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ORIGINAL ARTICLE

Outcomes of blood flow suppression methods of treating high flow access in hemodialysis patients with arteriovenous fistula

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ABSTRACT

Purpose: A high flow access (HFA) may cause heart failure in patients with an arteriovenous fistula (AVF) undergoing hemodialysis (HD) and is associated with poor prognosis. There are a variety of blood flow suppression techniques for treating HFA; however, the therapeutic outcome is still unclear.
Methods: The following three different blood flow suppression methods were performed on 74 patients with HFA: proximal artery banding with distal artery ligation (A-ban with A-lig: 12 cases); shunt vein banding (V-ban: 37 cases); and anastoplasty (Ana: 25 cases).
Results: There were no differences in the sex or mean age or duration of HD between the treatment groups. The A-ban with A-lig method was mainly selected for patients with a distal AVF and the anastoplasty method was selected most often for patients with a cubital AVF. The techniques were equally effective in reducing flow volume (FV) and the FV/cardiac output ratio (Flow/CO) to target levels, and clinical symptoms improved in all patients. The rates of HFA recurrence and AVF occlusion were significantly higher in the V-ban group (18.9% and 24.3%, respectively). A small proportion of patients in each treatment group developed a postoperative infection.
Conclusions: Each method proved to be an effective means of treating HFA. The choice of surgical method should be informed by the type of vascular access; however, the A-ban with A-lig and Ana methods appear to achieve clinically significant reductions in FV and have lower rates of HFA recurrence and AVF occlusion.

Keywords: Arteriovenous fistula, Anastoplasty, Banding, High flow access, Ligation, Surgical method

Introduction

Vascular access, for example via an arteriovenous fistula (AVF) or arteriovenous graft, is required for hemodialysis (HD) therapy; however, the resultant excessive nonphysiologic shunt significantly influences hemodynamic status and cardiac function (1). It has been reported that excessive blood flow volume (FV) often results in high-output heart failure, and that the excessive FV substantially contributes to the poor prognosis of patients requiring HD (2). In Japan, 27% of patients needing HD are reported to die from heart failure (3). In order to prevent heart failure, it is important to create, manage, or restore vascular access that can reduce the burden on the heart.

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The risk of high-output heart failure is reportedly significantly increased when the FV of the vascular access exceeds 1500-2000 ml/min, or the FV/cardiac output ratio (Flow/CO) exceeds 30-35% (4). Even when FV is less than 1500 ml/min, the Flow/CO ratio may be elevated in patients with impaired CO. A vascular access route is described as high flow access (HFA) when there is evidence that elevated FV is impairing circulatory dynamics (4), and a method of reducing FV should be identified. There are a variety of techniques for suppressing blood flow in an AVF (5-7), but the therapeutic outcomes are not completely understood. We examined the therapeutic outcomes of three different methods of blood flow suppression in patients with HFA.

Methods

Patients

We enrolled 74 patients undergoing maintenance HD who had high-output heart failure caused by HFA in an AVF between October 2007 and September 2014. Their demographic and clinical characteristics were recorded from their hospital records. The study protocol complied with the guidelines of the 2004 revision of the Declaration of Helsinki and

