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Clinical Research

Clinical Outcomes of Arteriovenous Graft in End-Stage Renal Disease Patients with an Unsuitable Cephalic Vein for Hemodialysis Access

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Background: As the population of patients with end-stage renal disease has grown older, the proportion of patients with poorly preserved vasculature has concomitantly increased. Thus, arteriovenous grafts (AVG) have been used more frequently to access blood vessels for hemodialysis. Despite this increasing demand, studies of AVG are limited. In this study, we examined the surgical outcomes of upper-limb AVG creation.
Methods: Among the arteriovenous fistula formation procedures performed between January 2014 and March 2019 at Dankook University Hospital, 42 cases involved AVG creation. We compared patients in whom the axillary vein was used (group A; brachioaxillary AVG [B-Ax AVG]; n=20) with those in whom upper limb veins were used (group B; brachiobasilic AVG or brachioantecubital AVG; n=22).
Results: The 1-year primary patency rate was higher in group A than in group B (57.9% vs. 41.7%; p=0.262). The incidence of postoperative complications was not significantly different between groups.
Conclusion: AVG using the axillary vein showed no major differences in safety or functionality compared to AVG using other veins. Therefore, accounting for age, underlying disease, and expected patient lifespan, B-Ax AVG can be considered an acceptable surgical method.

Keywords: Fistula, Axillary vein, Renal diaslysis

Introduction

Hemodialysis is the most common type of renal replacement therapy in patients with end-stage renal disease (ESRD), and stable vascular access is important for successful hemodialysis [1,2]. Creation of an autologous arteriovenous fistula (AVF) is the most commonly used method of hemodialysis access, since it has the highest patency and the fewest complications [3,4]. However, some patients do not have sufficiently suitable preservation of the vasculature for AVF and instead undergo arteriovenous graft (AVG) formation using a prosthetic graft. As the population of patients with ESRD has aged, there has been an increase in the number of patients with unsuitable vasculature for AVF formation; consequently, the number of patients undergoing AVG surgery has also increased [5]. With increases in mean lifespan, the demand for AVG is expected to rise [6,7], meaning that AVG will play a more prominent role as a form of access for hemodialysis.

There are several types of AVG, categorized by the autologous blood vessel used for anastomosis with the prosthetic graft; the most commonly used methods are brachioaxillary AVG (B-Ax AVG), brachioantecubital AVG (B-Ac AVG), and brachio-upper arm basilic AVG (B-Bs AVG). AVG creation prioritizes the use of distal veins; however, when this is not possible, the axillary vein can be used. The axillary vein is a deep, proximal vein; thus, when the axillary vein is used for AVG creation, surgical outcomes, such as patency and complication rates, may differ from those associated with other veins in the upper arm.

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Despite the increasing demand for AVG, studies of this technique are limited. In particular, even though B-Ax AVG, which uses the axillary vein, may be a good option for patients with poorly preserved upper limb veins, few studies on this procedure are available. Hence, we aimed to investigate the surgical outcomes of AVG creation in the upper arm at Dankook University Hospital.

Methods

Patients

We identified a total of 393 patients who were diagnosed with ESRD and who underwent AVF or AVG creation between January 2014 and March 2019. Of these, we excluded 347 cases involving AVF formation; of the remaining 46 cases of AVG creation, we included 42 patients for whom follow-up information was available.

The clinical data of each patient were analyzed retrospectively based on patients' medical records. For patients who did not receive regular outpatient follow-up at the department of nephrology at our hospital, we collected data via phone interviews. As clinical indices, we examined patients' age; sex; and the presence or absence of underlying disease, including diabetes mellitus, hypertension, hyperlipidemia, and cardiovascular disease. As surgical factors, we examined the type and diameter of the blood vessels used for anastomosis, the time of the first obstruction, the time of re-obstruction, and the presence or absence of complications.

