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Original article

The role of SFA lesion length in the success of percutaneous transluminal angioplasty for chronic limb-yhreatening ischemia

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ABSTRACT

Background: Superficial femoral artery (SFA) lesions are a significant cause of critical limb ischemia (CLI). Particularly occlusion length, play an important role in management outcomes. **Objective**: This study aims to uncover the relationship between the length of SFA lesions and the outcome of endovascular intervention. **Methods**: This prospective study included 30 patients with chronic limb-threatening ischemia (CLTI) due to SFA occlusion between February 2022 and August 2022. The patients underwent percutaneous transluminal angioplasty (PTA). Follow-up continued for six months after endovascular revascularization of the limb. **Results**: The mean age of participants was 59.60±7.70 years. The success rate was 66.7% from the first time with SFA lesions 13.30 ±7.11 cm, 23.3% success after the second trial of re-angioplasty with SFA 22±7.94 cm length of occlusion, and 10% of cases underwent major amputation. **Conclusion**: The length of SFA occlusion does not significantly affect the initial outcome of endovascular revascularization. However, occlusion length is a good predictor of secondary patency.

Introduction

Peripheral artery disease (PAD) is often characterized by occlusive arterial disease, which can range from being asymptomatic to requiring revascularization or even amputation. It affects approximately 20% of the general population. Critical limb ischemia (CLI) or chronic limb-threatening ischemia (CLTI) is harder to define and shows considerable variability in prevalence across various studies. Unlike asymptomatic PAD or exertional claudication, CLI occurs when there is insufficient blood flow at rest. [1]

The definition of CLTI/CLI has been defined as lasting more than two weeks of pain in the extremities at rest, along with ulcers or gangrene, resulting from objectively diagnosed PAD. [2]

More than half of all PAD cases involve the superficial femoral artery (SFA), making it the most frequently affected artery in the peripheral vascular system. [3]

Endovascular treatments for CLTI/CLI show inconsistent results. However, satisfactory limb salvage rates can be obtained in patients undergoing multilevel interventions for CLI, and better patency rates are observed with these multilevel interventions compared to single-site procedures. [4]

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When treating patients with rest pain, long-term patency is very important since restenosis will lead to recurrent rest pain; however, patients with ischemic ulceration require patency long enough for wound healing and the prevention of limb loss. [5] At 1 year, a high percentage of the patients with CLI treated conservatively undergo an amputation. However, this percentage is lower with CLI undergoing revascularization. Many factors related to the limb arteries and occlusion characteristics can imfluence the success or failure of an endovascular intervention. [6]

Thus, this study aims to determine the relationship between the length of superficial femoral artery occlusion and the outcome of endovascular intervention and whether this relationship is affected by any other factors.

Patients and methods

This is a prospective descriptive study conducted on 30 patients aged ≥18 who presented to the Vascular and Endovascular Surgery Department of a tertiary university-based hospital from February 2022 to August 2022.

We included patients suffering incapacitating claudication or CLI (tissue loss, gangrene, or rest pain) who had SFA occlusion alone or with popliteal or tibial disease. Patients with vasculitis, acute limb ischemia, or previous stenting for any vessel in the target limb were excluded.

Ethical consideration: The institutional Ethical Research Committee reviewed and granted approval for the study protocol (Code: MS-84-2022).

All participants received detailed information regarding study procedures and purpose of the study. Written informed consent was secured from the participants after discussing the advantages and disadvantages of the procedure. Participants were free to withdraw from the study at any time; their involvement was completely voluntary. In line with the Declaration of Helsinki, all processes related to data collection, entry, and analysis were carried out with strict confidentiality and privacy.

Pre-operative preparations

Patients were recruited after a detailed history, including medical and surgical history. They underwent a full clinical assessment, with an emphasis on local leg and foot examinations. The degree of ischemia was staged using Rutherford [7] and WIFI [8] classifications. Pre-operatively, complete blood counts (CBC), fasting blood glucose, coagulation profile, liver and renal functions, lipid profile, serum K level, and creatine kinase tests were performed.

