When AVF Angioplasty Fails…

Defining procedural success and overcoming common problems.

BY THOMAS M. VESELY, MD

Angioplasty remains the most common method of treating obstructive vascular stenoses associated with hemodialysis fistulas and grafts. Balloon dilatation of neointimal hyperplastic stenoses is easy, safe, and effective, with reported success rates of 85% to 90%. But this 10% to 15% rate of angioplasty failure represents 50,000 to 75,000 patients per year.[1] Some stenoses simply fail to improve after dilatation, and some stenoses may worsen after the angioplasty procedure.

Recognition of failed angioplasty requires accurate characterization and precise measurement of the treated stenosis. This requires high-quality imaging both before and after the angioplasty procedure. Clinical, anatomic, and hemodynamic information is used to define successful angioplasty. The criteria used to define a successful angioplasty procedure are also used to define a failed one. All of the relevant national standards of reporting guidelines are in agreement regarding the criteria that should be used for assessment of this procedure.[2-4] Physicians performing angioplasty of hemodialysis access-related vascular stenoses should be able to recognize a failed angioplasty procedure and be familiar with the standard interventional techniques for managing common problems.

INDICATIONS FOR ANGIOPLASTY

There are two general indications for an angioplasty procedure: (1) the patient has a clinical or hemodynamic abnormality with his or her hemodialysis fistula or graft and (2) the presence of a vascular stenosis causing > 50% reduction in the luminal diameter of the blood vessel.[2-4] High-quality angiography should be performed to identify, characterize, and measure all stenoses located along the vascular access circuit. Angiographic images obtained in different imaging planes may be necessary to thoroughly evaluate the lesion prior to an angioplasty procedure. When measured on a two-dimensional angiographic image, a 50% reduction in the luminal diameter of a blood vessel corresponds to a 75% to 80% decrease in cross-sectional area and is considered to represent a hemodynamically significant stenosis. Accurate measurement of the degree of stenosis should be performed before and after the angioplasty procedure. Preangioplasty measurements are needed to determine if the lesion is appropriate for angioplasty (> 50% stenosis), and postangioplasty measurements are needed to determine the success of the angioplasty procedure.

An angioplasty procedure should not be performed unless the clinical and angiographic findings are both abnormal and correlative. The stenosis identified on angiography should correlate with the patient's clinical problem. When angioplasty is performed on a stenosis that meets the angiographic criteria (> 50% stenosis) but lacks a corresponding clinical indication, there may be no appreciable benefit derived from the procedure.

The criteria that define successful angioplasty, which are based upon the original indications for the procedure, are (1) resolution of the clinical or hemodynamic indication for the procedure and (2) < 30% residual stenosis at the site of angioplasty. Resolution of the original clinical problem is a subjective assessment, and improvement may not be apparent until several days after the angioplasty procedure.

There are different methods to determine the success of an angioplasty procedure, including clinical success, anatomic success, and hemodynamic success. It is important to understand that none of these methods is predictive of long-term patency.

