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Arteriovenous Fistula Anastomosis Diameter Association with the Ischemic Steal Syndrome Occurrence

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Abstract

AIM: Symptomatic steal syndrome is one of the major complications following arteriovenous access fistula (AVF). The aim of this study is to investigate the association between AVF anastomosis diameter and the incidence of symptomatic steal syndrome.

METHODS: A total of 103 patients with AVF were enrolled retrospectively in the study. There were two groups in the study, 77 patients with clinical symptomatic steal syndrome and 26 controls with mature AVF with no symptoms. Anastomosis diameter was measured at the site of anastomosis and recorded at different fistula locations. Patient demographic, risk factors, and access characteristics were recorded.

RESULTS: Symptomatic steal syndrome was more common among female patients (75.4%). Symptomatic steal syndrome was more prevalent in patients with diabetes mellitus (DM), 77.8%, $p < 0.001$. The mean anastomosis diameter in patients with symptomatic steal syndrome was 3.74 (± 1.47) mm and in the control group 4.07 (± 1.79) mm, which indicates no significant difference in the anastomosis diameter, $p = 0.425$. Analysis of covariance (ANCOVA) indicated that cardiovascular disease [$F (1.94) = 15.691$, $p = 0.008$] and peripheral vascular diseases [$F (1.94) = 13.059$, $p = 0.016$] are associated with steal syndrome incidence.

CONCLUSION: The findings of this study conclude that there is no significant association between increased anastomosis diameter and the incidence of AVF steal syndrome.

Introduction

Arteriovenous fistula (AVF) construction is essential for hemodialysis access. AVF can be created using either a native vein or AV graft. AVF is preferred for long-term hemodialysis access due to longer patency and lower complications [1]. However, fistula complications, such as aneurysm, infection, thrombosis, venous hypertension, and steal syndrome, could occur [1], [2], [3], [4]. Steal phenomena can be defined as retrograde flow in the feeding artery distal to the AVF anastomosis with no symptoms. The patient who develops symptoms such as pain, nail changes, cold hand, muscle weakness, rest pain, fingertip ulceration, and tissue loss is considered a symptomatic steal syndrome [5], [6]. Therefore, steal syndrome can be classified as physiologic steal having retrograde flow with no symptoms and pathological symptomatic steal syndrome that led to distal ischemic steal syndrome (DISS). DISS is one of the severe complications which may lead to severe morbidity and limb loss [1], [2], [3], [4], [5], [6].

Technically, AVF is created to increase the vein pressure, which will lead to vein dilatation. As result of this, cardiac output increases to allow the fistula to mature. This process generally occurs with the retrograde flow in the feeding artery at the distal region after anastomosis bed. Retrograde flow occurs in the distal radial artery in 70% of AVF cases and may not cause distal ischemia [2]. When the retrograde flow becomes an extreme phenomenon, steal syndrome occurs [3].

Symptomatic ischemia of the hand is an uncommon disorder among patients undergoing hemodialysis (HD); approximately <15% of cases develop a symptomatic steal syndrome following the placement of arteriovenous access. However, a major problem with this kind of disease is that it could be life-threatening and result in both gangrene and unnecessary amputation of the hand [7], [8].

As the population of patients afflicted with chronic kidney disease (CKD) and end-stage renal disease (ESRD) is rising internationally, symptomatic steal syndrome could significantly affect public health if it goes undetected and is not managed. Knowledge of the cause of DISS in a patient with upper limb AVF is essential to understanding the pathophysiology and cause of steal syndrome. Arterial inflow disease, high access flow, diabetes mellitus (DM), and arterial insufficiency are among the most common factors that could cause steal syndrome. Therefore, understating

this phenomenon's causes and pathophysiological components may save a patient's life and time and significantly impact the healthcare budget [3], [4], [7].