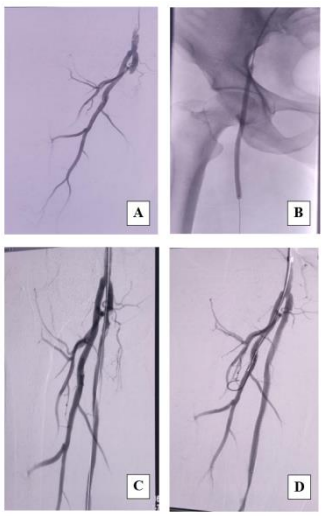
Arterial duplex scan with ankle-brachial index (ABI) and peak systolic velocities (PSV) was performed together with computed tomography angiography (CTA), and the variables were applied to TASC classification [9], distal runoff, and foot arches assessment to determine the number of patent tibial vessels and visualize the foot arches.

Endovascular Procedure

All procedures were performed under local anesthesia with lidocaine. Patients on acetylsalicylic acid therapy received a loading dose of clopidogrel (300 mg) prior to the intervention.

The procedure typically began with an antegrade approach for mid- or distal SFA occlusion; a contralateral cross-over sheath was used for flush occlusions. Catheter-based techniques involved hydrophilic guidewires, and balloon angioplasty was performed with balloons between 4 and 6 mm in diameter. Bare metal stents were used when necessary, and completion angiography confirmed the absence of residual stenosis **(Figure 1)**.

Figure (1): A: Right superficial femoral artery flush occlusion. B: Right superficial femoral artery balloon angioplasty. C: Right superficial femoral artery post-balloon angioplasty. D: Right superficial femoral artery post-stenting showing dissection flap.



All patients were discharged on 75 mg of daily clopidogrel.

Procedure success is defined by uninterrupted blood flow in the treated vessel, absence of significant residual stenosis, and complete wound healing within three months. Limb salvage is considered successful if pain disappears **(Figure 2)**. Angioplasty failure occurs with persistent or recurrent significant SFA stenosis, with or without worsening symptoms, and any above-the-ankle amputation is deemed a failure criterion **(Figure 3)**.

Follow-up evaluations, including clinical examination and duplex ultrasound, tracked amputation-free survival and limb salvage at 3 and 6 months, were performed. Patients whose limbs were deemed non-salvageable proceeded to major amputation.

Figure (2): Healed forefoot amputation stump post-angioplasty.

Figure (3): Ischemic forefoot amputation stump due to re-occlusion.

Statistical methods: Data entry was carried out using Statistical Package for Social Science (SPSS) version 28.0 (IBM® Corp, SPSS, Armonk, NY, USA). Data was summarized using mean, standard deviation, median, minimum, and maximum in quantitative data and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Kruskal-Wallis and Mann-Whitney tests. [10] To compare categorical data, the Chi-square (c2) test was performed. Exact test was used instead when the expected frequency is less than 5. [11] *P*-values less than 0.05 were considered statistically significant.

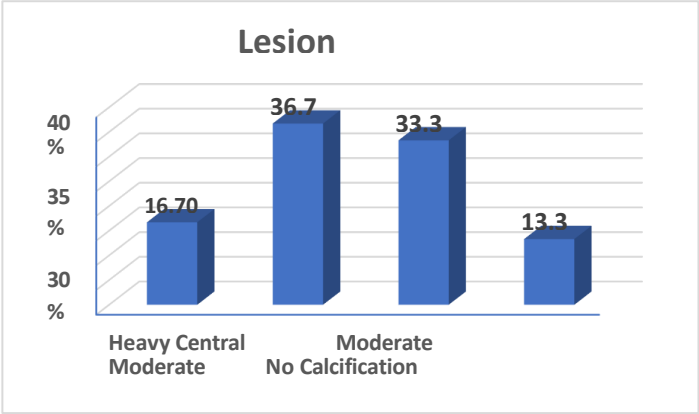
Results

A total of 30 patients were included in this study. Their mean age was 59.60±7.70 years. Males were more prevalent among the included patients, 73.3% males versus 26.7% females. All the included patients suffered from diabetes mellitus (DM), followed by hypertension in 70% and cardiac disease in 26.67%. A large portion of the participants (83.3%) were smokers.

Regarding clinical presentation, 43.3% complained of lower limb short-distance claudication, and 43.3% had major tissue loss in the form of gangrene. However, only 6.7% of patients presented with rest limb pain.

