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Frequency of Swing-Segment Stenosis in Referred Dialysis Patients With Angiographically Documented Lesions

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Abstract

Background—The segment of the vein mobilized for arterial anastomosis in the creation of an arteriovenous fistula (AVF) is the swing segment. This segment may experience turbulent flow and altered shear mechanical stress that result in stenosis. We sought to determine the frequency of stenotic lesions in the swing segment.

Study Design—Case series.

Settings & Participants—From January 31, 2003, to June 30, 2005, records of all patients referred to an outpatient hemodialysis vascular access center for AVF dysfunction were reviewed (n = 484). Of these, 278 patients had angiographically documented stenosis (any degree of luminal narrowing) on their first visit.

Outcomes & Measurements—Distribution of stenoses in different segments of the AVF. Swing-segment stenoses were classified as proximal (outflow into axillary vein system), distal or juxta-anastomotic (adjacent to the anastomosis), and the cephalic arch.

Results—Overall prevalence of angiographically documented swing segment stenosis (proximal, distal or juxta-anastomotic, and cephalic arch) was 45.7% (127 of 278 patients), whereas the remaining stenoses (151 of 278 patients) were distributed among the puncture zone, arterial, arterial anastomosis, and central veins. The most frequent location of the swing-segment stenosis was juxta-anatomosis (63%; 80 of 127 patients), followed by cephalic arch (19%; 24 of 127 patients) and proximal swing segment (18%; 23 of 127 patients). The distribution of swing-segment stenosis (n = 127) was equivalent among the various fistulas (brachial-cephalic, 35.4%; radial-cephalic, 33.9%; and brachial-basilic, 30.7%). Eighty-three percent of swing-segment stenoses were significant (>50% luminal narrowing) and underwent percutaneous transluminal angioplasty, with a 93% success rate.

Limitations—Retrospective nature of the study and potential selection bias.

Conclusion—In our population, swing-segment stenosis is the most common lesion in dysfunctional AVFs; juxta-anastomotic stenosis is the predominant lesion independent of fistula type. Whether the occurrence of swing-segment stenosis is caused by mobilization of the vein during surgery is not clear.

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Keywords

Swing segment; stenosis; arteriovenous fistula (AVF); angioplasty; prevalence

Arteriovenous fistulas (AVFs) currently are regarded as the gold standard for dialysis access because of their superior long-term patency and lower intervention and infection rates compared with other types of dialysis accesses.[1-3] However, AVFs are prone to early failure because of poor maturation and subsequent thrombosis resulting from several factors, including inadequate inflow or limited venous outflow.[4]

The Fistula First project was initiated by the Centers for Medicare & Medicaid Services with the goal of AVF rates of 50% in incident and 40% in prevalent hemodialysis patients.[5] With this increasing trend toward predialysis fistula placement and imminent increase in problems, early identification of lesions associated with this preferred type of vascular access becomes a necessity.

Swing-segment lesions[4,6,7] predispose to early fistula failure, defined by some as failure of a new AVF to mature within 3 months of creation. A distal swing segment is the segment of the native vein that is mobilized during radialcephalic, brachial-cephalic, and transposed brachial-basilic fistula creation. It is located about 2 to 3 cm above the anastomotic region known as the juxta-anastomotic segment. A proximal swing segment occurs in the basilic vein near the axillary region during transposition surgery. A naturally occurring swing segment occurs in the arch of the cephalic vein or cephalic arch segment as it drains into the axillary vein. This segment of the vein may experience turbulent flow and altered shear mechanical stress because it forms the outflow conduit for autogenous radial-cephalic and brachial-cephalic fistulas.[8] These swing segment stenoses (Fig 1) were described previously,[6,7] and here we determine their prevalence and anatomic locations in a large population of patients with end-stage renal disease with dysfunctional AVFs.

