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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE



# Staged angioplasty using a full-length balloon catheter to achieve maturation of arteriovenous fistulas

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**PURPOSE**

To evaluate the efficacy of staged full-length balloon-assisted maturation (BAM) for the maturation of arteriovenous fistulas (AVFs) on entire segmental veins, including stenosis, causing primary AVF failure.

**METHODS**

This study included patients who underwent AVF surgery using an autogenous vein between February 2020 and June 2021 and received staged angioplasty with a full-length balloon catheter. To minimize balloon overlap and the risk of barotrauma to the immature vein, serial-staged upsizing balloon angioplasty with a long balloon catheter covering the entire vein segment was employed approximately 2 weeks apart.

**RESULTS**

Twenty-three patients (mean age, 69.50 years; mean follow-up, 620.62 days) with average diameters of the radial artery and cephalic vein at 2.14 ± 0.5 mm and 2.43 ± 0.5 mm, respectively, were enrolled. In the first procedure, the average AVF diameter and flow were 4.03 ± 0.57 mm and 438.08 ± 220.95 mL/min, respectively, with juxta-anastomotic stenosis (JAS) present in 61.5% of cases. After staged full-length BAM, the average fistula diameter and flow improved to 5.95 ± 0.86 mm and 717.52 ± 305.95 mL/min, respectively. Maturation was achieved in 87% of the cases. No hematomas or ruptures occurred around the arterialized veins. Despite successful maturation and cannulation, 65.2% of the patients required additional percutaneous transluminal angioplasty (PTA) during the follow-up period. The necessity for PTA was determined by the presence of JAS prior to the first staged full-length BAM, with an odds ratio of 11.74 (95% confidence interval: 1.31–104.96, $P = 0.03$).

**CONCLUSION**

Staged full-length BAM can be safely used in patients with small veins requiring further maturation. Most patients achieved successful cannulation following maturation without post-procedural complications.

**CLINICAL SIGNIFICANCE**

Staged full-length BAM is a safe and effective method for enhancing maturation in patients with underdeveloped small veins.

**KEYWORDS**

Arteriovenous fistula, balloon-assisted maturation, hemodialysis, maturation, stenosis

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Due to the increasing number of patients requiring hemodialysis, efforts are underway to create arteriovenous fistulas (AVFs) in arteries or veins previously considered too small for AVF surgery. Although technological advancements have raised expectations for improved maturation rates, this issue remains a substantial challenge.[1] Several studies have addressed the failure of AVF maturation. Suggested interventions include preoperative vein preservation,[2] exercise,[3] and enhanced examination methods for veins and arteries, along with various surgical techniques introduced during the procedure.[4] Post-AVF forma-

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tion, treatments such as balloon angioplasty for stenosis that impedes maturation, surgical ligation, or endovascular coil embolization of the collateral veins where flow steal occurs may be performed.[5-7] Additionally, techniques aimed at forcibly increasing vein size through surgical intervention have been attempted.[8]

Numerous studies have explored the application of balloon angioplasty following AVF creation to address the strictures causing primary AVF failure; however, the results, including technical and clinical success, remain unsatisfactory.[9-14] When balloon angioplasty is performed for anastomosis or juxta-anastomotic stenosis (JAS), although flow improvement is typically observed, the diameter of the entire vessel within the AVF circuit does not always increase. Consequently, the fistula cannot be immediately needled, requiring more time before the AVF is usable. Moreover, there are relatively few reports on balloon maturation in small veins ≤3 mm in diameter, and the clinical significance of such interventions, including long-term outcomes, remains unclear.[15,16]

In this study, we performed percutaneous angioplasty on the entire vein segment, addressing the stenosis responsible for primary AVF failure. To minimize the risk of barotrauma to the immature vein, we utilized two approaches: serial-staged upsizing balloon angioplasty and a long balloon catheter covering the entire vein segment to minimize balloon overlap. We analyzed the technical success of this staged full-length balloon-assisted maturation (BAM) and investigated clinical success rates, including AVF salvage, long-term AVF patency, and the occurrence of additional stenosis during long-term follow-up.