Depending on the location of the arteriovenous anastomosis during surgery, patients for whom the axillary vein was used (B-Ax AVG) were classified as group A, and patients for whom the antecubital vein or the basilic vein were used (B-Ac AVG or B-Bs AVG, respectively) were classified as group B. Clinical and surgical outcomes were compared between the 2 groups.

Surgical procedure

Prior to the administration of anesthesia, ultrasonography was used to assess the state of the patient's vasculature. The radial artery, brachial artery, and cephalic vein of the non-dominant arm were assessed. After first checking for arteriosclerosis and venous stenosis, blood vessel diameter was measured. If the blood vessels of the non-dominant arm were unsuitable for AVF, the vessels of the dominant arm were assessed. If the cephalic veins were not preserved on either side, AVG creation was performed, preferably in the non-dominant arm. Once it was decided to perform AVG creation based on the state of the patient's vasculature, the diameters of the antecubital vein and the basilic vein were assessed. If the diameter of the basilic vein was ≥3 mm, the basilic vein was selected for anastomosis preferentially. If the diameter of the basilic vein was <3 mm and the diameter of the antecubital vein was ≥3 mm, the antecubital vein was selected for anastomosis. If the diameters of both the basilic vein and antecubital vein were <3 mm, the axillary vein was selected for anastomosis. Surgery was performed after inducing anesthesia via a supraclavicular nerve block in cases in which the axillary vein was used and via a brachial plexus block in cases where the antecubital vein or the basilic vein was used. For the prosthetic graft, a 4- to 6-mm or 4- to 7-mm tapered and expanded standard wall-type polytetrafluoroethylene tube was utilized. Continuous anastomosis was performed using 7-0 polypropylene sutures, and heparin was not used postoperatively.

In group A, ultrasonography was used to verify the position of the vein in the axilla, and a skin incision was made. After the axillary vein was identified, it was carefully exposed while avoiding injury to the axillary artery and the branches of the brachial plexus. After making an additional incision near the brachial artery in the upper elbow, the brachial artery was exposed. Subsequently, a tunneling device was used to create a subcutaneous tunnel between the vein and the artery, and the prosthetic graft was placed in the tunnel and cut to the length required for anastomosis. After administering intravenous heparin (3,000 U) to prevent thrombus formation, the distal part of the axillary vein was ligated, and end-to-end anastomosis was performed between the axillary vein and the prosthetic graft. Next, the brachial artery was clamped above and below the anastomosis site, a longitudinal incision was made, and end-to-side anastomosis was performed with the prosthetic graft. Here, the length of the incision in the artery was made to be shorter than the artery diameter to prevent overflow. Immediately before completing the arterial anastomosis, the clamps were removed, first from the vein and then from the artery, to allow air to exit the blood vessels before completing surgery.

In group B, after using ultrasonography to verify the locations of the veins, a skin incision was made in the upper elbow joint or the antecubital area. After identifying the location of the vein for anastomosis, it was dissected and exposed; thereafter, the brachial artery was also exposed. If the basilic vein was found in the upper elbow joint, an additional skin incision was made close to the brachial artery.

Table 1. Patients' characteristics

Characteristic	Overall (N=42)	Group A (n=20)	Group B (n=22)	p-value
Age (yr)	70.6±14.3	77.5±10.4	64.3±14.7	0.003
Sex				0.504
Male	24 (57.1)	13 (65)	11 (50)	
Female	18 (42.9)	7 (35)	11 (50)	
Arterial diameter	4.7±0.8	4.7±0.8	4.6±0.8	0.449
Vein diameter	5.1±1.6	5.9±1.7	4.3±1.0	0.001

Values are presented as mean±standard deviation or number (%).

Unlike when using the axillary vein, the subcutaneous tunnel was made in the forearm, and a loop-shaped prosthetic graft was placed in the tunnel. In order to prevent thrombus formation, heparin (3,000 U) was administered via a previously secured vein in the lower limb. Anastomosis was performed using the same method as in group A, and surgery was completed.

