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Microsurgical approach for hemodialysis access

A pilot study of Brescia–Cimino fistulas constructed under microscopic guidance

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Abstract

The distal forearm is the preferred site for hemodialysis access. However, forearm vessels have small diameter, which may lead to complications of arteriovenous fistulas constructed at this site. Indeed, the mean patency rate of such fistulas has been reported at 65.2% (range, 56–79%) at 1 year postoperatively. In this study, we aimed to evaluate the patency rate of Brescia–Cimino arteriovenous fistulas constructed under microscopic guidance. We retrospectively evaluated the records of patients with chronic renal failure who received a Brescia–Cimino arteriovenous fistula between 2014 and 2015 for hemodialysis access. Preoperative venography and Doppler mapping were used to evaluate vein diameter at the wrist. Veins with a diameter of >2 mm were chosen. End-to-side microanastomosis was performed using Nylon #9-0 suture under microscopic guidance. Postoperatively, monthly follow-up (first with venography; with Doppler ultrasound thereafter) was conducted to detect vessel obstruction and evaluate blood flow. Six of the seven patients included in this study received hemodialysis without signs of obstruction or complications. On Kaplan–Meier survival analysis, the mean patency rate at 2 years postoperatively was 85.7%. One patient (female, 60 years) had vessel obstruction and underwent percutaneous transluminal angioplasty 3 times after receiving the arteriovenous fistula. The median follow-up duration was 41 months (range, 25–47 months). Our experience indicates that, for relatively healthy vessels with a diameter of >2 mm, Brescia–Cimino arteriovenous fistulas at the wrist can be safely constructed using microsurgical suturing under microscopic guidance, without complications such as ischemic hand syndrome or infection.

Abbreviations: AV = arteriovenous, IRB No. = Institutional Review Board Number, NY = New York, US = United states of America.

Keywords: arteriovenous fistula, microscopy, plastic surgery, shunt, vascular patency ;

1. Introduction

The arteriovenous (AV) fistula for hemodialysis was first described by Brescia et al.[1] Since then, dialysis therapy has undergone major modifications. Moreover, many patients are referred to the nephrologist late, which represents a well-known cause of poor outcome in dialysis patients.[2] Clinical practice guidelines endorse the AV fistula as the preferred method for vascular access because, compared to AV grafts and central venous catheters, AV fistulas are associated with fewer complications, improved access survival, and lower mortality risk.[3] Substantial effort has been expended to develop strategies for improving the long-term patency of the fistula and maintaining adequate blood flow without complications such as infection and thrombosis.

Many surgical techniques for AV fistula construction are available. The technique is chosen according to the condition of the patient's vessels and the preference of the surgeon. For instance, vascular access can be achieved at different sites such as the proximal forearm (radioantecubital), upper arm (brachiocephalic), and wrist or hand (radiocephalic).[4] Because upper arm fistulas carry a higher risk of vascular access steal syndrome, anastomosis of the radial artery and cephalic vein at the level of the distal forearm is often preferred.[1] Moreover, patients with chronic renal failure have high risk of ischemic symptoms especially at the level of the AV fistula; this risk is increased in individuals with poor peripheral vasculature secondary to diabetes, calcification, or peripheral arterial disease.[4] However, forearm fistulas may develop complications such as obstruction due to small vessel diameter. Radiocephalic AV fistulas reportedly have a mean patency rate of 65.2% (range, 56–79%) in the first year after surgery.[3] If adequate vessels are not available in the distal forearm for fistula creation (e.g., due to stenosis), then more proximal vessels are used, and brachiocephlic or brachiobasilic fistulas are created.[5]

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Microanastomoses are successfully used in reconstructive surgery involving radial forearm free flaps. In such cases, a microanastomosis is created between 2 segments of the same vessel, and the radial artery is generally considered suitable if the external diameter is 2.5–3.5 mm at the proximal end and 2–3 mm at the distal end.[6] A Brescia–Cimino fistula is recommended for vessels with diameter of >2 mm.[7] Because microanastomosis techniques provide a magnified view, we hypothesized that a microscope may be more helpful than a surgical telescope for guiding anastomosis creation during the construction of AV fistulas for hemodialysis access at the distal forearm. The fine focus technique offers 12.5–20× magnification, which facilitates the use of advanced surgical tools such as Nylon #9-0 and #10-0 sutures.