**Main points**

- Balloon-assisted maturation (BAM) for an arteriovenous fistula (AVF) involves adjusting the balloon catheter size to match the vein's actual size. Balloon dilation is performed along the entire length of the anatomical segment to minimize barotrauma in areas of overlapping balloon exposure.
- Among the patients, 34.6% underwent three or more procedures. The average AVF diameter increased from 4.03 mm to 5.95 mm, and the average AVF flow from 438.08 mL/min to 717.52 mL/min.
- No hematomas or ruptures were observed following full-length staged BAM; however, 65.2% of patients required additional percutaneous transluminal angioplasty to maintain patency during the follow-up period.

## Methods

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the Institutional Review Board of Pusan National University Hospital, Republic of Korea (IRB no: 2308-024-130, date: 19.08.2023). Due to the retrospective nature of this study, the requirement for informed consent was waived.

### Patient selection and data collection

Among 275 patients who underwent AVF surgery using autogenous veins at our hospital between February 2020 and June 2021, we collected data from patients who underwent staged angioplasty using a full-length balloon catheter. Patients who visited the outpatient clinic at 4–6 weeks post-AVF surgery underwent ultrasonography to evaluate AVF maturation. Staged full-length BAM was recommended for patients who exhibited an unsatisfactory increase in vein size, generally defined as no more than 4.5 mm in diameter. Additionally, even if the vein diameter exceeded 4.5 mm, challenges in cannulation could occur if the vessel was deeply situated. Out of these, 23 patients who consented to the procedure and have been under continuous observation with no loss to follow-up were included in the analysis (Figure 1).

Variables such as age, sex, follow-up duration, type of AVF, comorbidities, and smoking history were recorded. Detailed information on the size and depth of the arteries and veins before surgery, as well as the size and depth of the AVF at the time of the first procedure, was collected. Blood flow data, the total number of procedures performed, the degree of balloon used, the size and depth of the AVF post-final procedure, subsequent blood flow information, and success rates of cannulation and maturation were further investigated.

### Staged balloon-assisted maturation using a full-length balloon catheter

Radiocephalic and brachiocephalic fistulas were assessed by puncturing the radial artery at the wrist, draining vein, or internal jugular vein under ultrasound guidance. During the procedure, the balloon diameter was set approximately 1 mm larger than the size of the native vein, and the balloon size was incrementally increased by 1 mm during subsequent procedures. The balloon length was determined by measuring the distance from the anastomosis to the tip of the anatomical section of the vein. The entire anatomical segment of the vein was dilated using a balloon measuring at least 120 mm in length. For patients on dialysis, a uniplanar angiography suite with a contrast agent was used; however, for pre-dialysis patients, a guidewire was inserted under ultrasound guidance to position the balloon, and fluoroscopy was used only for additional ballooning (Figure 2).

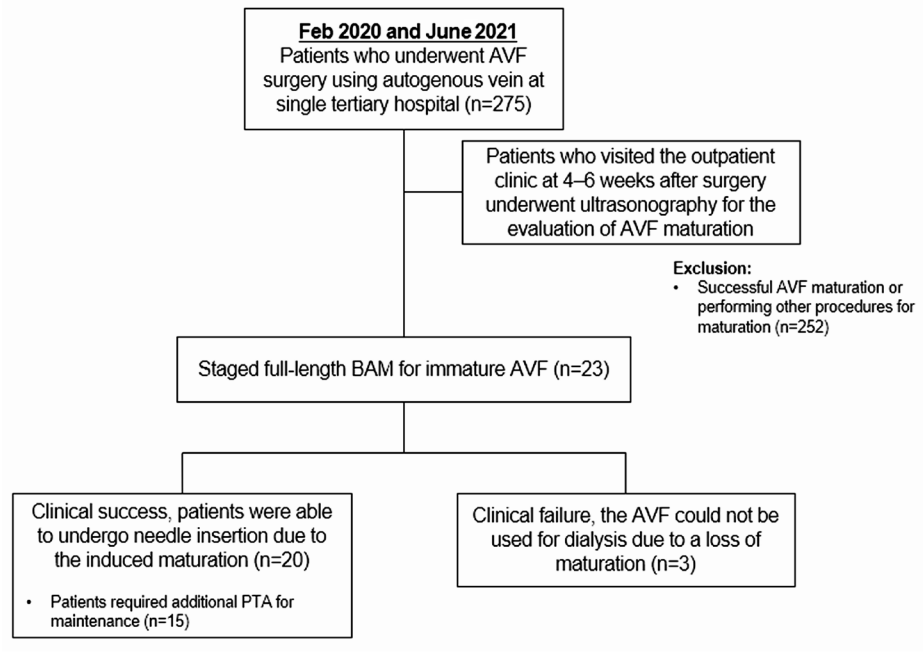


**Figure 1.** Flow chart depicting the patient selection process-arteriovenous fistula (AVF); balloon-assisted maturation (BAM); percutaneous transluminal angioplasty (PTA).

