (136-140) | 138 (136-140) | 136 (136-139) | 0.107 |
| Potasium (mmol/L) | 4.4 (4.1-4.7) | 4.4 (4.2-4.8) | 4.3 (4.0-4.6) | 0.189 |
| Uric acid (mg/dL) | 5.4 (4.8-6.3) | 5.4 (4.85-6.25) | 5.85 (5.1-6.3) | 0.734 |
| Albumin (mg/dL) | 4.4 (4.1-4.6) | 4.4 (4.25-4.6) | 4.25 (4-4.5) | 0.088 |
| Calcium (mg/dL) | 9.3 (8.9-9.6) | 9.36 (9.09-9.62) | 9.2 (8.8-9.3) | 0.106 |
| Glucose (mg/dL) | 106 (91-131) | 103 (91-131) | 108 (92-125) | 0.848 |
| TRG (mg/dL) | 191.8±134.1 | 202.4±143.9 | 139.8±42.6 | 0.181 |
| Total cholesterol (mg/dL) | 194.4±49.5 | 196±50.8 | ±186.8 | 0.442 |
| HDL (mg/dL) | 40 (35-46) | 40 (36-46) | 43 (35-46) | 0.887 |
| LDL (mg/dL) | 113.1±42.3 | 112.57±43.9 | 115.5±36.3 | 0.836 |
| CRP (mg/L) | 5 (3.2-8) | 5 (3.1-8) | 8.6 (4.1-11) | 0.139 |

BMI: Body mass index, CRP: C-reactive protein, Hb: Hemoglobin, Htc: Hematocrit, WBC: White blood cell, PLT: Platelets, MPV: Mean platelet volume, Neut: Neutrofil, Lym: Lymphocytes, ALT: Alanine aminotransferase, AST: Aspartate aminotransferase, BUN: Blood Urea Nitrogen, TRG: Triglycerides, HDL: High density lipoprotein, LDL: Low density lipoprotein, DM: Diabetes mellitus, HTN: Hypertension, CKD: Chronic renal failure, CAD: Coronary artery disease, CHF: Chronic heart failure, COAD: Chronic obstructive airway disease, AF: Atrial Fibrilation, CVD: Cerebrovascular Disease, CABG: Coronary Artery Bypass Greft, HPL: Hyperlipidemia local ethics committee for our study. All patients were older than 18 years. Demographic data, clinical history, and laboratory values of the patients were obtained from the patient files with the hospital information operating system. All lesions were of atherosclerotic etiology and were located in the LSA proximal to the left internal mammary artery. Interventions for true and pseudoaneurysmal lesions of the LSA were excluded from the study. In our study, SA CTO was diagnosed by Doppler ultrasound (retrograde reverse flow observed in the left vertebral artery), computed tomographic angiography, magnetic resonance angiography or conventional anjiography. Patients were included in the procedure if they had a systolic arterial pressure difference of at least 20 mmHg between the two upper extremities before the procedure. In our study, reproducible left arm pain with exercise, vertigo (due to SA steal syndrome), and the presence of a patent LIMA-LAD graft constitute the 3 main indications for intervention. After the intervention, all patients were assessed in outpatient clinics during the first month and then were followed up annually. In post-intervention follow-up assessments, clinical symptom relief was recorded, and distal pulse palpation and inter-arm blood pressure difference were monitored. Technical success was defined as residual stenosis of <30%, absence of major complications (any access-site complications, flow-limiting dissection, rupture), and a difference in blood pressure between the two arms below 10 mmHg after the procedure.

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the University of Health Sciences Türkiye, Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Clinical Researchs Ethics Committee (approval no: 2023.06-67, date: 22.08.2023). Written informed consent was obtained from each patient.

### Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA). Data are expressed as n (%) for categorical variables. Pearson's chi-square and Fisher's exact tests were performed for categorical variables. After normal distribution was analyzed with the Kolmogorov-Smirnov test, the data were expressed as median ($25^{th}$ and $75^{th}$ percentiles) for variables without a normal distribution and mean±standard deviation for variables with normal distribution. Student's t-test was used to compare quantitative variables with a normal distribution, while the Mann-Whitney U test was used to compare quantitative variables with a non-normal distribution. Univariate and multivariate logistic regression analyses were used to determine the independent predictors of technical success.

