

Arteriovenous Fistulas: Etiology and Treatment

Important considerations from initial evaluation to treatment planning.

**BY RAFIUDDIN PATEL MB ChB (HONS), MRCS, FRCR, AND
ANTHONY A. NICHOLSON, BSc, MSc, MB ChB, FRCR, FFRRCSI, EBIR**

An arteriovenous fistula (AVF) is an anomalous direct communication between an artery and a vein that results in shunting of blood between the two. This bypasses the high-resistance capillary vasculature, producing a low-resistance, high-flow situation with pulsatile blood flow in the veins that denies local tissue perfusion.

AVFs may be congenital or acquired. Many AVFs are traumatic (Figure 1) and often iatrogenic due to the increasing number of invasive procedures. Attempted percutaneous femoral artery cannulation accounts for most iatrogenic AVFs. Inexpert central venous cannulation can also injure adjacent arteries, resulting in an AVF.¹ This is true even when ultrasound is used if training in ultrasound-guided procedures is inadequate or nonexistent. Surgery, such as total knee replacement or lumbar disc surgery, may rarely produce an AVF.^{2,3} Arterial injury from percutaneous biopsies, most frequently of the kidneys, nearly always results in AVF development, but these are often self-healing and only a few cause problems. Noniatrogenic trauma due to penetrating injuries or long bone fractures causing direct arterial trauma can lead to AVF formation.^{4,5} Up to two-thirds of patients with traumatic AVFs are diagnosed within a week of injury; however, a significant subset will present with delayed symptoms weeks to years later.⁶⁻⁸

Congenital AVFs include (1) central nervous system lesions, such as carotid-cavernous fistulas and dural

AVFs; (2) pulmonary vascular malformations (these have a simple architecture that resemble AVFs more than true malformations); and (3) coronary artery, intrarenal, and hepatic AVFs, which rarely occur.

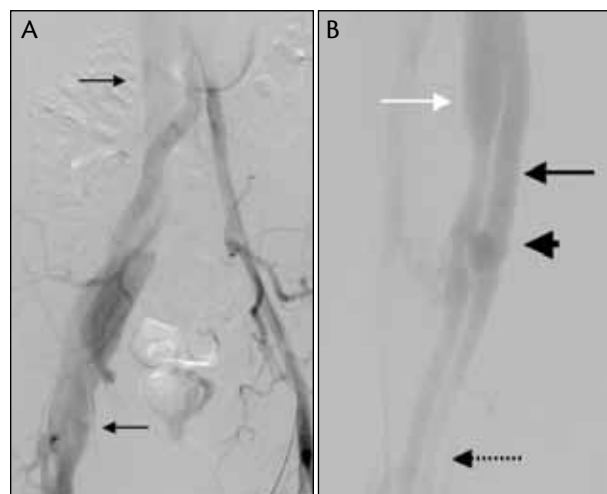


Figure 1. Delayed presentation after penetrating trauma to the mid-thigh. Catheter angiography demonstrates brisk venous filling (black arrows) following arterial injection (A). In the right thigh, the site of the traumatic AVF between the superficial femoral artery and femoral vein is demonstrated (arrowhead) with enlargement of the afferent artery (black arrow) and draining vein (white arrow), as well as poor arterial flow distal to the fistula (dashed arrow) indicating steal (B).

Surgical AVFs may be constructed for the purpose of hemodialysis (usually in the upper limb) to provide a superficial arterialized vein that can be easily punctured with flow that is high enough to allow efficient hemodialysis in patients with end-stage renal failure.

A patient with an AVF may present with local symptoms and signs such as a palpable thrill, audible bruit, ischemia distal to the lesion, dilatation of the feeding artery and draining vein, or with changes of sustained venous hypertension.⁷ If the AVF is large enough to reduce total peripheral resistance, it will induce increased cardiac output and increased circulating volume to maintain arterial pressure. In severe, chronic cases or in patients with poor cardiac reserve, this may lead to cardiac dilation and high-output cardiac failure.^{6,7} A resting tachycardia with slowing of the pulse during compression of the fistula or afferent artery is termed the *Branham-Nicoladoni sign* and indicates a high-output state.^{9,10}

AVFs are distinct from arteriovenous malformations (AVMs), which are congenital lesions that arise due to failure of embryonic or fetal vascular differentiation. Although AVMs may be high flow, they tend to have a more complex nidus of anatomic communications compared to AVFs. As a consequence, high-flow, complex AVMs have a higher resistance to flow and may remain asymptomatic, whereas AVFs usually increase in size if left untreated. High-flow AVMs are more likely to require treatment due to pain, mass effect, ulceration, bleeding, distal ischemia, or growth disturbance (and only rarely for high-output failure).¹¹

DIAGNOSTIC IMAGING

Duplex imaging confirms the presence of an AVF by demonstrating low-resistance flow in the enlarged afferent artery, a turbulent, high-velocity flow spectrum at the fistula site and a high-velocity, arterialized waveform in dilated, thick-walled draining veins (Figure 2).