METHODS

Study Population

Between January 31, 2003, and June 30, 2005, all records of patients referred to an outpatient hemodialysis vascular access center for AVF fistula dysfunction were reviewed (n = 484). Eligibility criteria included end-stage renal disease, treatment with hemodialysis, AVF as access type, referral to the access center for the first time for AVF dysfunction, and adequate medical records. Patients were excluded if they had no evidence of stenosis on fistulography or physical examination of the fistula had normal findings precluding fistulography. Only patients with angiographically documented stenosis of any degree were included in the final analysis. Reasons for referral included evaluation for AVF maturation, arm swelling, difficult cannulation, decreased Kt/V, clot aspiration during access cannulation, increased venous pressure, clotted access, prolonged bleeding from puncture sites, and decrease in access flow rate greater than 20% from baseline or absolute access flow rate less than 600 mL/min by means of ultrasound dilution technique (Transonic Flow-QC; Transonic Systems, Ithaca, NY). Lesions were considered angiographically significant if there was stenosis greater than 50% of the vascular luminal diameter and percutaneous transluminal angioplasty was performed. The first episode of stenosis was recorded for analysis.

Procedural Technique

After physical examination and determination of the site of cannulation, a diagnostic fistulogram was obtained down to the central veins by using the digital subtraction technique, and the site and severity of stenosis were determined by using radiopaque contrast. A retrograde arteriogram was obtained to evaluate the artery, arterial anastomosis, and juxta-anastomosis. Conscious sedation before balloon angioplasty or thrombectomy was achieved by using intravenous fentanyl citrate, 50 μg, and midazolam, 1 mg. Patients were monitored by using blood pressure, electrocardiography, and pulse oximetry throughout the procedure. Any lesion greater than 50% of the vascular luminal diameter underwent angioplasty with an appropriately sized noncompliant balloon catheter advanced over the wire through a corresponding sheath, using a hand syringe assembly. The success of angioplasty was defined as residual stenosis less than 30%. Balloon sizes used were 8 mm × 4 cm, 6mm × 2 cm, or 4 mm × 2 cm, depending on the site and severity of the lesion. Heparin was administered at a dose of 5,000 units in the case of a thrombosed fistula by means of a mechanical thromboaspiration technique using a Fogarty catheter. After interventions, balloon catheters and sheaths were withdrawn and hemostasis was obtained with manual compression.

Data Collection

Data collected include demographics (age, sex, and race), comorbidities (diabetes, hypertension, peripheral vascular disease, heart disease, human immunodeficiency virus, stroke, contrast allergy, and history of smoking), previous history of a failed access, access type and location, site and severity of stenosis, and procedure outcomes. The study was approved by the Institutional Review Board at Emory University (Atlanta, GA).

Statistical Analysis

Descriptive analysis was used for continuous variables, and frequency analysis, for categorical variables. Results are expressed as mean ± SD and percentages, respectively. Data was analyzed using SPSS, version 13.0 (SPSS Inc, Chicago, IL).

RESULTS

A total of 484 patients were reviewed, 278 of whom had angiographically documented stenosis on their first visit. The remaining patients (n = 206) were excluded from analysis because they had either no stenosis on a fistulogram or initial clinical examination findings that did not suggest a need for a fistulogram. Characteristics of the study population are listed in Table 1. Most patients were African American (93%), mean age was 55 ± 18 years, and 64% were men. Upper-arm brachial-cephalic fistulas comprised 42%; forearm radial-cephalic fistulas, 37%; upper-arm transposed brachial-basilic fistulas, 21%; and Gracz fistulas (anastomosis of the brachial artery or beginning of the radial artery to the perforating vein in the elbow), 1%. As listed in Table 2, access evaluation, cannulation difficulties, and prolonged bleeding were the most frequent reasons for referral.

Figure 2 shows frequencies of the various types of stenoses seen on angiography. These are presented as percentages, which represent number of stenoses. Most stenoses were in the swing segment, accounting for 45.7%, followed by the puncture zone (area of cannulation, usually middle third of the fistula) at 31.2%. Arterial anastomosis stenosis comprised 15.5%; central venous stenosis, 6.5%; and arterial stenosis, 1.1%. Of all swing-segment stenoses (Fig 3), juxtaanastomotic lesions accounted for the majority (63%), whereas cephalic arch and proximal swing-segment lesions accounted for 18% and 19%, respectively. These swing segments as well as other segments of AVF anatomy are schematically illustrated in Fig 4.

