Proximalization of arterial inflow with adjunctive arterial pressure measurements for management of hemodialysis access-induced distal ischemia

Samuel Paci, MD,[a,b] Vincent Narvaez, MD,[a,b] *and* Yana Etkin, MD,[a,b] *New Hyde Park and Manhasset, NY*

ABSTRACT

Hemodialysis access-induced distal ischemia (*HAIDI*) is an uncommon, yet potentially devastating, complication of hemodialysis access surgery. Management of HAIDI depends on the access' volume flow and may involve banding, proximalization of arterial inflow, revision using distal inflow, distal revascularization interval ligation, or access ligation. Various adjunctive techniques have been used to confirm improved distal arterial flow intraoperatively. Here, we present a case of a patient with grade 3 HAIDI treated with proximalization of arterial inflow technique with the adjunctive use of intra-arterial pressure gradient measurements. (J Vasc Surg Cases Innov Tech 2024;10:101590.)

Keywords: dialysis access, hemodialysis access-induced distal ischemia, proximalization of arterial inflow

In the United States, approximately 35.5 million people have chronic kidney disease.[1] An estimated 500,000 of these patients are hemodialysis-dependent. In 2021, an estimated 135,972 patients progressed to end-stage renal disease and 83.8% of these patients initiated in-center hemodialysis in the same year.[2] Hemodialysis access-induced distal ischemia (HAIDI) is an uncommon, yet potentially devastating, complication of hemodialysis access surgery affecting approximately 4% to 10% of patients.[3-5] Risk factors include peripheral vascular disease, large outflow conduits, multiple prior access procedures, diabetes mellitus, female sex, age >60 years, access relying on brachial artery inflow, and prior episodes of HAIDI.[5,6] Based on Society for Vascular Surgery guidelines, HAIDI has been classified into 4 grades ranging from no symptoms in grade 0 ischemia, slight coldness or numbness in grade 1, loss of sensation or pain during dialysis in grade 2, to ischemic rest pain and tissue loss in grade 3 ischemia.[7,8]

Diagnosis is based on a thorough history and physical exam and confirmed with noninvasive digital photoplethysmography with and without arteriovenous (AV) access compression. Augmentation of distal flow upon compression of AV access is diagnostic for HAIDI. Furthermore, duplex ultrasound examination is essential in determining the appropriate intervention for HAIDI based on the volume flow in the AV access.[9] Management is dependent on the degree of ischemia. Grades 0 and 1 can be managed with close observation, whereas grades 2 and 3 require intervention. There are multiple treatment options for HAIDI including banding, distal revascularization interval ligation (DRIL) procedures, proximalization of arterial inflow (PAI), and revision using distal inflow.[6,10] Various techniques have been developed to monitor the success of these procedures intraoperatively, including digital photoplethysmography, intraoperative flow monitoring using Doppler ultrasound examination, and intra-arterial pressure measurements.[11-13]

In this case, we highlight a patient with grade 3 HAIDI treated with PAI using a greater saphenous vein (GSV) conduit with adjunctive intraoperative intra-arterial pressure measurements to assess adequate distal perfusion. This case highlights the applicability of this technique in the different procedures that are used to treat HAIDI. The patient consented to publication.

CASE REPORT

This case is of a 48-year-old male patient with a history of insulin-dependent diabetes mellitus, bilateral below-knee amputations, and end-stage renal disease on hemodialysis via a right brachiocephalic AV fistula (AVF). He presented with an acutely infected right third digit with purulent drainage and evidence of ascending infection in the forearm. On further history, the patient noted hand pain with dialysis sessions that recently progressed to pain at rest, and he developed a nonhealing wound over the third digit >1 year earlier. He was taken to the operating room emergently by the orthopedic surgery team for right third digit open amputation and forearm incision and drainage. Vascular surgery was consulted after the initial source control procedure. On examination, the patient had nonpalpable radial and ulnar pulses, but a palpable brachial pulse in the affected extremity. With compression of the fistula, he had

From the Northwell Health, New Hyde Park[a] and the Department of Surgery at Zucker School of Medicne, Manhasset.[b]

Correspondence: Yana Etkin, MD, Northwell Health, 2000 Marcus Ave, Suite 300, New Hyde Park, NY 11042-1069 (e-mail: yetkin@northwell.edu).

