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Original Article

Six different surgical method options according to etiology in repair of arteriovenous fistula aneurysms

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Abstract

Aim: This study aims to evaluate the considerations that should be taken into account when choosing a surgical method and the early results of six methods used for repair in patients who underwent surgical repair due to arteriovenous fistula (AVF) aneurysms.
Material and Methods: One hundred and five patients who underwent AVF aneurysm repair between 2012 and 2020 were reviewed retrospectively. Methods for surgical repair were used according to the etiology: Plication, Arteriotomy constrictions and plication, Aneurysm excision and creation of a new fistula, Saphenous vein or synthetic graft interposition, End-to-end anastomosis and plication after aneurysm excision, Banding method.
Results: Sixty-one of the cases were male and 44 were female. The mean age was 56.6 (27-75) years. The total number of surgeries was 119, including the surgeries and reoperations performed in 2 planned sessions. As surgical method, 44 Plication, 13 Arteriotomy constrictions and plication, 10 Aneurysm excision and creation of a new fistula, 25 Saphenous vein or synthetic graft interposition, 13 End-to-end anastomosis and plication after aneurysm excision and 14 Banding methods were used. AVF flow of 38 patients was measured to be over 1700 ml/min, and 34 of these patients had an arteriotomy length of more than 7 mm. In patients who underwent repair due to high flow rate, an average of 30-65% flow reduction was achieved compared to the preoperative period. In the first postoperative 3 months, 7 (6%) patients required reoperation. Fistula loss did not occur in any of the patients who underwent repair.
Conclusion: The etiology of aneurysm, flow rate, aneurysm localization, and the presence of intimal hyperplasia or chronic thrombus are important in choosing an aneurysm repair method. We think that the results will be positively affected if the surgical method is determined according to the association of one or few of these factors.

Keywords: Aneurysm, plication, banding, fistula, arteriotomy

INTRODUCTION

Aneurysmal degeneration is one of the common complications of long-term AVF use. The risk of fistula aneurysm formation has been reported to be 6-60% [1-3].

If AVF aneurysm is not repaired, various complications can occur, even fistula may fail. There are different surgical techniques in the treatment of AVF aneurysms such as plication, banding, new fistula creation, arteriotomy narrowing, saphenous vein (SV) or synthetic graft interposition.

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Of these techniques, the use of plication method is at the forefront. In the literature, there is insufficient data about the issues that should be considered when choosing a surgical method (Which method should we apply to whom?) Detailed knowledge of the aneurysm features (etiology, flow rate, wall structure etc.) in the preoperative period will affect surgical method preference and thus, the postoperative outcomes.

The objective of this study was to evaluate the considerations that should be taken into account when choosing a surgical method and the early results of six different methods used for repair in patients who underwent surgical repair due to AVF aneurysms.

MATERIAL AND METHODS

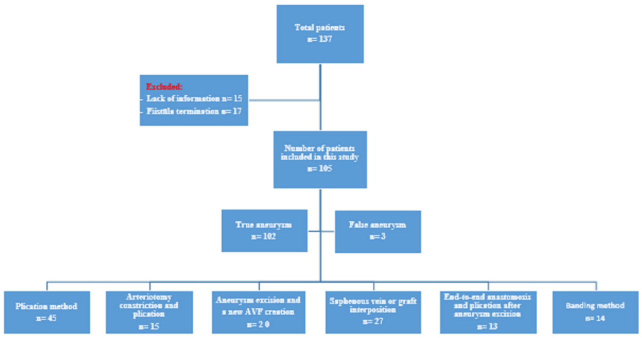
A total of 137 patients who underwent surgical repair due to AVF aneurysms in our clinic between November 2012 and January 2020 were studied retrospectively. The study included a total of 105 patients who were operated due to several reasons such as high flow, rate size >40mm, aneurysms threatening the skin, cosmetic reasons, prolonged bleeding after dialysis and whose detailed data were available. Fifteen patients with insufficient information about the repaired fistula due to death, migration etc. and 17 patients who had fistula cancellation were excluded from the study. Study design and surgical repair methods are shown in Graphic 1. In patients with central vein occlusion who could be opened with interventional procedures (stent, etc.), the aneurysm was repaired later. If it could not be opened with interventional procedures, then fistula cancellation was performed (Figure 1).