Only a few studies in the literature appreciate the increased diameter of anastomosis as one of the causes of symptomatic steal syndrome in patients with arteriovenous access; this has not been thoroughly investigated. Hence, this study hypothesizes a strong association between the anastomosis diameter and steal syndrome occurrence. The main aim of this study is to determine whether increased diameter of the anastomosis is a cause of symptomatic steal syndrome.

Materials and Methods

The data for this study were collected retrospectively. Data of patients with native vein fistula who had been referred to the vascular laboratory with symptomatic steal syndrome or ischemic hands based on the clinical evaluation were incorporated into the study. Institutional review board approval for this monocentric and retrospective study was obtained. A total of 103 patients were collected from our database between 2018 and 2021. Seventy-seven native veins fistula with a symptomatic steal syndrome and 26 control (mature asymptomatic native vein fistula with no retrograde flow in distal artery) patients were included in the study. Patients with symptoms of hand ischemia, tissue loss, and pain were included in the study. The previous scans and diagnoses with symptomatic steal syndrome and retrograde flow of distal arterial flow by Doppler spectral and color Doppler were included in the study (Figure 1).

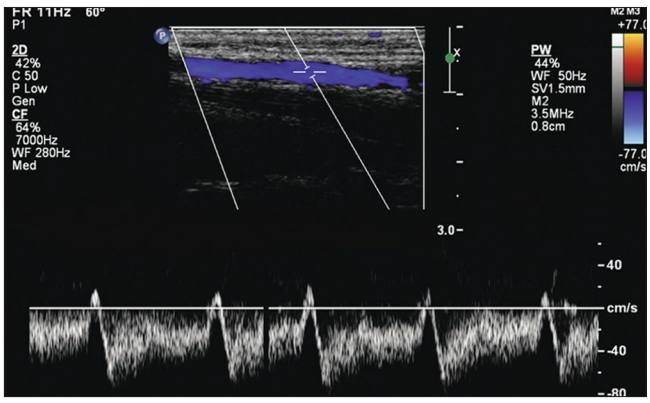

Figure 1: Spectral pulse shows reversed flow in distal region of radial artery to the anastomosis

An accurate measurement of the anastomosis diameter on the transverse scan was included in the study (Figure 2). Anastomosis diameters were measured postoperatively at 6 months interval after AVF creation. A mixture of symptomatic steal syndrome grades or severity was included in the study. The exclusion criteria were follow-up patients who had been both previously diagnosed and treated with steal syndrome, patients with a low volume flow (<300 ml/min) in either a feeding artery or draining vein, and patients with missing data, such as the diameter of the artery or volume flow, whether in the draining vein or feeding artery. Anastomosis diameter on longitudinal view was excluded due to possible error of the actual diameter. Patients with stenotic anastomosis were excluded from the study.

The scanning protocol that used for AVF assessment in our center as follows:

1. Three measurements of PSV and diameter of the feeding artery (proximal, mid, and pre the anastomosis site).
2. Measurement of the PSV and diameter at the anastomosis site.
3. Measurements of the draining vein diameter at three sites, proximal to anastomosis, mid vein, and distal to anastomosis.
4. Three measurement of volume flow at the feeding artery proximal, mid, and 1−2 cm proximal to the anastomosis.
5. Volume flow rate in the draining vein was measured 3 times at single site, where the vein diameter is reasonably uniform.
6. The flow direction and PSV were measured in distal radial and ulnar arteries.

Demographic data such as age, risk factors, and fistula location were recorded. Diagnostic parameters of AVF duplex ultrasound scans were recorded, such as the anastomosis diameter, peak systolic velocity (PSV), volume flow (VF), distal arterial flow waveforms, and direction from the anastomosis.

Statistical analysis and data management

All the data recorded were entered into Microsoft Excel and then transferred to SPSS Statistics for Windows, Version 23.0. (IBM Corp, Armonk, NY, USA) for statistical analysis. Descriptive statistics in frequencies and percentages was used to present categorical data, whereas mean and standard deviation were used for continuous variables after testing the normality of data (Shapiro–Wilk test; $p > 0.05$). The student's independent t-test was used to compare the difference between continuous variables, and any relationship between categorical variables was tested using Pearson's Chi-square (χ^2) test. A general linear model univariate analysis was performed to know the effect (influence) of independent variables with anastomosis diameter. $p < 0.05$ was considered statistically significant.