The editors and reviewers of this article have no relevant financial relationships to disclose per the Journal policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

2468-4287

https://doi.org/10.1016/j.jvscit.2024.101590

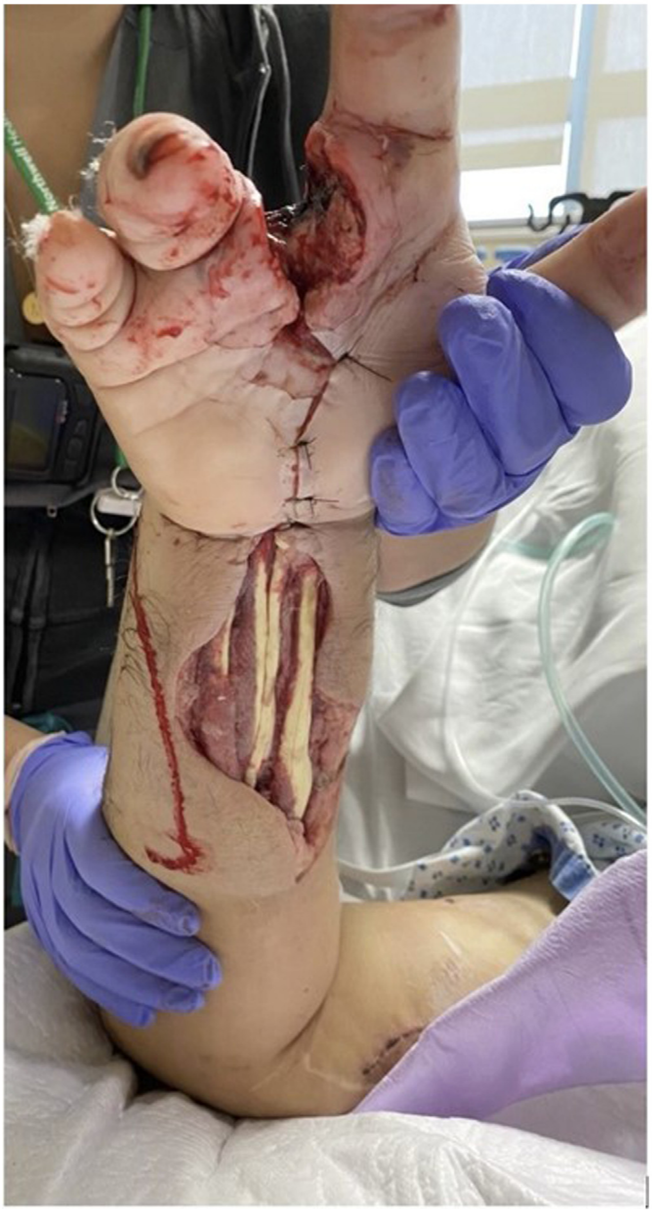

Fig 1. Grade 3 hemodialysis access-induced distal ischemia (*HAIDI*) after amputation and incision and drainage of right third digit.

a palpable ulnar pulse. There was ischemic ulceration at the tip of the right second digit, along with open wounds from his recent third digit amputation and incision and drainage (Fig 1). The duplex of the fistula demonstrated a volume flow of >2000 mL/min and retrograde flow in the brachial artery distal to the AVF. Digital photoplethysmography showed flat digital waveforms with augmentation upon compression of the fistula (Fig 2). A computed tomographic angiography of the right upper extremity was performed to evaluate proximal arterial anatomy. Computed tomographic angiography showed no significant arterial inflow disease and demonstrated severely calcified and diffusely diseased forearm vessels.

Based on the patient's clinical presentation and imaging, he was diagnosed with grade 3 HAIDI. Owing to the severity of his symptoms, the patient was not a good candidate for banding, because it carries a high risk of failure.[14] Furthermore, the patient did not have adequate forearm vessels that could be used as outflow for a DRIL procedure. The two viable treatment options included PAI or AVF ligation. Given that the patient had multiple failed AV accesses on the contralateral arm with limited options for future access if this AVF was ligated, the decision was made to perform an urgent PAI procedure using the GSV as a conduit and attempt to salvage his otherwise working dialysis access. We planned to obtain intra-arterial pressure measurements intraoperatively to guide the success of the procedure with the plan to ligate the AVF if adequate perfusion pressures were not achieved after PAI.

