# Treatment of High Flow Arteriovenous Fistulas after Successful Renal Transplant Using a Simple Precision Banding Technique

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**Background:** Observation versus ligation of a functional arteriovenous fistula (AVF) after successful renal transplantation (SRT) has been a controversial topic of debate. Congestive heart failure and pulmonary hypertension are common in dialysis patients, and more frequent when vascular access flow is excessive. Renal transplant failure may occur in up to 34% of patients after 5 years, therefore maintaining a moderate flow AVF appears warranted. We review SRT patients with high flow−AVFs (HF−AVF) and clinical signs of heart failure where a modified precision banding procedure was used for access flow reduction.

**Methods:** Patients referred for HF−AVF evaluation after SRT were identified and records reviewed retrospectively. In addition to recording clinical signs of heart failure, each patient had ultrasound AVF flow measurement before and after temporary AVF occlusion of the access by digital compression. Pulse rate and the presence or absence of a cardiac murmur was noted before and after AVF compression. Adequacy of access flow restriction was evaluated intraoperatively using ultrasound flow measurements, adjusting the banding diameter in 0.5 mm increments to achieve the targeted AVF flow.

**Results:** Twelve patients were evaluated over a 19-month period. Eight (66%) were male and one (8%) obese. Ages were 15−73 years (mean = 42). The AVFs were established 24−86 months previously. The mean pulse rate declined after AVF compression from 90/min to 72/min (range 110−78). Six patients had a precompression cardiac flow murmur that disappeared with temporary AVF compression. One patient with poor cardiac function underwent immediate AVF ligation with dramatic improvement in cardiac status. All other patients underwent a precision banding procedure with real-time flow monitoring. Mean access flow was 2,280 mL/min (1,148−3,320 mL/min) before access banding and was 598 mL/min (481−876) after flow reduction. The clinical signs of heart failure disappeared in all patients. All AVFs remained patent although one individual later requested ligation for cosmesis. Two patients had renal transplant failure and later successfully used the AVF. Follow-up postbanding was 1−18 months (mean = 12).

**Conclusions:** Patients with successful renal transplants and HF−AVFs had resolution of heart failure findings and maintenance of access patency using a modified precision banding procedure. Flow reduction in symptomatic renal transplant patients with elevated access flow is recommended. Further study is warranted to substantiate these recommendations and clarify the appropriate thresholds for such interventions.

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## INTRODUCTION

The dilemma of observation versus ligation of a functional vascular access after successful renal transplantation (SRT) has long been an unresolved subject of debate among nephrologists, surgeons, cardiologists, and patients. Cardiac disease is common in dialysis patients including congestive heart failure, left ventricular (LV) hypertrophy, high-output cardiac failure, and myocardial ischemia. These conditions are more common in patients with a high flow vascular access.[1–4] Pulmonary hypertension, outflow or central venous stenosis, steal syndrome, and pseudoaneurysm formation may also be aggravated by excessive access flow.[1–7] These findings are thought to be more common when access flow exceeds 1,200–1,500 mL/min.[8] Maintaining a safe, moderate flow vascular access is warranted as kidney transplant failure may occur in up to 34% of patients after 5 years.[9] We reviewed a series of patients with SRTs and high flow–arteriovenous fistulas (HF–AVFs) where flow reduction was established using a modified precision banding procedure with intraoperative ultrasound flow measurements.