Results

A total of 77 patients with symptomatic steal syndrome were identified in our database during the selected period. There were 28 male (36.4%) and

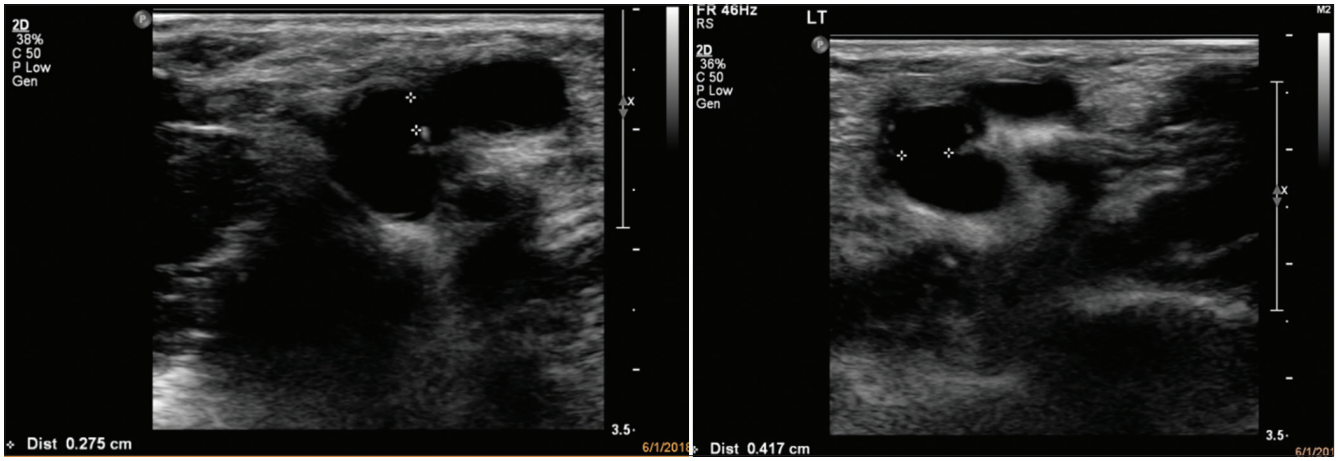

Figure 2: Transverse section of anastomosis diameter measurements using ultrasound B-mode imaging

49 (63.7%) female. Ten patients with symptomatic steal syndrome were < 50 years old and 67 patients > 50 years old. Most patients with symptomatic steal syndrome had DM, and only 38 patients had hypertension (Table 1). Symptomatic steal syndrome was more frequently seen in patients with DM, p < 0.001.

Table 1: Demographic and clinical data of both distal ischaemic steal syndrome and control group in patient with arteriovenous fistula

Variables	Study groups (%)		Total (%)	p
	Controls	Symptomatic steal syndrome		
Gender				
Male	10 (26.3)	28 (73.7)	38 (100.0)	0.848
Female	16 (24.6)	49 (75.4)	65 (100.0)	
Age (years)				
<50	6 (37.5)	10 (62.5)	16 (100.0)	0.219
>50	20 (23.0)	67 (77.0)	87 (100.0)	
DM				
No	4 (100.0)	0	4 (100.0)	< 0.001
Yes	22 (22.2)	77 (77.8)	99 (100.0)	
Hypertension				
No	5 (11.4)	39 (88.6)	44 (100.0)	0.005
Yes	21 (35.6)	38 (64.4)	59 (100.0)	
Cardiovascular disease				
No	17 (29.8)	40 (70.2)	57 (100.0)	0.233
Yes	9 (19.6)	37 (80.4)	46 (100.0)	
PVD				
No	26 (31.3)	57 (68.7)	83 (100.0)	0.004
Yes	0	20 (100.0)	20 (100.0)	
Fistula type				
Radiocephalic	5 (9.8)	46 (90.2)	51 (100.0)	0.001
Brachiocephalic	16 (37.2)	27 (62.8)	43 (100.0)	
Brachiobasilic	5 (55.6)	4 (44.4)	9 (100.0)	