All patients returned for follow-up as outpatients 10 days after the initial procedure, at which point clinicians assessed the need for a second procedure. If necessary, the second treatment was conducted approximately 2 weeks after the first. These procedures were repeated until the vein size reached or exceeded 6 mm.

### Outcomes and complications

Technical success was defined as the intentional expansion of the vein diameter without rupture, as confirmed by outpatient ultrasonography 10 days following the staged full-length BAM procedure. Clinical success was defined as the ability to conduct stable dialysis using an AVF within 3 months of performing the staged full-length BAM.

Postprocedural complications such as skin bruising, perivascular hematoma, rupture, and infection were monitored-additionally, progress after AVF maturation was observed, including cases where further procedures or surgeries were necessitated. The main lesions targeted in additional interventions were also documented.

### Statistical analysis

Statistical analyses were conducted using basic descriptive statistics, with results presented as means and standard deviations. Logistic regression analysis was employed to estimate factors influencing failures and additional interventions post-maturation, whereas the chi-square test was used to compare characteristics between groups (intervention vs. non-intervention). Primary patency rates were calculated using Kaplan–Meier life-table analysis. Statistical significance was established at $P$ values <0.05. All analyses were performed using MedCalc Statistical Software version 20.106 (MedCalc Software, Ostend, Belgium).

## Results

The mean age of the patient cohort was 69.50 ± 11.12 years, and 39% of the patients were women. The average follow-up duration was 620.62 days. Among the comorbidities, 80.8% of the patients had diabetes, and the current smoking rate was 8.7%. Additionally, 88.5% of the patients had radiocephalic fistulas at the wrist, with the mean diameter of the radial artery being 2.14 ± 0.5 mm and that of the brachial artery being 4.5 ± 0.14 mm. The mean diameter of the veins used for surgery was 2.43 ± 0.5 mm. At the time of the first procedure, the mean diameter was 4.03 ± 0.57 mm, and the average flow rate was 438.08 ± 220.95 mL/min. JAS was present in 61.5% of the cases. The median time from the AVF operation to the first staged full-length BAM was 51 days. The patient characteristics are summarized in Table 1.

