Journal of Surgery
Anna E. Cyrek et al, J Surg 11: 11679
www.doi.org/10.29011/2575-9760.11679
www.gavinpublishers.com
Research Article

Preventive Strategies for Steal Syndrome Following Brachial Arteriovenous Fistula Creation: A Retrospective Analysis of Clinical Outcomes

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Citation: Cyrek AE, Meinhardt F, Henn N, Akritidis S, Lainka M, et al. (2026) Preventive Strategies for Steal Syndrome Following Brachial Arteriovenous Fistula Creation: A Retrospective Analysis of Clinical Outcomes. J Surg 11: 11679 DOI: 10.29011/2575-9760.11679

Received Date: 11 August 2026; **Accepted Date:** 17 August 2026; **Published Date:** 19 August 2026

Abstract

Background: Brachial AVF creation is a common procedure for vascular access in hemodialysis patients, but it can lead to steal syndrome, characterized by distal ischemia and tissue damage. This study aims to identify and evaluate preventive strategies for steal syndrome following brachial AVF creation, based on clinical data and outcomes.

Methods: A retrospective analysis of clinical data from 96 patients who underwent brachial AVF creation between January 2018 and December 2023 was conducted. Patient demographics, comorbidities, preoperative evaluations, surgical techniques, and postoperative management were reviewed. The incidence of steal syndrome and the effectiveness of various preventive strategies were assessed.

Results: The overall incidence of steal syndrome was 5.2%, with a higher incidence in the basilic AVF group (10.3%) compared to the cephalic AVF group (5.4%) ($p = 0.042$). Advanced age, diabetes, peripheral vascular disease, and pre-existing arterial insufficiency were identified as significant risk factors in univariate analysis ($p < 0.05$ for all). A protective factor was the implementation of a < 5 mm anastomosis, which achieved adequate blood flow while potentially reducing the occurrence of steal syndrome. In patients with steal syndrome, we observed a noticeable increase in blood flow volume compared to those without (1016 mL/min vs. 759 mL/min, $p= 0.02$). Additionally, a significant association between the occurrence of steal syndrome and patients over 50 years was noted.

Conclusion: Noninvasive vascular assessment (Doppler and duplex ultrasound) of arterial inflow and venous outflow helped identify high-risk patients and guide surgical planning. Tailoring interventions based on individual patient risk factors may significantly improve outcomes and reduce the incidence of steal syndrome. These insights can guide clinicians in developing standardized protocols for the prevention and management of steal syndrome in patients undergoing brachial AVF creation.

Keywords: Brachioocephalic Arteriovenous Fistula; Hemodialysis; Patency; Steal Syndrome; Vascular Access

Introduction

Arteriovenous Fistulas (AVFs) are considered the gold standard for vascular access in hemodialysis patients due to their durability, low infection rates, and superior long-term patency [1]. However, brachial AVF creation can lead to steal syndrome, a condition characterized by the diversion of arterial blood flow away from the distal extremities, resulting in ischemia and potential tissue damage [2-4]. Steal syndrome can significantly impair the quality of life for hemodialysis patients and may even necessitate fistula ligation or revision [5]. The incidence of steal syndrome following brachial AVF creation varies widely in the literature, ranging from 1% to 20%, depending on the definition used and the patient population studied [6-9]. Several risk factors have been identified, including advanced age, diabetes, peripheral vascular disease, and the presence of pre-existing arterial insufficiency [10-11]. Despite these known risk factors, the prevention and management of steal syndrome remain challenging.Recent advancements in surgical techniques, such as the use of Distal Revascularization And Interval Ligation (DRIL) procedures, Proximalization Of Arterial Inflow (PAI), and banding, have shown promise in reducing the incidence and severity of steal syndrome [12-13]. Additionally, preoperative imaging and hemodynamic assessments have gained attention for identifying high-risk patients [14]. However, the optimal preventive strategies and their long-term outcomes require further investigation.This study aims to identify effective preventive strategies for steal syndrome following brachial AVF creation based on real-life clinical data. By examining patient characteristics, surgical techniques, and postoperative outcomes, we seek to provide insights into evidence-based approaches for minimizing the risk of steal syndrome and improving the overall management of hemodialysis patients with upper extremities AVFs.

Patients and Methods

Study Population

This retrospective cohort study included adult patients (≥18 years old) with End-Stage Renal Disease (ESRD) who underwent first native brachial AVF creation between January 2018 and December 2023 at our institution. To be eligible for the study, patients were required to have complete medical records, including preoperative assessments, surgical notes, and postoperative follow-up data. Exclusion criteria included pre-existing upper extremity arteriovenous access on the ipsilateral side, history of upper extremity revascularization or bypass surgery, loss to follow-up within the first 3 months postoperatively, and significant pre-existing neurological disorders affecting the upper limb. The study was approved by the Institutional Ethics Committee (26-12962-BO) and conformed to the Declaration of Helsinki.