This operation was performed under general anesthesia. The proximal brachial artery and fistula just above the AV anastomosis were exposed and the right GSV was harvested. Before performing the proximalization, we measured perfusion in the hand by inserting a 20G catheter into the proximal fistula just after the arterial anastomosis, directing it toward the hand. The catheter was connected to an arterial line pressure transducer (Fig 3). At baseline, there was a flat waveform and no pressure measurements could be obtained. However, with compression of the fistula, the systolic blood pressure in the affected hand was comparable to the cuff pressures on the opposite side and there were pulsatile waveforms (Figs 4 and 5). The patient had adequate saphenous vein from the saphenofemoral junction down to the knee. PAI was performed by anastomosing one end of the reversed GSV to the outflow vein and the other end to the proximal brachial artery. Fistula was then ligated just distal to the proximalization. During the original AVF creation, distal brachial artery just above the antecubital fossa was used for inflow. During the PAI, the distal brachial artery just below the axilla was used to create a new arterial anastomosis, with the goal to use as proximal of an arterial inflow in the arm as possible. Distal perfusion was measured again by inserting the catheter in the fistula stump below the proximalization. The resultant arterial tracing was pulsatile and systolic blood pressure was comparable with the cuff systolic blood pressure in the left upper extremity and with initial pressures obtained with compression of the fistula (Fig 6). Our plan was to ligate the AV access if the pressure measurements were not adequate after PAI rather than using a more proximal inflow, such as the axillary artery in the chest. This decision was based on our belief that tunneling the vein conduit from the chest wall to the arm might lead to kinking of the vein and decreased patency.

Postoperatively, the patient underwent multiple debridements and eventual closure of his forearm wound. Throughout this time, the patient continued to get regularly scheduled hemodialysis via the right upper extremity AVF. During 1-year follow-up, the patient had a completely healed hand without any ischemic ulcerations or rest pain and well-functioning AVF (Fig 7). The measured volume flow on follow-up duplex examination was 873 mL/min.