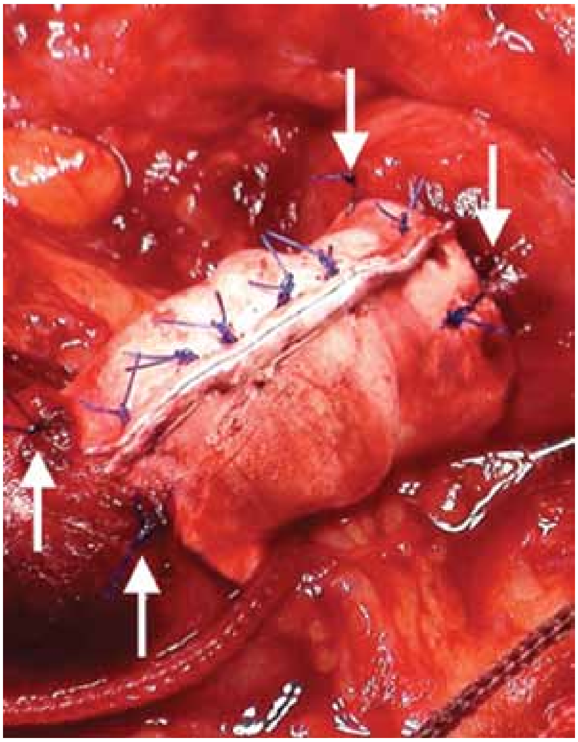

Fig. 1 - Site of banding with a vascular graft. In order to prevent slippage at the banding site, the vascular graft is turned inside out and wrapped around the blood vessel. Both ends of the vascular graft are fixed by two Z-sutures on the proximal and distal sides (arrow). The tightness of the banding is adjusted to the target FV according to blood flow volume measurement by ultrasound.

was approved by the ethics committee of Shinshu University (approval number: 2047). Written informed consent for use of clinical data was obtained from each patient.

Blood flow suppression methods

Three methods of blood flow suppression are employed at the Kanno Dialysis and Vascular Access Clinic; all were performed by one experienced surgeon and were selected according to an individual patient's requirements and the characteristics of their AVF.

Proximal artery banding and distal artery ligation of the AVF anastomosis (A-ban and A-lig)

The proximal and distal arteries of the AVF anastomosis are exposed; the proximal artery is banded and the distal artery ligated. An expanded polytetrafluoroethylene (ePTFE) vascular graft cut to a length of 2-4 cm is used for banding; ePTFE is chosen, as it is easy to handle and associated with a reduced incidence of infection. The vascular graft is turned inside out and wrapped around the blood vessel to prevent slippage at the banding site and recurrence of the HFA (Fig. 1). Both ends of the vascular graft are fixed by two Z-sutures on the proximal and distal sides. During surgery, FV is measured using Doppler ultrasound, and the extent of banding is adjusted to achieve an FV of 350-1000 ml/min.

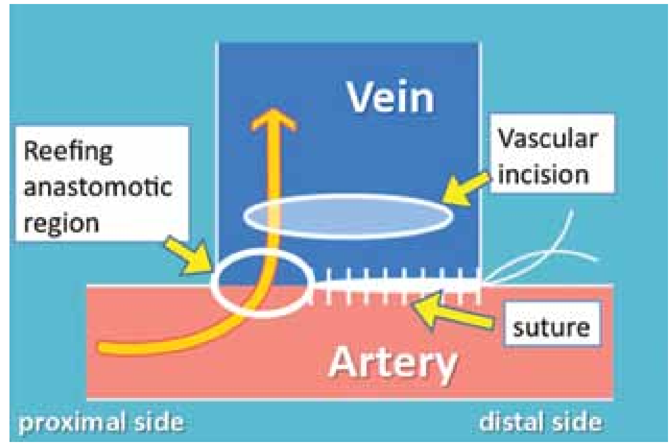

Fig. 2 - A schema showing the anastoplasty technique. After stopping blood flow, a transverse incision is made in the wall of the shunt vein. Under direct vision of the anastomotic site, the anastomotic lumen is reefed with a running suture, sewn in the internal vessel wall from the distal to the proximal side and back again, using a surgical suture applied from outside the blood vessel.

Shunt vein banding of the AVF anastomosis (V-ban)

The shunt vein of the AVF anastomosis is exposed and then banded using the same technique as for A-ban with A-lig.

Anastoplasty of the AVF anastomosis (Ana)

The proximal and distal arteries of the AVF and shunt vein are exposed and clamped temporarily to completely stop blood flow. A 1.0-1.5 cm transverse incision is made in the shunt vein wall immediately above the anastomotic site. Under direct vision, the lumen of the anastomosis is reefed using a running suture from the outside of the vessel to the inside, alternating between the distal aspect of the internal vessel wall to the proximal aspect and back again (Fig. 2). As this technique cannot be performed without stopping blood flow, FV cannot be measured by real-time Doppler ultrasound during the procedure, but can be altered by means of an adjustable suture once flow has been restored.