DM: Diabetes mellitus, PVD: Peripheral vascular disease

In terms of fistula location and occurrence of symptomatic steal syndrome, our analysis revealed that 46 (90%) were radiocephalic, 27 (62%) were brachiocephalic, and 4 (44%) patients in brachiobasilic (Table 1). The patient with a radiocephalic fistula had commonly developed a symptomatic steal syndrome in this study.

Regarding the anastomosis diameter and symptomatic steal syndrome occurrence, our study indicates that the mean anastomosis diameter in the symptomatic steal syndrome group was 3.74 (± 1.47) mm, and in the control, group was 4.07 (± 1.73) mm. Statistically, it was not significant (p = 0.425), Table 2. In addition, these finding was presented in the box plot, which showed no significant association between symptomatic steal syndrome and the control group (Figure 3).

Table 2: Comparison of anastomosis diameter between two groups

Groups	n	Mean±SD	p
Symptomatic steal syndrome	77	3.794±1.4703	0.425
Controls	26	4.073±1.7329	
Total	103	3.864±1.5367	

SD: Standard deviation.

An analysis of covariance (ANCOVA) was performed to see the effect of anastomosis diameter with other independent variables. Among the independent variables, there were significant differences (high) in anastomosis diameter observed in patients with cardiovascular diseases [F (1.94) = 15.691, p = 0.008] with a small effect size (0.072) and with peripheral vascular diseases [F (1.94) = 13.059, p = 0.016] with a small effect size (0.061) (Table 3).

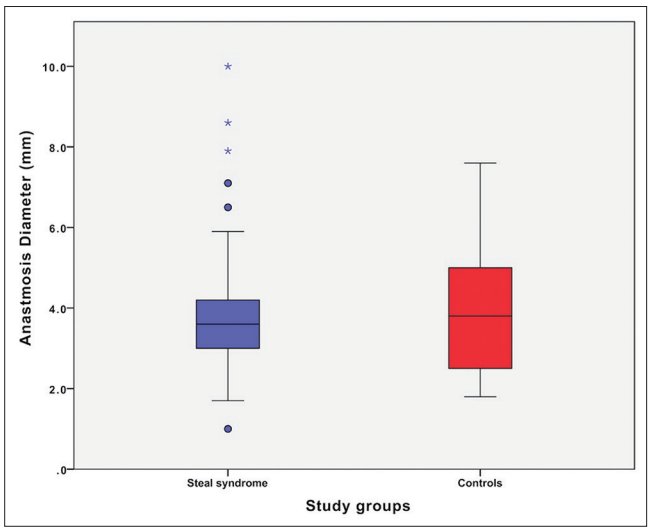

Figure 3: Box plot showed the anastomosis diameter association between the positive steal syndrome and control groups

Discussion

The present study aimed to investigate an association between the anastomosis diameter and

Table 3: General linear model univariate analysis for each independent variable and anastomosis diameter

Source	Type III sum of squares	df	Mean square	F	p	Partial eta squared
Corrected model	38.738*	8	4.842	2.252	0.030	0.161
Intercept	15.763	1	15.763	7.330	0.008	0.072
Gender	0.105	1	0.105	0.049	0.825	0.001
DM	3.383	1	3.383E-7	0.000	1.000	0.000
Hypertension	5.695	1	5.695	2.648	0.107	0.027
Cardiovascular diseases	15.691	1	15.691	7.297	0.008	0.072
PVD	13.059	1	13.059	6.073	0.016	0.061
Age>50 years	2.763	1	2.763	1.285	0.260	0.013
Location of fistula	1.026	1	1.026	0.477	0.491	0.005
Steal syndrome	0.414	1	0.414	0.193	0.662	0.002
Error	202.140	94	2.150			
Total	1778.780	103				
Corrected total	240.877	102				

*R^2=0.161 (adjusted R^2=0.089). DM: Diabetes mellitus, PVD: Peripheral vascular disease.

the prevalence of symptomatic steal syndrome. The present retrospective study suggested no significant association between symptomatic steal syndrome and the control group regarding the anastomosis diameter.