All patients in the study presented with SFA lesions of varying lengths, with a mean length of 15.33 ± 8.20 cm. The locations of occlusion were distributed as follows: 40% occurred at the level of the adductor canal, 33.3% were classified as total occlusions, 23.3% were proximal occlusions from the origin of the SFA, and 3.3% featured mid-occlusions. Additionally, 43.3% of the patients had SFA lesions with associated popliteal lesions, while 66.7% had SFA lesions with tibial involvement. Furthermore, 30% of the patients presented with both popliteal and tibial lesions alongside the SFA lesion. Lesion morphology shows calcifications in most of the patients, as shown in **Figure 4**.

Figure (4): Bar chart showing lesion morphology types among study patients.



According to the operative details, 90% of our patients had balloon angioplasty alone, while

10% of cases had stent deployment with balloon angioplasty.

In terms of the lesion crossing technique, intraluminal crossing was used in 96.7% of our patients, and 3.3% used the subintimal track technique.

The outcome after endovascular intervention during a 6-month follow-up revealed three failed cases (10%), where two underwent major amputations, and one case suffered a failed healing stump; seven cases needed to repeat the angioplasty (23.3%); and 20 cases were successful (66.7%).

As regards the redo cases, 6 of them have complete total SFA occlusion, 2 of them had stent deployment at first, one of them occluded after 1 month, and the other cases occluded after 3 months. Three of the redo cases were associated with popliteal lesions, and 5 of them were associated with tibial lesions; none of the redo cases needed a new stent deployment.

Relationship between the length of SFA occlusion & outcome of endovascular intervention

Table 1 shows the relationship between the length of SFA occlusion & outcome of endovascular intervention, which showed a high successful rate when the SFA occlusion is (12.30 cm) ±7.11 and a high re-angioplasty rate when it is (22 cm) ±7.94. This finding was statistically significant with a *P*-value of 0.015.

Table (1): The relationship between the length of SFA occlusion & outcome of endovascular intervention among the study participants.

		Outcome of endovascular intervention			*P*-value
		Failed	Re-angioplasty	Successful	
Length of SFA lesion (cm)	Mean	20.00	22.00	12.30	0.015
	Standard Deviation	5.00	7.94	7.11	
	Median	20.00	25.00	10.00	
	Minimum	15.00	4.00	3.00	
	Maximum	25.00	25.00	25.00	

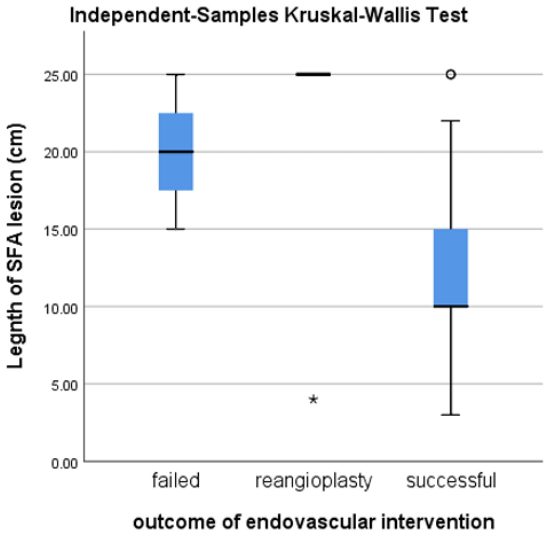
SFA: Superficial Femoral Artery.

When the length of occlusion was (12.30cm) ±7.11, the angioplasty was successful and didn't need redo; when the length of occlusion was (22cm) ±7.94, the patients needed redo angioplasty.

Post-hoc pairwise comparisons

A significant *P*-value was found between successful and re-angioplasty cases (*P*-value =0.021), which means we found the length of SFA occlusion, which can suspect successful cases and re-angioplasty cases. Still, no statistically significant difference (*P* >0.05) was found between successful and failed cases, nor between failed and re-angioplasty cases, denoting failure to reach a conclusion on the need for repeating angioplasty according to the length alone, as it depends on many other factors **(Figure 5)**.

Figure (5): Relation between the length of the lesion and the outcome of endovascular intervention.



The impact of the popliteal and tibial lesions on this outcome

The table below shows that no significant impact of the presence of a popliteal lesion or tibial lesion on the outcome of endovascular revascularization of SFA if proper angioplasty is done (*P*-values >0.05).

The impact of the site of SFA occlusion on this outcome.