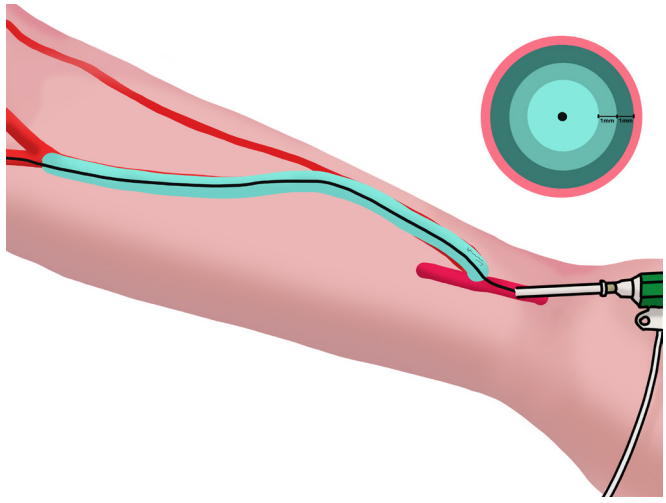

**Figure 2.** Illustration of staged full-length balloon-assisted maturation.

**Table 1.** Demographic data of the study participants

| Variables | | n = 23 |
|---|---|---|
| **Age (mean, SD) (years)** | 69.50 | 11.12 |
| **Sex (M:W)** | 17:9 | |
| **Follow-up duration (mean, SD) (days)** | 620.62 | 260.40 |
| **Type of AVF (n, %)** | | |
| Radiocephalic | 23 | 88.5% |
| Brachiocephalic | 2 | 7.7% |
| Radiobasilic (with transposition) | 1 | 3.8% |
| **Preoperative condition (mean, SD)** | | |
| Artery diameter (mm) | | |
| Radial | 2.14 | 0.5 |
| Brachial | 4.5 | 0.14 |
| Vein diameter (mm) | 2.43 | 0.5 |
| **Duration (days) between surgery to the first staged balloon PTA* [median, (range)]** | 51 | 11–343 |
| **Preprocedural condition (mean, SD)** | | |
| Fistula diameter (mm) | 4.03 | 0.57 |
| Fistula depth (cm) | 3.3 | 1.06 |
| Fistula flow (mL/min) | 438.08 | 220.95 |
| **Comorbidities (n, %)** | | |
| Diabetes | 21 | 80.8% |
| Hypertension | 17 | 23.1% |
| CAOD | 5 | 19.2% |
| CVA | 5 | 19.2% |
| Malignancy | 2 | 7.7% |
| Glomerulonephritis | 2 | 7.7% |
| **Smoking status (n, %)** | | |
| Ex-smoker | 12 | 46.2% |
| Current smoker | 2 | 8.7% |

Normally distributed data are presented as means and standard deviations; otherwise, medians and minimum-maximum values* are used. AVF, arteriovenous fistula; CAOD, coronary artery occlusive disease; CVA, cerebrovascular accident; W, women; M, men; PTA, percutaneous transluminal angioplasty; SD, standard deviation.

### Staged full-length balloon-assisted maturation

Ten patients (28.5%) underwent a single procedure, whereas nine (34.6%) underwent three or more procedures (Table 2). The Mustang balloon (Boston Scientific, Marlborough, MA, USA) was the most commonly used balloon catheter. The balloons typically had a diameter of 5 mm and a length of 150 mm. After the final procedure, the AVF diameter was measured separately at the arterial and venous needle cannulation areas (Table 2). These measurements were taken during hemodialysis sessions using the fistula. Detailed information on the balloons used, the condition of the AVF prior to the procedures, and the outcomes are provided in the Supplementary Table.

### Outcomes and complications

There was a substantial increase in both the pre- and postoperative diameters of the AVF at the arterial and venous cannulation sites. Additionally, there was a considerable increase in blood flow within the AVF (Table 3). The fistula matured successfully in 87% of the patients. However, clinical failure occurred in 3 of the 23 patients, as their AVFs could not be used for dialysis due to unsuccessful maturation, as noted with an asterisk (*) in the Supplementary Table. Logistic regression analysis was conducted to identify potential factors contributing to these failures, but no statistically significant factors were identified.

Despite successful maturation and cannulation, 15 of the 23 patients (65.2%) required additional percutaneous transluminal angioplasty (PTA). The frequency of additional PTA and the number of these procedures are detailed in the Supplementary Table. The decision to perform additional PTA was influenced by the presence of JAS prior to the first full-length balloon angioplasty. The odds of requiring additional PTA for patients with pre-existing JAS were significantly higher, with an odds ratio of 9.33 ($P$ = 0.03; 95% confidence interval: 1.22–97.62). When comparing AVF data between patients who underwent additional PTA and those who did not, a notable difference in the incidence rate of JAS was observed (Table 4). Additional PTA targeted the JAS in 7 of the 15 patients and was performed on various venous zones outside the JAS in the remaining 8 patients. The 1-year primary patency rate of these interventions was 49.2% (Figure 3).

In terms of postoperative complications, bruising occurred in 3 patients; however, there were no cases of hematoma, vascular rupture, procedure-related infections or access-site complications.

## Discussion

BAM is a method for the forced maturation of immature AVFs that initially appears effective; however, there is an ongoing debate about its long-term patency.[7,17-22] A recent meta-analysis by Tordoir et al.[5] reported BAM success rates ranging from 43% to 97%. The most frequent complication was a hematoma, occurring in about 40% of cases, typically caused by using overly large balloons in the forearm. The study also noted a low long-term primary patency rate (28%–72%), indicating that multiple interventions might be necessary to maintain patency.[5]

In previous research, de Oliveira Harduin et al.[23] conducted percutaneous angioplasty on the entire vein segment to expand the vessel wall and enhance blood flow by inducing controlled rupture or controlled intramural hematoma from the intima, media, and adventitia layers. This technique resulted in the formation of a large-diameter AVF circuit with patency comparable to that of a mature AVF. Although this approach achieved a high success rate of approximately 91%, substantial complications such as massive pseudoaneurysm from large-sized ballooning, uncontrolled steal, and juxta-anastomosis rupture requiring AVF ligation still occurred in about 5% of cases.[23]