In the present study, we investigated the long-term patency of AV fistulas created under microscopic guidance between vessels with a diameter of >2.0 mm at the wrist. We report the successful creation of Brescia–Cimino AV fistulas under microscopic guidance, with good long-term patency for hemodialysis access in a case series of adults. Our findings regarding the patency rate of such fistulas for hemodialysis access are similar to previously reported patency rates of Brescia–Cimino AV fistulas used for other purposes.[8]

2. Methods

2.1. Patients and study design

We retrospectively reviewed the records of patients with chronic renal failure who, between 2014 and 2015, received a Brescia–Cimino AV fistula at the distal forearm for hemodialysis access. The study was approved by the Institutional Review Board of our facility (IRB No. 2016-12-164), and all clinical investigations were in accordance with the Declaration of Helsinki principles. The researchers were blinded to the patient identification data until the analysis; the patients later provided written informed consent for the use of surgery photographs for research purposes, presentations, and publications.

2.2. Preoperative evaluations

Patients with chronic renal failure were referred to the Department of Nephrology for long-term hemodialysis. A permanent catheter for hemodialysis was inserted under ultrasound guidance in the right internal jugular vein. Next, the patients were referred to the Department of Plastic and Reconstructive Surgery to receive an AV fistula. Since the fistula creation procedure is relatively simple and short, the patients were not advised to stop anticoagulant or antiplatelet medication prior to the operation. To find an appropriate vessel for the AV fistula, physical examination, laser Doppler mapping, and venography were performed 1–2 days before surgery. Cephalic veins with a diameter of >2 mm at the wrist were considered appropriate for fistula creation. Before surgery, arterial patency was checked via the Allen test, while venous patency was checked by observing subcutaneous vein filling after applying a tourniquet to the humeral region (Fig. 1).

2.3. Surgical procedures

First, local anesthesia was induced by injecting 2% lidocaine. A Z-shape or linear incision was designed along the direction of the vessel, with care to preserve the lateral antebrachial cutaneous nerves. The vein was released using a wide dissection. A segment of the vein, 2 to 3 cm in length, was separated from the surrounding tissue and ligated at the distal end, followed by end-to-side anastomosis with the radial artery. To prevent thrombosis, 5,000 units of heparin (diluted 1–25,000) were administered to the venous access before vein ligation. Irrigation was frequently done to prevent desiccation, and the vessels were connected after trimming the adventitia. The vessels were anastomosed under microscopic guidance (OPMI Pentero; Carl Zeiss Surgical GmbH, Oberkochen, Germany) at up to 20× magnification. Stitching was performed in a simple interrupted or continuous pattern using Nylon #9-0 or #10-0 sutures (Fig. 2).[8] After stitching, the anastomosed segment was palpated to check for thrill and anastomosis patency was confirmed on Doppler ultrasonography. The nonanastomosed end of the vein was electrocauterized using a bipolar cautery device.

2.4. Follow-up protocol

Postoperatively, the patients underwent monthly checks (venography at 1 month after surgery and Doppler ultrasonography thereafter) to detect any obstruction in the AV fistula, measure the vein diameter, and evaluate blood flow. To promote vessel maturation of the anastomosed segment, the patients were instructed to exercise the forearm by gripping and releasing a tennis ball.