The site of SFA occlusion played an important role in the outcome of endovascular intervention. Sixty percent of patients with total SFA occlusion underwent repeating the angioplasty, and thirty percent of them passed successfully. These results show a statistically significant difference (*P* =0.022) where total SFA occlusion may lead to repeat the angioplasty, while other sites are mainly successful **(Table 2)**.

SFA: Superficial Femoral Artery.

The impact of morphological lesions on this outcome.

There was no statistically significant impact of morphological lesion on the outcome of endovascular intervention (*P* =0.445) **(Table 3)**.

The impact of operative details on outcome

We used stents in only three cases out of 30, two of which developed into stent stenosis after 1 month in one case and after 3 months in the other. However, these results show no statistically significant difference regarding the procedures' outcomes, as shown in **Table 4**.

SFA: Superficial Femoral Artery.

- Complications were observed in four patients within the study cohort. Specifically, there was one instance of distal acute thrombosis, which necessitated a successful femoral-popliteal bypass, representing a complication rate of 13.3%. Additionally, one patient developed a hematoma in the popliteal fossa, which required compression therapy; this approach effectively alleviated the hematoma, allowing for successful completion of an angioplasty, accounting for 3.33% of complications. Furthermore, two patients experienced superficial femoral artery (SFA) dissection, both of whom required stenting, contributing to a complication rate of 6.67%.

Table (2): Relation between the site of SFA occlusion and the outcome among study participants**.**

		Site of SFA occlusion								*P*- value
		Mid SFA occlusion		Distal SFA occlusion		Occlusion from the origin		Total SFA occlusion		
		Count	%	Count	%	Count	%	Count	%	
Outcome of endovascular intervention	Failed	1	8.3%	0	0.0%	1	14.3%	1	10.0%	0.022
	Re-angioplasty	1	8.3%	0	0.0%	0	0.0%	6	60.0%	
	Successful	10	83.3%	1	100.0%	6	85.7%	3	30.0%	

SFA: Superficial Femoral Artery.

Table (3): Relation between the site of the morphological lesion and the outcome among study participants**.**

		Lesion morphology								*P*- Value
		Heavy central calcification		Moderate central calcification		Moderate partial calcification		No calcification		
		Count	%	Count	%	Count	%	Count	%	
Outcome of endovascular intervention	Failed	1	20.0%	1	9.1%	1	10.0%	0	0.0%	0.445
	Re-angioplasty	2	40.0%	4	36.4%	1	10.0%	0	0.0%	
	Successful	2	40.0%	6	54.5%	8	80.0%	4	100.0%	

Table (4): Relation between the operative procedures and the outcome among study participants.

		Operative details						*P*-value
		Balloon dilatation		Balloon dilatation & stent deployment in proximal & mid SFA		Subintimal track		
		Count	%	Count	%	Count	%	
Outcome of endovascular intervention	Failed	2	7.7%	0	0.0%	1	100.0%	0.074
	Re-angioplasty	5	19.2%	2	66.7%	0	0.0%	
	Successful	19	73.1%	1	33.3%	0	0.0%	

SFA: Superficial Femoral Artery.

Discussion

Peripheral arterial disease affecting the superficial femoral artery (SFA) is the leading cause of intermittent claudication. Stenosis or blockage of the SFA typically leads to reduced blood flow to the leg, causing ischemic pain, which may manifest as rest pain and tissue damage, also referred to as critical limb ischemia (CLI). In terms of management, the Tran-Atlantic Inter-Society Consensus Document II suggests that percutaneous transluminal angioplasty (PTA) with provisional stenting or primary stenting is among the recommended treatment options for lesions or occlusions in the SFA.[12]

In the current study, 30 patients with chronic limb ischemia due to SFA occlusion were recruited. Endovascular revascularization was done, and they were followed up for six months to assess the outcome and determine the impact of many factors that could affect this outcome.

The mean length of SFA occlusion in the current study was 15.33±8.20 cm. According to the site of occlusion, 40% of the occlusions were at the level of the adductor canal, and 33.3% were total occlusions.

Previous studies concluded that most patients had an average length of SFA occlusion between 10 and 20 cm. [13,15]

In our study, most patients underwent balloon angioplasty alone (90%), while a 10% of cases performed stent deployment. The intraluminal crossing technique was successful in the majority of cases, with only a few requiring the subintimal crossing technique (3.35%).