Selection of blood flow suppression technique

The A-ban with A-lig method is mostly indicated for an AVF in the anatomical snuffbox or a radiocephalic fistula above or at the wrist. It is particularly useful in cases wherein the V-ban method cannot be used due to significant enlargement or calcification of the shunt vein. The diameter of the banded proximal artery can be increased compared with other methods, as there is no blood flow from the distal artery, and thus the risk of AVF occlusion can be reduced.

The V-band method is indicated for an AVF in any part of the forearm except for the antecubital area at the elbow. This method is technically relatively easy and the arteries are not affected, making it suitable in many cases. In order to prevent HFA recurrence, it has been reported that banding using a long vascular graft (10 cm) is effective (8). When significant enlargement or calcification of the shunt vein or an anastomotic aneurysm is observed, it is not possible to achieve sufficient suppression of blood flow using this method.

The Ana method is indicated for AVF in most sites except the anatomical snuffbox and is suitable when the artery and/or shunt vein are enlarged, and—like the V-ban—the arteries are not affected. Nevertheless, the Ana method is technically challenging and is not suitable when there is anastomotic calcification.

Method of measuring flow volume

The mean blood FV (Vm-mean) was measured in both brachial arteries by Doppler ultrasound (Aplio 500, TUS-A500; Toshiba Medical Systems Co., Otawara, Japan) (9). FV was defined as the difference between flow in the arm with the shunt and the contralateral arm (10), and FVs were compared before and after blood flow suppression.

Statistical analysis

The extent of differences in continuous variables between the groups was examined using the Kruskal–Wallis test, and the Chi-square test was used to compare categorical variables. All statistical analyses were performed using SPSS version 18.0J (SPSS, Inc., Chicago, Illinois, USA). The level of statistical significance was set at p value less than 0.05.

Results

Patients' demographic and clinical characteristics

The A-ban with A-lig method was used in 12 out of 74 cases (16.2%), the V-ban method in 37 cases (50.0%) and the Ana method in 25 cases (33.8%). The demographic and clinical characteristics of the patients are summarized in Table I. There was no difference between the groups in terms of sex, mean age or the mean duration of HD therapy. The A-ban with A-lig method was mostly selected for patients with an AVF distal to the midpoint of the forearm. The other methods were selected regardless of the site of HFA; however, anastoplasty was most often selected for patients with an AVF in the cubital region.

Therapeutic outcomes

There was no significant difference between the respective methods in terms of the diameter of the vessel subjected to reefing. Although the mean preoperative FVs and Flow/COs of the groups were broadly comparable, theses ranges of those undergoing the V-ban method were greater than that of the other methods, suggesting that the patients in the V-ban group exhibited various level of FV (Tab. II, Fig. 3). Those patients who underwent the A-ban with A-lig method tended not to have as high an FV and Flow/CO than those who underwent V-ban or Ana surgery. The group of patients subjected to anastoplasty did not include patients with substantially higher FV, but did include some with higher Flow/CO, suggesting that some of the patients in this group had impaired cardiac function.

The median FV for the A-ban with A-lig method decreased from 1423 ml/min before surgery to 600 ml/min after surgery, the median FV for the V-ban method decreased from 1266 ml/min before surgery to 501 ml/min after surgery, and the FV for the Ana method decreased from 1333 ml/min before surgery to 614 ml/min after surgery. The target FV was achieved for all methods. Similarly, there were significant reductions in Flow/CO for all methods, but there was no difference in the extent of the reduction between the methods. There were also no significant differences in the proportion in which blood flow suppression was achieved, or the rate of

TABLE I - Baseline characteristics of patients undergoing maintenance hemodialysis (n = 74)