2.5. Outcome measures

The main outcome measure was the fistula patency rate, which was obtained using the Kaplan–Meier method by measuring the proportion of living patients with a patent fistula at various times after surgery using IBM SPSS Statistics for Windows (Version 22.0, IBM, Armonk, NY). On follow-up examination, the AV fistula was considered to have failed if blood flow was found to be <500 mL/min or obstruction occurred requiring emergent intervention or percutaneous transluminal angioplasty.[9] The fistula was considered mature if still patent at 1 month after surgery.[10]

3. Results

3.1. Patient characteristics

Between 2014 and 2015, 7 patients (1 female, 6 males; age range, 41–60 years; median age, 54 years) with chronic renal failure received a Brescia–Cimino AV fistula for hemodialysis. All patients were on anticoagulants or antiplatelets such as aspirin, clopidogrel, and beraprost sodium. Hypertension and diabetes mellitus were diagnosed in 5 patients, while hypertension alone was diagnosed in one patient. Pre-operatively, the mean vessel diameter was 2.32 mm. Because all patients were right-handed, the AV fistula was created at the left wrist. The median follow-up duration after the procedure was 41 months (range, 25–47 months) (Table 1).

3.2. Fistula patency outcomes

Of the 7 patients included in this study, 6 received hemodialysis without signs of fistula obstruction or complications. At 2 years postoperatively, the mean patency rate was 85.7%(6 out of 7 patients). One male patient died of cardiac arrest but his fistula was well-functioning at the time. At approximately 4 years postoperatively (i.e., excluding the patient who died), the patency rate was 71.4% (5 out of 7 patients).

Figure 1. Representative findings in a 54-year-old male patient (case #1). (A) Preoperative venogram revealing that the left cephalic vein had a diameter of >2 mm, which was appropriate for arteriovenous fistula creation. (B) Venogram at 1 month postoperatively, revealing adequate blood flow and vessel diameter, with a properly functioning arteriovenous fistula. (C) Vessel anastomosis at the left wrist.

In 6 patients, postoperative radiologic and Doppler follow-up revealed optimal blood flow rates of 5 mL/s and a mean venous diameter of 2 mm, giving a total flow rate of 500 mL/min, with a properly functioning AV fistula.[8] The other patient (a 60-year-old female) underwent percutaneous transluminal angioplasty at 4 months after the operation due to vessel obstruction, then again for low flow, and then again for thromboembolism (Fig. 3). Other complications known to occur after AV fistula creation, such as

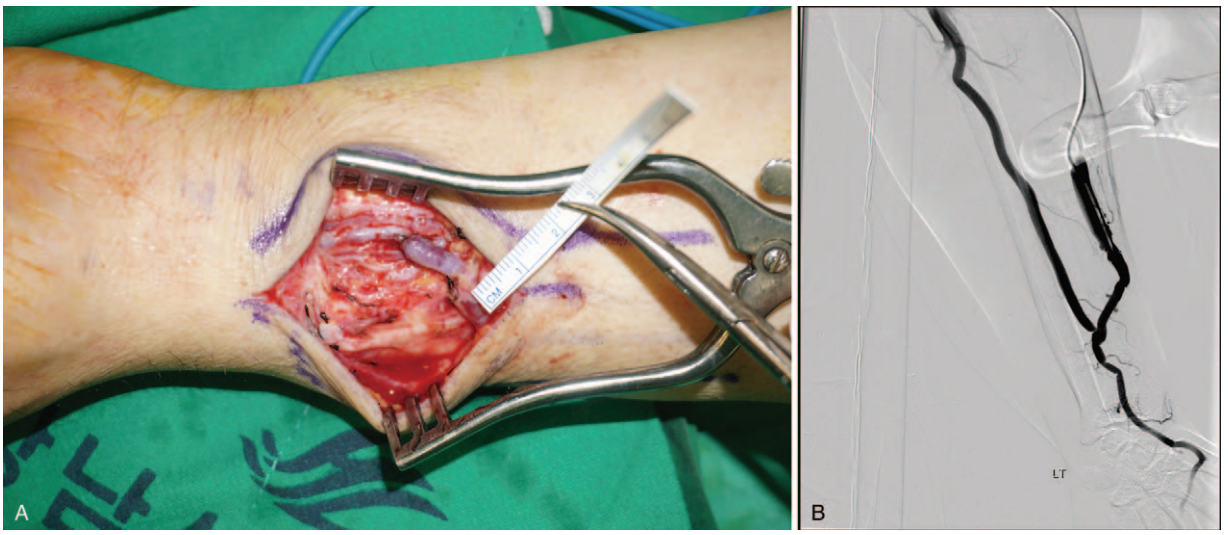

Figure 2. Representative findings in a 41-year-old male patient (case #2). (A) Vessel anastomosis at the left wrist, created via simple interrupted stitching with Nylon #9-0 suture under microscopic guidance with 10× magnification. (B) Venogram at 1 month postoperatively, revealing adequate blood flow and vessel diameter, with a properly functioning arteriovenous fistula.