Computed tomographic and magnetic resonance angiography can provide images of the anatomy of the arteriovenous communication, typically with early contrast filling in the vein during the arterial phase. Detailed anatomical views of the involved vessels and the site and size of the AVF is helpful when making decisions about the best treatment option.

Digital catheter angiography is usually performed immediately before treatment, or it may be undertaken

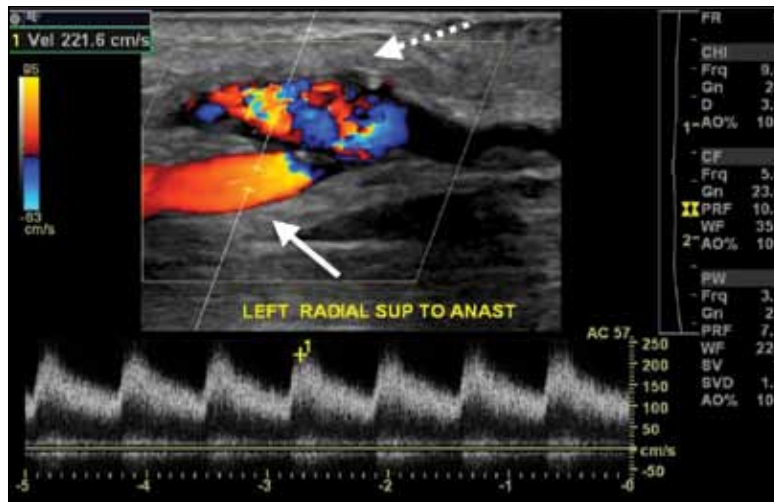


Figure 2. Duplex ultrasound image showing a typical low-resistance arterial waveform in the afferent radial artery (arrow) of a radiocephalic fistula. Turbulent color flow in the immediate draining vein (dashed arrow) is also visualized.

diagnostically if noninvasive imaging is not sufficient for diagnosis or if a detailed vascular study is required to plan treatment. Catheter angiography can show flow dynamics and the precise anatomy of AVF communication, often uncovering previously unsuspected involvement of vessels or collaterals and variant anatomy. Selective catheter angiography of individual branch vessels and high frame rates are usually required.

INDICATIONS FOR TREATMENT

Patients with distal arterial ischemia (“steal”), venous hypertension causing symptoms or end-organ dysfunction, as well as patients with high-output cardiac failure, require treatment. Most AVFs enlarge over time.¹² The benefits of early therapy to prevent secondary complications with technically less-challenging treatment is therefore considered a good indication for treatment in nearly all patients with asymptomatic AVF, except in cases involving very small fistulas such as those occasionally associated with biopsy or other medical procedures when a conservative expectant policy can be adopted.¹³

TREATMENT OPTIONS

The goal of treatment is to isolate and close the site of arteriovenous communication. Simply occluding or ligating the proximal feeding artery is insufficient and counterproductive. Collateral vessels will be recruited almost immediately due to the low-pressure “sump” effect of the draining vein and local vascular biologic factors, leading to an increase in complexity of the vascular lesion and making it much more difficult to treat completely.

The choice of treatment is dictated by an understanding of the detailed vascular and surrounding anatomy, including the size and type of arteriovenous communication, the territory distal to the fistula, flow dynamics, and the potential consequence of inadvertent nontarget embolization via the AVF.

Surgical treatment may be possible and appropriate in superficial lesions with simple arteriovenous communications such as superficial traumatic AVFs in the extremities with a single afferent artery and few draining vessels. The use of an endovascular stent graft may also be appropriate in this circumstance to close the AVF and preserve flow in the involved vessel.¹⁴⁻¹⁶

Embolization

In the treatment of complex AVFs with many feeding and draining vessels, embolization is indicated and surgery is specifically contraindicated. In these cases, surgery is more challenging and incomplete treatment risks making subsequent therapy more difficult with recruitment of collaterals. Surgery is also undesirable in the treatment of AVFs that can be treated more simply by endovascular means, such as lesions that are deep-seated, within solid organs, or adjacent to critical anatomy that may be at risk during surgery.

As with all endovascular procedures, contraindications to embolization are relative, and the merits of treatment must be weighed against the risks of not performing therapy or the risks involved in undertaking an alternative treatment. In general, contraindications to angiography are contrast allergy, an uncorrectable bleeding disorder, or renal impairment. Concerning AVF embolization, a technical inability to reach the target vascular site or a high risk of unacceptable nontarget embolization, either in distal arterial territory or pulmonary vessels, are contraindications.