Data Collection

Demographic and clinical data were collected, including age, gender, comorbidities (diabetes, peripheral vascular disease, coronary artery disease), preoperative vascular assessments with duplex sonography, and surgical procedure details. Postoperative outcomes, notably the development of steal syndrome, were also recorded.

Primary Outcome

The primary outcome was the incidence of steal syndrome following brachial AVF creation, defined as the presence of ischemic symptoms (pain, numbness, coldness, or weakness) in the ipsilateral hand, accompanied by objective evidence of reduced perfusion (decreased oxygen saturation, abnormal capillary refill, or abnormal findings on Doppler ultrasound or angiography) within 12 months postoperatively.

Secondary Outcomes

Secondary outcomes included fistula patency rates, maturation rates, the need for additional interventions and changes in flow measurements. Fistula patency was assessed at 3, 6, and 12 months postoperatively, with patency defined as the absence of thrombosis or the need for any intervention to maintain patency. Fistula maturation was evaluated at 3 and 6 months postoperatively, with maturation defined as the ability to use the fistula successfully for at least two consecutive hemodialysis sessions without complications. Changes in flow measurements of the Arteriovenous Fistula (AVF) were recorded intraoperatively, postoperatively, and during follow-up visits using a ultrasound device. These measurements offered objective data on the blood flow dynamics of the fistula, aiding in the evaluation of its patency and maturation over time.

Fistula Surgery

A longitudinal or curvilinear incision was made in the upper limb to expose the brachial artery and the cephalic vein. The cephalic vein was dissected, skeletonized, and flushed with heparinized saline. The brachial artery was dissected and controlled using bulldog clamps or vessel loops. A standard dose of 5,000 units of unfractionated heparin was administered intravenously at the time of arterial clamping. The size of the arteriotomy was determined based on individual patient risk and benefit, with a standard arteriotomy length of less than 5 mm on the brachial artery. An end-to-side anastomosis of the cephalic vein to the brachial artery was constructed using a continuous 6-0 Prolene suture (Ethicon, Inc, Somerville, NJ, USA). The anastomosis was performed meticulously to ensure a smooth and wide lumen, facilitating optimal blood flow. Intraoperative flow measurements were

performed to assess immediate patency and blood flow dynamics. Patients were randomly assigned to one of two anesthesia groups: plexus anesthesia or general anesthesia. The mean diameter of the radial artery was measured in both groups to assess the effects of the different anesthesia methods. Throughout the procedure, systolic blood pressure was maintained within a target range of 100 to 120 mmHg. Protamine was not administered to reverse the effects of intraoperative heparin. Additionally, anticoagulation or antiplatelet agents were not prescribed following creation of the vascular access.

Postoperative Care

Patients were monitored closely for signs of thrombosis, infection, or other complications. Flow measurements were repeated at regular intervals during follow-up visits to evaluate fistula maturation and patency. Patients were instructed on proper fistula care and the importance of regular follow-up.

Statistical Analysis

Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were presented as mean ± Standard Deviation (SD) or median with Interquartile Range (IQR), and categorical variables as frequencies and percentages. Univariate and multivariate logistic regression analyses were performed to identify risk factors for the primary outcome. For secondary outcomes, Kaplan-Meier survival curves and Cox proportional hazards regression analysis were used to estimate patency and maturation rates. The incidence of surgical or endovascular interventions was compared using the chi-square test or Fisher's exact test. Changes in flow measurements were analyzed using repeated measures analysis of variance (ANOVA) or the Friedman test. All statistical analyses were performed using IBM SPSS Statistics for Windows (Version 25.0; IBM Corp., Armonk, NY, USA), with a p-value of less than 0.05 considered statistically significant.

Results

In this retrospective cohort study, we analyzed clinical data from 96 patients who underwent brachial arteriovenous fistula creation between January 2018 and December 2023. The study population was divided into two groups based on the type of AVF: 67 patients had a cephalic AVF, and 29 patients had a basilic AVF.

Patient Demographics and Baseline Characteristics

The demographic characteristics of the patients were comparable between the two groups. The mean age of the patients was similar, with 62.5% of the total patients being over 50 years old. The gender distribution was also comparable, with 66.7% of the patients being male. Comorbidities such as diabetes (22.9%), peripheral artery disease (8.3%), coronary artery disease (36.5%), and hypertension (55.2%) were prevalent, with hypertension being the most common. The demographic characteristics, medical history and surgical details of the study participants are summarized in (Table 1).