Data collection and statistical analysis

To assess patency, we evaluated the events associated with graft flow during the study period and the time and frequency of salvage, as well as surgical thrombectomy, angioplasty, and percutaneous angiography with balloon therapy. Postoperative complications were defined as incidents occurring during the follow-up period that required inpatient treatment. We investigated the incidence of complications, such as hemorrhage, infection, pseudoaneurysm, seroma, venous hypertension, and hand ischemia due to steal syndrome, as well as preoperative underlying disease, particularly the presence or absence of diabetes mellitus, hypertension, hyperlipidemia, and vascular disease (cardiovascular, cerebrovascular, and peripheral vascular disease).

The endpoint of the trial was set as June 30, 2019, the last day of use of the original AVG, or death, whichever came first. Statistical analysis was performed using R ver. 3.1.3 (R Foundation, Vienna, Austria; Comprehensive R Archive Network: http://cran.r-project.org). We plotted Kaplan-Meier curves using the survival package and used the log-rank test to identify statistically significant differences between the 2 groups. All tests were 2-tailed with a significance level of 5%.

This study was reviewed and approved by the Institutional Review Board of Dankook University Hospital and informed consent was waived (IRB approval no., 2020-02-020).

Table 2. Underlying diseases of the patients

Underlying disease	Group A	Group B	p-value
Diabetes mellitus	11 (55.0)	19 (86.4)	0.057
Hypertension	18 (90.0)	20 (90.9)	>0.999
Dyslipidemia	2 (10.0)	0	0.221
Cardiovascular disease	45 (25)	4 (18.2)	0.714
Cerebrovascular disease	2 (10.5)	4 (18.2)	0.668
Peripheral artery disease	0	0	NA
Duration of chronic kidney disease (yr)	58.6±54.1	59.8±43.8	0.874
Preoperative dialysis	12 (63.2)	17 (77.3)	0.504

Values are presented as number (%) or mean±standard deviation.
NA, not applicable.

Results

Patients' clinical characteristics

A total of 42 patients were included in the study, including 24 men (57.1%) and 18 women (42.9%). There were 20 patients (47.6%) in group A (B-Ax AVG) and 22 patients (52.4%) in group B (B-Bs AVG and B-Ac AVG). The duration of follow-up ranged from 2 months to 60 months; the mean follow-up duration for groups A and B was 14.6±8.8 months and 23.2±15.6 months, respectively. At the time of surgery, patients' age ranged from 24 to 92 years; the mean age was significantly different between groups A and B (77.5±10.4 years versus 64.3±14.7 years, p=0.003). Table 1 shows the characteristics of the patients in both groups, including the mean artery and vein diameter. The mean vein diameter was significantly different between groups A and B (5.9±1.7 mm versus 4.3±1.0 mm, p=0.001).

Table 2 presents the details of the underlying diseases in both groups, with no statistically significant differences between them. The number of patients who had received hemodialysis or peritoneal dialysis as renal replacement therapy for ESRD before surgery and the mean time from ESRD diagnosis to surgery were also recorded (Table 2); however, the groups showed no statistically significant differences with regard to these factors.

Arteriovenous graft patency and complications

One-year primary patency analyzed using Kaplan-Meier survival curves was higher in group A than in group B (57.9% versus 41.7%, p=0.262), indicating that group A had higher survival than group B; however, this difference was not statistically significant (Fig. 1). Furthermore, there were no significant differences in the percentage of patients

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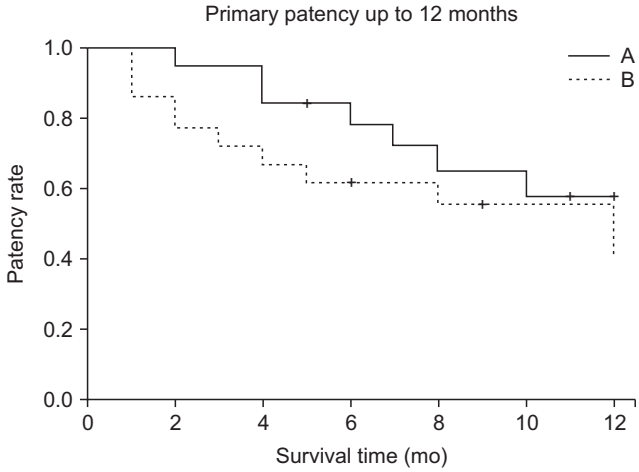