Retrospective information of the patients was obtained from the hospital software system. The approval of the study protocol was obtained from the faculty Local Ethics Committee (2020/2752) and written informed consent was obtained from each patient. The study was conducted by the principles of the Helsinki Declaration.

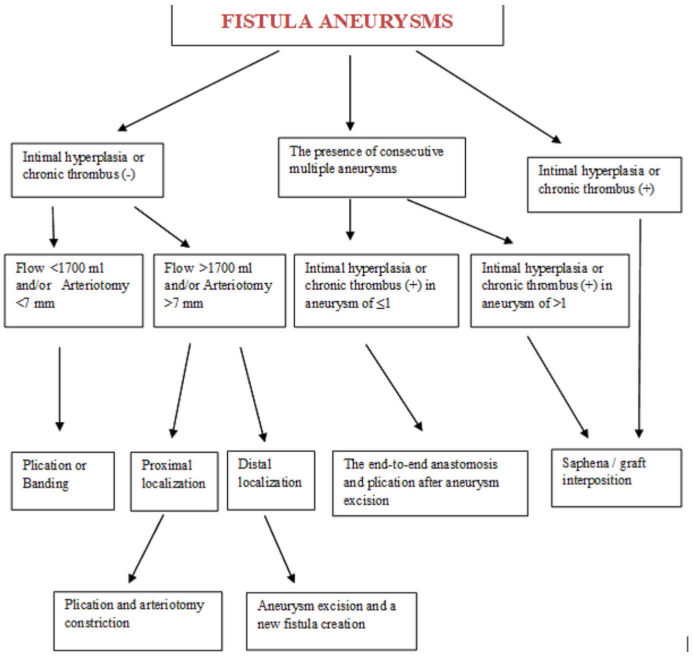
Preoperative physical examination and Doppler ultrasonography (DUS) were applied to all of the patients. The flow rate was measured with DUS (attention was paid for the number of heart beats per minute to be 70-90 during the measurement), the wall structure, the central vein occlusion and the presence of thrombus were examined. Of the procedures, 89 were performed under local anesthesia, while 30 were performed under general anesthesia. General anesthesia was applied to cases requiring large incision due to sequential aneurysm sacs and to patients who preferred it. The patients were followed up in the outpatient clinic in postoperative 1st and 3rd months.

For surgery, the arm with aneurysmatic AVF was placed on the operating table in the supine position. Aneurysm boundaries were determined, and longitudinal skin incision was performed from the upper-middle section of the sac. When the skin incision was planned, the excision of aneurysm related thin skin segments were also taken into consideration at the end of the surgery. The incision was extended to include the AVF site in patients for whom an intervention for the anastomosis line was considered. The subcutaneous tissue was dissected, and the well-developed venous side branches were ligated. The aneurysmatic AVF was initially controlled by releasing the arterial side and then the remaining part of the aneurysm was uncovered. The aneurysm sac was then manually examined in terms of wall thickness and it was determined whether or not there was a thrombus inside (by considering the DUS report). When a vascular clamp had been planned to be used, 5000 IU heparin was administered intravenously. For patients to whom the anastomosis line would be intervened, vascular clamps were placed in the proximal and distal sites of anastomosis in the artery and in the venous segment, where the aneurysm sac was terminated. Clamps were placed at the entry and exit of the sac in patients, who would only be subjected to an intervention in the aneurysmal sac.

Figure 1. Pseudoaneurysm that caused necrosis on the skin



Graphic 1. Study design and surgical methods



Graphic 2. The algorithm of our surgical approaches to fistula aneurysms

Plication method: After releasing the aneurysm sac, it was manually checked for any intimal hyperplasia/chronic thrombus (IH/CT), in accordance with the DUS report. Continuous suturing technique with 5/0 prolene was used without opening the sac and without requiring a vascular clamp. The first plication layer with a less depth was constricted, then the depth was increased slightly, and after suturing the second floor, the plication process was completed. Some patients had consecutive aneurysm sacs with intact segments and in the form of nodes. In these patients, 1 or 2 aneurysms at the most distal side were plicated via local anesthesia. When suitable recovery was obtained for dialysis from the plicated segments, plication was applied to the remaining proximal aneurysm sacs.

