Therapeutic Outcomes from Blood Flow Suppression Methods of Arteriovenous Fistula in Japan

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Short title: Clinical outcomes by flow volume suppression methods

Abstract

Purpose: High flow access (HFA) causes heart failure in hemodialysis (HD) patients and is associated with poor prognosis. There are a variety of blood flow suppression methods 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 due to arteriovenous fistula (AVF): proximal artery banding + distal artery ligation (A-ban + A-lig: 12 cases); shunt vein banding (V-ban: 37 cases); and anastoplasty (Ana: 25 cases).

Results: There was no difference among the method group in age, sex, and the duration of HD. The A-ban + A-lig method was mainly selected for cases with distal AVF. The other methods were selected to various HFA, and the Ana method was often selected for cases with cubital AVF. The flow volume (FV) and the FV/cardiac output (Flow/CO) decreased to target levels by each method identically, and clinical symptoms were improved in all patients. In the V-ban method group, the rates in HFA recurrence and AVF occlusion were significantly high, 18.9% and 24.3% respectively. Only a small number of cases had postoperative infection for each method.

Conclusion: Each method achieved sufficient clinical outcomes against HFA. Surgical method should be selected depending on the vascular access type; however the both the A-ban+A-lig and the

Ana methods might be useful because of stable FV suppression and low rates of HFA recurrence and AVF occlusion.

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

Introduction

Arteriovenous fistula (AVF) and arteriovenous graft (AVG) are vascular accesses that are necessary for performing hemodialysis (HD) therapy. However, excessive unphysiological shunt blood flow significantly influences hemodynamics and the cardiac function (1). It has been reported that excessive blood flow volume (FV) often causes high-output heart failure, indicating that the excessive FV considerably contributes to a poor prognosis of HD patients (2). In Japan, 27% of HD patients were reported to die from heart failure (3). In order to prevent heart failure, it is important to create/manage/restore a vascular access that can reduce heart strain.

It has been reported that high-output heart failure is easily induced, when the FV of vascular access exceeds 1,500–2,000 mL/min or the flow volume/cardiac output (Flow/CO) exceeds 30–35% (4). Even if the FV is less than the above range, the patients can be diagnosed as having a relative high FV in case with poor circulatory condition. When the FV exceeds the acceptable range of circulatory dynamics in each patients, the vascular access should be determined as a high flow access (HFA) (4). In order to manage the HFA, the blood flow suppression method is needed. There are a variety of blood flow suppression methods for AVF (5–7). However, therapeutic outcomes of blood flow suppression methods are still unclear. This study investigated the therapeutic outcomes of three different blood flow suppression methods against HFA.

Methods

Patients

In this study, 74 maintenance HD patients, who had high-output heart failure caused by HFA in AVF, were examined from October 2007 to September 2014. The backgrounds and clinical data of the patients were analyzed based on information in their clinical records. The study protocol complied with the guidelines of the 2004 revision of the Declaration of Helsinki, and was approved by the ethics committee of Shinshu University (approval number: 2047). Written informed consent about using the clinical data for this study was obtained from each patient.

Blood flow suppression methods

At the Kanno Dialysis and Vascular Access Clinic, the following three different blood flow suppression methods were performed. Each surgical method was performed by an identical surgeon of this clinic.

The respective methods are described below.

1) Proximal artery banding + distal artery ligation for AVF anastomosis (A-ban+A-lig)

2) Shunt vein banding for AVF anastomosis (V-ban)

In the case of 1), the proximal artery and the distal artery of AVF anastomosis are exposed, and then banding of the proximal artery and ligation of the distal artery are performed.

In the case of 2), the shunt vein of AVF anastomosis is exposed, and then banding of the shunt vein is performed. In both techniques, a vascular graft cut to a length of 2–4 cm is used for banding. The material of vascular graft is ePTFE due to its ease of handling and infection prevention. Since a slip at the banding site often causes recurrence of HFA, the vascular graft is turned inside out and wrapped around the blood vessel in order to prevent a slip at the banding site (Fig. 1). Both ends of the vascular graft are fixed by a Z suture on the proximal side and the distal side with two threads. FV is measured using an ultrasound Doppler system during surgery, and the degree of banding was adjusted for controlling FV to the target level (350 to 1000 ml/min).

