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Analysis and Classification of Postcatheterization Femoral Arteriovenous Fistulas Based on Color Doppler Examinations

William D. Middleton, MD, Kathryn A. Robinson, MD

Objective—To analyze and classify arterial supply and venous drainage of postcatheterization femoral arteriovenous fistulas (AVFs).

Methods—A review of extremity Doppler reports identified 77 femoral AVFs in 75 patients. Doppler exams were reviewed retrospectively. Fistulas were classified as above or below the common femoral artery bifurcation and subclassified based on the location of arterial inflow and venous outflow.

Results—Arterial inflow originated above the femoral bifurcation in 32 cases. The communication was between the common femoral artery and the superficial circumflex iliac vein in 25 of 32 cases and between a branch of the common femoral or external iliac artery and the common femoral or external iliac vein in 4 of 32 cases. In 3 of 32 cases, AVFs arose from the common femoral artery, but the venous outflow was not determined. Arterial inflow originated from the superficial femoral artery in 23 cases. Venous outflow originated from the common femoral vein in 10 of 23 cases, the femoral vein in 7 of 23 cases, and the lateral circumflex femoral vein in 6 of 23 cases. Arterial inflow originated from the deep femoral artery in 12 cases. Venous outflow originated from the common femoral vein in 6 of 12 cases and from the lateral circumflex femoral vein 6 of 12 cases. In 8 cases, the AVF originated below the bifurcation, but the arterial inflow was not classified. In 2 cases, it was impossible to determine if the AVF originated above or below the bifurcation.

Conclusions—Iatrogenic femoral AVFs arise above the femoral bifurcation more often than previously recognized. Classification based on the arterial inflow and venous outflow provides a straightforward means of describing these fistulas.

Key Words—classification femoral arteriovenous fistula; complications femoral catheterization; femoral arteriovenous fistula; iatrogenic arteriovenous fistula; postcatheterization arteriovenous fistula

Femoral arteriovenous fistulas (AVFs) are a well-known but rare complication following catheterization with an incidence of 0.23–2.8%. An accepted and widely used classification system for iatrogenic femoral fistulas does not exist. It has been recognized for some time that low puncture sites below the bifurcation increase the risk of AVFs and other complications following femoral catheterizations. AVFs develop below the femoral bifurcation because the superficial femoral and deep femoral arteries overlap with the corresponding veins and the common femoral vein (CFV). This makes it possible to puncture both vessels simultaneously, thus creating communication between...
the two. Above the bifurcation, the common femoral artery and vein are located side by side, so it is difficult to create a direct fistula between the two from an anterior femoral puncture. Nevertheless, AVFs have been reported above the bifurcation. The purpose of this study was to analyze the anatomy of iatrogenic femoral AVFs, to compare the frequency of those that occur above and below the bifurcation, and to develop a system for their classification based on their vascular anatomy.

Methods

Subjects
In this HIPAA-compliant study, the authors performed a computer search of ultrasound reports at a single institution over a 12-year period using the limited extremity arterial Doppler CPT code. The key words of fistula and/or AVF were identified in 107 reports of patients 18 years old or older. Patients with AVFs in locations other than the femoral region (n = 5), nondiagnostic images (n = 2), images not supportive of an AVF (14), and images not available on the Picture Archiving and Communication System (n = 9) were excluded. A total of 75 patients (38 women, 37 men) with 77 AVFs met our inclusion criteria and form the basis of this analysis. The mean age was 65.5 years (range 29–95 years). Our institutional review board approved this retrospective study with waiver of informed consent.