Arteriotomy constriction and plication: Anastomosis region and aneurysm sac were released. Anastomosis was unstitched by placing vascular clamps. The arteriotomy line was constricted with 6/0 prolene in order to narrow it to approximately 5mm (Figure 2). The aneurysmatic vein sac was then plicated with 5/0 prolene. AVF was re-created by 7/0 prolene between the plicated vein and constricted arteriotomy. All the cases in which we applied a surgical correction in the anastomosis line had a flow rate higher than 1700ml/min.

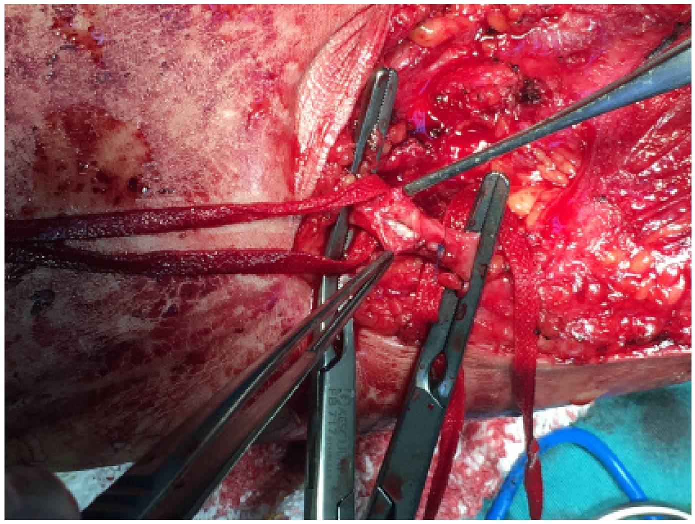


Figure 2. Situation of a constricted arteriotomy larger than 7 mm via prolene

Aneurysm excision and a new AVF creation: Anastomosis line and aneurysm sac were released. Anastomosis was unstitched by placing vascular clamps. Arteriotomy was primarily repaired with 7/0 prolene. Vascular clamps on the artery were removed. On the vein, only the aneurysmatic segment, of the vein was excised. Due to the excision of the aneurysm, the length of the venous graft was shortened. The skin incision was extended approximately 2cm toward the proximal direction (near the artery route) through the cephalic vein, so that the vein was released. Thus, it was aimed to extend the length of the shortened venous graft. Then, a new and smaller arteriotomy was performed over 1-2 cm of the level of the repaired arteriotomy (according to the cephalic vein extending to arteriotomy). A radiocephalic AVF was created between the cephalic vein and the new arteriotomy (Figure 3).

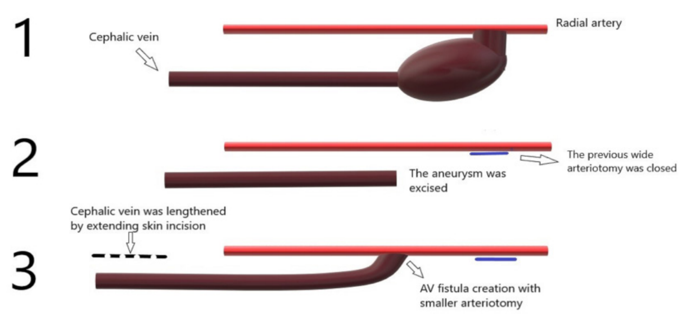


Figure 3. Aneurysm excision and a new AVF creation

SV or graft interposition: The aneurysm sac was longitudinally opened from the upper-middle region until the segment without IH/CT. After excision of the aneurysmatic segment, a SV (Figure 4) or 6 mm polytetrafluoroethylene graft (PTFEG) was interposed with 7/0 prolene sutures. PTFEG was preferred in patients operated under local anesthesia, those with varicose veins and patients who had undergone bypass operation.

