

Surgical Outcomes of Forearm Loop Arteriovenous Fistula Formation Using Tapered versus Non-Tapered Polytetrafluoroethylene Grafts

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Background: Tapered grafts, which have a smaller diameter on the arterial side, have been increasingly used for arteriovenous fistula (AVF) formation. We compared the outcomes of 4-6-mm tapered and 6-mm straight forearm loop arteriovenous grafts. **Methods:** A total of 103 patients receiving forearm loop arteriovenous grafts between March 2005 and March 2015 were retrospectively analyzed and separated into 2 groups (group A, 4- to 6-mm tapered grafts, n=78; group B, 6-mm straight grafts, n=25). In each group, complications and patency rates after surgery were assessed. **Results:** Clinical characteristics and laboratory results, except for cerebrovascular disease history (group A, 7.7%; group B, 28.0%; p=0.014), were similar between the groups. No significant differences were found for individual complications. Kaplan-Meier survival analysis revealed no significant differences in 1-year, 3-year, and 5-year patency rates between groups (61.8%, 44.9%, and 38.5% vs. 62.7%, 41.1%, and 35.3%, respectively). **Conclusion:** We found no significant differences in complication and patency rates between the tapered and straight graft groups. If there are no differences in complication and patency between the two graft types, tapered grafts may be a valuable option for AVF formation in light of their other advantages.

Key words: 1. Arteriovenous fistula
2. Outcomes
3. Graft

Introduction

With increases in life expectancy, the number of patients requiring renal replacement therapy for chronic renal failure has also increased. Although most hope to receive a kidney transplant, the number of organ donors is insufficient. Therefore, many patients receive maintenance therapy through hemodialysis [1]. For hemodialysis, stable arteriovenous fistulae (AVFs) with high patency rates and low incidence of complications are essential. AVFs using autogenous vessels are known to have high patency

and survival rates compared to arteriovenous grafts (AVGs) using artificial conduits. Vascular surgeons, however, use AVGs in clinical practice for cases with vascular aging, vascular damage caused by frequent blood sampling, and peripheral vascular stenosis caused by an underlying disease, such as diabetes. Much effort has been devoted to improving the patency rate of AVGs, including the development of new graft materials, improvement in surgical techniques, and better patient management before and after surgery.

Straight grafts, in which the diameters of both

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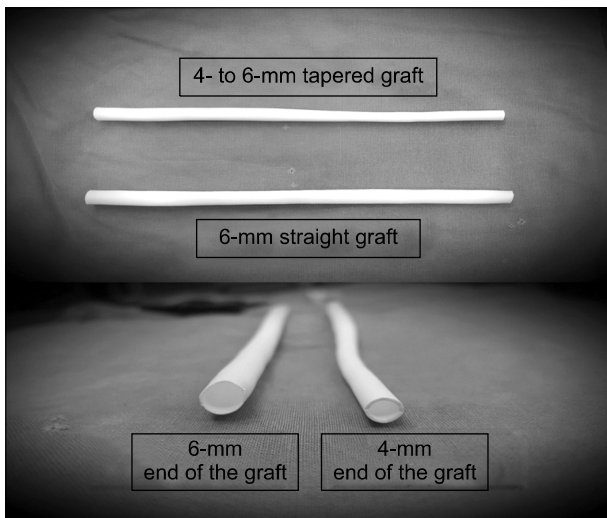


Fig. 1. Configuration of 4- to 6-mm tapered grafts and 6-mm straight grafts.

ends are the same, are the main kind of graft in use, but tapered grafts, the arterial side diameters of which are smaller, have been increasingly utilized in recent years (Fig. 1). Tapered grafts avoid excessive arteriotomy during arterial anastomosis, and anastomosis can be performed easily because the diameters of the artery and the graft are similar. Moreover, hemodynamic complications, such as ischemic steal syndrome or heart failure, may be decreased by preventing overflow. However, there are limited studies on surgical outcomes according to graft shape. The current study compared the patency rate and incidence of complications between patients who underwent 4- to 6-mm tapered and 6-mm straight forearm loop AVG operations.