Baseline characteristics	All patients (n = 74)	A-ban with A-lig (n = 12)	V-ban (n = 37)	Anastoplasty (n = 25)
Age (years)	64 (29-86)	72 (39-86)	64 (38-83)	64 (29-86)
Sex (male, %)	62.2%	50.0%	62.2%	68.0%
Duration of HD (years)	7 (1-35)	6.5 (2-14)	7 (1-24)	7 (1-35)
Position of AVF, n (%)				
Anatomical snuffbox	1 (1.4%)	0 (0%)	1 (2.7%)	0 (0%)
Wrist	34 (45.9%)	11 (91.7%)	16 (43.2%)	7 (28.0%)
Above the wrist	25 (33.8%)	1 (8.3%)	13 (35.1%)	11 (44.0%)
Near the cubital region	4 (5.4%)	0 (0%)	3 (8.1%)	1 (4.0%)
Cubital region	10 (13.5%)	0 (0%)	4 (10.8%)	6 (24.0%)
Cause of CKD, n (%)				
Diabetes mellitus	13 (17.6%)	1 (8.3%)	7 (18.9%)	5 (20.0%)
CGN	24 (32.4%)	2 (16.7%)	14 (37.8%)	8 (32.0%)
Hypertension	9 (12.2%)	1 (8.3%)	5 (13.5%)	3 (12.0%)
Other	28 (37.8%)	8 (66.7%)	11 (29.7%)	9 (36.0%)

Continuous variables are shown as median (minimum–maximum).
AVF = arteriovenous fistula; CKD = chronic kidney disease; HD = hemodialysis; CGN = chronic glomerulonephritis.

TABLE II - Characteristics and outcomes of arteriovenous flow suppression surgery (n = 74)

Characteristic	All patients (n = 74)	A-band + A-lig (n = 12)	V-ban (n = 37)	Anastoplasty (n = 25)
Diameter of reefing region (mm)	2.5 (1.6-5.5)	2.5 (1.9-3.6)	2.2 (1.6-5.5)	2.6 (1.7-3.2)
FV(pre) (ml/min)	1303 (628-4612)	1423 (707-2453)	1266 (628-4612)	1333 (649-2408)
FV(post) (ml/min)	540 (167-1298)	600 (325-840)	501 (167-1298)	614 (343-1081)
ΔFV (%)	55.8 (21-91)	55.7 (31-78)	59.5 (21-91)	53.9 (24-83)
Flow/CO (%) (pre)	30 (13-77)	30 (13-53)	29 (15-75)	31 (20-77)
Flow/CO (%) (post)	13 (3-37)	16 (6-29)	12 (3-32)	14 (8-37)
ΔFlow/CO (%)	56 (10-91)	49 (38-70)	58 (10-91)	59 (10-87)
Recurrence (%)	9 (12.2)	1 (8.3)	7 (18.9)	1 (4)
Occlusion, n (%)	10 (13.5)	0 (0)	9 (24.3)*	1 (4)
Infection, n (%)	3 (4.1)	1 (8.3)	2 (5.4)	0 (0)
NYHA (pre), n (%)				
I	2 (2.7)	1 (8.3)	1 (2.7)	0 (0)
II	66 (76.7)	10 (83.3)	31 (83.8)	25 (100)
III	6 (7.0)	1 (8.3)	5 (13.5)	0 (0)
IV	0 (0)	0 (0)	0 (0)	0 (0)
NYHA (post), n (%)				
I	72 (97.3)	12 (100)	35 (94.6)	25 (100)
II	2 (2.7)	0 (0)	2 (5.4)	0 (0)
III	0 (0)	0 (0)	0 (0)	0 (0)
IV	0 (0)	0 (0)	0 (0)	0 (0)
Improvement of symptoms (%)	100	100	100	100

Continuous variables are shown as median (minimum–maximum).
CO = cardiac output; FV = flow volume; NYHA = New York Heart Association functional classification.
*p<0.05.

decrease in Flow/CO, between the treatment groups. However, the ranges of decreasing rate in FV and Flow/CO of the V-ban group tended to be greater than those of the other methods.

The rates of recurrence of HFA and AVF occlusion that required another intervention were 18.9% and 24.3%, respectively, in the V-ban group, which were both significantly higher than those for the other methods. Only a small proportion of patients developed a postoperative infection in each treatment group. Clinical symptoms caused by the HFA, and the New York Heart Association heart failure score, improved in all groups, and there were no significant differences between the treatment groups (Tab. II).