Image Review
The scans were jointly reviewed retrospectively by two fellowship-trained attending radiologists with 10 and 30 years of experience in interpreting extremity Doppler examinations, and a consensus interpretation was established. The diagnosis and origin of the AVF were based on previously described criteria. Findings used to detect and localize AVFs included (1) identification of perivascular tissue vibration, (2) direct visualization of the communication on color Doppler or grayscale, (3) detection of localized low-resistance waveforms with elevated diastolic velocities in the artery of origin, (4) turbulent flow with or without a recognizable arterial pattern in the draining vein, (5) localized aliasing in the artery and vein near the site of the AVF, and (6) a low-resistance waveform with very high systolic and diastolic velocities directly at the site of the fistula. In most cases, many of these findings coexisted.

The locations of the AVFs were first categorized based on the artery of origin and was divided into common femoral artery (CFA), superficial femoral artery (SFA), deep femoral artery (DFA), or smaller femoral or external iliac artery branches. They were then subcategorized based on the vein involved with the initial arteriovenous communication. For instance, an AVF that originated from the SFA and initially communicated with the lateral circumflex femoral vein (LCFV) prior to draining into the CFV would be categorized as SFA to LCFV. The veins that could be distinctly identified on Doppler were the external iliac vein (EIV), CFV, femoral vein (FV), deep femoral vein (DFV), superficial circumflex iliac vein (SCIV), and LCFV. Figure 1 illustrates the location of these vessels.

Results
A total of 43 fistulas were below the bifurcation, and 32 were above the bifurcation. In two cases, it was
not possible to determine if the fistula was above or below the bifurcation due to a combination of extensive tissue vibration artifact, infiltrative hemorrhage, hematoma, and an adjacent pseudoaneurysm (Table 1). Two patients who had AVFs with incorporated pseudoaneurysms were treated surgically. Further angiographic or surgical therapy was not documented in any of the other patients.

In 25 of the 32 fistulas above the bifurcation, the communication was between the CFA and the SCIV. The SCIV is a venous branch anterior to the CFA that drains into the greater saphenous vein near its junction with the CFV (Figure 2). In three of these cases, there was a pseudoaneurysm incorporated into the AVF (Figure 3, Video S1). Pseudoaneurysms were not incorporated into any of the other fistulas in this patient cohort, but separate pseudoaneurysms coexisted with the AVF in five patients. In three cases, the fistula arose from the CFA, but venous communication could not be determined.

In two cases, the fistula arose from the inferior epigastric artery and communicated with the distal EIV (Figure 4, Video S2). In two other cases, the fistula arose from a branch of the CFA located anterior to the CFV (n = 1) and posterior to the CFV (n = 1). In these cases, actual visualization of the arterial branch responsible for the fistula was limited, and the location of the fistula was primarily based on localized tissue vibration and hemodynamic changes. In all four of these cases, there was a FV catheterization, and in two, there was concurrent femoral artery catheterization.

There were 43 AVFs below the bifurcation; 23 arose from the SFA. The communications in these 23 cases were with the CFV (n = 10) (Figure 5, Video S3), FV (n = 7), and LCFV (n = 6) (Figure 6, Video S4). Twelve fistulas arose from the DFA. The communications in these 12 cases were with the CFV (n = 6) and LCFV (n = 6) (Figure 7, Video S5). In eight cases, the AVF was located below the bifurcation, but it was unclear if it arose from the SFA or DFA, and the draining vein could not be determined.

**Table 1.** Classification of Postcatheterization Femoral Arteriovenous Fistulas Based on the Arterial Inflow and Venous Outflow