bleeding, edema of the upper arm, bacterial infection, wound dehiscence, and ischemic hand syndrome, were not observed in case series over the course of up to 4 years after surgery (Table 1).

4. Discussion

In the absence of an AV fistula, a central venous catheter is used for hemodialysis. Central venous catheterization is a relatively safe and technically simple strategy to secure venous access but does carry a risk of side serious effects such as arrhythmia, pneumothorax, hemothorax, arteriopuncture, infection, formation of an unplanned AV fistula, and angiostenosis. Among these side effects, angiostenosis is relatively common and difficult to treat.[5] In 1966, Brescia et al[1] described the construction of an AV fistula between the radial artery and the cephalic vein. This strategy overcomes the main limitations of central venous catheterization, facilitating long-term repeated hemodialysis through an arterialized vein, and has since become adopted as the primary surgical method for AV fistula creation.

The ideal AV fistula fulfills 3 conditions, namely that it is easy to use for hemodialysis, it maintains the target blood flow at all times, and it remains patent for long-term use.[8] In practice, many patients eventually develop obstruction or stenosis of the fistula and require the construction of multiple AV fistulas in order to continue hemodialysis. Such complications occur due to injury to the vascular endothelium caused by repetitive vascular puncturing.

With the development of medical technology and increase in life expectancy, the number of patients who require long-term hemodialysis is steadily increasing. Therefore, to improve the long-term patency of the AV fistula, it is necessary to identify and, if possible, manage the relevant risk factors early after surgery.[11] Aging-related decrease in arterial wall expansibility and increase in vascular resistance result in reduced blood flow from the artery to the vein, which has a negative effect on the maturation of the arteriovenous fistula. The current literature suggests that age, female sex, and diabetes mellitus are predictors of fistula failure. Although some reports discourage creation of an AV fistula in patients aged >60 years, a retrospective review by Burt et al[12] found that fistula patency is not affected by age, supporting the use of the AV fistula as the vascular access of choice in patients of any age group. A retrospective study by Wetzig et al[13] suggested that tobacco smoking may detrimentally affect the patency of the AV fistula.

Vessel maturation is impeded primarily by decreased blood flow after surgery, which may be related to problems in the

Table 1

Demographics, clinical characteristics, and outcomes of patients with chronic renal failure who received a Brescia–Cimino arteriovenous fistula for hemodialysis access.

No.	Sex	Age, years	Preoperative vessel diameter, mm	Follow-up, months	Obstruction or low flow	Complications (ischemic hand syndrome or infection)
1	M	54	2.5	47	No	No
2	M	41	2.2	43	No	No
3	M	54	2.4	40	No	No
4	M	53	2.3	42	No	No
5	M	50	2.4	25*	No	No
6	F	60	2.2	41	3 times†	No
7	F	56	2.3	40	No	No

* The patient died of cardiac arrest.

† The patient underwent percutaneous transluminal angioplasty.