Discussion

We found that the A-ban with A-lig method can achieve reliable suppression of FV, with very low rates of HFA recurrence, AVF occlusion, and postoperative infection. The advantages of this method are that the artery can be banded relatively loosely as the distal artery is ligated, and FV can be measured accurately by ultrasound during surgery. These advantages likely account for the favorable therapeutic outcomes that we observed, but our findings may also be explained at least partly by the distal location of the AVF at the wrist, wherein FV and Flow/CO are relatively low compared with other positions. This technique, however, is much less suitable for HFA in the proximal arm, as it could induce a severe steal syndrome. We recommend that the A-ban with A-lig method is best suited for cases of HFA in a distal AVF near the wrist.

The V-ban method is indicated for various types of HFA and is less technically challenging than the other methods. Nonetheless, there is concern that sufficient FV suppression cannot be achieved by V-ban in cases with substantial enlargement and/or calcification of the shunt vein, cases with an anastomotic aneurysm, or cases in which the banding site includes the elbow. We avoided using V-ban in these circumstances. Nevertheless, we found that the ranges of diameters of the reefing region and of the extent of blood flow suppression were wider than those for the other methods, which might account for the high rates of HFA recurrence and AVF occlusion. These findings could also be explained by the presence of patients with very high initial FV and/or Flow/CO in this treatment group; more extensive HFA might also have resulted in less favorable outcomes compared with the other methods. Simple banding of the shunt vein may not reliably suppress FV, even for AVFs in relatively