## METHODS

The medical records of all patients referred for HF–AVF evaluation after SRT were reviewed. Clinical signs and symptoms of heart failure such as shortness of breath, palpitations, or newly developed systolic murmur in addition to physical findings were indications for access flow reduction. In addition to obtaining a clinical history and physical examination, each patient had ultrasound AVF flow measurements before and after temporary access compression with digital occlusion for 3 min. Adequate AVF compression was ensured by the disappearance of the access bruit. Each patient's pulse rate and the presence or absence of a cardiac murmur was noted before and after AVF compression. In addition to the final diameter of each banding (flow restriction), prebanding and postbanding flow rates were included in the analysis. Ultrasound was used preoperatively by the surgeon to examine the AVF anastomosis, to ensure all outflow branches were identified and for planning the incision. Banding sites were located adjacent to the AVF anastomosis on the venous outflow conduit, just past of the mature HF–AVF operative field. Each banding was established with a transverse 2–3 cm incision and consisted of 2-0 polypropylene sutures (2) secured over a coronary dilator that served as a sizing dowel (Fig. 1). Two sutures were placed at the same site simply for security. This small incision was adequate for exposure and avoided the previous longitudinal AVF incision whereas leaving nearby cannulation sites undisturbed. The initial banding diameter created was 4 mm and ultrasound access flow was remeasured. The targeted postbanding flow was 500–800 mL/min, and the banding was made smaller or larger in one-half mm increments according to the flow recorded. Ultrasound access flow was measured in the brachial artery 5-cm proximal to the HF–AVF (Terason t3000; Teratech Corporation, Burlington, MA and Logiq-e; GE Healthcare Corporation, Fairfield, CT). Brachial artery flow volume was used as a surrogate for total AVF flow. Arterial flow distal to the AVF was judged to be insignificant when compared with the total access flow and the brachial artery site offered a reliable and simple location to measure flow with less turbulence and tortuosity.

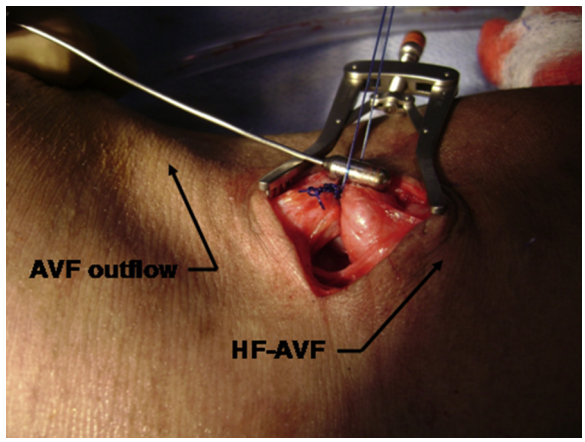


**Fig. 1.** The photo shows a precise banding of a HF–AVF using a coronary dilator as a dowel for reliable sizing of the restriction site. This simple flow restriction is created adjacent to the AVF anastomosis using polypropylene suture and sized in 0.5-mm increments. AVF flow rates are remeasured until the target access flow is achieved (500–800 mL/min). A second suture was placed at the same site for security.

Operations were performed in the outpatient surgery department of a university-affiliated tertiary medical center using local anesthetic and sedation. Data were analyzed using Prism 4 software with significance of differences determined at $P \leq 0.05$ (GraphPad Software, Inc., San Diego, CA). This study was approved by our institutional review board.

## RESULTS

Twelve patients with SRTs were evaluated for HF–AVFs during a 19-month period. Eight (66%) were