TECHNIQUE

Access

Access is usually arterial and is gained via a site best placed with respect to the individual anatomy and location of the AVF. The arterial route allows access to the venous segment via the AVF if required and offers the advantage of imaging the AVF in the antegrade direction to flow. A venous approach to an AVF can also be used and has been described.¹⁷ This approach is particularly well suited in situations where the arterial inflow has been demonstrated to be simple and the vein can be completely occluded (ie, sacrificed), as this will result in immediate blockage of the AVF as long as there is no other venous communication. The vein can be accessed by direct puncture if accessible or via venous catheter-

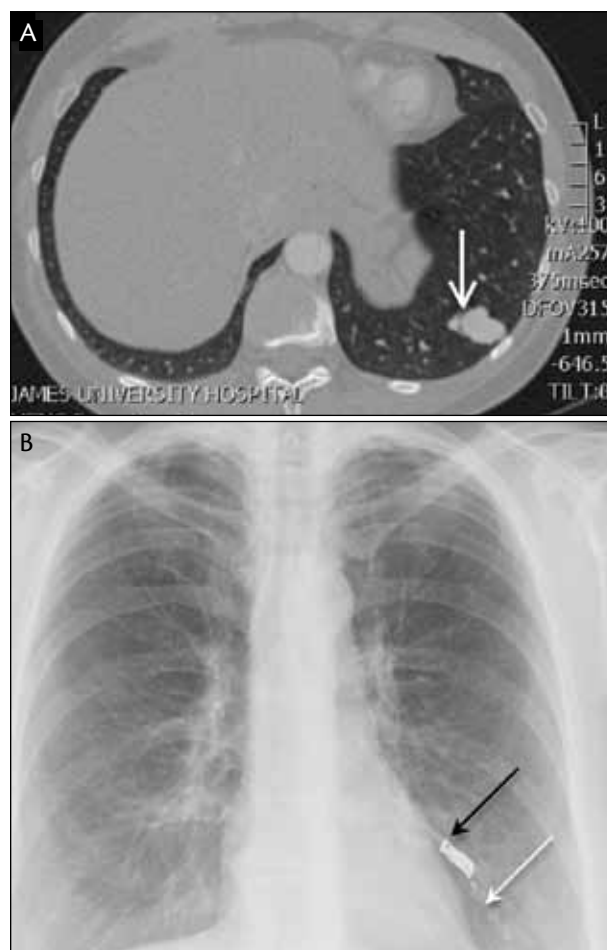


Figure 3. Pulmonary AVM demonstrated on computed tomography (A) and chest x-ray appearances after embolization of the feeding artery with coils (black arrow) and an Amplatzer plug (St. Jude Medical, Inc., St. Paul, MN) (white arrow) (B).

ization if remote. With this approach, the draining vein is usually completely packed with either coils or liquid embolics alone, or in combination.

Embolization Material

The most appropriate embolic agent is determined by the anatomy of the AVF, particularly with regard to the type and size of arteriovenous communication and vessels, the flow velocity, whether the involved vessels can be sacrificed or require preservation, and the risks and consequences of nontarget distal embolization, either arterially or via the venous communication.

Embolization of the feeding artery with coils is akin to selective microsurgical ligation and is appropriate if the artery can be safely sacrificed and also if the flow velocity and size of the fistula allow accurate and secure coil positioning without the risk of coils dislodging.

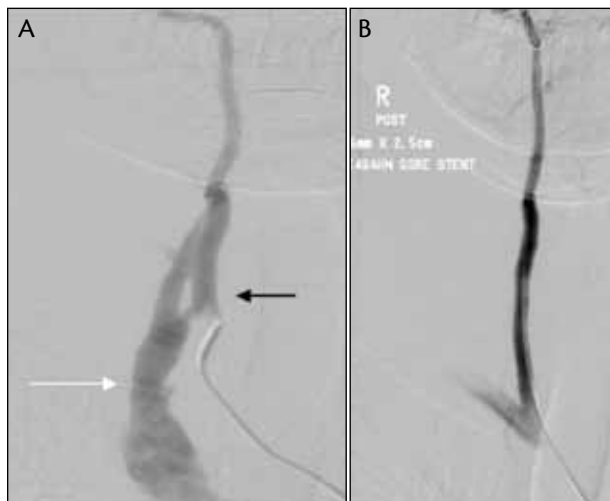


Figure 4. Iatrogenic trauma due to attempted central venous cannulation resulting in an AVF between the vertebral artery (black arrow) and internal jugular vein (white arrow) (A). The fistula was successfully occluded with preservation of the vertebral artery after insertion of a stent graft (B).

Coils need to be appropriately oversized compared to the target vessel so they are not at risk of migration but not so large that they elongate and occupy nontarget territory. It is often a good idea to anchor the distal end of a coil in a nonvital side branch and use this as a skeleton for further coil deployment. In very large or particularly high-flow AVFs, a detachable plug, such as an Amplatzer device (Figure 3) or a detachable coil system, can be used to ensure safe sizing and accurate positioning before final release and deployment.