In situations where the balloon diameter exceeds the AVF size by more than 2 mm, the vessel circumference increases by approximately 6 mm, substantially raising the risk of rupture. Therefore, the present study utilized staged full-length BAM to reduce this risk and increase the size of the entire venous segment where maturation was inadequate. The clinical outcomes of this staged approach did not substantially differ from earlier reports. Despite the intended uniform

**Table 2.** Characteristics of staged balloon percutaneous transluminal angioplasty

| | | |
|---|---|---|
| **Number of procedures performed (median, [range])** | 2 | [1–4] |
| 1 | 10 | 28.5% |
| 2 | 7 | 26.9% |
| 3 | 6 | 23.1% |
| 4 | 3 | 11.5% |
| **Median diameter of the first balloon (median, [range]) (mm)** | 5 | [3–7] |
| **Median length of the first balloon (median, [range]) (mm)** | 150 | [120–220] |
| **Type of the first balloon (n, %)** | | |
| Mustang[a] | 18 | 69.2% |
| Passeo[b] | 3 | 11.5% |
| Achilles[c] | 4 | 15.4% |
| Sterling[d] | 1 | 3.8% |
| **Postprocedural fistula diameter (mean, SD) (mm)** | | |
| Arterial needle cannulation area | 5.94 | 0.86 |
| Venous needle cannulation area | 5.7 | 0.81 |
| **Postprocedural fistula depth (mean, SD) (mm)** | | |
| Arterial needle cannulation area | 2.9 | 0.71 |
| Venous needle cannulation area | 2.6 | 1.03 |
| **Postprocedural fistula flow (mean, SD) (mL/min)** | 716.25 | 663.5 |
| **Success rate of maturation and needling (n, %)** | 24 | 92.3% |

[a]Mustang balloon: Boston Scientific, Marlborough, MA, USA; [b]Paseo balloon: Biotronik AG, Bülach, Switzerland; [c]Achilles balloon: BrosMed Medical, Guangdong, China; [d]Sterling balloon: Boston Scientific, Natick, MA, USA. SD, standard deviation.

**Table 3.** Independent t-test results comparing pre- and postprocedural fistula diameter and flow

| Parameter | Preprocedural | Postprocedural | *P* value |
|---|---|---|---|
| **Arterial needle cannulation area (mm)** | 4.15 | 5.94 | <0.01 |
| **Venous needle cannulation area (mm)** | 4.09 | 5.70 | <0.01 |
| **Flow (mL/min)** | 438.08 | 716.25 | <0.01 |

increase in size not occurring in all patients, there were no procedure-related complications, such as hematoma or rupture.

The immediate technical success rate in this study was 100%, and the clinical success rate of the dialysis access technique described was 87%. For the 3 patients in whom the procedure failed, vein size was maintained during follow-up at the outpatient clinic 2 weeks post-procedure. However, severe intimal hyperplasia developed within 3 months, preventing lumen maintenance and rendering the AVFs unusable. Consequently, AVFs that underwent unsuccessful BAM were ligated, and new AVFs were created.

In patient 26 (Supplementary Table), the fistula was a left wrist radiocephalic type. Ultrasound examination conducted 15 weeks post-fistula formation showed an ambiguous vein size of 5.3 mm. Despite attempts at puncture, repeated hematomas occurred due to the deep placement and small size of the vein, which is unsuitable for dialysis. The staged full-length BAM was selected to potentially facilitate easier puncture by increasing the vein diameter. The procedure was performed at 2-week intervals using 6 mm and 7 mm balloons. Immediately after the procedure, the diameter and flow were confirmed to be sufficient for maturation success. However, for reasons not well understood, severe intimal hyperplasia developed throughout the forearm cephalic vein, leading to fistula failure (Figure 4). Prior to balloon angioplasty, the vein was cleaner and well-maintained. At the time of radiocephalic fistula formation, the cephalic vein in the upper arm increased in size, and the balloon did not traumatize the area. Subsequently, a brachiocephalic fistula was created and maintained successfully for 2 years without further intervention. In such cases, it may have been preferable to perform superficialization without BAM or PTA. Even if the vein diameter was initially large, staged full-length BAM did not consistently induce maturation, and the veins could fail during the maturation process due to intimal damage along the entire length of the vein caused by the balloon.