Methods

1) Patients

Patients who underwent forearm loop AVG operations by 2 cardiovascular surgeons at Dankook University Hospital between March 2005 and March 2015 were included. From among a total of 125 patients, the medical records of 103 patients for whom follow-up information was available were retrospectively analyzed. Patients were divided into 2 groups based on graft shape: those who received a 4- to 6-mm tapered graft were classified as group A (n=78), while those with a 6-mm straight graft were

classified as group B (n=25). The clinical characteristics of each patient, including age, gender, presence of an underlying disease (diabetes, hypertension, cerebrovascular disease, peripheral artery disease, coronary artery disease, hyperlipidemia, etc.), and smoking history were examined. The laboratory test results at the time of surgery (i.e., hemoglobin, hematocrit, creatinine, and estimated creatinine clearance) were investigated. In addition, the side of the arm that was operated on was analyzed and compared in each group.

2) Surgical procedure

A brachial plexus block was administered in the axilla of the arm that was to undergo surgery. After selecting the vein to be used for anastomosis, a skin incision was made in the venous area, and the vein was dissected and exposed. An additional skin incision was made to expose the brachial artery. If both a vein and an artery were accessible in the same area, surgery was performed via 1 skin incision. In all 103 patients, a loop-type graft was placed in the forearm, followed by intravenous infusion of heparin (3,000 units). After cutting the vein, end-to-end anastomosis with the graft was performed. Then, the artery was clamped and arteriotomy was performed, and side-to-end anastomosis with the graft was performed. The suture thread used for anastomosis was 6-0 or 7-0 polypropylene.

3) Surgical results and endpoint

In each group, the postoperative complications and patency rates 1 year, 3 years, and 5 years after surgery were assessed. Complications related to AVG surgery were defined as those occurring within 12 months after surgery that required hospital admission and surgical treatment(s); these included hand ischemia, infection, pseudoaneurysm, and seroma. The patency rate was analyzed according to the timing of the first AVG occlusion that occurred after surgery. If the patency of the graft was maintained within the study period, the study endpoint was set as March 31, 2016. If the patient died for reasons that were not related to the graft or graft surgery during the follow-up period, the time of death was considered the patient endpoint.

Table 1. Demographics of the patients

Characteristic	Total	Group A: 4- to 6-mm tapered	Group B: 6-mm straight	p-value
Total	103 (100.0)	78 (75.7)	25 (24.3)	
Age at operation (yr)	62.4±14.5	61.1±14.6	66.6±13.4	0.096
Sex				0.447
Male	48 (46.6)	38 (48.7)	10 (40.0)	
Female	55 (53.4)	40 (51.3)	15 (60.0)	
Combined diseases				
Diabetes mellitus	73 (70.9)	59 (75.6)	14 (56.0)	0.060
Hypertension	91 (88.3)	68 (87.2)	23 (92.0)	0.726
Coronary artery disease	33 (32.0)	26 (33.3)	7 (28.0)	0.619
Peripheral artery disease	9 (8.7)	6 (7.7)	3 (12.0)	0.684
Cerebrovascular attack	13 (12.6)	6 (7.7)	7 (28.0)	0.014
Hyperlipidemia	6 (5.8)	5 (6.4)	1 (4.0)	>0.999
Smoking	17 (16.5)	14 (17.9)	3 (12.0)	0.757
Lab findings				
Hemoglobin (g/mL)	9.7±1.3	9.7±1.3	9.9±1.2	0.591
Hematocrit (%)	29.2±3.8	28.9±3.8	30.0±3.8	0.183
Creatinine (mg/dL)	6.6±2.9	6.6±3.0	6.5±2.6	0.902
Estimated creatinine clearance (mL/min/1.73 m ²)	9.3±4.1	9.4±4.1	9.1±4.3	0.730
Location				0.072
Left	84 (81.6)	67 (85.9)	17 (68.0)	
Right	19 (18.4)	11 (14.1)	8 (32.0)	

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

4) Statistical analysis

For statistical analysis, R ver. 3.1.3 (GNU General Public License, Boston, USA) was used. To determine any statistical differences in gender, age, underlying disease, smoking history, or laboratory results, the Student t-test, the chi-square test, and the Fisher exact test were performed. The Fisher exact test was used to determine the differences in the incidence of postoperative complications. Patency rates were obtained through Kaplan-Meier survival analysis, and the survival curves of both groups were schematized. The patency rate follow-up period was divided into 1 year, 3 years, and 5 years, and a log-rank test was performed to determine any statistical differences between the groups. Two-sided tests were performed for all statistical analyses at a 5% significance level.