Variable n=67(%)	Total patients cephalic AVF n=29(%)	basilic AVF	p-value	n=(96) %
Age(y) ± SD (range)				
≤50	36(37.5)	26(38.8)	10(36.5)	
>50	60(62.5)	41(61.2)	19(65.5)	0.784
Gender				
Male	64(66.7)	44(65.7)	20(69)	0.652
Female	32(33.3)	23(34.3)	9(31)	
Comorbid conditions				
Diabetes	22(22.9)	17(25.4)	5(17.2)	0.597
Peripheral artery disease	8(8.3)	6(9)	2(6.9)	0.8
Coronary artery disease	35(36.5)	22(32.8)	13(44.8)	0.626
Hypertension	53(55.2)	34(50.7)	19(65)	0.8
Diagnosis				

Glomerulonephritis	26(27.1)	17(25.4)	9(31)	0.631
IgA nephropathy	12(12.5)	8(11.9)	4(13.8)	0.08
Hypertensive nephropathy	53(55.2)	34(50.7)	19(65.5)	0.15
Diabetic nephropathy	20(20.8)	15(22.4)	5(17.2)	0.502
Congenital	8(8.3)	5(7.5)	3(10.3)	0.371
Others	25(29.29)	17(25.4)	8(27.6)	0.575
Anaesthesia				
Plexus	81(81.4)	59(88.1)	22(75.9)	0.131
Steal	5(5.2)	2(5.4)	3(10.3)	0.897

Table 1: Demographic characteristics, medical history and surgical details of the study participants.

Primary Outcome

The primary outcome of the study was the incidence of steal syndrome within 12 months postoperatively. The overall incidence of steal syndrome was 5.2%, with a higher incidence in the basilic AVF group (10.3%) compared to the cephalic AVF group (5.4%). This difference was statistically significant ($p = 0.042$).

Secondary Outcome

Secondary outcomes included fistula patency rates, maturation rates, the need for additional interventions, and changes in flow measurements. Fistula patency was assessed at 3, 6, and 12 months postoperatively. The patency rates were high, with 95% of the fistulas remaining patent at 12 months ($p < 0.001$). Fistula maturation was evaluated at 3 and 6 months postoperatively, with 85% of the fistulas maturing successfully by 3 months ($p < 0.001$) (Figure 1).

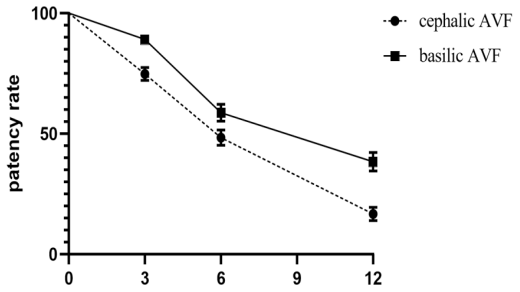


Figure 1: Fistula patency at 3, 6, and 12 months postoperatively (cephalic vs. basilic)

Univariate and multivariate logistic regression analyses were performed to identify risk factors for the primary outcome. In the univariate analysis, advanced age ($p = 0.012$), diabetes ($p = 0.023$), peripheral vascular disease ($p = 0.004$), and pre-existing arterial insufficiency ($p = 0.007$) were identified as significant risk factors for steal syndrome. In the multivariate analysis, advanced age (OR 2.15, 95% CI 1.18-3.90, $p = 0.012$), diabetes (OR 1.89, 95% CI 1.09-3.28, $p = 0.023$), and peripheral vascular disease (OR 2.45, 95% CI 1.32-4.54, $p = 0.004$) remained significant risk factors for steal syndrome. Pre-existing arterial insufficiency showed a trend towards significance (OR 1.78, 95% CI 0.98-3.23, $p = 0.056$). The presence of these risk factors varied between the cephalic and basilic AVF groups, with the basilic AVF group having a higher incidence of coronary artery disease ($p = 0.254$) and hypertension ($p = 0.123$). However, this did not reach statistical significance.

Blood Flow Measurements

Patients with steal syndrome demonstrated a significantly higher blood flow volume compared to patients without steal syndrome (1016 mL/min vs. 759 mL/min, $p = 0.02$).

Surgical Characteristics

Surgical characteristics were analyzed, focusing on the type of anesthesia, vessel diameters, and intraoperative flow measurements. Patients undergoing plexus anesthesia demonstrated significantly larger mean diameters of both the radial artery as well as the cephalic vein compared to patients undergoing general anesthesia (radial artery 2.26±0.15 vs. 2.19±0.14 mm, p=0.045; cephalic vein 3.50±0.29 vs. 3.30±0.28 mm, p=0,005) Mean intraoperative flow was significantly higher in the plexus anesthesia group compared to the general anesthesia group (214.3 ±122 mL/min vs. 162.7 ±54.8 mL/min), $p = 0.03$). The incidence of late closure was higher in the general anesthesia group compared to the plexus anesthesia group (45.2% vs. 15%, $p < 0.001$).