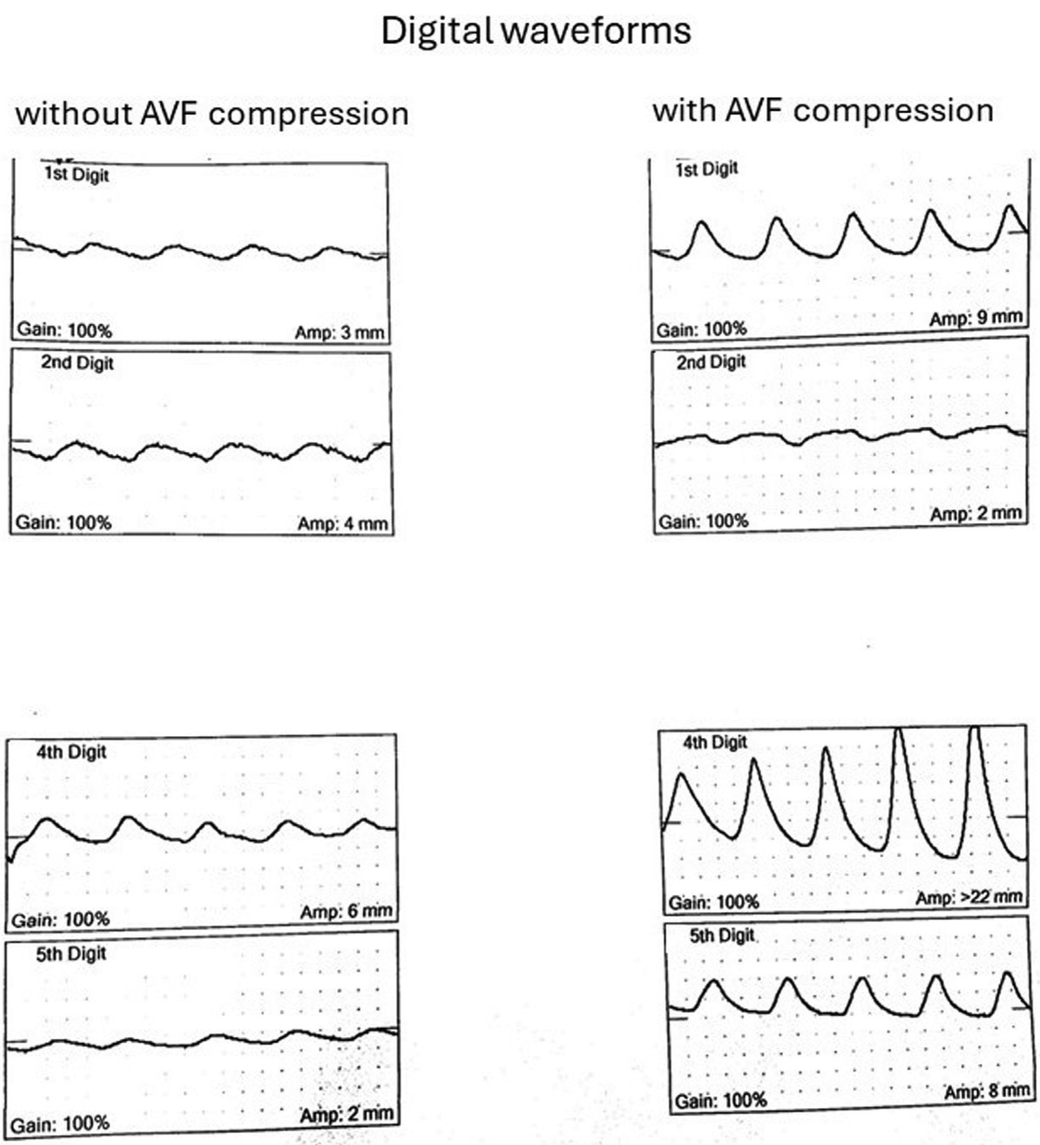

Fig 2. Digital photoplethysmography showing flat digital waveforms of the right upper extremity digits augmented by compression of arteriovenous fistula (*AVF*).

DISCUSSION

Although uncommon, HAIDI is a devastating complication of hemodialysis access surgery that can lead to increased morbidity. The prevalence of HAIDI ranges from <1% for forearm fistulas to ≤8% for brachial artery based access.[15] If clinically significant, HAIDI requires interventions to correct distal ischemia or ligation of a patient's working dialysis access, the lifeline for patients with end-stage renal disease. This procedure, in turn, could lead to multiple future interventions such as creation of a new AV access and temporary dialysis catheter placement.

Treatment should be individualized based on the patient's risk factors, clinical severity of ischemia, and the access characteristics such as location and volume flow.[8] Banding is the least invasive procedure and should be considered for high flow (>1 L) access. However, banding is associated with the highest rate of failure to manage HAIDI (33%), as well as the highest rate of access thrombosis (11%).[14] In our case, the degree of tissue loss and ischemia was too great to attempt banding.

Traditionally DRIL has been considered the gold standard for managing HAIDI. Multiple studies have demonstrated the safety and efficacy of this procedure, and a systematic review in 2019 demonstrated an 81% success rate at resolving ischemic symptoms and preserving AVF patency at 22 months.[10] DRIL reliably restores antegrade flow and eliminates the potential physiological pathway for steal and maintains continuous dialysis access, which is especially important in patients with difficult access.

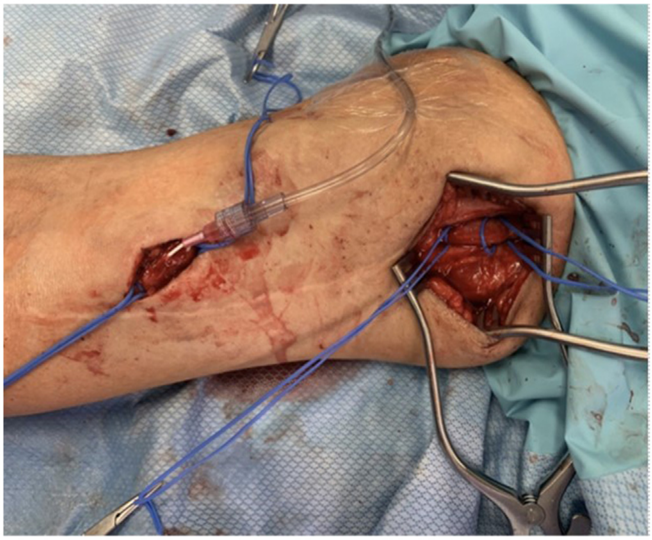

Fig 3. Measurement of distal arterial perfusion using arterial line set-up before proximalization.