<table>
<thead>
<tr>
<th>Type</th>
<th>Artery</th>
<th>Vein</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td>Common femoral</td>
<td>Superficial circumflex iliac</td>
<td>25</td>
</tr>
<tr>
<td>1 B</td>
<td>Inferior epigastric</td>
<td>External iliac</td>
<td>2</td>
</tr>
<tr>
<td>1 C</td>
<td>Common femoral branch</td>
<td>Common femoral</td>
<td>2</td>
</tr>
<tr>
<td>1 D</td>
<td>Common femoral or external iliac</td>
<td>Not clearly identified or common femoral or external iliac</td>
<td>3</td>
</tr>
<tr>
<td>2 A</td>
<td>Superficial or deep femoral</td>
<td>Lateral circumflex femoral</td>
<td>12</td>
</tr>
<tr>
<td>2 B</td>
<td>Superficial or deep femoral</td>
<td>Common femoral</td>
<td>16</td>
</tr>
<tr>
<td>2 C</td>
<td>Superficial femoral</td>
<td>Femoral</td>
<td>7</td>
</tr>
<tr>
<td>2 D</td>
<td>Deep femoral</td>
<td>Deep femoral</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Cannot determine if above or below the bifurcation</td>
<td>Not clearly identified</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Not clearly identified</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 2. 36 year-old woman postcardiac catheterization with right groin bruising. Transverse color Doppler image of a type 1A fistula between the common femoral artery (CFA) and the superficial circumflex iliac vein (SCIV). Also seen is the saphenous vein (SV) and the common femoral vein (CFV).
Discussion

This study used color Doppler ultrasound examinations to evaluate the anatomy of iatrogenic femoral AVFs. Contrary to traditional teaching, we showed that fistulas were frequently above the bifurcation. An anatomic classification system was developed using an analysis of the artery supplying the inflow and the vein providing the outflow.

AVFs are a rare complication of catheterizations from a femoral approach. The reported incidence varies depending on the method used to detect the fistulas. When all patients are scanned with Doppler ultrasound, the incidence ranges from 0.25% to 2.8%. When only patients with a suspicious physical exam are scanned, the incidence ranges from 0.1% to 0.9%. When AVFs are only noted based on surgical findings, the incidence is 0.03%. Clinical factors of female gender and hypertension predispose to AVFs, while body mass index and age do not. Procedural factors that predispose to AVFs include the use of anticoagulation, performance in an emergency situation, and a left-sided puncture.

Acquired femoral AVFs are rarely symptomatic. Symptoms reported primarily in case reports following vascular trauma or hemodialysis catheters include heart failure, lower extremity pain and/or swelling, and venous ulcer. AVFs following femoral catheterization are even less often symptomatic, and surgery can almost always be avoided.
To our knowledge, there is no well-recognized classification scheme for iatrogenic femoral AVFs. Our analysis suggests that the types of fistulas seen on color Doppler are very predictable based on vascular anatomy and that a relatively simple classification system is possible. In our proposed system, fistulas

**Figure 5.** A 23-year-old woman with history of heart transplant who developed right groin pain and a palpable thrill following a failed attempt at right femoral catheterization. Longitudinal (A) and transverse (B) dual color Doppler and grayscale images show a type 2B fistula (*) between the superficial femoral artery (SFA) and the common femoral vein (CFV). Pulsed Doppler waveform from the SFA proximal to the fistula (C) shows a lower resistance waveform and greater than expected diastolic flow than is normal for an extremity artery. Dual transverse grayscale and color Doppler video (Video S3) from superior to inferior shows the communication between the superficial femoral artery and the common femoral vein. Minimal tissue vibration is seen primarily in systole.
are first divided into those above and below the bifurcation and referred to as types 1 and 2, respectively. They are then subdivided based on the involved artery and vein. Figure 1 displays the relevant anatomy and shows the vessels involved for each type of fistula. Table 1 shows the distribution of the fistulas in our cohort of patients.

It is well known that the likelihood of vascular complications in general increases when the arteriotomy is below the bifurcation.\(^1,3\)–\(^5\) With respect to AVFs, this is believed to be related to the relative location of the femoral artery and vein. As shown in Figure 1, immediately below the femoral bifurcation, the LCFV passes between the superficial femoral and deep femoral arteries prior to entering the CFV and is the draining vein in type 2A fistulas. In our experience, this occurred equally with the SFA \((n = 6)\) and DFA \((n = 6)\). Overall, type 2A fistulas accounted for 15.6% \((12/77)\) of all cases.