In patients 14 and 24 (supplement), there was little or no increase in vein size following balloon angioplasty; in some instances, the actual vein diameter was smaller than before the procedure. Ultrasound imaging revealed extensive intimal hyperplasia throughout the forearm cephalic vein, and an AVF occlusion developed within a month, necessitating a switch to an arteriovenous graft. Logistic regression analysis was conducted to identify

**Table 4.** Comparison of groups that required and did not require additional treatment after maturation

| Variable | Additional intervention (+) | Additional intervention (-) | *P* value |
|---|---|---|---|
| **Preoperative factors** | | | |
| Artery diameter (mm) | 2.24 ± 0.82 | 2.43 ± 0.79 | 0.56 |
| Vein diameter (mm) | 2.39 ± 0.46 | 2.49 ± 0.59 | 0.64 |
| **Preprocedural factors** | | | |
| Fistula diameter (mm) | 4.19 ± 0.80 | 4.09 ± 0.49 | 0.71 |
| Fistula flow (mL/min) | 407.01 ± 227.59 | 480.45 ± 214.73 | 0.41 |
| JAS [n (%)] | 12 (80%) | 4 (36.3%) | 0.03 |
| **Postprocedural factors** | | | |
| Fistula diameter (mm) | 6.20 ± 0.75 | 5.57 ± 0.89 | 0.06 |
| Fistula flow (mL/min) | 699.43 ± 315.66 | 739.20 ± 299.25 | 0.75 |

JAS, juxta-anastomosis stenosis.

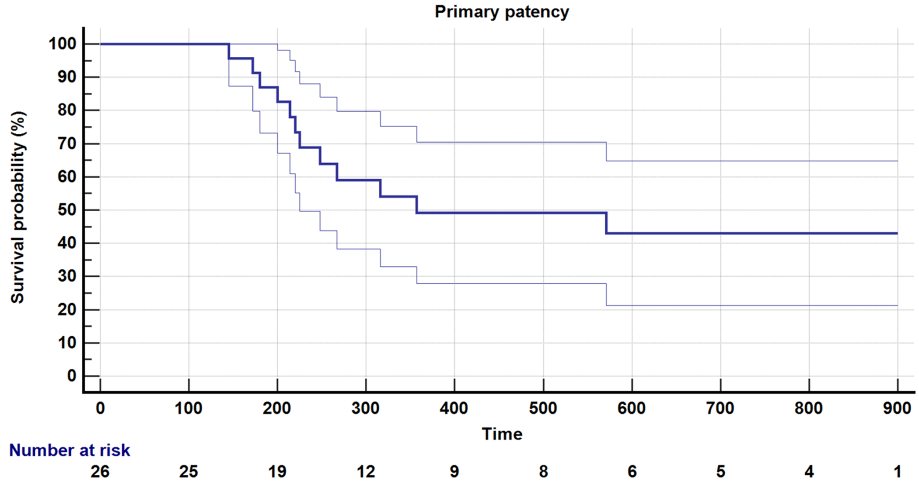


**Figure 3.** Primary patency of arteriovenous fistulas following staged full-length balloon-assisted maturation. The 1-year primary patency rate was 49.2%.

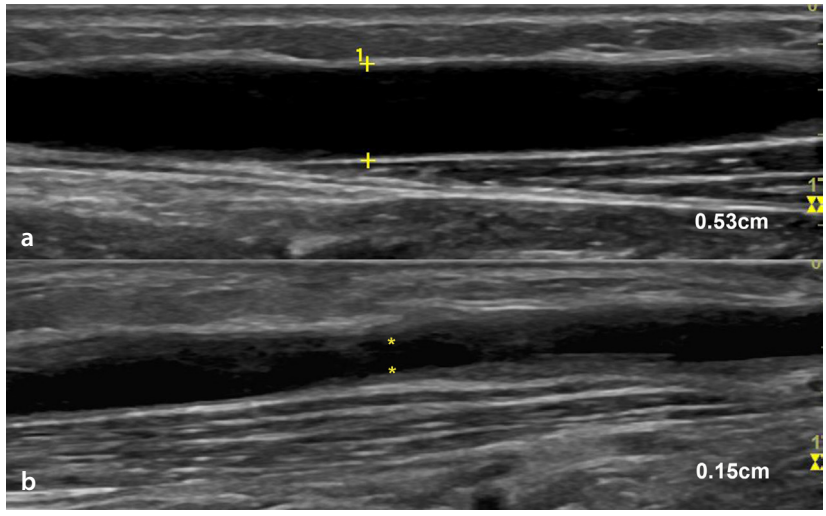


**Figure 4.** An example case of a patient who failed to achieve staged full-length balloon-assisted maturation (BAM). **(a)** Arteriovenous fistula image before cannulation showing a vein diameter of 0.56 cm and a clean, undamaged wall. **(b)** Severe intimal hyperplasia observed 3 months after staged full-length BAM.