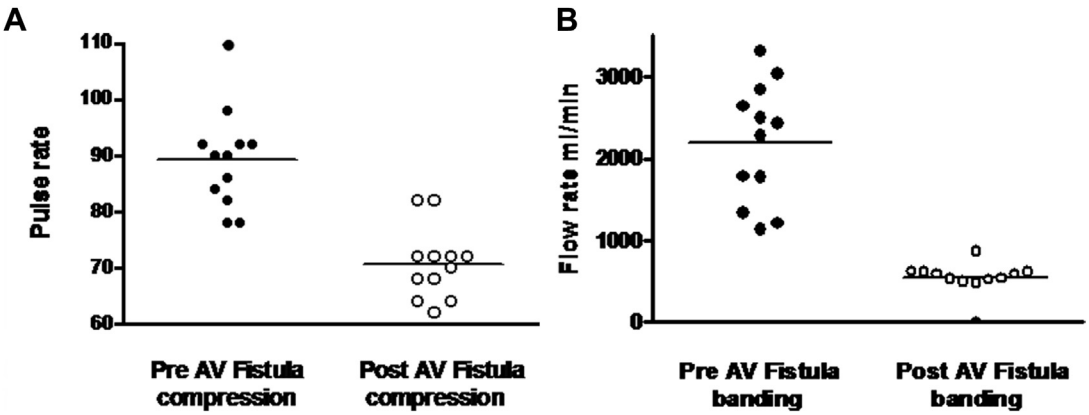


**Fig. 2.** (**A**) Temporary digital AVF occlusion resulted in a decrease in the mean pulse rate from 90/min to 72/min (range, 110−78), $P < 0.05$. (**B**) Mean access flow was 2,280 mL/min (1,148−3,320 mL/min) before flow reduction and was 598 mL/min (481−876) after flow reduction, $P < 0.01$. One patient with poor cardiac function underwent immediate AVF ligation.

male, and only one (8%) was obese. Ages were 15−73 years (mean = 42). The AVFs were established 24−86 months before this evaluation. The mean pulse rate declined after temporary digital AVF occlusion from 90/min to 72/min (110−78; Fig. 2A). One patient with poor cardiac function underwent immediate AVF ligation with dramatic improvement in cardiac status. All other patients underwent a precision banding procedure with intraoperative ultrasound access flow measurements. Mean access flow was 2,280 mL/min (1,148−3,320 mL/min) before access banding and was 598 m:/min (481−876) postprocedure, (Fig. 2B). Patients were generally seen 1-week postoperatively for wound evaluation and at 3−4 weeks for access flow and physical examination. Clinical signs of heart failure disappeared in each patient, and all AVFs remained patent after banding. Post banding access flow volumes remained stable. None of the patients developed recurrent signs of heart failure during the study period. One individual's AVF was pulsatile with chronic arm swelling and discomfort from venous hypertension due to recurrent central venous stenosis with large chest wall venous collaterals. After banding, the AVF was soft and asymptomatic; however, the patient later requested ligation for cosmesis. No other patients required access revision or intervention. Two patients had renal transplant failure and later successfully used the AVF. Follow-up post banding was 1−18 months (mean = 12). Patients were instructed to return for our evaluation at 12 months, and other follow-up was by dialysis clinic staff, nephrologist, and patient contact. Regular clinical follow-up was provided by the referring nephrologist who was fully informed of the findings and treatment. Absence of symptoms and physical findings of heart failure along with ultrasound AVF flow volume measurement confirmed the status of flow reduction.

Table I shows individual patient data for prebanding and postbanding AVF flow measurement, heart rate, clinical symptoms, and the presence or absence of a cardiac murmur in the study patients.

## DISCUSSION

This study demonstrated disappearance of clinical signs of heart failure using a modified simple banding procedure. The effects of AVFs on cardiac function in hemodialysis patients have been the subject of many research studies. Iwashima et al. evaluated patients before and up to 2 weeks after AVF creation and found significant elevations in LV end-diastolic diameter, ejection fraction, and cardiac output (CO). They also noted elevated levels of atrial and brain natriuretic peptides.[10] Similar findings were reported by Ori et al. at 1 and 3 months after AVF creation. They found increased cardiac index, LV mass, inferior vena cava diameter, and atrial natriuretic peptide, whereas systemic vascular resistance, plasma rennin, and aldosterone levels decreased.[11]

AVFs in postrenal transplant patients were included in a report by Cridlig et al. They noted a relationship between AVF flow volume and cardiac alterations. The highest access flow group had higher LV mass index, cardiac index, and right ventricular systolic function.[3] Other reports have similar findings before and after AVF creation with