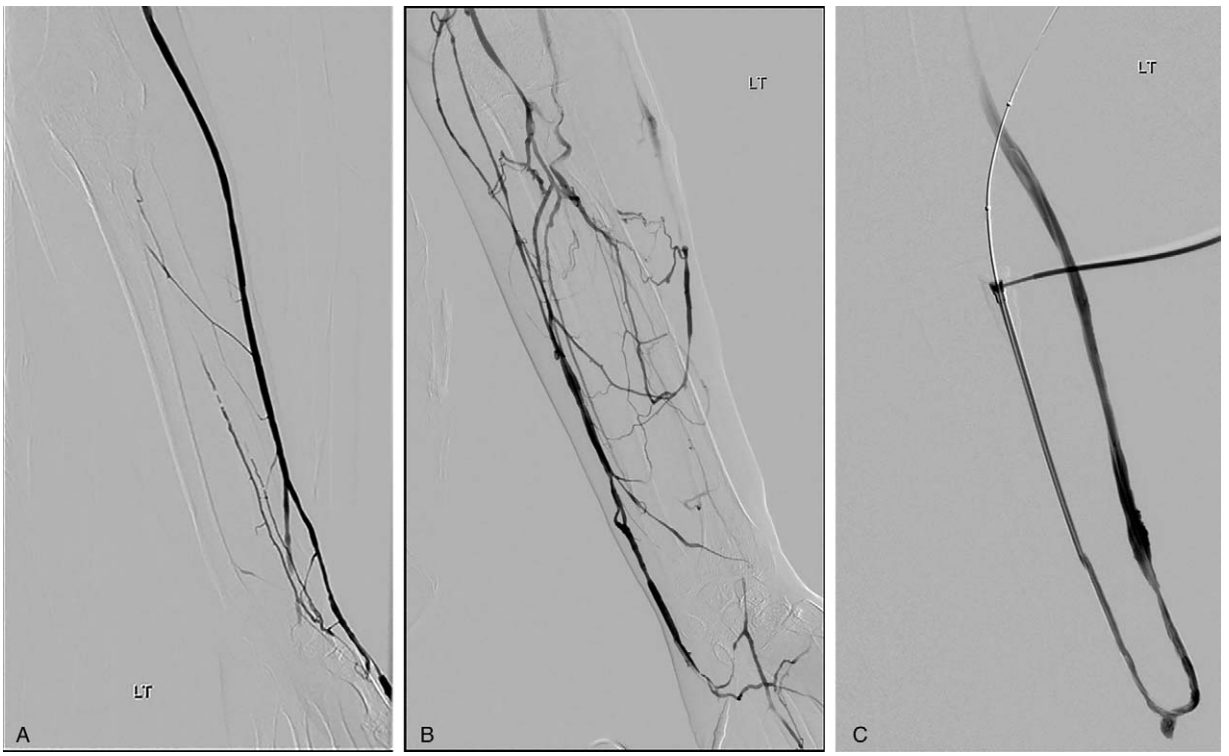

Figure 3. Representative findings in a 60-year-old female patient (case #6). (A) Pre-operative venogram revealing that the left cephalic vein had a diameter of >3 mm at the wrist, which was appropriate for arteriovenous fistula creation. (B) Venogram at 1 month postoperatively, revealing adequate blood flow and vessel diameter, with a properly functioning arteriovenous fistula. (C) At 4 months postoperatively, the patient underwent percutaneous transluminal angioplasty due to multifocal stenosis of the cephalic vein.

surgical techniques used for vessel anastomosis, calcification of the artery wall, small diameter of the vein, stiffening of the vein, and hypotension. Therefore, when planning to create an AV fistula, it is desirable to use Doppler ultrasonography for identifying an artery capable of maintaining appropriate blood flow.[14] Based on the current literature, arteries with a diameter of >2 mm are suitable for AV fistula creation. A meta-analysis found a success rate of 59% when the radial artery diameter was >2 mm versus 40% when the diameter was <2 mm.[10] Many other studies have shown that smaller arterial diameters (<2.0 mm) are associated with decreased maturation rate of the AV fistula.[15] One article suggested that microsurgical techniques could be applied for the construction of the AV fistula, but reported a primary patency rate of 68±10% at 1 year,[16] which has so far not been considered sufficient to justify the application of microsurgical techniques for this purpose. Therefore, we focused on patients with relatively stable vascular condition, as reflected in the flow rate of 500 mL/min. Another consideration was the location of incisions. Specifically, scars of relatively distal incisions are more easily concealed. Finally, we only employed vessels with a diameter of >2 mm at the wrist. Employing these inclusion criteria, we identified 7 patients, of whom only one had failed AV fistula, whereas another died of cardiac arrest with a fully functioning fistula; the patency rate at 4 years was 71.4%(5 out of 7 patients), which seems promising.