The distribution of swing-segment stenoses was equivalent among the various fistulas: 35.4% in brachial-cephalic fistulas, 33.9% in radialcephalic fistulas, and 30.7% in transposed brachial-basilic fistulas. Furthermore, the severity of stenosis (<50%, 50% to 70%, 70% to 90%, and >90%) was equivalent among the various swing segments (chi-square = 2.7; P = 0.8).

Most patients referred for arm swelling, increased venous pressure, and prolonged bleeding had stenosis involving the proximal swing segment and/or central outflow veins, whereas most patients referred for access evaluation and decreased Kt/V typically had lesions involving the juxta-anastomosis swing segment and arterial anastomosis. The majority of patients with swing segment stenosis (83%) underwent balloon angioplasty, with a 93% technical success rate. There were patients (1.1%) with major complications after balloon angioplasty. One complication was a grade 2 rupture that resulted in fistula loss, whereas the other 2 complications were grade 1 ruptures that were successfully salvaged. There was no incidence of symptomatic arterial embolization or clinical signs of pulmonary embolism.

DISCUSSION

We observed that the lesions most frequently identified in patients referred for a dysfunctional AVF were located at the swing segment or swing point, most commonly in the juxta-anastomotic region. Our study examines the largest patient population referred to an outpatient hemodialysis vascular access center and provides greater understanding of the frequency and location of AVF stenotic lesions.

In previous work, Beathard et al[4] found that the juxta-anastomotic segment accounted for 43% of stenoses in 100 patients with early fistula failure in 2004, and Turmel-Rodrigues et al[9] reported that 55% of first symptomatic stenoses occurred at or near the anastomosis in a study involving 209 forearm fistulas. Clark et al[10] reported a 47% prevalence of stenosis involving the initial 2 cm of the anastomosis (juxtaanastomosis) in a prospective study involving 25 patients with radial-cephalic fistulas followed up from the time of fistula creation by using serial duplex and color flow ultrasound. Sivanesan et al[11] found that stenosis developed at or near the anastomosis within 3 months in all patients. Progressive narrowing of the stenosis occurred in 13 patients, with resultant fistula loss in 6 patients.[11] Interestingly, this lesion, the juxtaanastomosis stenosis, is more common in forearm than upper-arm AVFs. Up to 77%[7,11] of forearm AVFs have a juxta-anastomosis stenosis compared with 56% of upper-arm AVFs. In our patient population, we experienced a juxtaanastomotic stenosis rate of 54% in dysfunctional forearm AVFs compared with 46% in upper-arm AVFs.

A similar observation was made regarding cephalic arch stenosis. Rajan et al[8] reported a 15% prevalence of cephalic arch stenosis in a cohort of 177 patients with dysfunctional AVFs in 2003. They observed a greater prevalence of cephalic arch stenosis (39%) in brachial-cephalic fistulas compared with radial-cephalic fistulas.

Reasons for the differences in cephalic arch stenosis between brachial-cephalic and radialcephalic AVFs are unclear. Rajan et al[8] proposed that the proximity of the cephalic arch to the anastomosis in a brachial-cephalic fistula compared with a radial-cephalic fistula might predispose this segment of the cephalic arch to greater flow and pressures. They also noted that venous drainage at the level of the elbow in forearm fistulas potentially enabled additional drainage through the basilic and brachial veins, thereby increasing the venous capacitance of radialcephalic AVFs and decreasing the degree of turbulence encountered. Similarly, brachial-basilic AVFs were prone to proximal swingsegment stenosis at the venous outflow region, where mobilization of the vein occurred during transposition surgery.

A cause is yet to be defined for these lesions. Mobilization of the swing segment of the vein during surgery may disrupt the vasa vasorium, leading to ischemic changes, coupled with intimal hyperplasia resulting from exposure to high blood flow in the region. One school of thought proposed a low wall shear stress and/or flow separation hypothesis, in which areas with decreased local flow and low wall shear stress were prone to intimal thickening. Several reports supporting decreased local flow as a predisposing factor to stenosis were published.