3) Anastoplasty for AVF anastomosis (Ana)

The proximal and distal arteries of the AVF anastomotic site, as well as the shunt vein, are totally exposed. These arteries and the shunt vein are clamped temporarily to completely block the blood flow. Then, the shunt vein wall immediately above the anastomotic site is transversely incised for about 1 to 1.5 cm. While observing inside lumen of the anastomotic site, reefing of anastomotic lumen is performed by running suture, which sew internal vessel wall from the distal side to the proximal side and then turn back to the distal side, using a surgical thread that are put into the inside lumen from outside of the blood vessel (Fig. 2). This technique cannot be performed without completely blocking the blood flow. Therefore, real-time ultrasound Doppler measurement of the FV is impossible during this surgery. In order to finely adjust the FV after the restart of the blood flow, utilization of an adjustable suture, which can make additional reefing of anastomotic lumen, might be useful.

Selection of the blood flow suppression method based on the features of the method

The A-ban + A-lig method is mainly indicated for AVF in the tabatiere, radiocephalic fistula at the wrist, and radiocephalic fistula above the wrist. In particular, it is actively indicated for cases for which V-ban method cannot be performed due to significant enlargement or calcification of the shunt vein. The banding diameter of the proximal artery can be increased as compared to other methods, because of no blood flow from the distal artery, and thus the risk of AVF occlusion can be reduced.

The V-band method is indicated for any region of the forearm except for the hinge cubital region. This method technic is relatively easy and advantageous in that the arterial system is not impaired. Therefore, this method can be indicated for many cases. In order to prevent recurrence of HFA, it is reported that banding using a vascular graft of long length (10 cm) is effective (8). When significant enlargement or calcification of the shunt vein or an anastomotic aneurysm is observed, sufficient blood flow suppression cannot be expected by this surgery method.

The Ana method is indicated for AVF in various sites except for in the tabatiere. This method is suitable for cases with enlarged artery and/or shunt vein, for which other banding methods are difficult to be indicated. This method is advantageous in that the artery is not impaired. However, this method is not suitable for cases with anastomotic calcification. In addition, since the operative site is an anastomotic site, the method is more difficult to perform than other methods.

In view of the above features of the respective methods, the surgeon made a decision on the selection of the method mainly based on the conditions of the AVF of each patient.

FV measurement technique

The blood flow volume (Vm-mean) of the brachial artery of a limb with a shunt and that of a limb without a shunt was measured by ultrasound Doppler measurement. The difference between the blood flows was determined to be FV (9). FV was measured using an APLIO500TSU-A500 ultrasound diagnostic system manufactured by TOSHIBA. FV results, obtained before and after the blood flow suppression method, were compared.

Statistical analysis

The continuous variables among groups were examined using the Kruskal–Wallis test. Categorical variable among groups were examined using Chi-squared test. All statistical analyses were performed using SPSS version 18.0J (SPSS, Inc., Chicago, IL, USA). The level of statistical significance was set at $P < 0.05$.

Results

Patient's background

For patients (74 cases) diagnosed with high-output heart failure due to the HFA of the AVF, A-ban + A-lig method (12 cases), V-ban method (37 cases), and Ana method (25 cases) were performed. Table1 shows the background of each patient who received treatment. There was no difference among the methods in age, sex, and the duration of HD therapy. The A-ban + A-lig method was mainly selected for cases with distal AVF below the middle of the forearm. The other methods were selected regardless of the site of HFA; however, the anastoplasty was often selected for cases with AVF formed on the cubital region.

Therapeutic outcomes

Therapeutic outcomes are obtained as follows (Table 2). There was no significant difference among the respective methods in the diameter of the vessel subjected to reefing; however, there was a large dispersion in V-band method compared with the other methods.

The group of patients subjected to the A-ban + A-lig method did not include patients having significantly higher FV and/or Flow/CO than those for patients in the other groups (Fig. 3). The group of patients subjected to the V-band method included patients with significantly high levels of FV and Flow/CO, and there was a large numerical dispersion in the group, suggesting that the patients in this group exhibited various level of FV. The group of patients subjected to anastoplasty did not include patients with obviously high levels of FV but included patients with high levels of Flow/CO, suggesting that the patients in this group exhibited the reduced cardiac function.

FV for A-ban + A-lig method decreased from 1423 ml/min (median value) (before surgery) to 600 ml/min (after surgery), FV for V-ban method decreased from 1266 ml/min (before surgery) to 501 ml/min (after surgery), and FV for Ana method decreased from 1333 ml/min (before surgery) to 614 ml/min (after surgery). Thus, FV decreased to the optimum level by each method. Similarly, Flow/CO also significantly decreased with no difference among the methods. There was no significant difference among the respective methods regarding the blood flow suppression rate and the rate of decrease in Flow/CO. However, there appeared to be larger numerical dispersion in V-band method than that in the other methods. In the V-band method group, the rates of recurrence of HFA and AVF occlusion that required another intervention were 18.9% and 24.3% respectively, which were significantly higher than those for the other methods. Only a small number of patients had postoperative infection for each method. The improvements of clinical symptoms of the HFA, as well as reduction in the heart failure score, were identically confirmed for each method (Table 2).