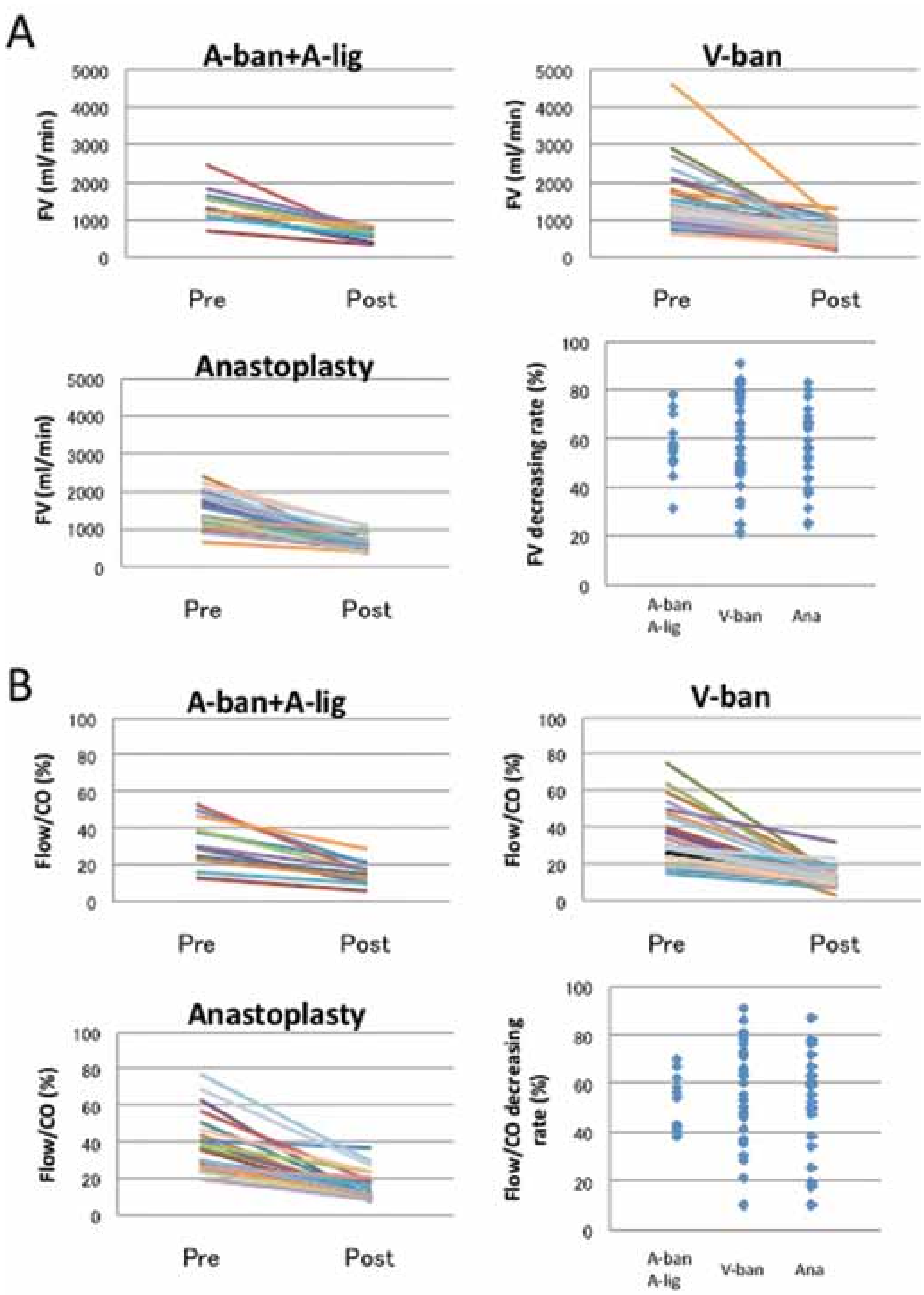

Fig. 3 - Changes in high flow access by blood flow suppression methods. (**A**) Changes in flow volume (FV) in the arteriovenous fistula in each treatment group. (**B**) Changes in FV/cardiac output (Flow/CO) in each group. A-ban with A-lig, proximal artery banding with distal artery ligation; V-ban, shunt vein banding; Ana, anastoplasty.

good condition. Further investigations of the indications for V-banding, as well as identifying a means of stabilizing or adjusting FV after V-banding, are needed.

The Ana technique can be used to achieve blood flow suppression in all cases of HFA. We selected the Ana method for patients with challenging AVF characteristics, such as patients with an AVF at the elbow. The V-ban method is not suitable for this type of AVF, because the vein is difficult to band by wrapping it with a vascular graft. Moreover, the A-ban with A-lig method is also not suitable, as there is a risk of peripheral distal ischemia due to artery ligation. We found that the Ana method achieved reliable and stable FV suppression, as well as low rates of HFA recurrence and AVF occlusion, even for difficult cases of HFA. We recommend that this method be selected as the first choice for managing HFA in the upper arm or cubital region. It has been reported that revision using distal inflow (RUDI) is useful for blood flow suppression in this area (11), but we believe that the Ana method can achieve equally favorable outcomes. Although the Ana method is not widely used in clinical practice at present, its popularity is likely to increase, as it is recognized that it can achieve good results in a wide range of cases of HFA.

In our cohort, sufficient FV suppression and improvement of clinical symptoms associated with the HFA were achieved by each method. Accordingly, the choice of method should be informed by the type of vascular access in an individual patient, and the indications for each method are different. The A-ban with A-lig and the Ana methods both appear to achieve reliable and stable suppression of FV with low rates of HFA recurrence and AVF occlusion. Further studies in larger cohorts are needed to confirm these findings. The long-term clinical outcomes of FV suppression methods are still not completely understood; however, the prognosis of the patient undergoing HD is likely to be improved by maintaining FV at the optimum level for as long as possible. Therefore, long-term follow-up studies are also required. In Japan, the number of elderly patients with cardiovascular disease who also require HD has been increasing. The leading cause of death in these patients is heart failure. As HD technology is refined and improves, the number of patients who will continue HD therapy for longer is also likely to increase, along with the importance of HFA as a complication. The development of more effective operative methods to control FV and a broader evidence base upon which to base clinical decision-making are therefore crucially important.

Our study had some limitations. First, the method was selected on the basis of the vascular access type and each patient's individual circumstances and was not randomized. Second, the technical difficulty of each method was not considered, and therapeutic outcomes might have been different if more than one surgeon had undertaken the procedures. Third, ours was a single-center investigation rather than a multicenter study.

Disclosures

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Conflict of interest: The authors have no competing interests to declare.
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