**Figure 6.** A 74-year-old woman postcardiac catheterization with right groin bruit. Transverse color Doppler image (A) and pulsed Doppler waveform (B) from the lateral circumflex femoral vein (LCFV) show a type 2A fistula between the superficial femoral artery (SFA) and the (LCFV). Also seen are the deep femoral artery (DFA) and the common femoral vein (CFV). Transverse color Doppler video (Video S4) plays from superior to inferior and shows the communication between the SFA and the LCFV with subsequent drainage into the common femoral vein. Minimal tissue vibration is seen in systole.

**Figure 7.** A 68-year-old woman postcardiac catheterization. Iliac angiogram at the time of the catheterization suggested a femoral arteriovenous fistula. Transverse (A) and longitudinal (B) color Doppler images show a type 2A fistula between the deep femoral artery (DFA) and the lateral circumflex femoral vein (LCFV). Also seen are the superficial femoral artery (SFA) and the common femoral vein (CFV). Transverse color Doppler video (Video S5) below the femoral artery bifurcation shows systolic flow in a normal sized SFA and both systolic and diastolic flow in an enlarged DFA. The communication between the DFA and the LCFV is best visualized during diastole when perivascular tissue vibration is least apparent.
Figure 1 shows that the lateral edge of the CFV is located between the SFA and DFA, allowing for fistulas to develop between the three vessels. These are type 2B fistulas, and in our experience, they were more common with the SFA \( (n = 10) \) than the DFA \( (n = 6) \). Based on the anatomy, this is predictable because there is greater overlap between the CFV and the DFA than between the CFV and the SFA. Overall, type 2B fistulas accounted for 20.8% \( (16/77) \) of all cases. All of the type 2C fistulas occur when the arterial puncture is too low in the groin. As with type 1A, type 1C fistulas are due to venous punctures that are too high in the groin. As small venous branches such as the SCIV are not avoidable when performing femoral artery punctures, type 1A fistulas are more attributable to misfortune than to faulty arterial catheterization technique.

After bifurcating, the FV and DFV move posterior to the corresponding arteries, allowing for fistulas to develop between the SFA and DFA and their corresponding veins. These are type 2C fistulas, and in our experience, they only occurred in the SFA/FV \( (n = 7) \) and not in the DFA/DFV. The lack of fistulas between the DFA and DFV is not surprising because the DFV is more often medial to the DFA (rather than posterior), particularly near the venous bifurcation. Overall, type 2C fistulas accounted for 9.1% \( (7/77) \) of all cases. All of the type 2 fistulas occur when the arterial puncture is too low in the groin.

The existence of AVFs arising above the bifurcation has been documented but has undergone little scrutiny. In a review of 107 patients with femoral AVFs due to cardiac catheterizations, Ohlow et al found that 16% \( (n = 17) \) arose from the CFA. In a pictorial essay focused on color Doppler evaluation of complications of femoral artery catheterizations, Paulson et al describe and illustrate a CFA AVF that involves an unnamed superficial venous branch. They also note that the hemodynamic changes in such fistulas may be confined to a small area around the communication and may not extend into the femoral artery and vein, making such branch fistulas more difficult to detect.

Veins crossing anterior to the CFA below the inguinal ligament include the SCIV, which drains into the greater saphenous vein (Figure 1), and is the vein involved with type 1A fistulas. In our experience, type 1A fistulas accounted for at least 78% \( (25/32) \) of the fistulas above the bifurcation. Of the 17 fistulas above the bifurcation described by Ohlow et al, \( (53\%) \) were reported to drain into the saphenous vein. The involvement of branch vessels was not described in this study, which focused primarily on the incidence and outcome of all vascular complications following cardiac catheterization. However, a direct communication between the CFA and the saphenous vein would be difficult to create based on the underlying anatomy. Therefore, it is very likely that the arteriovenous communication was with the SCIV in all 9 of the cases described by Ohlow et al, with drainage ultimately into the saphenous vein. As small venous branches such as the SCIV are not avoidable when performing femoral artery punctures, type 1A fistulas are more attributable to misfortune than to faulty arterial catheterization technique.