Discussion

The results of this study revealed that the A-ban + A-lig method can achieve stable FV suppression and very low rates of HFA recurrence and AVF occlusion. This method is advantageous in that banding of the artery can be performed relatively loose because of ligation of the distal artery, and accurate measurement of FV by echography is possible during surgery. These advantages probably resulted in favorable therapeutic outcomes. Since this method was actively indicated to the patients with distal AVF on the wrist, it is possible that their relative low level of original FV and Flow/CO caused stable therapeutic outcomes. The current results demonstrated that the A-ban + A-lig method is a very useful stable method with low rates of HFA recurrence, AVF occlusion, and postoperative infection. However, this method might be hardly indicated to the HFA on the proximal side of the arm, since it might induce the severe steal syndrome. This method should be indicated for cases with distal AVF near the wrist.

The V-ban method can be indicated for various types of HFA, and it can be more easily performed than the other methods. However, there is concern that sufficient FV suppression cannot be achieved by the V-ban methods, in cases with an obvious enlarged and/or calcification of shunt vein, cases with an anastomotic aneurysm, and cases in which the banding site includes the hinge cubital region. In this study, the V-ban methods were not selected when the patient was determined to correspond to above cases. Nevertheless, the results of this study show that there was a larger dispersion in the diameter of the reefing region and the blood flow suppression rate than those in the other methods, which might result in high rates of HFA recurrence and AVF occlusion. Since patients with very high initial FV and/or Flow/CO were included, these severe HFA condition might have caused unstable therapeutic outcomes compared with the other methods. Meanwhile, the current results might suggest that the simple banding of the shunt vein is difficult to suppress FV stably, even when AVF with relatively good conditions are selected. Further investigation on indications of V-band method, as well as development of novel method for stabilization of FV after V-banding, will be required.

The Ana method is a blood flow suppression method that can be applied to all cases of HFA. In this study, the Ana method was actively selected for the cases with AVF of difficult conditions, such as cases with AVF on the hinge cubital region. The V-ban method is not suitable for this type of AVF, because vein banding by wrapping with a vascular graft is difficult. Moreover, the A-ban + A-lig method is also not suitable, because there is the risk of ischemia of peripheral tissue due to artery ligation. The current study demonstrated that the Ana method provides good and stable effects of FV suppression, as well as good outcomes with low rates of HFA recurrence and AVF occlusion, even for difficult condition of HFA. This method should be selected as a first choice for HFA ranging from the cubital region to the upper arm. It has been reported that revision using distal inflow (RUDI) is useful for blood flow suppression in such region (10). However, the Ana method is considered a good method comparable to RUDI. Although the Ana method is not widely known at present, it is expected to be indicated for various HFA cases because of good performance.

In the current study, sufficient FV suppression and improvement of clinical symptoms associated with HFA could be obtained by each method. Accordingly, when selecting a method, it would be most important to select the most appropriate method depending on the vascular access type of each patient. Indications of the respective methods are different. However, the A-ban + A-lig method and the Ana method would be very useful because of stable blood flow suppression and low rates of HFA recurrence and AVF occlusion. Further accumulation of the cases is necessary in the future. Today, long-term clinical results due to FV suppression methods remain unclear; however the prognosis of the HD patient is expected to be improved by long-term controlling FV to the optimum level. Thus, there is a need to conduct a long-term observation study. In Japan, the number of elderly HD patients with various cardiovascular diseases has been increasing. The leading cause of death among them is heart failure. In addition, along with the progress in HD technology, the number of patients who will continue HD therapy for a longer period increases. In the future, it is highly probable that the HFA will be a further important issue for HD patients. Therefore, the development of more effective operative methods and decision-making on indications are important.

The limitations of this study are as follows: (1) since the method was selected based on the vascular access type and patient’s general conditions, the selection of blood flow suppression method was not randomized; (2) since the technical difficulty level of each surgery method was not considered, different therapeutic outcomes could be obtained if a different surgeon performed the method; and (3) this study was conducted as a single-center investigation and thus multiple-center investigation is also necessary.