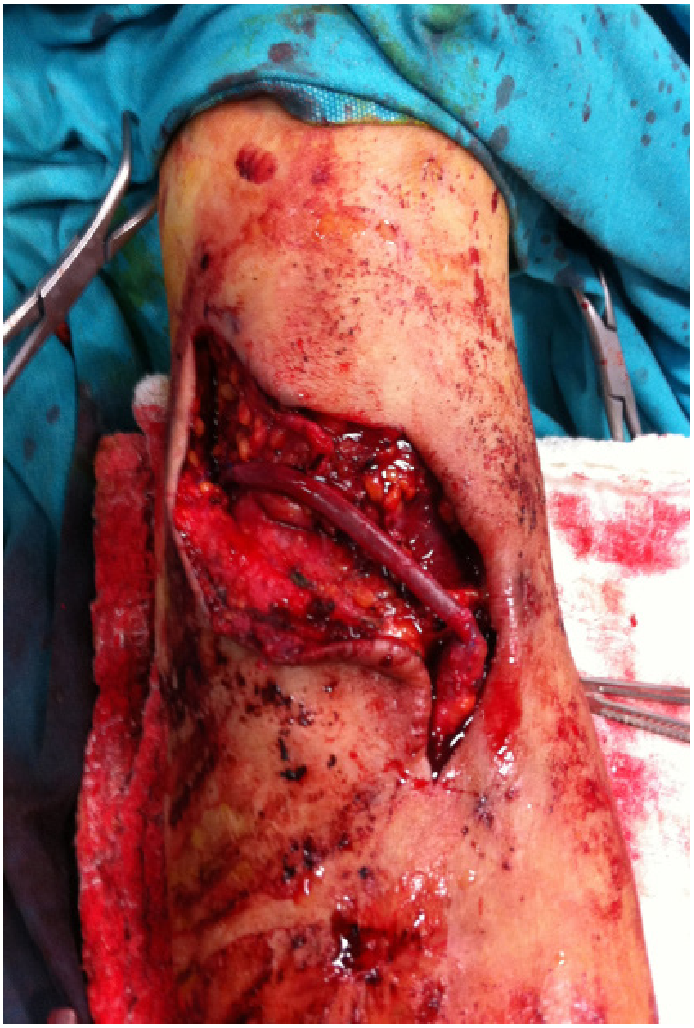


Figure 4. The view of saphena interposed after the aneurysm excision

End-to-end anastomosis and plication after aneurysm excision: When all of the aneurysm sacs were released, huge aneurysms emerged due to the plicated course of the vein (Figure 5A). Initially, aneurysm sac with IH/CT was opened; then the aneurysmatic sac was excised between the proximal and distal vein segments which were healthy. The remaining (non-aneurysmatic) venous parts were anastomosed in an end-to-end fashion. Thus, while the aneurysm sac with IH/CT was being eliminated, the extended length was also shortened. Plication was additionally applied to all remaining aneurysm sacs (Figure 5B).

Figure 5A. The view of consecutive three aneurysm sacs after exploration. 5B: The status of the patient in Figure 5A after the application of the method of an end-to-end anastomosis and plication after aneurysm excision

Banding: PTFEG was wrapped on the aneurysmatic vein and the tips were sutured with 5/0 prolene. Attention was paid to ensure that the PTFEG was completely wrapped around the widest sections of the aneurysm sac. The vascular clamp was not used.

After the removal or plication of the aneurysms, the excessive skin tissues were excised and the remaining skin tissues were sutured without leaving any dead space, with the hemostatic drain placed subcutaneously.

IBM SPSS Statistics (v21) was used for the frequency analysis.

RESULTS

Sixty-one of the cases were male and 44 were female. The mean age was 56.6 ± 11.7 (ranging between 27 and 75) years. Demographic data of patients are shown in Table 1. Of the operated patients, 102 were true aneurysms and 3 were pseudoaneurysms. The total number of surgeries was 119, including the surgeries and reoperations performed in 2 planned sessions.