In concordance, the earlier study by *Krishnappa et al.* used stents in 16.95% of the cases only due to factors such as flow-limiting dissection, residual stenosis greater than 30%, vessel recoil, or failure to establish adequate flow with balloon angioplasty alone. [15]

On the other hand, *Biagioni et al.* provisionally reported the use of stents in the popliteal group in more than half of the cases. However, the use of stents was closely associated with limb loss, possibly because of the likelihood of stent use in more complex cases rather than because of stent use itself. [14] Furthermore, their results were supported by others who deployed stents in almost half of their study participants. [13]

In our study, Successful outcomes, defined as symptom resolution and wound healing, were achieved in 66.7% of patients. Unfortunately, 23.3% underwent re-angioplasty due to unhealed ulcer after debridement and recurrent symptoms suggestive of re-stenosis, and their procedures were successful; however, 10 % of the cases had failed reintervention in the form of major amputation or the need for femoropopliteal bypass. Those who needed amputations had uncontrolled diabetes, coinciding with heavy smoking.

The current study's findings revealed that 60% of patients with SFA total occlusion underwent re-angioplasty due to re-stenosis, while 83.3% of the cases that presented with SFA occlusion at the level of the adductor canal had successful revascularization denoting the important impact of the occlusion site on the success of the intervention (P =0.022).

Longer SFA lesions are more likely to result in reintervention due to several anatomical, mechanical, and procedural factors:

- **Restenosis** is the re-narrowing of the artery after treatment, Longer lesions involve a greater area of endothelium being damaged or treated, increasing the biological

response (inflammation, neo-intimal hyperplasia) that leads to restenosis.

- **Challenging Biomechanics :** The SFA passes through the adductor canal, a region subject to bending, stretching, and compression during leg movement. A longer stented or treated segment is more prone to mechanical stress
- **Procedural Complexity :** Treating longer lesions usually requires:
    - Multiple stents or longer drug-coated balloons (DCBs)
    - More complex wire and catheter navigation
    - Potential for subintimal dissection or re-entry
- This increases the risk of technical failure, incomplete treatment, or complications like embolization or perforation. [14]

Re-interventions in the study by *Biagioni et al.* were necessary in 11.1% of the patients. Primary patency in their study at 30 days and 1 year was 91%, 60.1%, respectively. Limb salvage at 30 days and 1 year was 95.2% and 82.2%, respectively. [14]

Similarly, in *Krishnappa et al.'s* study, the success rate of endovascular therapy was 91.52%, and restenosis happened in 16.67% of the cases that needed repeated angioplasty. [15]

Torres-Blanco et al. projected that sustained hemodynamic improvement would be 62.5% after 12 months and 50% after 24 months. Reintervention was performed on twenty-one limbs; most of them were PTA. Limb salvage rate was 80 % at 12 and 24 months. [13]

As regards the relationship between the length of SFA occlusion and the outcome of endovascular intervention, our research revealed that the mean length of SFA occlusion that is suspected to be responsible for a successful outcome or repeat the angioplasty was 12.30±7.11 cm and 22±7.49 cm, respectively.

The length of SFA lesions has significant implications for clinical decision-making and patient selection in peripheral arterial disease (PAD) management.

Treatment Modality Selection:

Short lesions (<10 cm) often treated successfully with endovascular techniques with high patency, low complication rate. Long lesions (>15–20 cm) Endovascular therapy still possible, but with Increased risk of restenosis, re-intervention, and stent fracture.

Device Selection and Strategy

Longer lesions often require Multiple or overlapping stents, Longer drug-coated balloons, Possible use of re-entry devices if subintimal techniques are needed or may necessitate hybrid procedures (e.g., endovascular + limited surgical exposure).

Anticipation of Re-intervention

Patients with longer lesions should be counseled about the increased likelihood of re-intervention. More aggressive surveillance protocols (e.g., duplex ultrasound at regular intervals) are warranted.

Limitations:

The current study's small sample size was one limitation. Additionally, methods to measure the length of occlusion, such as angiograms, are not always available. Determination of the SFA length of occlusion is not routine in duplex or CTA examination, and unfortunately, the length of SFA occlusion in duplex is not always accurate.

Conclusion

The success of endovascular revascularization is influenced not only by the employed techniques but also by the inherent characteristics of the target lesion, particularly with respect to its length and anatomical location.

Competing interests:

The Authors declare no conflict of interest is present.

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