It is worth noting that 3 of the type 1A fistulas had a pseudoaneurysm incorporated between the CFA and the SCIV (Figure 3). In such cases, it is important to recognize that the outflow of the pseudoaneurysm is directly into the SCIV so that thrombin injection is not used as a form of treatment. If the venous outflow is not visualized initially, the low-resistance and high-velocity waveform arising from the neck of the pseudoaneurysm is a feature that distinguishes this from the to-and-fro waveform typical of a standard pseudoaneurysm. The presence of an incorporated pseudoaneurysm is one of the rare situations when surgical or angiographic intervention should be considered.

We also found that branches of the external iliac and common femoral arteries that travel across the CFV or EIV can rarely be the origin of fistulas. Based on the location above the inguinal ligament, 2 of the fistulas very likely arose from the inferior epigastric artery (type 1B) (Figure 4). In 2 fistulas that occurred below the inguinal ligament, it was more difficult to confidently identify the arterial branch that supplied the fistula (Type 1C). The most likely possibilities are the superficial and deep external pudendal arteries. In all of these cases, there was a FV catheterization, and it is very likely that the arterial branches were punctured as the needle approached the vein. Type 1B fistulas are due to venous punctures that are too high in the groin. As with type 1A, type 1C fistulas are more attributable to misfortune than to faulty venous catheterization technique.

In some cases, it is not possible to determine the inflow and outflow of femoral fistulas. Type 3 indicates those fistulas where it was not possible to determine if the inflow arose above or below the bifurcation. The subclassification D indicates those fistulas that could be classified as type 1 or type 2, but the exact artery of origin and/or the draining vein...
could not be determined. Based on the normal lack of overlap between the CFA and CFV and the distal EIA and EIV, it would be very unusual for femoral catheterizations to produce direct fistulas between these vessels, and we did not encounter any such AVFs in our cohort. Nevertheless, a tortuous or aneurysmal artery could overlap with the adjacent vein, so this type of fistula is included in type 1D. Table 1 lists the classification system and indicates the frequency of occurrence of each type of fistula.

Although rare, intervention is occasionally performed on iatrogenic AVFs. Therefore, accurate diagnosis and characterization is important. Ohlow et al found that 11% (12/107) of iatrogenic AVFs were symptomatic and ultimately required repair. In an analysis of 6 patients with iatrogenic AVFs, Kent et al found that 2 ultimately required surgical repair due to enlargement or development of symptoms. In a review of the records from 23,291 cardiac catheterizations, Glaser et al discovered 6 patients who required repair of femoral AVFs due to worsening heart failure, claudication, leg swelling, varicose veins, or some combination of these symptoms. Others have also described the need for surgical or angiographic repair.

Even in patients who do not require intervention, follow-up examinations are frequently requested, and knowledge of the type of AVF is helpful in comparing one exam to another. In general, imaging follow up of AVFs is not necessary unless clinical symptoms develop. This is particularly true if a bruit is reliably detected on auscultation, and the patient can be followed clinically. If the AVF is shown to be large, follow up might be reasonable. Using cross-sectional arterial areas and time-averaged mean velocities, Kelm et al measured flow volumes in the ipsilateral artery supplying the fistula and compared them to flow volume in the contralateral artery and showed that arterial venous shunting ranged from 160 to 510 ml/minute. Although they could not speculate on the relationship of measured shunt flow and likelihood of closure, they did note that the shunt volumes were considerably lower than dialysis shunts and were unlikely to have a negative effect on cardiac function. Calculating flow volumes is probably not realistic in most institutions. A good substitute is simply to compare the waveforms of the ipsilateral and contralateral femoral artery proximal to the AVF. If there are considerably higher overall velocities on the symptomatic side, particularly in diastole, then one can assume a relatively larger AVF that might warrant Doppler follow-up. The timing of the first follow-up should be between 4 and 12 months. This time frame is based on evidence that one-third of AVFs close spontaneously within 12 months, and most of those closed in the first 4 months.