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Figure legends

Figure 1

The site of banding with a vascular graft. In order to prevent a slip at the banding site, the vascular graft is turned inside out and wrapped around the blood vessel when used. Both ends of the vascular graft are fixed by a Z suture on the proximal side and the distal side with two threads (arrow). The strength of banding is adjusted by controlling the flow volume by echography.

Figure 2

The schema of anastoplasty. After blocking the blood flow, the shunt vein wall is transversely incised. While observing inside lumen of the anastomotic site, reefing of anastomotic lumen is performed by running suture, which sew internal vessel wall from the distal side to the proximal side and then turn back to the distal side, using a surgical thread that are put into the inside lumen from outside of the blood vessel.

Figure 3

The changes of high flow access by blood flow suppression methods. (A) The changes of flow volume (FV) of arteriovenous fistula in each therapeutic group of HD patients. (B) The changes of flow volume/cardiac output (Flow/CO) in each group. A-ban + A-lig, proximal artery banding + distal artery ligation; V-ban, shunt vein banding; Ana, anastoplasty.

Table 1 Baseline characteristics of maintenance HD patients (N = 74)

Baseline characteristics	All Patients (n=74)	A-ban+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%	62.2%	68%
Duration of HD (years)	7 (1–35)	6.5 (2–14)	7 (1–24)	7 (1–35)
Position of AVF, n (%)				
Tabatier	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 2 Clinical effects of arteriovenous flow depression surgeries (N = 74)

Clinical effects	**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)
Δ FV (%)	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)
Δ Flow/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 symptom (%)	100	100	100	100