## RESULTS

Sixty (41 males 68.3%) patients with a mean age 61.2±7.72 years were performed percutaneous angioplasty and stenting procedure. Fourty nine patients (81.6%) achieved technical success, whereas 11 patients (18.4%) failed to achieve technical success. There were no differences in baseline characteristics between the two groups, except for left ventricular ejection fraction (p<0.045), hemoglobin (p<0.015), and hematocrit (p<0.045) (Tables 1 and 2). Baseline laboratory test results are also shown in Table 2. Procedural indications were 15 (25%) vertebrobasilar insufficiency, 28 (46.7%) coronary ischemia had a LIMA coronary artery by-pass greft and 17 (28.3%) arm claudications.

Left subclavian total occlusion was diagnosed in the patients by Doppler ultrasound (n=11), computerized tomographic angiography (n=30), DSA (n=18), and magnetic resonance imaging angiography (n=1).

The arcus aorta morphology of the patients in the study was categorized either by arcus aortogram or by computed tomographic angiography. Thirty (55%) patients had type 1, 18 (30%) patients had type 2, and 9 (15%) patients had type 3 arcus aorta; there were no statistical differences in procedural success between the groups (Table 3).

The preprocedural systolic and diastolic blood pressure between the upper extremities did not differences between two group.

In the percutaneous procedure, only the femoral route was used in 17 (28.3%) of the patients, while the dual approach (femoral+brachial or radial access) was preferred in 43 (71.7%). Dual access side was attempted in all 11 unsuccessful patients and retrograde crossing of the total lesion was not attempted in only 2 patients. Although the length of the CTO segment was longer in the unsuccessful group, the difference was not statistically significant. The impact on procedural success of CTO segment length (p=0.232) and of the presence of calcification (p=0.317) within the segment has not been determined. Guidewire diameter and structure (hydrophilic or non-hydrophilic) did not differ between the two groups with respect to procedural success (p=0.273) (Table 3).

All CTO lesions were initially attempted to be crossed with the antegrade method. Success was achieved in 26 of 27 (45%) patients in whom only the antegrade route, and not retrograde crossing, was attempted. In the remaining

**Table 2.** Physical examination and etiology variables of the study population

| Parameters | All (n=60) | Successful (n=49) | Unsuccessful (n=11) | p-value |
|---|---|---|---|---|
| LUESP (mmHg) | 77.31±14.45 | 78.42±15.6 | 72.45±5.82 | 0.220 |
| LUEDP (mmHg) | 52.5±8.9 | 52.88±9.51 | 51.09±6.10 | 0.556 |
| RUESP (mmHg) | 134.9±12.9 | 135.8±13.7 | 131.1±8.02 | 0.289 |
| RUEDP (mmHg) | 81.8±7.5 | 81.59±7.99 | 82.73±5.17 | 0.655 |
| PİSGBUE (mmHg) | 3.8±10.6 | 1.86±3.87 | 52.50±3.53 | <0.001 |
| **Indications** | | | | |
| VBI | 15 (25) | 13 (26.5) | 2 (18.2) | 0.100 |
| Arm claudication | 28 (46.7) | 25 (51) | 3 (27.3) | |
| Coronary ischemia with patent LIMA-LAD graft | 17 (28.3) | 11 (22.5) | 6 (54.5) | |
| **Diagnostic tools** | | | | |
| Doppler USG | 11 (18.3) | 8 (16.3) | 3 (27.3) | 0.100 |
| CTA | 30 (50) | 28 (57.1) | 2 (18.2) | |
| MRA | 1 (1.7) | 1 (2.0) | 0 | |
| DSA | 18 (30) | 12 (24.5) | 6 (54.5) | |
| LV EF (%) | 60 (55-60) | 60 (55-65) | 59 (55-60) | 0.045 |

VBI: Vertebrobasilar insufficiency, LVEF: Left ventricular ejection fraction, USG: Ultrasonography, CTA: Computed tomographic anjiography, MRA: Magnetic resonance angiography, LUESP: Left Upper Extremity Systolic Pressure, LUEDP: Left Upper Extremity Diastolic Pressure, RUESP: Right Upper Extremity Systolic Pressure, RUEDP: Right Upper Extremity Diastolic Pressure, PISGBUE: Post-intervention Systolic Pressure Gradient between upper extremities, DSA: Digital Subtraction Angiography, LIMA-LAD: Left internal mammamry artery-left anterior descending artery

32 (53.3%) patients, retrograde true lumen transition was attempted, of whom 22 were successful and 10 were unsuccessful. Successful recanalization with reverse controlled antegrade and retrograde tracking technique was achieved in 1 (1.6%) patient.