Fig. 1. Kaplan-Meier curve for primary patency of the arteriovenous graft in groups A and B.

requiring salvage due to graft obstruction or in the mean frequency of salvage (Table 3), although these parameters had slightly lower values in group A. Table 4 presents the surgery-related complications during the follow-up period that required inpatient treatment.

Discussion

Our study showed that AVG using the axillary vein had no major differences in safety or functionality compared to AVG using other veins. Therefore, accounting for age, underlying disease, and expected patient lifespan, B-Ax AVG was found to be an acceptable surgical method.

According to data published by the Korean Society of Nephrology, there were 103,984 registered patients with ESRD (2,006.4 patients per million population) in 2018; this was almost twice as many as 10 years before, and during this period, the mean patient age increased from 56.7 years to 62.3 years. In 2018, there were 77,617 patients (75%) using hemodialysis, which was the most common form of renal replacement therapy. Interestingly, the percentage of patients on hemodialysis who were using an AVG was around 15% and had not changed greatly within the previous 5 years. Despite efforts to prioritize AVF surgery, which shows superior surgical outcomes, the demand for AVG is not decreasing, most likely due to the increased proportion of elderly patients with ESRD who are more likely to have poorly preserved vasculature. As the mean lifespan increases worldwide, the average age of patients with ESRD will continue to increase. Therefore, the use of AVG to facilitate access to hemodialysis is not expected to decrease in the future.

Table 3. Data on patency and salvage

Variable	Group A	Group B	p-value
1-year patency	57.9	41.7	0.262
Need for salvage	50	63.6	0.874
Average time of salvage (yr)	0.7±0.8	0.8±0.9	0.874

Values are presented as number or mean±standard deviation.

Table 4. Postoperative complications

Complication	Overall	Group A	Group B	p-value
Bleeding	1 (2.4)	0 (0)	1 (4.5)	>0.999
Infection	2 (4.8)	1 (5)	1 (4.5)	>0.999
Hand ischemia	1 (2.4)	1 (5)	0	0.476

Values are presented as number (%).

We have performed AVF/AVG surgery in a large number of patients with ESRD over the past several years and have made great efforts to construct and maintain AVF/AVG with high patency. Although most patients were able to undergo AVF surgery, the use of prosthetic grafts was unavoidable in some patients due to poorly preserved vasculature. When we attempt to create an AVG, we try to use distal veins, such as antecubital veins or the basilic vein; when these veins are poorly preserved, we use the axillary vein. For AVF, it has been suggested that veins with a preoperative diameter of ≥3 mm have high patency [8,9], but there are no such criteria for AVG; consequently, there is some ambiguity in vein selection. Therefore, in order to maximize AVG patency, as with AVF, we only perform AVG creation in cases where the vein diameter is ≥3 mm. In the present study, the mean vein diameter was 5.9 mm in group A and 4.3 mm in group B, both of which were much larger than the criterion of 3 mm. A possible explanation for this observation is that if the other vasculature is poorly preserved, the remaining veins may develop to handle the increased blood flow. At our hospital, we set the criterion of a diameter of ≥3 mm for the veins used in AVG creation, but further studies will be needed to verify whether this is an appropriate criterion for veins of the upper arm.

While performing AVG surgery, we had predicted that there would be a difference between the groups because the vein diameter in group A was larger and the vein was located proximally; therefore, we believed that it would be easier to ensure sufficient blood flow and that the patency of group A would be higher. In contrast, however, because the axillary vein is anatomically deeper and its diameter is larger, AVG using this vein was expected to have a higher incidence of complications such as infection, hemorrhage,

and hand ischemia. In group B, because the vein was located more distally, we expected a higher rate of venous stenosis, and because the diameter was smaller, we also expected a lower patency. Conversely, because we used a more superficial vein, we expected group B to have a lower rate of complications than group A.

