Arteriovenous Fistula

Christopher K. Zarins
Stanford University School of Medicine, Division of Surgery, Stanford, CA, USA

Synonyms
AV fistula; AVF; AV shunt

Definition and Characteristics
An arteriovenous (AV) fistula is an abnormal high flow connection between an artery and vein which allows blood to flow directly from an artery into a vein, thus bypassing the capillary bed.

Normally, oxygenated blood flows from arteries into the capillary bed, where oxygen is released into the tissues. Deoxygenated capillary blood then flows into veins and returns to the heart. When there is a direct connection between a high-pressure artery and low-pressure vein, a short circuit is created which bypasses the high resistance capillary bed. This results in a high flow situation and pulsatile blood flow in the veins. This can cause the veins to bulge and enlarge and become varicose. If the AV communication is very large, tissues downstream may receive insufficient blood supply. In some cases, the volume of diverted blood may be so great that heart failure may occur.

AV fistulas may be present at birth (congenital fistula), or develop after birth (acquired fistula). Congenital arteriovenous fistulas are birth defects and are also known as arteriovenous malformations (AVMs). AVMs may occur anywhere in the body, including intracranially. Acquired arteriovenous fistulas may result from a penetrating knife or bullet injury that damages both an artery and an adjacent vein. Arteriovenous fistulas may also develop as a complication of arterial and venous punctures performed during angiographic catheterization procedures. In patients with kidney failure who require hemodialysis, arteriovenous fistulas and shunts are surgically created in the wrist or arm in order to increase blood flow and pressure in the veins of the forearm. This enlarges the veins and creates a high flow situation in order to allow sufficient blood to flow through the dialysis machine.

Prevalence
Congenital AVMs are uncommon and occur with equal frequency among males and females. AVMs are present at birth, may regress after birth and may progress during puberty or pregnancy. Surgically created AV fistulas and shunts are very common in kidney failure patients undergoing hemodialysis. Traumatic and angiographic catheter induced fistulas are being increasingly recognized.

Genes
Experimental studies reveal that high flow arteriovenous fistulas result in up-regulation of candidate genes involved in cellular proliferation and differentiation. In animals with patent AVF 168 genes with significantly increased expression ($p \leq 0.05$) were identified, including APBA1, PRKDC, TAP1, NEK2, GC, TGFβ1, GBA, F8, IMPDH2, AFM, NBL1, LECT2, ANGPT1, KHDRBS1, ITGAM, and RAD52.

Molecular and Systemic Pathophysiology
A direct connection between a high pressure artery and a low pressure vein short circuits the capillary bed and results in a marked increase in blood flow in the afferent artery. This results in high wall shear stress and compensatory enlargement of the afferent artery with ultimate normalization of wall shear stress levels as the artery dilates. This adaptive enlargement is endothelial dependent and is mediated by endothelial nitric oxide (NO) release. In addition there is up-regulation of pro-inflammatory gene expression, endothelial and smooth muscle proliferation and restructuring of the elastin-collagen extracellular matrix. On the venous side, the increase in intraluminal blood pressure and flow velocity induces up-regulation of monocyte chemotactrant protein-1, plasminogen activator inhibitor-1, endothelin-1 and transforming growth factor-B1. Intimal and smooth muscle proliferation results in thickening of the wall of the vein and neointimal hyperplasia.
Large, high-flow arteriovenous fistulae can induce increased cardiac output with systemic effects which may lead to cardiac failure. This clinical situation is associated with increased activity of vasoconstrictor neurohormonal systems such as the renin-angiotensin system, the sympathetic nervous system, the endothelin system and arginine vasopressin. At the same time there is compensatory activation of systemic vasodilating systems such as atrial natriuretic peptide and nitric oxide. In decompensated patients enhanced sodium-retaining systems overwhelm the effects of vasodilating, sodium excretion systems with net reduction in sodium and water excretion and congestive heart failure.

**Diagnostic Principles**

Superficial AV fistulas can be identified by the presence of distended and bulging veins, discoloration and swelling and increased warmth in the region of the fistula. High velocity blood flow in an AVF can be heard with a stethoscope as a continuous pulsating flow signal (bruit or machinery murmur). The turbulence of flow in the AVF induces vibrations in the vein which can be palpated as a thrill over the fistula. Increased pressure in veins close to the fistula can result in pulsatility in the veins, swelling of an extremity, venous varicosities and venous insufficiency. Alternatively, decreased pressure in arteries distal to an AVF can result in ulcerations and distal tissue ischemia. Increased cardiac output and stroke volume due to large AV fistulas can lead to tachycardia, left ventricular dilation and heart failure. Compression and temporary occlusion of an AV fistula may lead to reflex slowing of the heart. A number of imaging modalities can identify and localize both superficial and deep arteriovenous fistulas, including Duplex ultrasound, magnetic resonance imaging, CT scanning with contrast and catheter based angiography.

**Therapeutic Principles**

Congential AVMs usually involve smaller arteries and veins and are most often managed conservatively. Small congenital AVMs can be excised or eliminated with laser coagulation therapy, however, they are often more extensive than they appear on the surface. If there are significant clinical symptoms or complications, treatment usually involves endovascular coiling or embolization. Acquired fistulas usually involve a single large connection which can be effectively treated surgically by repairing the defect in the artery and repairing or ligating the associated vein or veins. Traumatic or catheter induced AV fistulas require direct surgical repair. AV fistulas in the brain, eye or other major structures can be especially difficult to treat. Endovascular treatment strategies with angiographic image guidance to embolize, coil, glue and occlude the arterial and venous branches feeding the fistula have been effective. These procedures are performed using catheters and x-ray imaging and do not require open surgery.

**References**