Balloon-expandable stents were implanted in 47 of the successful patients, and self-expandable stents were implanted in 2 of them. Post-dilatation was performed in 13 patients after stent implantation. In 2 patients, a second stent was implanted distally because of edge dissection following implantation of the first stent. In one patient, brachial artery dissection and occlusion were observed due to the uncontrolled advancement of the distal end of the 0.035 hydrophilic guidewire, and they were successfully treated with balloon angioplasty. The mean diameter of the implanted stents was 8.37±1.06 mm and the length was 40.56±14.22 mm.

Among the proximal left SA CTOs included in the study, the morphological subgroup counts were 10 (16.7%) peak type, 18 (30%) hilly type, 18 (30%) plain type, 12 (20%) rat-tail type, and 2 (3.3%) in-stent restenosis. Frequencies of plain type CTO of LSA (81.8 vs. 18.4%, $p<0.001$), dual approach (femoral and radial) (100 vs. 65.3%, $p=0.017$), and lesion crossing-retrograde (90.9 vs. 44.9%, $p=0.022$) were notably higher in the technical success (-) group than in the technical success (+) group. Logistic regression analysis showed that the presence of plain-type CTO lesions (odds ratio: 14.85, 95% confidence interval: 2.498-88.334, $p=0.003$) was an independent predictor of technical success. Among the CTO morphological types, only the plain type differed with respect to procedural success (Table 3).

There was no statistically significant difference in the complication rate during the percutaneous procedure between the two groups (Table 4). No procedure-related transient ischemic attack or cerebrovascular accident was observed in either group. CSB operations were performed in 5 of 11 patients in whom the percutaneous procedure was unsuccessful.

## DISCUSSION

Our study is one of the largest isolated left subclavian proximal segment CTO PTA series in the literature so far. The main findings of this study are: (1) only the plain type, as a CTO morphology, negatively predicted the success of the procedure; (2) arcus aorta type did not affect the success of the procedure; and (3) lesion length and the presence of calcification did not affect procedure success.

The procedural success rate observed in our study is similar to that reported in previous publications. Among the CTO morphological classification subtypes, only the plain type was found to be effective for processing success. We think that one major reason for this may be that the CTO segment is very close to the aorta and that the proximal cap region is ambiguous in the current morphological subtype. For this reason, it may be more appropriate to start cases of this CTO morphology primarily via the retrograde route.

**Table 3.** Data regarding morphological and technical characteristics affecting procedural success

| Parameters | All (n=60) | Successful (n=49) | Unsuccessful (n=11) | p-value |
|---|---|---|---|---|
| **Morphological type, n (%)** | | | | |
| Peak type | 10 (16.7) | 10 (20.4) | 0 | 0.109 |
| Hilly type | 18 (30) | 16 (32.7) | 2 (18.2) | 0.289 |
| Plain type | 18 (30) | 9 (18.4) | 9 (81.8) | <0.003 |
| Rat-tail type | 12 (20) | 12 (24.5) | 0 | 0.066 |
| ISR-CTO | 2 (3.3) | 2 (4.1) | 0 | 0.664 |
| **Arcus aorta type, n (%)** | | | | |
| 1 | 33 (55) | 28 (57.1) | 5 (45.5) | 0.447 |
| 2 | 18 (30) | 15 (30.6) | 3 (27.3) | |
| 3 | 9 (15) | 6 (12.2) | 3 (27.3) | |
| **Approach, n (%)** | | | | |
| Femoral | 17 (28.3) | 17 (34.7) | 0 | 0.017 |
| Dual (BA or RA with FA) | 43 (71.7) | 32 (65.3) | 11 (100) | |
| Lenght of occlusion (mm) | 25 (17.2-32.7) | 24 (17-32) | 29 (25-36) | 0.232 |
| Calsifications, n (%) | 30 (50) | 23 (46.9) | 7 (63.6) | 0.317 |
| **Guidewire covering, n (%)** | | | | |
| Hydrophilic | 40 (66.7) | 34 (69.4) | 6 (54.5) | 0.273 |
| Non-hydrophilic | 20 (33.3) | 15 (30.6) | 5 (45.5.) | |
| **Guidewire diameter, n (%)** | | | | |
| 0,014 inches | 26 (43.3) | 21 (42.9) | 5 (45.5) | 0.567 |
| 0,035 inches | 34 (56.7) | 28 (57.1) | 6 (54.5) | |
| **Microcatheter, n (%)** | | | | |
| None | 9 (15.0) | 9 (18.4) | 0 | 0.148 |
| 1.8 Fr coronary | 12 (20) | 8 (16.3) | 4 (36.4) | |
| 4 Fr peripheral | 39 (65) | 32 (65.3) | 7 (63.6) | |
| **Lesion crossing, n (%)** | | | | |
| Antegrade | 27 (45) | 26 (53.1) | 1 (9.1) | <0.022 |
| Retrograde | 32 (53.3) | 22 (44.9) | 10 (90.9) | |
| CART | 1 (1.7) | 1 (1.7) | 0 | |
| **Baloon predilation, n (%)** | 49 (81.6) | 49 (100) | | |
| Stent type, n (%) | | | | |
| Baloon expendable | 46 (95.8) | 46 (95.8) | | N/A |
| Self expendable | 2 (4.2) | 2 (4.2) | | |
| Stent diameter (mm) | 8.37±1.06 | 8.37±1.06 | | |
| Stent lenght (mm) | 40.56±14.22 | 40.56±14.22 | | |
| Post-dilatation PTA | 13 (27.1) | 13 (27.1) | | |