We found that the 1-year primary patency rate was higher in group A than in group B, but the difference was not statistically significant. Moreover, no significant differences were noted in the mean frequency of salvage or in the percentage of patients requiring salvage due to obstruction; however, both of these parameters had slightly lower values in group A than in group B. Although the results were not statistically significant, we can conclude that a more stable route of access for hemodialysis was secured in group A than in group B.

Statistically significant between-group differences were found for age and the diameter of the vein used in anastomosis, while other indices, such as the rates of diabetes mellitus, hypertension, and preoperative dialysis, showed no significant differences. The mean age of group A was 13.2 years higher than that of group B because the veins of the arm tend to be less well-preserved with increasing age. The mean diameter of the vein used in anastomosis was 1.6 mm larger in group A than in group B. The difference in patency between the 2 groups might have arisen simply from the difference in diameter, but anatomical differences in the veins may have also affected patency. Bleeding, graft infection, and hand ischemia were observed as postoperative complications, and these were treated with hematoma evacuation, graft removal, and medical treatment, respectively. None of these complications showed significant differences between groups, and the incidence of complications in both groups was below 10%. Although not statistically significant, group A, in which the axillary vein was used, was found to have better function than group B, without having a higher rate of complications.

The most recent study of B-Ax AVG was reported by Marques et al. [10] in 2015. That study analyzed the results of B-Ax AVG creation in 102 patients. The mean age of the patients in that study was 68.3 years, which is lower than that of the patients in the present study (77.5 years), but the 1-year primary patency rate was 56%, which is similar to our results (57.9%). The rate of complications was 6.9%, which was slightly lower than in our study (10%). However, given the differences between the studies with regard to sample size and patient age, this should not be considered a meaningful difference. Although there have been previous studies of B-Ax AVG, there have not been many. Nevertheless, due to the increasing age of ESRD patients, we anticipate an increase in the demand for B-Ax AVG and in the number of studies investigating this procedure.

The number of patients with ESRD in South Korea is growing annually, and due to aging of the patient population, the number of patients using AVG is also increasing [5,11-13]. Accordingly, research on AVG is needed, but the majority of research until now has focused on the superiority of AVF over AVG. Studies on AVG conducted in South Korea are particularly difficult to find. Hence, the present study focused solely on AVG creation and investigated the function and safety of B-Ax AVG, which uses the most proximal vein. Of course, the function and safety of B-Ax AVG are not superior to those of AVF. However, given that B-Ax AVG can be performed in patients whose upper limb vasculature is poorly preserved and since the expected lifespan of these patients is relatively short, this is a valuable procedure for certain patients with poorly preserved vasculature.

This study had some limitations. First, the sample size was small. Second, even though the study period was set to at least 5 years, we were only able to investigate 1-year patency because of the short survival duration of patients. Specifically, of the 20 patients in group A, 11 patients (55%) died within the follow-up period, and 5 of these patients (25%) died within 1 year postoperatively. Given that group A consisted of old patients with short expected lifespans, in order to assess the long-term patency of B-Ax AVG, it will be necessary to perform further studies using a longer period of data collection. Third, due to the significant difference in mean age between the groups, it was difficult to compare outcomes under the same conditions. Therefore, further research is required to facilitate an effective comparison.

In conclusion, the present study revealed that, in patients with poor preservation of all veins of the upper limb, B-Ax AVG showed no major differences in functionality or safety compared to AVG using other upper limb veins. The complication rates in both study groups were below 10%, and there was no statistically significant difference in this rate between groups. Therefore, considering the age, underlying disease, and expected lifespan of the patient group, B-Ax AVG creation is an acceptable surgical method for select patients.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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