The surgical indications included an aneurysm size >40 mm (n:91), high flow (n:38), aneurysms threatening the skin (n:29), central vein occlusion (n:14), prolonged bleeding after dialysis (n:6) and cosmetic reasons (n:3).

AVF flow of 38 patients was measured to be over 1700 ml/min and 34 of these patients had an arteriotomy length of more than 7 mm. Due to the high flow rate (1700-3100 ml/min), an average of 30-65% flow reduction was achieved compared to the preoperative period. Of the patients, 51 had radiocephalic, 53 had brachiocephalic and 1 had brachiobasilic anastomosis. AVFs of all patients had the form of end to side anastomosis technique.

Table 1. Demographic data and comorbidities

Demographic Characteristics	Patient (n=105)	%
Gender: Female / Male	44 / 61	42 / 58
Age (mean)	56.6 ± 11.7	
Hypertension	72	68
Cigarette smoking	61	58
Diabetes mellitus	35	33
Coronary artery disease	23	21
Chronic obstructive pulmonary disease	13	12
Autoimmune or rheumatic diseases	11	10
Peripheral artery disease	11	10
Cerebrovascular disease	11	10
History of malignancy	7	6
Body mass index (mean)	27.8 ± 6.4	

No complications requiring reoperation were observed in the first 3 months of follow-up period of the patients who underwent methods 1, 2 and 3. Fistula thrombosis occurred in the early period in 1 patient who underwent method 4 and in 1 patient who underwent method 5. Fistula thrombectomy was performed in the patient who underwent method 4.

PTFE graft interposition was performed in the reoperation of the patient who underwent method 5. The cause of early thrombosis in this patient was excessive narrowing of the lumen due to both plication and end-to-end anastomosis.

We observed that the flow rates of 5 patients who were applied method 6 increased again in the first three months, postoperatively. Either method 1 or 2 was used in the reoperations of these patients.

Strategies for non-routine situations

One patient had two consecutive separate aneurysms with different wall structures. Since an aneurysm had IH/CT, graft interposition was performed, whereas, plication was applied to the other aneurysm (Figure 6).

Figure 6. Treatment of consecutive two aneurysms via two different methods (graft interposition and plication) due to the different wall structure

One patient with brachiocephalic fistula had a long segment aneurysm. A well-developed lateral branch that was separated from the proximal side of the aneurysm was detected (Figure 7A). Aneurysmatic fistula was unstitched from the anastomosis line. Aneurysm sac was removed by connecting from the site where it gave a side branch in the proximal. The distal end of the well-developed side branch was anastomosed to the constricted arteriotomy line and a new fistula was formed. Plication was applied to the most proximal aneurysmatic section (Figure 7B).

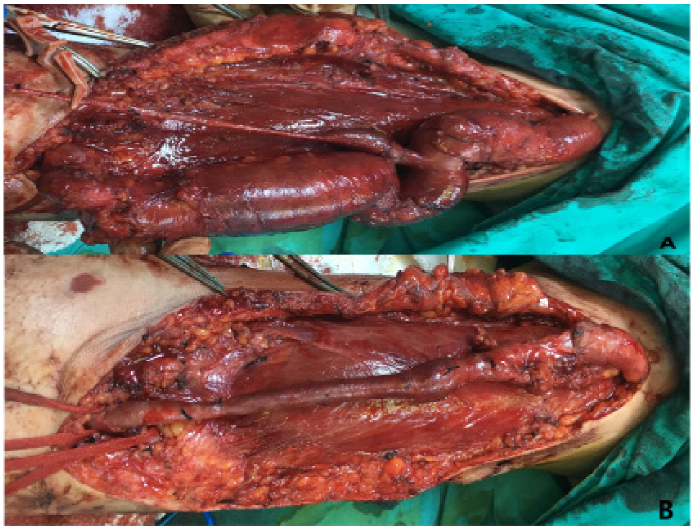


Figure 7A: Aneurysm sac and the well-developed side branch associated with the sac of the patient with a brachiocephalic fistula. **7B:** The view of the patient in Figure 7A for whom a new fistula was formed with the well-developed side branch after the aneurysm sac was excised

DISCUSSION

AVF aneurysms may occur due to genetic wall abnormalities, increased pressure due to stenosis, trauma, infection, inaccuracies in anastomotic technique, anastomotic opening greater than 5 mm, and repetitive cannulation procedures from the same area [3–8].