factors influencing the failure of the procedure due to severe intimal hyperplasia, but no substantial factors were identified; even after a thorough review of the raw data and images, no singular cause was determined.

Overall, 73.9% of the patients included in this study had small veins (≤2.5 mm) before AVF formation. The smallest recorded vein diameter was 1.3 mm, with 3 patients presenting veins ≤1.6 mm in diameter. Despite these small diameters, a radiocephalic fistula was chosen for these patients as a radial-based native fistula, which was expected to increase blood flow gradually while minimizing the impact on existing heart disease. Notably, 2 of the 3 patients with preoperative vein diameters of ≤1.6 mm successfully achieved maturation using staged full-length BAM.

In this study, the presence of JAS at the time of the first procedure was a substantial factor when additional PTA was required. JAS was the primary target of PTA in 46.7% of cases, with considerable stenosis occurring at various sites, including drainage veins and puncture sites. This suggests that the findings from previous studies remain relevant. The 1-year primary patency rate in this study was 49.2%. To minimize venous trauma, balloons were gradually expanded, starting with smaller sizes; however, the gradual stenosis could not be fully mitigated. These results underscore that forcibly inducing maturation of native AVFs by PTA inevitably damages the venous intima, leading to substantial stenosis over time.

This study had several limitations that should be noted. First, its single-center, retrospective design may have introduced patient selection bias. Second, the small sample size could lead to statistical inaccuracies. Third, it was not possible to ascertain the cause of clinical failure using only the data collected in this study. Further research is needed to confirm these findings.

In conclusion, in attempting BAM for AVF in this study, balloon size was gradually increased, and ballooning was performed along the full-length anatomical segment to minimize barotrauma where the balloon overlapped. As a result, 87% of patients succeeded in reaching maturation sufficient for needling, although 62.5% required additional procedures during follow-up to maintain patency. Despite the burden of repeated procedures on patients and clinicians, these findings suggest that this approach is a safe option for patients with small, immature veins.


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### Conflict of interest disclosure

The authors declared no conflicts of interest.

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**Supplementary Table.** Overview of the procedural details