[12-15] The juxtaanastomotic segment was described as an area of lower wall shear stress.[10] Ojha et al[16] used an in vitro model of an end-to-side 45° anastomosis similar to a radial-cephalic anastomosis and found high correlation between areas of low wall shear stress and intimal hyperplasia. They admitted that this low wall shear stress and/or flow separation pathogenesis might not explain events in the arterial end, which seems to be subjected to a complex hemodynamic environment. High-flow mechanics leading to intimal hyperplasia resulting in low-flow states and resultant stenosis is a possibility.

Hofstra et al[17] characterized cellular proliferation patterns within stenotic segments of dysfunctional AVFs of 12 patients after resection and placement of an interposition bypass using ultrasound. Areas of intimal proliferation correlated with areas of low shear stress. The presence of endothelial cells covering the stenosis was also an associated finding with increased intimal thickening.[17] The report also indicated that approximately 90% of proliferating cells in the subendothelial area of the intima were possibly vascular smooth muscle cells; a fraction of proliferating cells in the stenotic area was macrophages and endothelial cells covering microvessels. However, several inhibitory pharmacological agents of vascular smooth muscle cell proliferation did not show much success in humans, as reported in animal models.[18-20] This suggests a varied pattern of cell injury and proliferation and opens the door for more histologic studies involving the stenotic segments of hemodialysis AVFs, particularly swing segments.

Our study is limited by its retrospective nature. Selection bias may be present because only patients referred for a dysfunctional AVF were included in analyses. Therefore, results cannot be generalized to all patients with an AVF.

We conclude that in patients referred for AVF dysfunction, stenosis most commonly occurs at the swing segment, with the juxta-anastomotic region the most common site. Although the cause of these lesions is poorly understood, nephrologists should be aware of common and likely locations of lesions to render early diagnosis, referral, and appropriate interventions to prevent early or late AVF failure.

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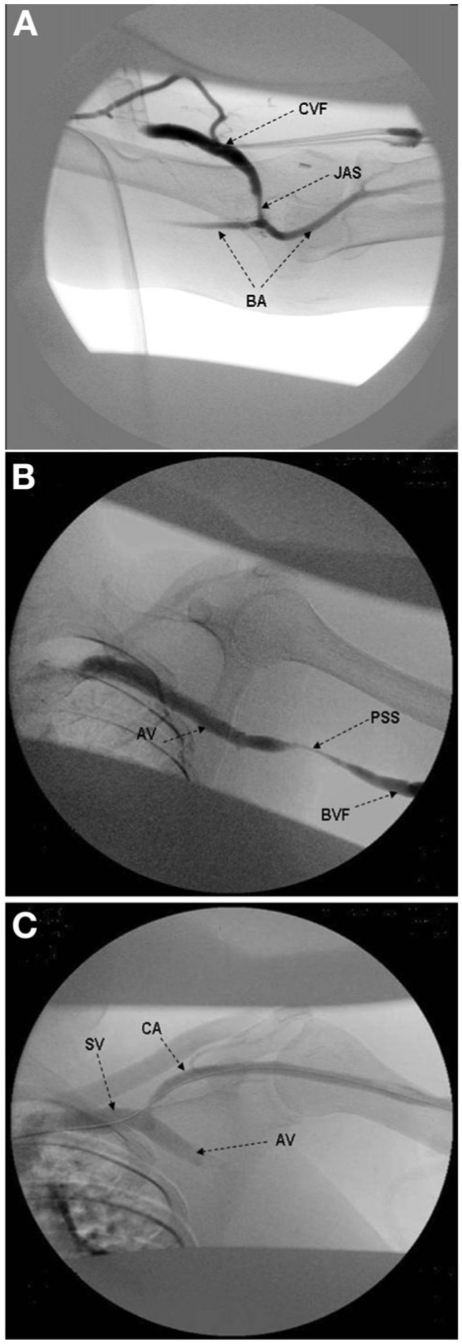

Figure 1.
Digital subtraction angiography of swing segments in arteriovenous fistulas: A. juxta-anastomotic stenosis (JAS), cephalic vein fistula (CVF), and brachial artery (BA); B. proximal swing-segment (PSS) stenosis, the adjacent basilic vein fistula (BVF), and axillary vein (AV); and C. the cephalic arch (CA), which joins the axillary vein (AV) to form the subclavian vein (SV).