With respect to management of postcatheterization complications, accurate diagnosis of AVFs is important for several reasons. In some cases, an AVF is suspected on another imaging study, and sonography with Doppler is ordered specifically to rule in or rule out an AVF. In patients with postcatheterization bruits, the differential diagnosis includes pseudoaneurysms, dissections, stenoses, and AVFs. A false-negative examination in a patient with an AVF may lead to additional unnecessary tests in search for another cause of the bruit.

Given that accurate diagnosis is important, we believe that there are several ways in which familiarity with our results will improve the diagnosis of iatrogenic femoral AVFs. In general, a better understanding of the anatomy and frequency of any pathologic condition leads to a higher likelihood of correctly identifying and characterizing the condition. Knowledge of this type of information allows one to focus attention in the correct areas and to prospectively search for certain findings. For instance, the relatively common occurrence of AVFs above the bifurcation should promote a more thorough investigation of this region, particularly when localized tissue vibration of no other cause is encountered. The existence of AVFs that involve the inferior epigastric artery should promote dedicated evaluation in the region of the distal external iliac artery and vein. Familiarity of common and uncommon types of AVFs also assists in proper interpretation of findings. For instance, the rarity of fistulas between the DFA and DFV should lead to a high degree of caution before such an AVF is diagnosed.

Knowledge of the different types of AVFs may also alter angiographic technique. As mentioned previously, it is well known that the CFA and CFV should be targeted during arterial and venous catheterization. The frequency of postcatheterization AVFs involving the SCIV should promote more active scrutiny of this vessel when sonographic localization is performed prior to femoral artery catheterization. Likewise, the possibility of AVFs between the inferior epigastric artery and distal EIV should encourage
identification of these vessels when sonographic localization is performed prior to FV catheterization.

There are a number of limitations in our study. Iatrogenic AVFs rarely cause symptoms, but the patients in this study were only scanned when there was a clinical suspicion of a complication. In most cases, the scans were performed on patients with pain, swelling, bruising, or detection of a bruit, and the indication was to rule out a pseudoaneurysm or hematoma. Given the increased incidence of pseudoaneurysms and hematomas occurring below the CFA bifurcation, it is likely that more patients with arteriotomies below the bifurcation were scanned. This would lead to increased detection of asymptomatic fistulas below the bifurcation. Therefore, asymptomatic AVFs above the bifurcation would be expected to be underrepresented in our patient population. In addition, it may be difficult to precisely map out the artery and vein involved with these fistulas using Doppler techniques. Lack of recognition of the potential sites of AVFs could have led to a systematic bias in the detection of fistulas arising from certain arteries and draining into certain veins. Finally, there are frequent variations in the presence and location of the smaller arterial branches arising from the femoral arteries and in the smaller venous branches draining into the FVs. These variations may have led to misclassification of some of the fistulas.

In conclusion, we have shown that iatrogenic femoral AVFs following catheterization occur above the femoral bifurcation more often than previously suspected. These fistulas most frequently involve the SCIV and likely occur due to unavoidable puncture of the vein despite proper targeting of the CFA. Fistulas below the femoral bifurcation can arise from the SFAs or DFAs and most often involve the CFV or the LCFV. Based on our findings, we propose a classification scheme for iatrogenic femoral AVFs that can be used in clinical practice to anticipate findings on color Doppler examinations, to standardize description, and to aid in communication between providers. In research studies, this system can be used to facilitate analysis and comparison between different cohorts of patients and different institutions.

Acknowledgment

Figure 1 was produced by Anne Robinson, PhD, in association with InPrint at Washington University in St. Louis.

References