The pathophysiology of steal syndrome is complex; however, physiological changes are predictable following a surgical construction of arteriovenous fistula [8]. One of these changes includes decreased resistance through the network and, thus, leads to an increase in cardiac output. There is a reversal flow in the distal arterial of the anastomosis bed in 80−90% of AVF. This process results in a retrograde flow in the artery distal to the anastomosis site. Regardless of these frequent and expected physiological changes from an AVF, clinical symptoms of ischemic steal syndrome occur in only 10−20% of cases, and severe symptoms occur in only 4% [9], [10].

It is very important to know the time of steal phenomenon occurrence and whether is early or late in the time course of the fistula. However, from the data available, it was not possible to know whether the steal phenomenon was late or early. Future studies with larger groups are recommended and it could address this important inquire.

Ischemic steal syndrome can lead to hypoxia, distal hypoperfusion, tissue necrosis, gradual loss of digits, and eventual peripheral ischemia. Steal syndrome is just one of the potential AV access complications [11], [12]. Although the occurrence of steal syndrome is relatively uncommon; it is still challenging to manage. It is important to understand the causes of this phenomenon, the following of which have been recognized and analyzed in the literature review: lack of collaterals, proximal stenotic lesion, reduced arterial pressure, and distal arteriopathy [10], [13].

This study revealed that patients >50 are at a higher risk of developing steal syndrome. In addition, Zamani *et al.* (2009) [14] reported similar findings, which showed a significant association between steal syndrome and elderly patients > 60 years old. However, our study found that patients >50 years old would also develop symptomatic steal syndrome. Our study clearly demonstrated that 77% of the study sample with symptomatic steal syndrome were > 50 years old.

Regarding the gender and steal syndrome association, the previous studies [12], [15], [16], [17] suggested that females would develop symptomatic steal syndrome more frequently than men. Our study revealed that female patients have more symptomatic steal syndrome incidence in comparison with men, and 49% of symptomatic steal syndrome were found in female patients. The size of the artery is smaller in women, which could be why women tend to develop symptomatic steal syndrome more than men.

AV access can influence the risk for the development of steal syndrome. A study by Tordoir *et al*. (2004) [18] reported that the radiocephalic (RC) access is recommended as the primary AV native vein access for patients with ESRD. If the RC matures, it provides long-term patency with the lowest risk factors associated with complications. In addition, when the RC fails, it does not affect the secondary AV access in the proximal site [16], [17]. The study also mentioned that brachiocephalic access is the second recommended access; however, BC access is associated with a higher risk of developing symptomatic steal syndrome than RC access [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21]. However, the findings of our study do not support the previous studies regarding the fistula location and symptomatic steal syndrome occurrence. Our study indicates that the radiocephalic fistulas were more associated with symptomatic steal syndrome (n = 46) than the brachiocephalic fistulas (n = 27). Perhaps, a larger study would clarify this grey area. Only four cases with brachiobasilic fistula had developed steal, and there was distal flow reversal in both radial and ulnar arteries.

It is well-established that symptomatic steal syndrome is associated with atherosclerosis risk factors and patients with DM, PVD, and cardiovascular disease will develop steal compared to other risk factors [21], [22]. General Linear Model Univariate Analysis was conducted to assess each independent variable and anastomosis diameter association. Our study shows that patients with DM, cardiovascular, and PVD are likely to develop symptomatic steal syndrome due to atherosclerosis, stenosis, and lack of collaterals.