If aneurysms are not treated, they may cause complications, such as pressure-related symptoms, endocarditis, rupture, thromboembolism, venous hypertension, and distal ischemia [9,10]. It has been reported that surgical treatments applied after the development of a complication reduce the rate of the fistula patency and therefore repair should be performed before the complication develops [11]. Endocarditis and distal ischemia were not observed in any of the patients included in the current study.

The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NFK-KDOQI) guidelines recommend revision of an AVF aneurysm if the skin overlying the fistula is compromised, when there is a risk of fistula rupture, or available puncture sites are limited [12].

Endovascular interventions used in aneurysm treatment include disadvantages, such as cost, infection, failure of cannulation from the stent site, and the lack of long-term follow-up results. Surgical repair remains the gold standard for treatment [3,13-15].

In studies with similar results, it has been reported that the frequency of complications can be reduced, the duration of discharge can be shortened, and dialysis can be performed from the aneurysm by performing plication to the fistula aneurysm. Therefore, it is recommended to perform plication rather than resection and ligation [16-18].

While performing aneurysm surgical treatment, we aimed to provide a new access route without fistula loss, with the least use of catheters, creating sufficient flow and eliminating cosmetic concerns. In addition, the surgical method was determined according to the etiology that was determined to have likely caused the formation of an aneurysm.

Graphic 2 shows our surgical algorithm in detail. The reason for creating the algorithm in this way is discussed below.

The Plication (method 1) can be applied by opening the aneurysm sac and placing a bougie or aspiration probe of a desired size inside [18]. It was considered the most appropriate method until sufficient experience was achieved, because over-constriction can lead to the loss of fistula and inadequate constriction may cause an unsuccessful result. The advantages of the method we use are not using the vessel clamp and shorter procedure time since the pouch is not opened.

Arteriotomy constriction and plication (method 2) is most performed on patients who have proximal (arm) AVF aneurysms with anastomosis diameter larger than 7 mm and/or fistulas with high flow rates. Only plication could be considered for such patients. However, it should be kept in mind that a high flow passing through a wide arteriotomy may regenerate an aneurysm or may trigger the heart failure symptoms in the following process. Another alternative method is aneurysm excision and opening of a new AVF. In this method, aneurysmal segment excision is performed, and the new anastomosis is carried to the proximal site. In case the new anastomosis of a fistula located in the arm region is moved to a more proximal site, the length of the vein required for dialysis entry is shortened.

Aneurysm excision and a new AVF creation (method 3); the common feature of these patients has a distal (forearm) AVF aneurysm and an anastomosis diameter larger than 7mm and/or fistulas with high flow rates. The disadvantages of opening a new fistula are that the old arteriotomy line requires a repair process and the anastomosis is moved to the proximal site. However, since an enlarged arteriotomy line is already present, the radial artery can be primarily repaired without any constriction. If the vein to be used in anastomosis is released well, it extends lengthwise due to its folds and a long venous graft occurs. Thus, when the aneurysm sac of approximately 5cm is excised, the new anastomosis line is moved to only 1-2cm proximal. Moreover, after removal of the aneurysms located at the distal side of forearm, even if the anastomosis is moved to the proximal site, there is sufficient length of vein in the forearm for the dialysis entry. If the patient has a single aneurysm longer than 5cm, the excised segment will extend in this case, thus the vein distance required for dialysis entry will be slightly shortened. In such patients, plication and arteriotomy constriction is an alternative method. The length of 5cm mentioned here may vary according to the length of the patient's forearm and the vein distance required for dialysis entry. The method of aneurysm excision and opening a new AVF should be considered to be advantageous in suitable patients. This is because the method allows the complete removal of the aneurysm via excision and opening of a new AVF with a small arteriotomy from the area having a robust wall structure. Furthermore, hemodialysis can be performed from the more proximal region without the need for catheter and waiting for the maturation process.