However, it requires ligation of antegrade native arterial flow to the hand. The success of the procedure also depends on adequate outflow in the forearm that can be used as the target vessel for the bypass. Our patient was not a good candidate for DRIL because he had diffusely diseased ulnar and radial arteries.

Although DRIL might be the most effective procedure, there is a reluctance to ligate normal arteries supplying the distal arm, which led to the development of alternative treatment options including PAI. This technique does not sacrifice natural arterial continuity. The creation of a proximal arterial anastomosis increases flow to the forearm by increasing pressure at the split point between the distal circulation and the dialysis access. It also initiates collateral flow at a higher point in the arm which is advantageous to prevent or treat ischemic symptoms in the hand. A study that evaluated the effects of six HD access modifications on forearm flow showed that PAI approached DRIL in degree of improvement of forearm flow and seemed to be as effective without sacrificing natural arterial continuity.[16] Prior studies have also demonstrated good primary patency of AV access after PAI, ranging from 62% to 87% at 12 months, and secondary patency rates of 90% at 12 months, with complete resolution of ischemic symptoms in 84% of patients undergoing PAI.[17,18]

In situations such as this case, in which emergent revascularization is necessary owing to the degree of tissue loss, PAI is useful in both maintaining the patient's current usable access and ensuring adequate distal perfusion. PAI is commonly performed using prosthetic conduit, as originally described by Zanow et al in 2006.[17] Although graft infection rates are low for PAI (3%-7.5%), it is well-known that the rate of infection of AV grafts as compared with AVFs is significantly higher in the broader world of AV access (20% vs 5%, respectively).[19] Given the higher rate of infection with synthetic conduit in AV access and the infected field in our patient, we elected to use an autologous conduit. The use of autologous conduit has been described previously with PAI, and there were no reported cases of AV access infection and rates of AV access patency were similar compared with those reported by Zanow et al.[17]

The clinical success of PAI can be evaluated postoperatively based on physical examination and follow-up vascular imaging. Owing to the severity of ischemia in our patient, it was paramount to determine the success of PAI intraoperatively to avoid progressive tissue loss and a return to the operating room for further interventions. Measuring distal arterial pressure intraoperatively played an important role in our decision-making process to attempt AV access salvage. There are different techniques described to assess the adequacy of distal perfusion during banding procedures, but none have been reported for PAI procedures. A report by Turner et al[20] described the use of intraoperative duplex measurements of volume flow during banding to allow for a more precise reduction of volume flow while avoiding too much restriction leading to fistula thrombosis. This technique is not useful during PAI because volume flow in the access may increase after PAI, but distal perfusion also paradoxically increases as demonstrated by Gradman and Pozrikidis.[16] Additionally, other groups have used intraoperative digital photoplethysmography during banding procedures to titrate the degree of banding.[13]

In a previous series, Etkin et al[21] demonstrated the success of using distal arterial pressure measurements