Results

1) Patient characteristics

The mean age of all 103 patients was 62.4±14.5 years (range, 17.8 to 88.6 years), and there were 55 females and 48 males. Underlying diseases prior to

AVG surgery included diabetes (73 patients, 70.9%), hypertension (91 patients, 88.3%), coronary artery disease (9 patients, 8.7%), and cerebrovascular disease (13 patients, 12.6%). Among these, only cerebrovascular disease showed a statistically significant difference between groups A (7.7%) and B (28%, $p=0.014$). A total of 17 patients (16.5%) had a history of smoking, but there was no significant difference between the groups regarding this variable. AVG surgery was performed on the left arm in 84 patients (81.6%) and the right arm in 19 patients (18.4%); the groups did not significantly differ in terms of the arm of operation. The mean hemoglobin, hematocrit, and creatinine levels for all 103 patients before surgery were 9.7±1.3 g/mL, 29.2%±3.8%, and 6.6±2.9 mg/dL, respectively, with an estimated creatinine clearance rate of 9.3±4.1 mL/min/1.73 m². No statistically significant differences were observed between the groups in terms of blood test results (Table 1).

2) Postoperative complications

Postoperative complications occurred in 21 pa-

Table 2. Postoperative complications in the 2 groups

	Total	Group A: 4- to 6-mm tapered	Group B: 6-mm straight	p-value
Ischemia	3 (2.9)	1 (1.3)	2 (8.0)	0.145
Infection	11 (18.4)	6 (7.7)	5 (20.0)	0.130
Pseudoaneurysm	4 (7.8)	3 (3.8)	1 (4.0)	>0.999
Seroma	3 (2.9)	2 (2.6)	1 (4.0)	0.570

Values are presented as number (%).

tients (20.4%) who required hospital admission and surgical treatment. Complications included 3 cases of hand ischemia (group A: 1 patient, 1.3%; group B: 2 patients, 8%), 11 cases of infection (group A: 6 patients, 7.7%; group B: 5 patients, 20.0%), 4 cases of pseudoaneurysm (group A: 3 patients, 3.8%; group B: 1 patient, 4.0%), and 3 cases of seroma (group A: 2 patients, 2.6%; group B: 1 patient, 4.0%). The incidence of each complication was not significantly different between the groups (Table 2).

3) Patency rate

Using Kaplan-Meier survival analysis, the 1-year, 3-year, and 5-year patency rates were determined to be 61.8%, 44.9%, and 38.5%, in group A, and 62.7%, 41.1%, and 35.3%, respectively, in group B. No statistically significant differences were found in the patency rates between the 2 groups (Fig. 2).

Discussion

Compared to AVFs, AVGs are known to have a higher incidence of complications, such as infection and thrombosis, and lower patency and survival rates. Thus, AVFs are preferentially considered in most clinical settings. However, when the patient's blood vessels are not suitable for surgery, artificial grafts are used. Kim et al. [2] reported that the 1-, 3-, and 5-year primary patency rates of AVFs were 84%, 67%, and 51%, respectively, whereas those of AVGs were much lower (51%, 22%, and 9%, respectively).

Many factors contribute to the low patency rate of AVGs, but intimal hyperplasia at the anastomosis site is known to be the most decisive factor. Tapered grafts were devised in an effort to slow intimal hyperplasia according to the concept of shear stress. Shear stress refers to a physical force that pushes by impacting vertically on the horizontal area. Hemodynamically, this refers to the force of the blood flow

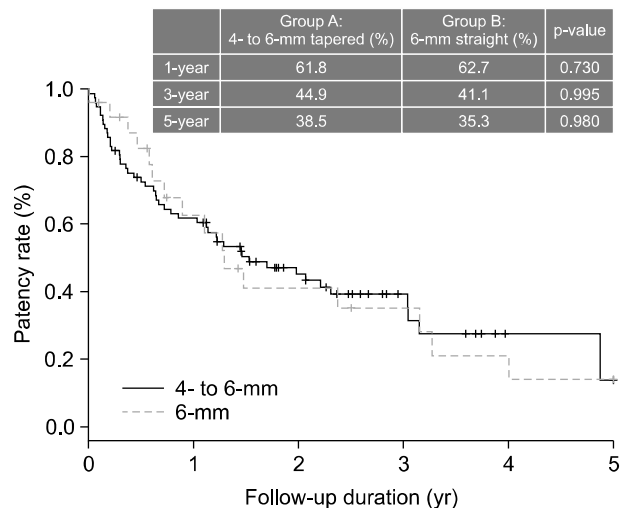


Fig. 2. Kaplan-Meier patency rate curves for arteriovenous fistulae in group A (4- to 6-mm tapered) and group B (6-mm straight).

entering the graft through the arterial anastomosis site that impacts the area perpendicular to the graft surface. When the shear stress is strong, less stenosis develops at the anastomosis site, and when the shear stress is weak, more intimal and medial hyperplasia occurs [3].