ISR-CTO: Instent restenozis chronic total occlusion, CART: Controlled antegrade and retrograde tracking technique, PTA: Percutaneous transluminal angioplasty, BA: Brachial artery, FA: Femoral artery, RA: Radial artery, Fr: French catheter size

**Table 4.** Complications associated with interventional procedures

| Parameters | All (n=60) | Successful (n=49) | Unsuccessful (n=11) | p-value |
|---|---|---|---|---|
| **Complications, n (%)** | | | | |
| None | 54 (90) | 45 (91.8) | 9 (81.8) | 0.302 |
| SA dissection | 4 (6.7) | 3 (6.1) | 1 (9.1) | |
| Access side Cx | 1 (1.7) | 0 (0) | 1 (9.1) | |
| Stent migration | 1 (1.7) | 1 (2.0) | 0 | |

SA: Subclavian artery, Cx: Complications

Contrary to popular belief, clinical conditions in which canalization of the LSA ostium is difficult, especially type 3 arcus aorta, are not statistically associated with procedural success.

Our study, consistent with other studies in the literature, showed that lesion length and the presence of calcification did not have a significant effect on procedural success. In our study, since routine CT angiography and quantitative calcium scoring were not performed on all patients before the procedure, the presence of calcification was mainly evaluated angiographically. Because the quantitative evaluation of calcification was not performed in our study, further studies are necessary.

Unlike other studies, the most common indication for intervention in our study was coronary ischemic symptoms in the presence of a patent LIMA-LAD graft rather than vertebrobasilar insufficiency or arm claudication. Our center is a tertiary cardiovascular branch hospital may have contributed to this clinical picture.

Our study showed that the success of the procedure in patients planned to undergo PTA can be increased by appropriate clinical indication, detailed morphological imaging, and careful procedural planning.

### Study Limitations

Our study has some limitations. Although it is one of the largest isolated left SA CTO intervention series described, the small number of cases,single center , the retrospective nature of the study, and the difference in intervention preferences between operators constitute the main limitations. For this reason, prospective multicenter studies are needed.

## CONCLUSION

Balloon angioplasty and stenting for isolated proximal LSA CTO cases is a safe, effective treatment , preferred over surgical intervention and antegrade approach is the first method of choice and, depending on some anatomical and clinical features, it increases the success of the procedure in the retrograde approach.

### ETHICS

**Ethics Committee Approval:** This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the University of Health Sciences Türkiye, Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Clinical Researchs Ethics Committee (approval no: 2023.06-67, date: 22.08.2023).

**Informed Consent:** Written informed consent was obtained from each patient.

### FOOTNOTES

#### Authorship Contributions

Surgical and Medical Practices: A.Y.Ç., A.G., S.K., A.A.Y., F.U., Concept: A.Y.Ç., A.G., S.K., Design: A.Y.Ç., A.G., S.K., Data Collection or Processing: A.Y.Ç., K.Ç., E.G.G., N.G.S., F.F.B., A.D., K.G., B.S., Analysis or Interpretation: A.Y.Ç., S.K., Literature Search: A.Y.Ç., A.G., E.G.G., N.G.S., A.D., K.G., B.S., Writing: A.Y.Ç., A.G., S.K.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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