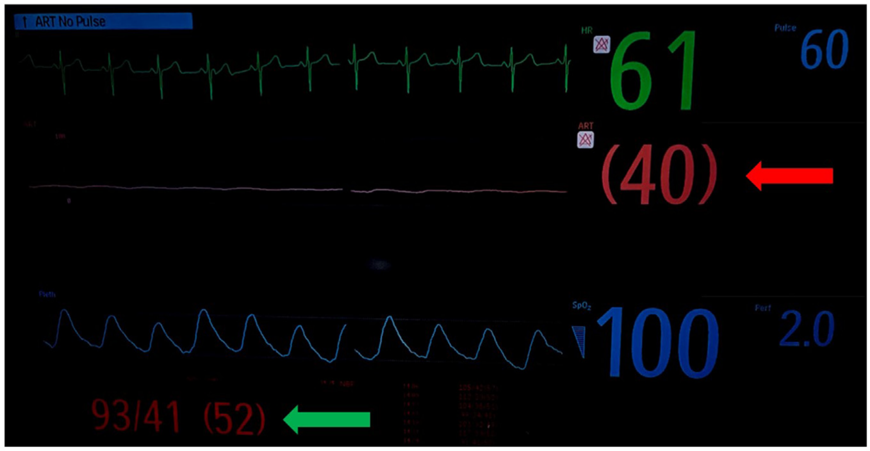

Fig 4. Distal perfusion pressure readings before proximalization without fistula compression showing flat waveforms (*red arrow*). Contralateral arm blood pressure (*green arrow*).

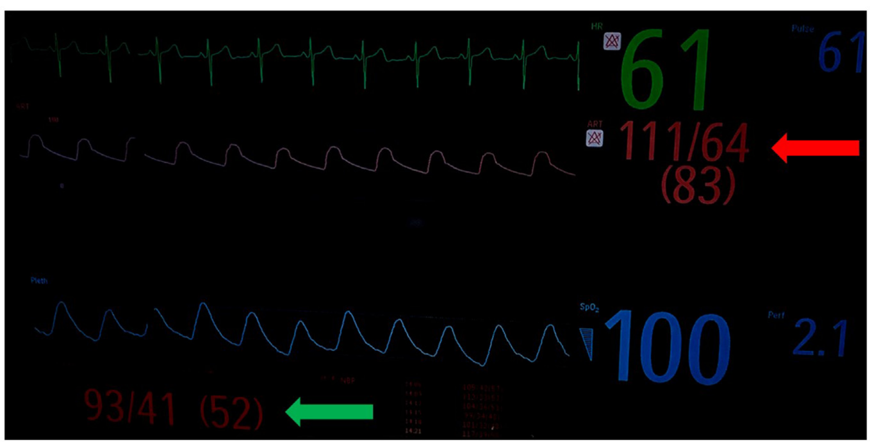

Fig 5. Distal perfusion pressure readings before proximalization with fistula compression showing augmented waveforms and systolic pressure of 111 mm Hg (*red arrow*), which correlated with contralateral arm pressures (*green arrow*).

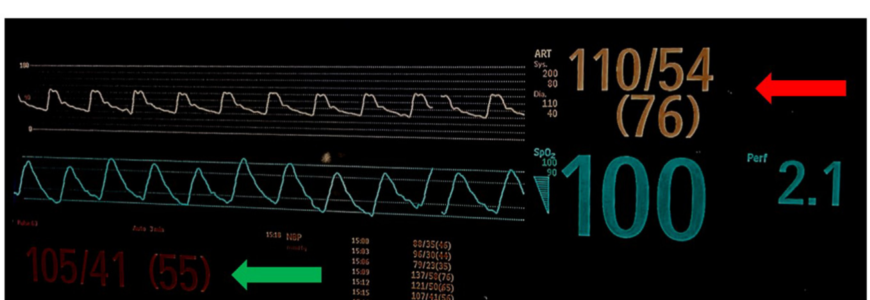

Fig 6. Distal perfusion pressure readings after proximalization of arterial inflow (*PAI*) without fistula compression showing improved waveforms and systolic pressure of 110 mm Hg (*red arrow*), correlating with the contralateral arm pressures (*green arrow*).

during banding procedures. Measurement of distal arterial pressure allowed the authors to titrate the degree of tightness of the banding to adequate distal perfusion measurements without sacrificing the flow through the fistula. In this series, 16 patients were treated with this method, and the authors achieved clinical success with resolution of HAIDI in 81% of patients without any incidence of access thrombosis.[21] In this report, we used

Fig 7. Completely healed hand 1 year after surgery.

the same technique to verify adequate distal perfusion with our PAI. This result highlights the portability and possible application of this simple technique in several methods of treating HAIDI. We advocate for this adjunctive technique to be used routinely during PAI and banding, especially in cases of severe tissue loss where prompt revascularization is imperative.

DISCLOSURES

None.