Compared to straight grafts, tapered grafts have a smaller diameter in the anastomosis site; therefore, the speed of the blood flow on entry is faster. Thus, the shear stress applied to the vessel wall is thought to be high. One in vitro study used a silicon rubber artery and vein to compare differences in pressure at different distances from the arterial anastomosis site between tapered (4–7 mm) and straight (6 mm) prosthetic grafts of extended polytetrafluoroethylene [4]. They determined that there was almost no pressure difference in the middle portion of either graft, but the pressure drop right after the arterial anastomosis site was greater in the tapered graft. However, a limitation of their study is that they used a model

in which there could be no change in resistance because of physiological vascular contraction. In addition, in a multicenter randomized trial that clinically compared a 4- to 7-mm tapered grafts with 6-mm straight grafts, no differences were found in the 1-year incidence rates of patency and thrombotic occlusion (4- to 7-mm tapered vs. 6-mm straight, 46% vs. 43%; $p=0.860$). Moreover, there were no significant differences in the mean graft flow and peak systolic velocity that were measured via ultrasound [5]. No correlation between graft shape and intimal hyperplasia has yet been identified in a human model.

Another concept related to the design of tapered grafts is the correlation between the size of the arterial anastomosis and ischemic steal syndrome. Ischemic steal syndrome is a serious complication that causes distal hand ischemia because of the shunt flow resulting from AVFs or AVGs, as well as pain, hypoesthesia, and necrosis in severe cases. In these cases, there have been reports of successful symptom resolution by decreasing the amount of blood shunted through the banding of the arterial anastomosis site [6]. Therefore, avoiding excessive initial arterial anastomosis may decrease the incidence of hand ischemia. Although ischemic steal syndrome only developed in 1 of the 78 patients (1.3%) in group A (tapered grafts) and in 2 of the 25 patients (8%) in group B (straight grafts), the difference was not statistically significant. Further studies performed in more patients could yield more overt differences. Considering that similar outcomes have been identified in other studies, ischemic steal syndrome cannot be explained only by the size of the arterial anastomosis, and many other factors, such as insufficient development of collateral flow because of an underlying disease (e.g., diabetes mellitus or peripheral artery occlusive disease), seem to exert a complex influence.

In addition, heart failure, which may be caused by overflow, needs to be considered. In general, it has been reported that shunt flow increases after AVF formation, which promotes left ventricular volume overload. Consequently, left ventricular hyperplasia and congestive heart failure are exacerbated. Congestive heart failure, however, seems to be relatively dependent on preoperative cardiac function, which is not directly affected by shunt flow. Therefore, if the patient's cardiac function is not good, using a tapered graft is a good alternative to prevent excessive

shunt flow [7].

To date, studies on surgical outcomes according to catheter shape have been very limited. Even in the Clinical Practice Guidelines for Hemodialysis Adequacy published by the Kidney Disease Outcomes Quality Initiative in the USA, the configuration of the graft that was used was not mentioned [8]. The reason for this seems to be that no large-scale study has been conducted on the use of tapered grafts. In our literature review, information on the advantages of using tapered grafts was found, but there was very little information on the disadvantages [9].

This current study was based on our experiences with tapered grafts, which were easy to anastomose at the arterial side. The similarity in diameters of the graft and the target vessel made anastomosis easier in comparison with the straight graft. This study confirmed that there is no difference in patency rate and complication rate between the 2 graft types. Although the superiority of the tapered graft has not been proven, the safety and the equivalent performance of the tapered graft have been demonstrated in clinical settings. The present study has several limitations, such as a small and uneven sample size in both groups. In the future, further studies must be conducted with larger sample sizes and more accurate statistical comparison methods, such as a propensity matching study. We expect that further studies will establish the superiority of the tapered graft.

In conclusion, in the current study, it was confirmed that patients who received a 4- to 6-mm tapered graft had no significant differences in complication rates and 1-year, 3-year, 5-year patency rates compared to those with a 6-mm straight graft. Given the absence of evident differences in safety and efficiency between the 2 graft types, it is reasonable to choose the tapered graft because of its advantage in terms of ease of anastomosis.

Conflict of interest

No potential conflicts of interest relevant to this article are reported.

Acknowledgments

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