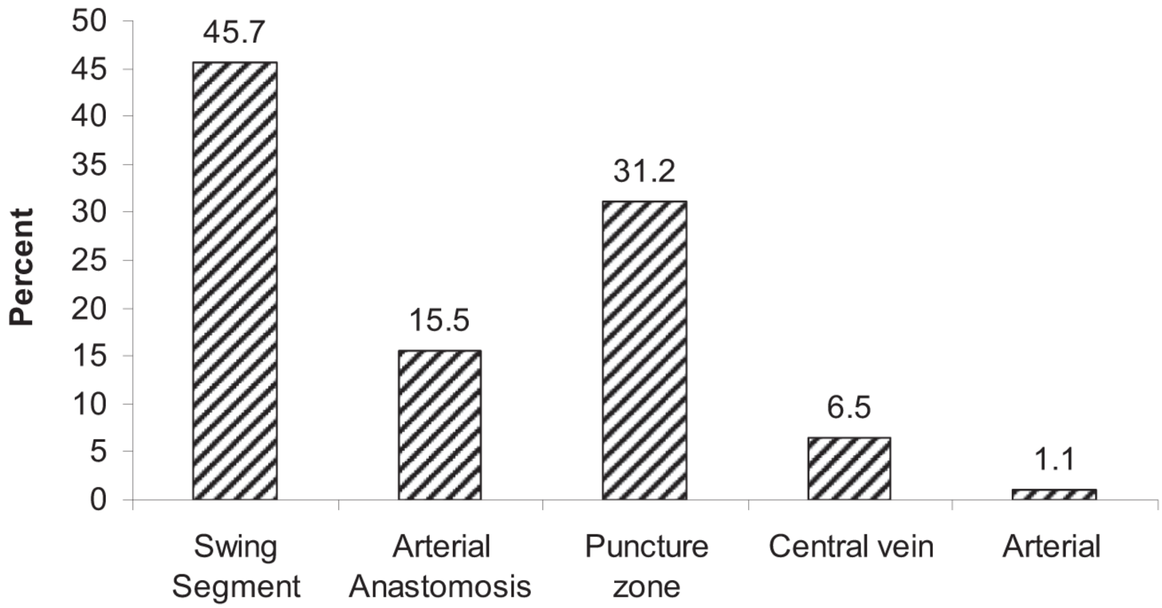

Figure 2.
Distribution of stenosis in the study population (n = 278). Percentage refers to stenosis. Stenosis in the swing segment accounted for 45.7% (n = 127); arterial anastomosis, 15.5% (n = 43); puncture zone, 31.2% (n = 87); central veins, 6.5% (n = 18); and arterial anastomosis, 1.1% (n = 3).