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

Fig 1

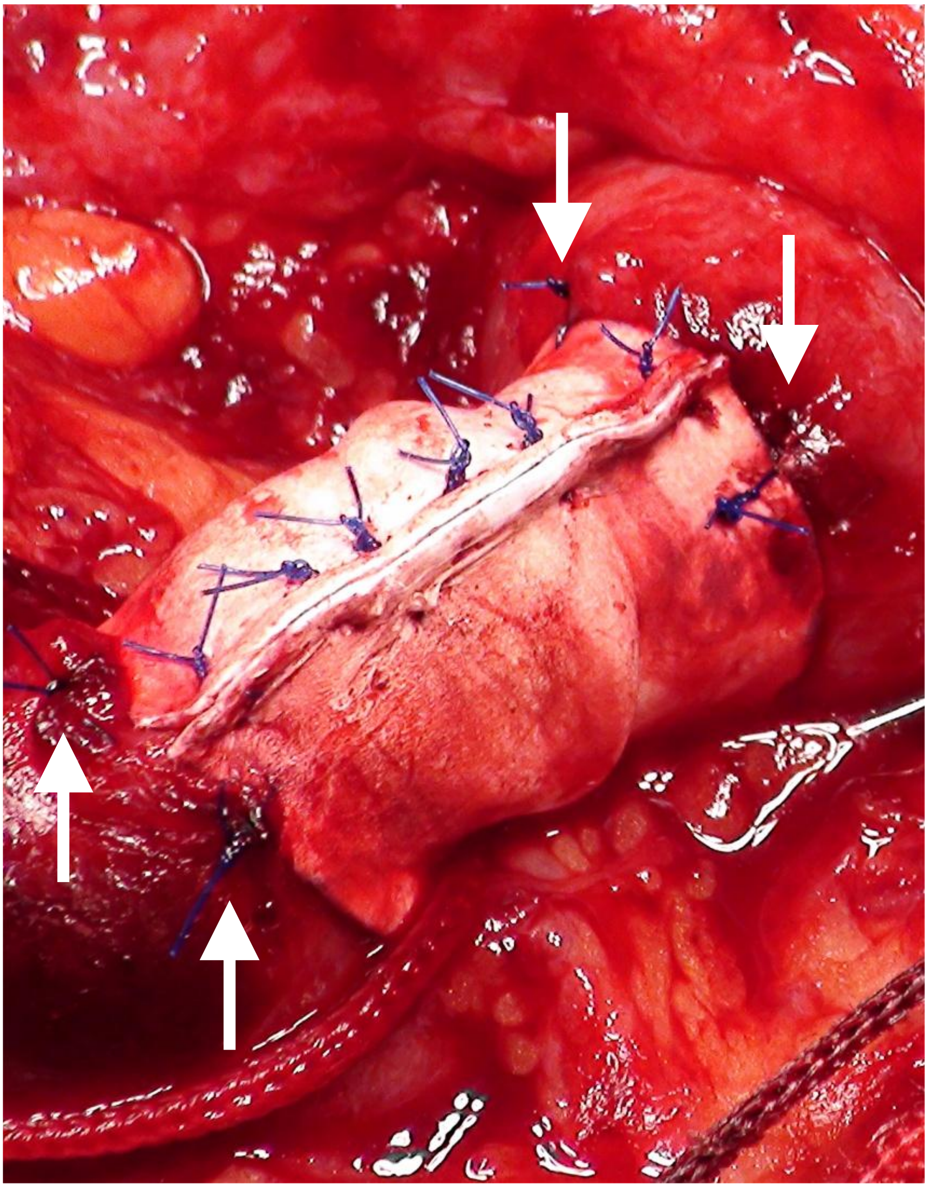


Fig 2

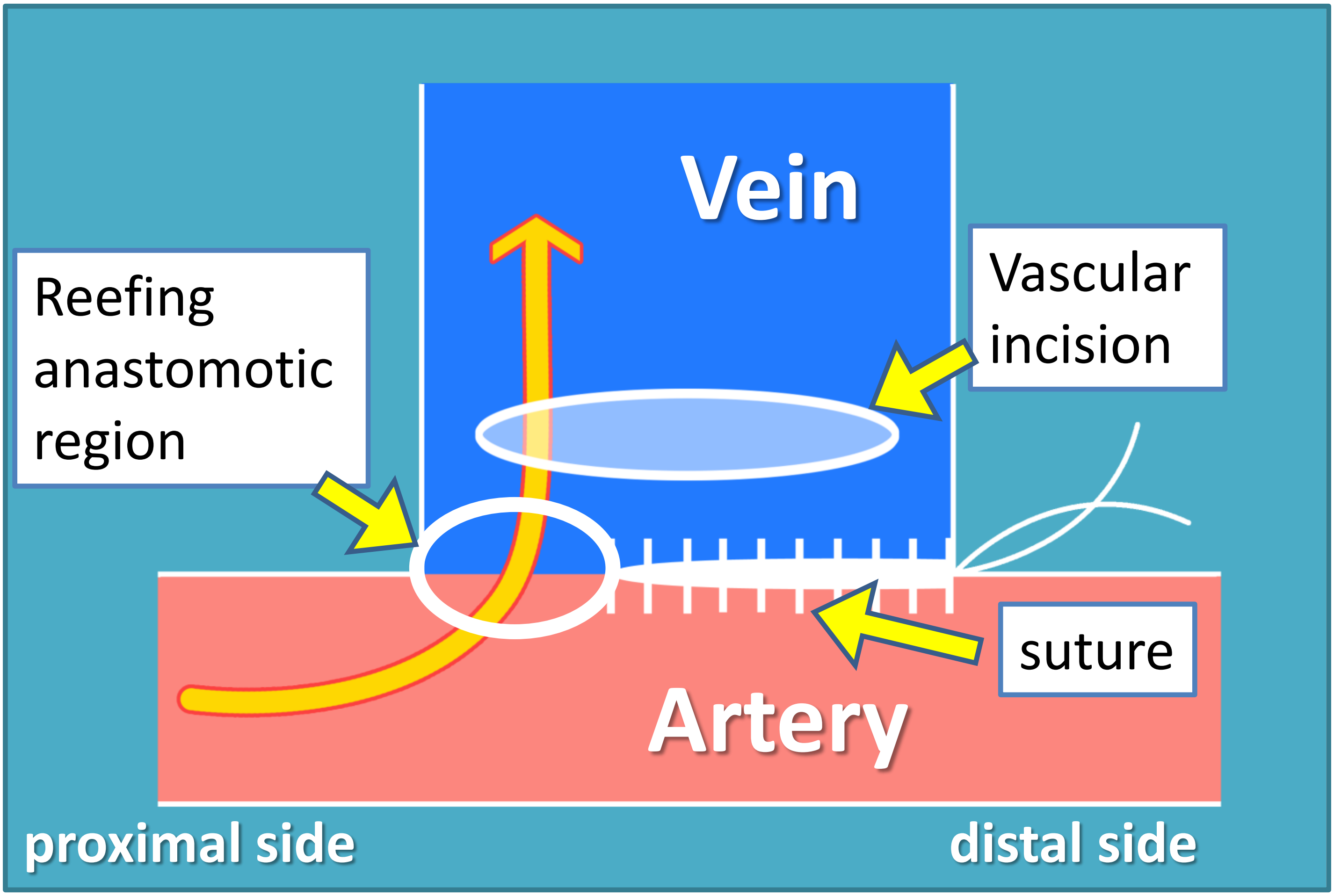
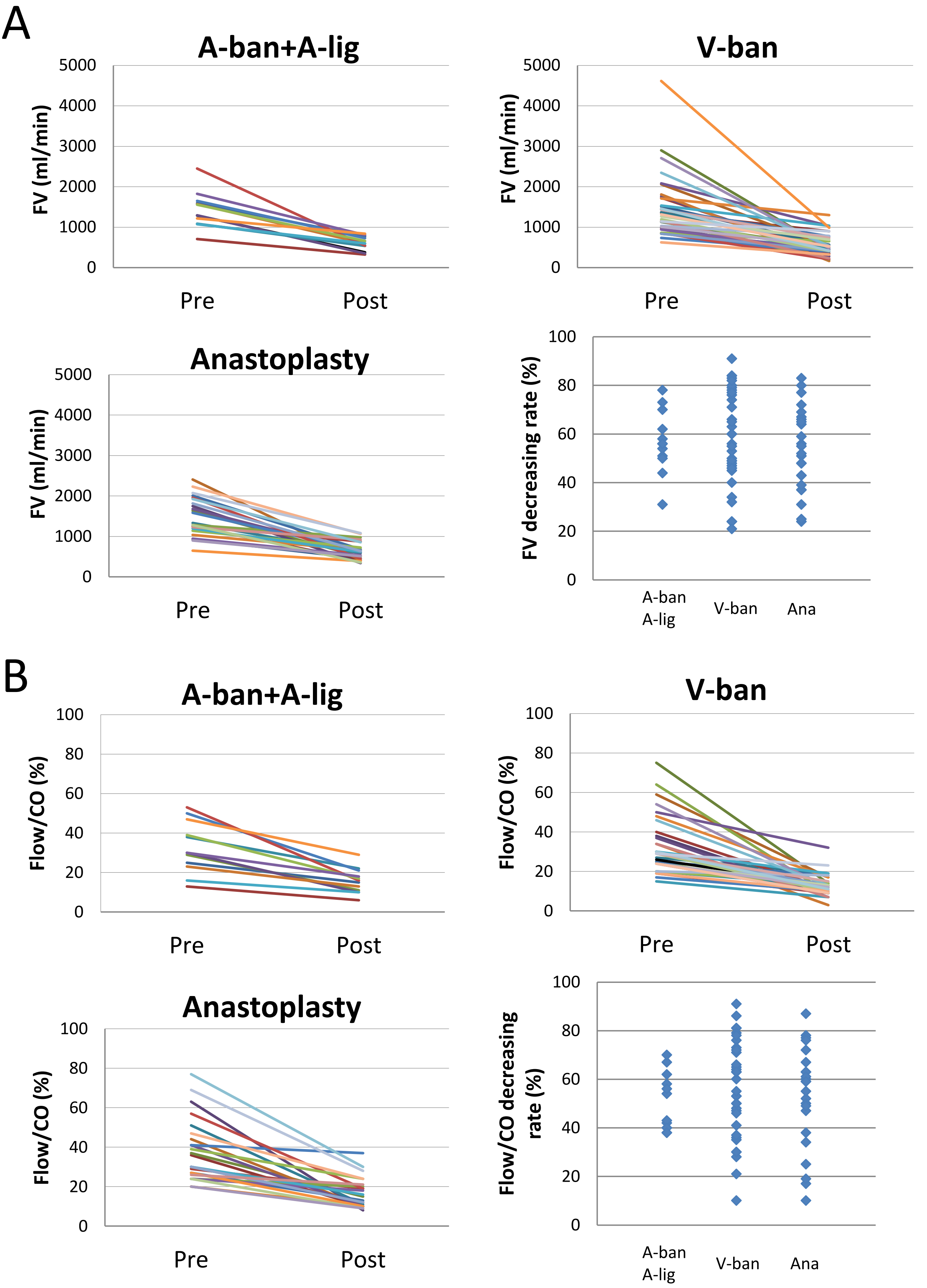

Vein
Reefing anastomotic region
Vascular incision
suture
Artery
proximal side
distal side

Fig 3


A
A-ban+A-lig
FV (ml/min)
5000
4000
3000
2000
1000
0
Pre
Post
V-ban
Anastoplasty
FV decreasing rate (%)
100
80
60
40
20
A-ban
A-lig
V-ban
Ana
B
Flow/CO (%)
Flow/CO decreasing rate (%)