**Table I.** Individual patient data for preb anding and postbanding of HF−AVFs

| Banding size | Access flow (mL/min) | | Pulse rate (rate/min) | | Cardiac murmur | | Dyspnea | | Palpitation | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter (mm) | Prebanding | Postbanding | Prebanding | Postbanding | Prebanding | Postbanding | Prebanding | Postbanding | Prebanding | Postbanding |
| 3 | 3,045 | 622 | 78 | 68 | No | | No | | No | |
| 3 | 1,789 | 488 | 90 | 72 | Yes | Resolved | No | | Yes | Resolved |
| 3 | 2,288 | 622 | 98 | 72 | No | | Yes | Resolved | Yes | Resolved |
| 3.5 | 1,780 | 598 | 82 | 64 | Yes | Resolved | No | | Yes | Resolved |
| 3.5 | 1,342 | 550 | 92 | 72 | Yes | Resolved | No | | No | |
| 3.5 | 1,148 | 510 | 84 | 82 | No | | No | | No | |
| 3.5 | 2,850 | 540 | 110 | 82 | No | | No | | Yes | Resolved |
| 4 | 3,320 | 599 | 78 | 62 | Yes | Resolved | Yes | Resolved | No | |
| 4 | 2,650 | 876 | 92 | 68 | Yes | Resolved | No | | No | |
| 4 | 2,510 | 632 | 86 | 72 | Yes | Resolved | No | | No | |
| Ligated | 1,220 | 0 | 92 | 64 | No | | Yes | Resolved | No | |
| 4 | 2,444 | 528 | 90 | 70 | Yes | Resolved | No | | No | |

an increase in LV end-diastolic and end-systolic diameter, left atrial diameter, LV mass index, and LV hypertrophy in addition to decreased ejection fractions.[12] A number of case report studies indirectly demonstrated the effects of AVFs in heart function when fistula ligation improved the LV function parameters.[13−17]

Several reports suggest that HF−AVFs with flow >1,500−2000 mL/min are frequently associated with high-output cardiac failure, decompensation of congestive heart failure, or with pulmonary hypertension.[8,18]

Studies specifically evaluating lower or moderate flow AVFs (500−1,200 mL/min) have not found a clear correlation between vascular access and heart failure in asymptomatic patients. Abbott et al.[19] after analyzing the United States Renal Data System Dialysis Morbidity and Mortality Wave II study concluded that there was no significant association between moderate flow AVF use and the incidence of heart failure or acute coronary syndrome. De Lima et al. followed successful renal transplant patients with functional AVFs (mean flow was 900 ± 350 mL/min) and other patients whose fistulas were closed. They concluded that the persistence of these moderate flow AVFs had little impact on cardiac morphology or function.[20] Soleimani et al. reached similar results. In their study group, the patients with patent AVF had mean fistula flow 560 ± 405 mL/min.[21]

Based on echocardiographic and clinical findings in dialysis patients, it seems reasonable to conclude that an HF−AVF is a key element in the appearance of heart failure. However, establishing parameters that define risk has been problematic. MacRae et al. suggested that patients who have a high ratio of access flow ($Q_a$) to CO (>30%) should undergo regular biannual echocardiographic assessment for LV end-diastolic and systolic dimensions, LV mass index, and ejection fraction. Patients who have elevated $Q_a$/CO ratios might be assessed for reduction of fistula flow.[2] Basile et al.[18] found high-output cardiac failure reliably predicted by AVF flow cutoff values ≥ 2.0 L/min. Valek et al. compared high flow AVFs (1,913 ± 447 mL/min) and moderate flow AVFs (610 ± 252 mL/min). The high flow group had statistically significant increase in the CO and LV volume and significant decrease in the peripheral resistance. They concluded that the moderate range of AVF flow (400−800 mL/min) does not increase the heart load significantly.[22] Malik et al.[8] retrospectively analyzed trials testing the influence of vascular access flow on the cardiovascular system and concluded that it is advisable to perform regular cardiac examinations and

echocardiography follow-up (at least once a year) in patients with access flow > 1,500 mL/min, with flow reduction surgery offered to patients with LV dilation, decreased ejection fraction, and/or the presence of cardiac symptoms. Although there is no clear upper limit of HF—AVFs above which an intervention is warranted, we feel that these reports justify access flow reduction for SRT patients with AVF flows higher than 1,200—1,500 mL/min, particularly in symptomatic patients.