SV or graft interposition (method 4) is applied to patients with serious IH/CT in the aneurysm sac. Inserting the dialysis needles continuously into the same site may cause IH/CT formation in this site together with aneurysm. It should be noted that, if plication is applied to the aneurysm with IH/CT in these patients, loss of fistula may occur due to the over-constriction of the lumen. Thus, it would be more appropriate to perform SV or graft interposition instead of the excision of the aneurysm with IH/CT.

End-to-end anastomosis and plication after aneurysm excision (method 5), was applied to patients who had aneurysms in nodes, composed of consecutive 3-4 aneurysm sacs and having intact vein segments in some areas. The surgical method of these patients was designed according to the presence of IH/CT in one or more aneurysms. The method of end-to-end anastomosis and plication after aneurysmatic (IH/CT) segment excision is suggested if there is only one IH/CT aneurysm sac. If there is IH/CT in more than one sac, the length of the remaining vein then becomes shorter and the excised (IH/CT) segment will be long. In such cases, SV/graft interposition is recommended.

It is suggested to perform plication in 2 sessions in order to prevent the need for catheter if there is no IH/CT in any sac. Staged surgical interventions are the main disadvantage of this method. However, it can be presented as an alternative method to patients who do not want a catheter insertion. If the aim is to finalize the surgery in one session, the method of end-to-end anastomosis and plication after aneurysmatic segment excision is recommended. The disadvantage of this method is that it requires general anesthesia and a larger incision.

Banding (method 6); Patients who underwent this method and needed reoperation (5 patients) were retrospectively examined. These patients were found to have high flow and wide anastomosis lines. It was thought that especially in aneurysms with high flow rate and large arteriotomy, stretching occurred in this region because of exposure of banding segment to continuous excessive flow. Hence, it is recommended to use the correction methods including the arteriotomy line in the fistulas having an arteriotomy length longer than 7mm and higher flow rate. It has been reported that in patients who undergo banding, the amount of flow in more than half cases increases again in the first few months. [19,20] Although the problem of the venous system was solved by performing banding and the low resistance in the venous system was increased, the increase in the flow again after a while caused us to think that the problem could be caused by the width of the anastomosis. In addition, the fact that reoperation was not required in the other 9 patients who underwent banding procedure and who did not have a wide anastomotic line supported our opinion.

In an AVF anastomosis, the arteriotomy line is a component of both the arterial side and venous side of the fistula. That is, it is also the beginning of the venous system. Increasing the resistance here (i.e. narrowing the arteriotomy) also means increasing the resistance on the venous side. Thus, we believe that the high flow can be reduced and potential complications that may occur can be prevented. In our cases who underwent narrowing of the arteriotomy line, an average of 30-65% flow reduction was observed.

Limitations of the study: It is a retrospective study without medium-long-term results. In addition, DUS results could not be given in detail since it was carried out at different postoperative times and some of the results could not be accessed.

Reoperation was required in 6% of the patients who were corrected during the follow-up period. Reoperations were revised with one of the 6 methods above without the need for fistula cancellation. In addition, in high flow cases, 30-65% postoperative flow reduction was achieved. These short-term results suggest that repair methods are effective. Prospective studies are needed to see long-term results.

CONCLUSION

In conclusion, the etiology of aneurysm, the presence of IH/CT, flow rate, and localization and length of aneurysms are important parameters for determining the optimal surgical treatment of AVF aneurysms. We think that more effective aneurysm repair can be performed if the surgical method is determined according to the association of one or more of these features.

Ethics Committee Approval: Approval of the study protocol was obtained from the Local Ethics Committee of Meram Faculty of Medicine (2020/2752).

Patient Consent for Publication: Individual informed consent was waived due to retrospective design.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed equally to the article.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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