When an AV fistula is made, the site of anastomosis should be designed to achieve a sufficiently broad cross-section to prevent stenosis and maintain appropriate blood flow. Based on this principle, some surgeons join the 2 vessels using continuous sutures tied by hand; typically, Nylon #6-0 or #7-0 sutures are applied under 2.5–3.5× magnification provided by a surgical telescope. On the other hand, microsurgical flap surgery involves simple interrupted stitching with Nylon #9-0 or #10-0 sutures and tying the sutures using a dedicated instrument under up to 20× magnification provided by a microscope. While the duration of the operation differs according to the stitching method, such procedures generally do not exceed 2 hours. Microscopy with fine focus enables the surgeon to assess the condition of the intima (i.e., check for intimal tear, atherosclerotic plaque, and friable lesions in calcified areas) and perform the anastomosis more meticulously and safely.

If it is difficult to find suitable autologous vessels for construction of the AV fistula, an artificial vessel may be considered.[17] While many factors such as age, sex, and incidence of complications may affect the long-term patency of the AV fistula, employing a careful and correct surgical technique is the most important aspect. The increased magnification provided by the microscope makes it possible to meticulously trim the adventitia and pass the Nylon #9-0 or #10-0 sutures. Thus, using microscopic guidance to construct the Brescia–Cimino AV fistula is expected to serve as a suitable strategy for fistula creation in patients requiring hemodialysis, as more of the vessel can be preserved via this procedure than via the standard procedure employing a surgical telescope.

The main limitation of this study is the small sample size, which precludes statistical analysis. However, the patency rate was as high as 85.7% (6 out of 7 patients), which urged us to report on these promising results. There are several reasons for the reduced sample size, including ethical reasons, indication criteria, and costs associated with the procedure. We did our best to recruit

more patients to undergo this type of microsurgery procedure, but this was not possible under the medical system in our institution. In fact, all patients were referred to us from the Department of Nephrology at a time during which vascular surgeons were not available in our hospital. Since plastic surgeons have the skill and experience to handle microvasculature, we believe these could be put to good use in helping the increasing number of patients requiring an AV fistula for hemodialysis. Furthermore, we did not indicate the microsurgery procedure in patients with small diameter of the artery (<2 mm) or with reduced blood flow rate expected for the fistula (<500 mL/min). Patients with chronic renal failure often have multiple comorbidities resulting in poor vascular condition, which may limit meticulous handling of the vascular access and may lead to fistula failure for reasons not related to the surgical procedure. Finally, some patients were unable or unwilling to undergo the microsurgery procedure due to low income. AV fistula creation using microsurgery is more expensive than the traditional approach and thus may not be a feasible option for patients with low socioeconomic status. On the other hand, our findings suggest that the patency rate is high, which helps reduce the need for further expensive procedures such as angioplasty. Therefore, we believe that the microsurgery procedure described here serves as a feasible option in terms of success rate and cosmetic results.

The limitations of our study are small number of sample size, relative short term follow up and retrospective design. The statistical analysis is infeasible because of these limitations. The small sample size was because most patients are referred to vascular surgeons for arteriovenous fistula formation. The small patients were referred to our department during the time when the vascular surgeons were absent on our hospital between 2014 and 2015. Further studies with large sample size, prospective and randomized controlled comparative design, and long-term follow-up are warranted for statistical analysis. It would clarify the contribution of the microsurgical technique in decreasing the incidence of early fistula failure and maintaining high patency. Moreover, a comparative cost-benefit analysis should be conducted for the microsurgical vs. conventional approaches. In this small case series, we found that, for relatively healthy vessels with a diameter of >2 mm at the wrist, AV fistula construction (Brescia–Cimino) using microsurgical suturing under 20× magnification is safe and provides high patency rates, without complications such as ischemic hand syndrome or early infection. We hope that these promising results highlight the potential of microsurgery in adults with chronic kidney failure requiring long-term hemodialysis.

Author contributions

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