| | Pre-AVF condition | | Preprocedural condition | | | Procedure details | | | | Postprocedural condition | | | | Result | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Patient | Artery size | Vein size | Size | Flow | JAS | First balloon | Second balloon | Third balloon | Fourth balloon | Size (A) | Size (V) | Flow | Needling | Additional PTA | F/U duration |
| 1 | 1.6 | 2.3 | 3.5 | 480.0 | Y | 5/120 Passeo | 6/150 Mustang | 7/150 Mustang | | 6.3 | 6.1 | 716.4 | Y | 3 | 785 |
| 2 | 1.8 | 1.6 | 4 | 440.0 | Y | 6/120 Mustang | | | | 5.2 | 4.7 | 624.9 | Y | 0 | 398 |
| 3 | 2 | 3 | 4.5 | 403.1 | N | 6/120 Passeo | 7/150 Mustang | | | 6.5 | 6.6 | 719.0 | Y | 1 | 575 |
| 4 | 1.6 | 2.3 | 4.1 | 227.0 | Y | 5/120 Mustang | | | | 5.2 | 5.4 | 551.0 | Y | 3 | 331 |
| 5 | 2.2 | 3 | 4.2 | 381.2 | Y | 5/170 Passeo | 6/150 Mustang | 7/150 Mustang | | 7.6 | 7.2 | 419.5 | Y | 1 | 571 |
| 6 | 2 | 3 | 3.5 | 140.5 | Y | 4/150 Mustang | 5/150 Mustang | 6/150 Mustang | 7/150 Mustang | 5.5 | 5.6 | 1140.0 | Y | 3 | 908 |
| 7 | 3.2 | 2.7 | 5.2 | 1000.0 | N | 7/20 Mustang | | | | 6.4 | 6.3 | 1618.0 | Y | 1 | 936 |
| 8 | 2.3 | 3.5 | 4.5 | 860.0 | N | 5/150 Mustang | | | | 6.2 | 6.3 | 800.0 | Y | 0 | 698 |
| 9 | 2.5 | 2.5 | 4.4 | 623.0 | N | 5/200 Mustang | 6/200 Mustang | | | 5.5 | 5.9 | 1074.0 | Y | 0 | 870 |
| 10 | 2.3 | 3 | 4.3 | 458.4 | N | 6/200 Mustang | 7/200 Mustang | | | 6.3 | 6.8 | 576.3 | Y | 0 | 876 |
| 11 | 1.9 | 2 | 3.6 | 436.2 | Y | 5/120 Mustang | | | | 6.1 | 5.1 | 451.5 | Y | 2 | 833 |
| 12 | 2 | 1.3 | 4.6 | 631.5 | N | 5/150 Mustang | 6/200 Mustang | 7/200 Mustang | | 7.8 | 6.5 | 868.2 | Y | 1 | 858 |
| 13 | **4.6 | 2.4 | 3.6 | 321.4 | N | 4/150 Mustang | 5/120 Mustang | 6/80 Mustang | 6/80 Mustang | 5.6 | 5.2 | 702.1 | Y | 4 | 752 |
| *14 | 2 | 1.4 | 3 | 388.0 | Y | 3/220 Sterling | 4/220 Sterling | 5/220 Sterling | | 4.2 | 4.2 | 341.0 | N | 0 | 110 |
| 15 | 1.5 | 2.4 | 4.1 | 332.0 | N | 5/150 Achilles | | | | 6.4 | 5.4 | 790.6 | Y | 0 | 675 |
| 16 | 2.8 | 2.5 | 3.8 | 168.0 | Y | 5/200 Mustang | 6/150 Achilles | | | 5.6 | 5.4 | 475.8 | Y | 1 | 734 |
| 17 | 2.8 | 2.5 | 3.4 | 794.9 | Y | 5/120 Mustang | 6/200 Mustang | 7/200 Mustang | | 6.5 | 6.1 | 912.0 | Y | 0 | 570 |
| 18 | 2.2 | 2.4 | 3.9 | 573.0 | Y | 5/200 Mustang | 6/200 Mustang | | | 5.9 | 6.5 | 774.0 | Y | 3 | 352 |
| 19 | 2 | 2 | 3.3 | 114.2 | Y | 5/200 Mustang | | | | 5.9 | 4.5 | 580.0 | Y | 1 | 797 |
| 20 | 2.2 | 2.5 | 4 | 220.0 | Y | 5/22 Mustang | | | | 5.8 | 5.8 | 624.4 | Y | 0 | 596 |
| 21 | 2.3 | 2.6 | 4.4 | 376.5 | Y | 5/150 Mustang | 5/150 Mustang | 6/120 Mustang | 6/170 Passeo | 5.5 | 5.4 | 539.5 | Y | 2 | 1013 |
| 22 | 3 | 2.6 | 4.5 | 509.7 | N | 5/200 Mustang | 6/200 Mustang | | | 5.4 | 5.4 | 980.0 | Y | 0 | 477 |
| 23 | **4.4 | 2.9 | 4.2 | 488.9 | Y | 5/150 Achilles | | | | 6.0 | 6.2 | 1203.0 | Y | 0 | 767 |
| *24 | 1.9 | 2.5 | 4.6 | 170 | N | 5/150 Mustang | | | | 3.8 | 3.9 | 220 | N | 0 | 82 |
| 25 | 1 | 2 | 4.5 | 297 | Y | 5/150 Achilles | 5/200 Achilles | | | 6.7 | 5.3 | 429 | Y | 0 | 325 |
| *26 | 2.2 | 2.4 | 5.3 | 555.6 | Y | 6/150 Achilles | 7/200 Mustang | | | 6.5 | 6.3 | 525.4 | Y | 0 | 161 |

*Failure within 3 months; ** Brachial artery. The unit of size is mm, and the unit of flow is mL/min. AVF, arteriovenous fistula; JAS, juxta-anastomosis stenosis; N, no; PTA, percutaneous transluminal angioplasty; size (A), diameter of arterial needle cannulation area; size (V), diameter of venous needle cannulation area, Y, yes.