Both Nicoladoni and Branham[23,24] are credited with noting the tachycardia associated with a high-flow AVF and the return of a normal pulse rate associated with compression of the fistula. The Nicoladoni—Branham sign is often used to describe these phenomena and reflects the change in CO and afterload after manually occluding the fistula. We felt the presence of this finding in SRT patients with HF—AVFs and other symptoms of heart failure was a clinical indication for access flow reduction.

AVF flow restriction by banding has been problematic for surgeons in the past. The dramatic change in access flows with very small incremental changes in outflow diameter is well established.[25] Empiric AVF banding too often results in negligible flow reduction from inadequate restriction or access thrombosis due to excessive narrowing. Miller et al developed a precise method of banding using an angioplasty balloon as a sizing dowel.[26] We used this technique successfully for both HF—AVF related hand ischemia and in patients with AVF associated venous hypertension due to recurrent central venous occlusion.[27] We modified the procedure as described here and find this technique to be simple, reliable, and less expensive; avoiding access cannulation, and angioplasty balloons used as a sizing dowel. Use of a precise sizing dowel assures a specific luminal restriction that may be easily changed in small, objective increments according to immediate postbanding ultrasound access flow measurement. Measuring brachial artery flow when evaluating a vascular access has been our practice for many years. The brachial artery is much straighter, superficial, and is a single conduit that allows quick and reliable ultrasound flow measurement. The distal arterial flow is proportionately quite small and will not impact clinical decisions based on this method of access flow measurement. AVF outflow veins often have many branches and changing dimensions in addition to circuitous pathways making direct outflow measurements problematic.

More complicated banding procedures such as wrapping the AVF with synthetic fabric are not necessary as the key element for success is flow measurement postbanding to confirm the proper restriction. We noted significant changes in access flow by adjusting the banding diameter in only 0.5-mm increments, emphasizing the precision afforded by this simple procedure. In our experience, this modified simple and precise banding technique is both reliable and durable and works well for AVFs of any size. The targeted AVF postbanding flow rate of 500—800 mL/min was chosen from our experience that AVFs offer adequate dialysis at 500 mL/min and remain patent at much lower flow, whereas access flow of 800 mL/min is well below the volume associated with heart failure.

We suggest that in patients with an SRT and an existing HF—AVF there is an important option other than access ligation or observation. Simple precision banding with intraoperative flow measurement is a reliable and reproducible method that allows the patient's AVF to remain functional with reduction of flow to an acceptable level, safe for long-term fistula preservation. We feel access flow restriction should also be considered for active dialysis patients with HF—AVFs, particularly in those individuals with heart failure symptoms. In our opinion, only rare dialysis patients with severe heart failure or pulmonary hypertension would be best treated by AVF ligation and placement of a dialysis catheter.

A limitation of this retrospective study is that more extensive investigations to confirm and stage the severity of heart failure were not judged to be necessary to proceed with flow reduction for this group of SRT patients with HF—AVFs. Palpitations occur frequently in patients suffering from hyperkinetic heart failure. A systolic murmur that disappears with AVF compression could be either ''functional'' because of hyperkinetic circulation or a result of secondary mitral regurgitation due to a failing left ventricle. The resolution of these clinical findings after flow reduction confirms the effectiveness of this simple procedure.

## CONCLUSIONS

Patients with successful renal transplants and high-flow AVFs had resolution of heart failure findings and maintenance of access patency using a modified precision banding procedure. Flow reduction in symptomatic renal transplant patients with elevated access flow is recommended. Further study is warranted to substantiate these recommendations and clarify the appropriate thresholds for such interventions.

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