If it is imperative that flow through the involved vessels is preserved or if the arteriovenous communication is side-to-side, then the use of a stent graft is indicated (Figure 4). An effective seal needs to be achieved, and there should be no additional branch vessels left that could lead to fistula recurrence.

In certain very high-flow or difficult situations, it may be desirable to use a liquid agent that polymerizes rapidly or in a more controlled manner, such as cyanoacrylate glue or Onyx (Covidien, Mansfield, MA), respectively.¹⁸ These agents may be used in conjunction with other devices or techniques (eg, after initial coil deployment or with a proximal occluding balloon) to reduce AVF flow and the risk of nontarget embolization.¹⁹

Successful initial treatment with exclusion of the AVF and minimal risk of persistence or complex recurrence requires intricate planning and execution. The procedure should not be considered complete until there is complete angiographic exclusion of any arteriovenous communication (Figure 5). After embolization of large

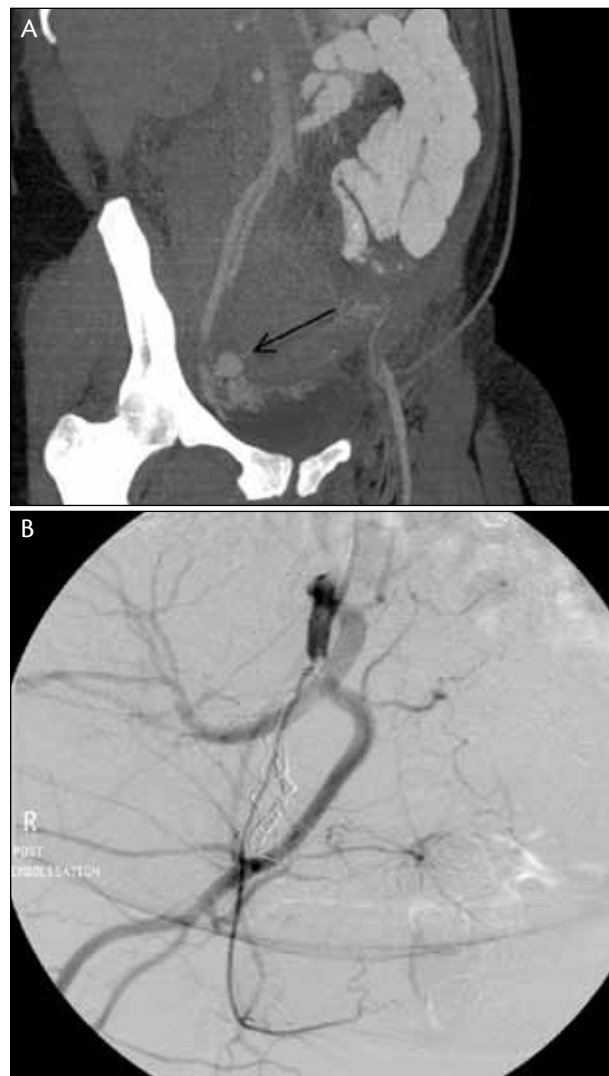


Figure 5. Iatrogenic pelvic AVF and false aneurysm (arrow) after Caesarean section (A). Successful coil embolization of the arterial supply with obliteration of the pseudoaneurysm and fistula (B).

AVFs or in patients with any cardiac disturbance due to the AVF, there may be immediate profound changes in hemodynamic status.¹⁰ This should be anticipated with appropriate anesthetic or intensive care monitoring and backup. Interval imaging follow-up after treatment is required to ensure that there is no persistence or recurrence of the AVF.

CONCLUSION

AVFs can be safely treated endovascularly, either by embolization or stent grafting. The aim of treatment is to definitively close the direct communication between the artery and vein. Individual anatomy and an understand-

ing of the functional result required will determine the most appropriate technique and approach. An incomplete treatment resulting in failure to occlude the site of direct arteriovenous communication will lead to certain recurrence with a more complex architecture that is more troublesome and challenging to treat. It is imperative that the initial treatment is carefully planned and executed for a successful and durable result. ■

Rafuiddin Patel, MB ChB (Hons), MRCS, FRCR is a Vascular & Interventional Radiology Fellow at the Bradford Teaching Hospitals NHS Foundation Trust, Bradford Royal Infirmary, in Bradford, UK. He has disclosed that he has no financial interests related to this article. Dr. Patel may be reached at rafpatel@gmail.com.

Anthony A. Nicholson, BSc, MSc, MB ChB, FRCR, FFRRCSI, EBIR is a Consultant Interventional Radiologist at the Leeds Teaching Hospitals NHS Trust in Leeds, UK. He has disclosed that he has no financial interests related to this article.

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