REFERENCES

1. Centers for Disease Control and Prevention. *Chronic Kidney Disease in the United States*. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention; 2023.
2. United States Renal Data System. *2023 USRDS annual data report: epidemiology of kidney disease in the United States*. Bethesda, MD: National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; 2023.
3. Morsy AH, Kulbaski M, Chen C, Isiklar H, Lumsden AB. Incidence and characteristics of patients with hand ischemia after hemodialysis access procedure. *J Surg Res*. 1998;74:8.
4. Padberg FT, Calligaro KD, Sidawy AN. Complications of arteriovenous hemodialysis access: recognition and management. *J Vasc Surg*. 2008;48:55S.
5. Davidson D, Lourdias G, Guzman R, et al. Steal syndrome complicating upper extremity hemoaccess procedures: incidence and risk factors. *Can J Surg*. 2003;46:408.
6. Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. *Am J Kidney Dis*. 2020;75(4 Suppl 2):S1.
7. Sidawy AN, Gray R, Besarab A, et al. Recommended standards for reports dealing with arteriovenous hemodialysis accesses. *J Vasc Surg*. 2002;35:603.
8. Beathard GA, Spergel LM. Hand ischemia associated with dialysis vascular access: an individualized access flow-based approach to therapy. *Semin Dial*. 2013;26:287–314.
9. Bavare CS, Bismuth J, El-Sayed HF, et al. Volume flow measurements in arteriovenous dialysis access in patients with and without steal syndrome. *Int J Vasc Med*. 2013;2013:328601.
10. Kordzadeh A, Parsa AD. A systematic review of distal revascularization and interval ligation for the treatment of vascular access-induced ischemia. *J Vasc Surg*. 2019;70:1364.
11. Fee HJ, Golding AL. Lower extremity ischemia after femoral arteriovenous bovine shunts. *Ann Surg*. 1978;183:42–45.
12. Schmidli J, Widmer MK, Basile C, et al. Vascular access: 2018 clinical practice guidelines of the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg*. 2018;55:757–818.
13. Odland MD, Kelly PH, Ney AL, Andersen RC, Bubrick MP. Management of dialysis-associated steal syndrome complicating upper extremity arteriovenous fistulas: use of intraoperative digital photoplethysmography. *Surgery*. 1991;110:664–669.
14. Leake AE, Winger DG, Leers SA, Gupta N, Dillavou ED. Management and outcomes of dialysis access-associated steal syndrome. *J Vasc Surg*. 2015;61:754–760.
15. Pirozzi N, De Alexandris L, Scrivano J, Fazzari L, Malik J. Ultrasound evaluation of dialysis access-related distal ischaemia. *J Vasc Access*. 2021;22(suppl):84–90.
16. Gradman WS, Pozrikidis C. Analysis of options for mitigating hemodialysis access-related ischemic steal phenomena. *Ann Vasc Surg*. 2004;18:59–65.
17. Zanow J, Kruger U, Scholz H. Proximalization of the arterial inflow: a new technique to treat access-related ischemia. *J Vasc Surg*. 2006;43:1216–1221.
18. Thermann F, Wollert U, Ukkat J, Dralle H. Proximalization of the arterial inflow (PAI) in patients with dialysis access-induced ischemic syndrome: first report on long-term clinical results. *J Vasc Access*. 2010;11:143–149.
19. Matoussevitch V, Konner K, Gawenda M, et al. A modified approach of proximalization of arterial inflow technique for hand ischemia in patients with matured basilic and cephalic veins. *Eur J Vasc Endovasc Surg*. 2014;48:472–476.
20. Turner AD, Chen M, Dahl N, Scoutt L, Dardik A, Ochoa Chaar CI. Intraoperative ultrasound guidance for banding of an arteriovenous fistula causing high cardiac output failure. *Ann Vasc Surg*. 2020;66:665.
21. Etkin Y, Silpe J, Mussa FF, Talathi S, Garuthara M, Landis GS. Modified banding of arteriovenous fistulas for the treatment of vascular access induced digital ischaemia. *Eur J Vasc Endovasc Surg*. 2021;53:26–29.

Submitted Jun 10, 2024; accepted Jul 12, 2024.