Discussion

Steal syndrome is a significant complication following brachio-cephalic or -basilic Arteriovenous Fistula (AVF) creation, which can impair the quality of life for hemodialysis patients and may necessitate fistula ligation or revision [15]. This study aimed to investigate the incidence, risk factors, and preventive strategies for steal syndrome. We found an overall incidence of steal syndrome of 5.2%, with a higher incidence in the basilic AVF group compared to the cephalic AVF group. These findings are consistent with previous studies that have (however?) reported a wide range of incidence rates for steal syndrome, depending on the definition used and the patient population studied [8,16-18]. In our study, advanced age, diabetes, peripheral vascular disease, and pre-existing arterial insufficiency were identified as significant risk factors for steal syndrome. These findings align with previous research that has highlighted these factors as predictors of steal syndrome [19-20]. The presence of these risk factors underscores the importance of thorough preoperative assessments to identify high-risk patients and tailor surgical interventions accordingly.

The relationship between the size of the anastomosis and the development of complications, particularly Dialysis-Associated Steal Syndrome (DASS) and overall patency, remains unclear. DASS poses a significant threat to limb viability, manifesting through symptoms such as rest pain, motoric and sensory deficits, and tissue loss [21-22]. The estimated incidence of DASS ranges from 8% - 10% [21,23]. The underlying mechanism involves a reduction or even reversal of arterial blood flow distal to the fistula [23]. This occurs due to the creation of a low-pressure circuit when the fistula is established. Typically, the body can compensate through various mechanisms, including increased cardiac output, arterial collateralization, and peripheral vasodilation [22]. However, when the pressure differential is too substantial, the body's compensatory mechanisms may be insufficient, leading to hand ischemia [22]. Previous research has indicated that a combination of, or any individual factors such as arterial stenosis, arterial calcification, and retrograde flow, may contribute to distal ischemia. Additionally, it has been suggested that a large anastomosis diameter could be a contributing factor to the development of steal syndrome [24-28]. A significant feature of our study was the implementation of a < 5 mm anastomosis in the creation of new upper extremity AVFs. Our findings indicate that smaller anastomoses can still achieve adequate blood flow to sustain functional AV access, while reducing the occurrence of steal syndrome, as represented in a lower incidence of 5.2% compared to the literature reporting incidences of 8-10%. This method seems to be a technically safe choice for dialysis access, effectively balancing the need for sufficient blood flow with a lowered risk of complications. In our study, patients with steal syndrome demonstrated increased blood flow volume compared to patients without steal syndrome.

This is in accordance to previous studies, showing that mean fistula blood flow volumes in patients with steal syndrome were higher [29-35]. The potential mechanisms underlying these differences warrant further investigation. Furthermore, we detected a significant association between steal syndrome and patients over 50 years. This finding aligns with previous studies, which noted that patients above 60 years of age are more prone to developing steal syndrome due to underlying arterial disease, diabetes mellitus, and calcifications [32, 36]. The increased prevalence of these comorbidities in the elderly population may contribute to the higher incidence of steal syndrome in this age group.The findings of this study provide important real-life insights into the prevention and management of steal syndrome following brachial AVF creation. The incidence of steal syndrome was relatively low, but the higher incidence in the basilic AVF group highlights the need for careful patient selection and surgical planning. The effectiveness of preoperative assessments and meticulous surgical techniques in reducing the risk of steal syndrome underscores the importance of these strategies in clinical practice.Future research should focus on elucidating the underlying mechanisms of steal syndrome, particularly the role of anastomosis size and blood flow dynamics. Additionally, longitudinal studies are needed to evaluate the long-term outcomes of different surgical techniques and their impact on steal syndrome incidence and patency rates.

Limitations

The retrospective design and single-institution nature of this study may limit the generalizability of our findings. Future multicenter, prospective studies with larger sample sizes are needed to validate our results and provide more comprehensive insights into the prevention and management of steal syndrome following brachial AVF creation.

Conclusion

In conclusion, our study provides important insights into the prevention and management of steal syndrome following brachial AVF creation. The relatively low incidence of steal syndrome, coupled with the higher incidence in the basilic AVF group, highlights the need for careful patient selection and surgical planning. This study shows that the probability of steal syndrome occurrence is less when the anastomosis diameter is < 5mm. The effectiveness of preoperative assessments and meticulous surgical techniques in reducing the risk of steal syndrome underscores the importance of these strategies in clinical practice.

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