The association of volume flow and symptomatic steal syndrome is well-investigated in the literature. The previous study showed that higher volume flow is associated with incidence of symptomatic steal syndrome especially in the brachiocephalic upper arm AVF [23]. In our study, there was noticeable increase of volume flow in patient with symptomatic steal syndrome. However, we have not reported these findings as our primary aim is to know the anastomosis diameter association between symptomatic steal syndrome versus control group.

This study was performed carefully to ensure minimal errors which were made; however, limitations are unavoidable. A small number of patients was

recruited in this study, which may have impacted the sample's accuracy and dependability. Another limitation includes the dependence of the ultrasound operator dependent on the machine. Therefore, further studies are recommended to assess the inter- and intraobserver variabilities. This study has raised many questions in need of further investigation. Further prospective study is required to determine the other clinical ultrasound diagnostic parameters such as flow volume, peak systolic velocities difference, flow volume, and diameter ratio difference between control and positive steal syndrome. A reproducibility study should be assessed when evaluating these parameters.

Conclusion

The incidence of steal syndrome is expected to increase due to the recent increase in the population of hemodialysis patients. The present study was designed retrospectively to demonstrate the association between anastomosis diameter and steal syndrome in hemodialysis patients with arteriovenous access. The study has shown no significant association between the anastomosis diameter and the incidence of steal syndrome. Further studies are essential to examine other diagnostic parameters of the AVF, such as flow volume and anastomosis diameter ratio and its association's impacts with the incidence of steal syndrome.

Ethics Approval

The University Ethics Committee approved this study (SCBR-033-2022); and the informed consent requirement was waived.

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References

1. McGrogan DG, Maxwell AP, Khawaja AZ, Inston NG. Current tools for prediction of arteriovenous fistula outcomes. Clin Kidney J. 2015;8(3):282-9. https://doi.org/10.1093/ckj/sfv019 PMid:26034589
2. Boyacıoğlu K, Kocamaz Ö, Mert B, Kayalar N, Erentuğ V. Distal radial artery ligation for treatment of steal syndrome in a distal radiocephalic arteriovenous fistula. Turkish J Thoracic Cardiovasc Surg. 2015;23(3):552-5. https://doi.org/10.5606/tgkdc.dergisi.2015.11142
3. Padberg FT Jr., Calligaro KD, Sidawy AN. Complications of arteriovenous hemodialysis access: Recognition and management. J Vasc Surg. 2008;48(5 Suppl):55S-80. https://doi.org/10.1016/j.jvs.2008.08.067 PMid:19000594
4. Malik J, Tuka V, Kasalova Z, Chytilova E, Slavikova M, Clagett P, *et al*. Understanding the dialysis access steal syndrome. A review of the etiologies, diagnosis, prevention, and treatment strategies. J Vasc Access. 2008;9(3):155-66. PMid:18850575
5. Yevzlin AS, Chan MR, Asif A. Hand ischemia in a patient with an arteriovenous fistula. Am J Kidney Dis. 2016;67(3):512-5. https://doi.org/10.1053/j.ajkd.2015.07.041 PMid:26612279
6. Leake AE, Winger DG, Leers SA, Gupta N, Dillavou ED. Management and outcomes of dialysis access-associated steal syndrome. J Vasc Surg. 2015;61(3):754-60. https://doi.org/10.1016/j.jvs.2014.10.038 PMid:25499703
7. Rutherford RB. Vascular Surgery. 6th ed. Philadelphia, USA: WB Saunders; 2005.
8. Lazarides MK, Staramos DN, Kopadis G, Maltezos C, Tzilalis VD, Georgiadis GS. Onset of arterial 'steal' following proximal angioaccess: Immediate and delayed types. Nephrol Dial Transplant. 2003;18(11):2387-90. https://doi.org/10.1093/ndt/gfg346 PMid:14551371
9. Visciano B, Riccio E, De Falco V, Musumeci A, Capuano I, Memoli A, *et al*. Complications of native arteriovenous fistula: The role of color Doppler ultrasonography. Ther Apher Dial. 2014;18(2):155-61. https://doi.org/10.1111/1744-9987.12073 PMid:24720406
10. Salman L, Maya ID, Asif A. Current concepts in the pathophysiology and management of arteriovenous access-induced hand ischemia. Adv Chronic Kidney Dis. 2009;16(5):371-7. https://doi.org/10.1053/j.ackd.2009.06.005 PMid:19695505
11. Leon C, Asif A. Arteriovenous access and hand pain: The distal hypoperfusion ischemic syndrome. Clin J Am Soc Nephrol. 2007;2(1):175-83. https://doi.org/10.2215/cjn.02230606 PMid:17699402
12. Stolic R. Most important chronic complications of arteriovenous fistulas for hemodialysis. Med Princ Pract. 2013;22(3):220-8. https://doi.org/10.1159/000343669 PMid:23128647
13. Alamshah SM, Nazari I, Nahidi A, Sametzadeh M, Khodabakhshi S. Prosthetic hemodialysis access-induced distal hand ischemia and its contributors in diabetics. Indian J Nephrol. 2017;27(3):199-204. https://doi.org/10.4103/0971-4065.202836 PMid:28553040
14. Zamani P, Kaufman J, Kinlay S. Ischemic steal syndrome following arm arteriovenous fistula for hemodialysis. Vasc Med. 2009;14(4):371-6. https://doi.org/10.1177/1358863X09102293 PMid:19808723
15. Wixon CL, Hughes JD, Mills JL. Understanding strategies for the treatment of ischemic steal syndrome after hemodialysis access. J Am Coll Surg. 2000;191(3):301-10. https://doi.