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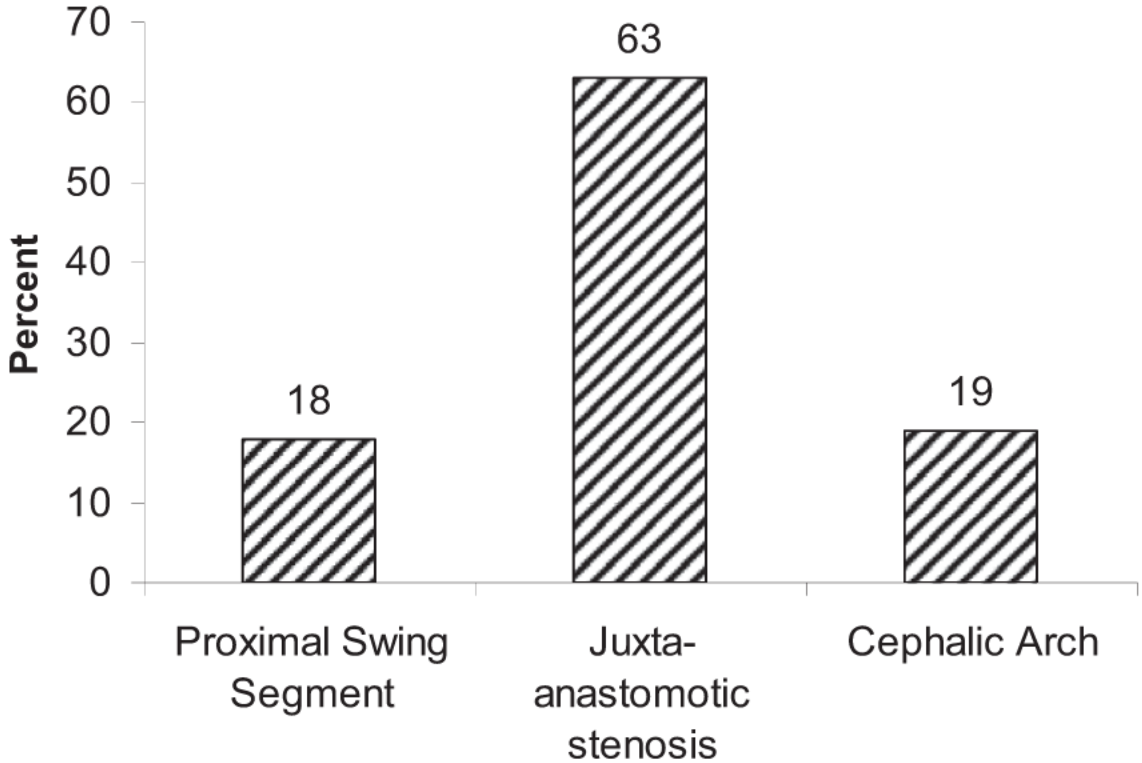

Figure 3.
Distribution of stenoses among the types of swing segments (n = 127). Percentage refers to stenosis. Stenosis of the proximal swing segment accounted for 18% (n = 23); juxta-anastomotic segment, 63% (n = 80); and cephalic arch, 19% (n = 24).