org/10.1016/s1072-7515(00)00335-5

PMid:10989904

16. Mickley V. Steal syndrome--strategies to preserve vascular access and extremity. Nephrol Dial Transplant. 2008;23(1):19-24. https://doi.org/10.1093/ndt/gfm673

PMid:17905806

17. Minion DJ, Moore E, Endean E. Revision using distal inflow: A novel approach to dialysis-associated steal syndrome. Ann Vasc Surg. 2005;19(5):625-8. https://doi.org/10.1007/s10016-005-5827-7

PMid:16052391

18. Tordoir JH, Dammers R, van der Sande FM. Upper extremity ischemia and hemodialysis vascular access. Eur J Vasc Endovasc Surg. 2004;27(1):1-5. https://doi.org/10.1016/j.ejvs.2003.10.007

PMid:14652830

19. Scheltinga MR, Bruijninckx CM. Haemodialysis access-induced distal ischaemia (HAIDI) is caused by loco-regional hypotension but not by steal. Eur J Vasc Endovasc Surg. 2012;43(2):218-23. https://doi.org/10.1016/j.ejvs.2011.10.018

PMid:22119228

20. Van den Bosch RP, Crowe PM, Mosquera DA. Endovascular treatment of arterial steal secondary to dialysis fistula. Nephrol Dial Transplant. 2001;16(11):2279-80. https://doi.org/10.1093/ndt/16.11.2279

21. Yu SH, Cook PR, Canty TG, McGinn RF, Taft PM, Hye RJ. Hemodialysis-related steal syndrome: Predictive factors and response to treatment with the distal revascularization-interval ligation procedure. Ann Vasc Surg. 2008;22(2):210-4. https://doi.org/10.1016/j.avsg.2007.12.005

PMid:18346574

22. Zanow J, Kruger U, Scholz H. Proximalization of the arterial inflow: A new technique to treat access-related ischemia. J Vasc Surg. 2006;43(6):1216-21;discussion 1221. https://doi.org/10.1016/j.jvs.2006.01.025

PMid:16765242

23. Bavare CS, Bismuth J, El-Sayed HF, Huynh TT, Peden EK, Davies MG, *et al*. Volume flow measurements in arteriovenous dialysis access in patients with and without steal syndrome. Int J Vasc Med. 2013;2013:328601. https://doi.org/10.1155/2013/328601

PMid:24066232