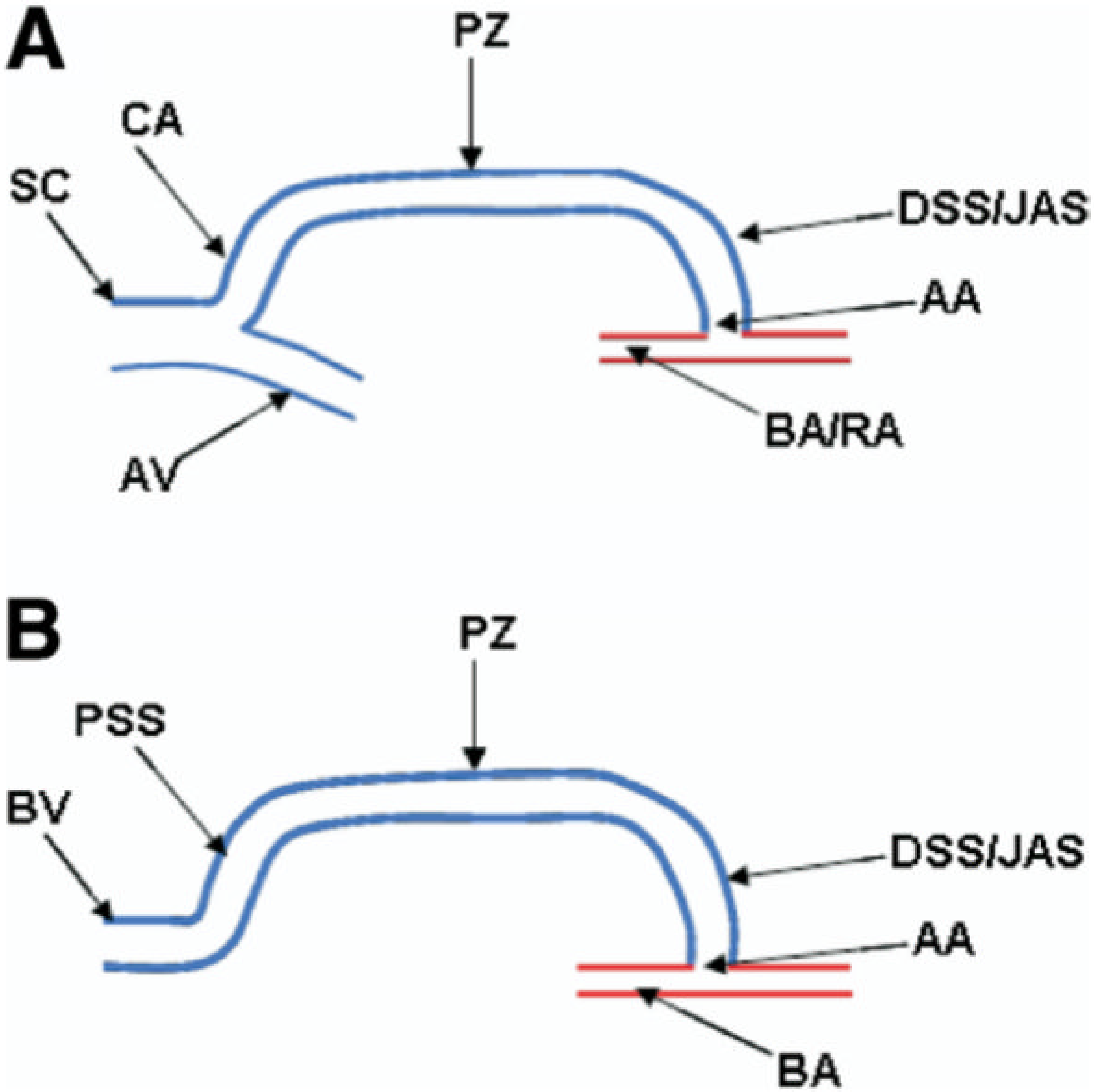

Figure 4.
Schematic diagram of arteriovenous fistula anatomy. A. Brachial or radial artery (BA/RA) cephalic fistula shows the arterial anastomosis (AA), distal swing segment or juxta-anastomotic segment (DSS/JAS), puncture zone (PZ), cephalic arch (CA), and axillary and subclavian veins (AS and SC). B. Brachial-basilic transposition fistula and proximal swing segment (PSS). Abbreviation: BV, basilic vein.

Table 1

Baseline Characteristics of the Study Population

Mean age (y)	58 ± 8
Sex	
Men	64 (178)
Women	36 (100)
Race	
African American	93 (258)
White	6 (17)
Hispanic	1 (3)
Cause of ESRD	
Hypertension	31 (86)
Diabetes	28 (78)
Polycystic kidney disease	2 (6)
Glomerulonephritis	1 (3)
Human immunodeficiency virus	3 (8)
Other	2 (6)
Unknown	33 (91)
AVF type	
Radial-cephalic	37 (103)
Brachial-cephalic	42 (117)
Brachial-basilic	21 (58)

Note: N = 278. Values expressed as mean ± SD or percent (number).

Abbreviations: ESRD, end-stage renal disease; AVF, arteriovenous fistula.

Table 2

Reasons for Referral

Prolonged bleeding	12.2 (59)
Clotted access	10.8 (52)
Arm swelling	4.1 (20)
Increased venous pressure	10.4 (50)
Decreased transonic flow	11.1 (53)
Difficult cannulation	17.6 (85)
Decreased Kt/V	6.4 (31)
Evaluate AVF maturation	25.9 (125)
Clot aspiration during cannulation	1.5 (7)

Note: Values expressed as percent (number).

Abbreviation: AVF, arteriovenous fistula.