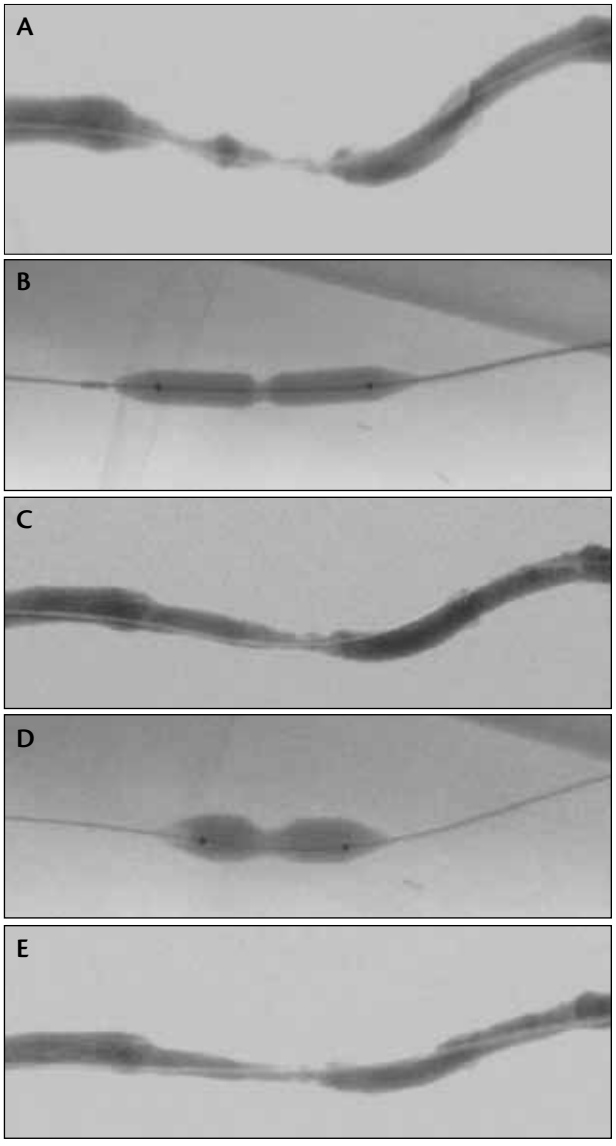

Figure 1. Angiographic image of a long, severe stenosis involving the venous anastomosis of a left forearm hemodialysis graft (A). Inability to fully inflate the angioplasty balloon at the site of stenosis. This is a technical failure of the procedure (B). Postangioplasty image shows some improvement but with significant residual stenosis (C). Inability to fully inflate a peripheral cutting balloon at the site of stenosis. This is also a technical failure (D). Final appearance shows anatomic failure with > 30% residual stenosis at the site of angioplasty (E).

DEFINITIONS OF SUCCESSFUL ANGIOPLASTY

Clinical Success

Clinical indications for angioplasty include abnormal findings during physical examination of the patient's hemodialysis fistula or graft, prolonged bleeding after removal of the hemodialysis needles, difficulty with cannulation, or swelling of a patient's arm or leg ipsilateral to a vascular access. During the procedure, it is not always possible to determine if angioplasty has been successful. Clinical success requires resolution of the clinical problem, and that information may not be apparent until several days after the angioplasty procedure. A nurse or technician at the patient's hemodialysis treatment center often assesses resolution of the clinical problem; the assessment of clinical signs and symptoms, before and after the angioplasty procedure, is a subjective process.

Hemodynamic Success

For hemodialysis fistulas and grafts, the two measures of hemodynamic performance are intra-access blood pressure and the rate of intra-access blood flow. When followed over time, these parameters can be indicators of access dysfunction. An abnormal hemodynamic parameter is an appropriate indication for angioplasty of a stenosis associated with a hemodialysis fistula or graft. Following angioplasty, hemodynamic success is defined as normalization of the previously abnormal hemodynamic parameter. One caveat is that hemodynamic measurements obtained in the angiography suite may differ from those obtained in the hemodialysis treatment center, so the values may not be directly comparable.

Anatomic Success

Anatomic success requires full inflation of the angioplasty balloon. A larger-diameter balloon or an ultra-high-pressure balloon may be needed to fully expand a recalcitrant stenosis. If the stenosis cannot be fully dilated, then the angioplasty procedure is considered a technical failure.

Anatomic success is defined as having < 30% residual stenosis. This criterion for anatomic success of an angioplasty procedure was adopted from the standards of reporting for arterial angioplasty. This value has become the de facto national standard for defining the success of any angioplasty procedure. However, its applicability and usefulness for hemodialysis access procedures has not been substantiated.[3]

In practice, the determination of successful angioplasty is made using the degree of residual stenosis, the appearance of the vessel wall, and the absence of a complication. If all of these factors are deemed acceptable, then the procedure is considered a success.

Technical Success

Technical success, sometimes called *procedural success*, is not a universally recognized reporting standard. It is

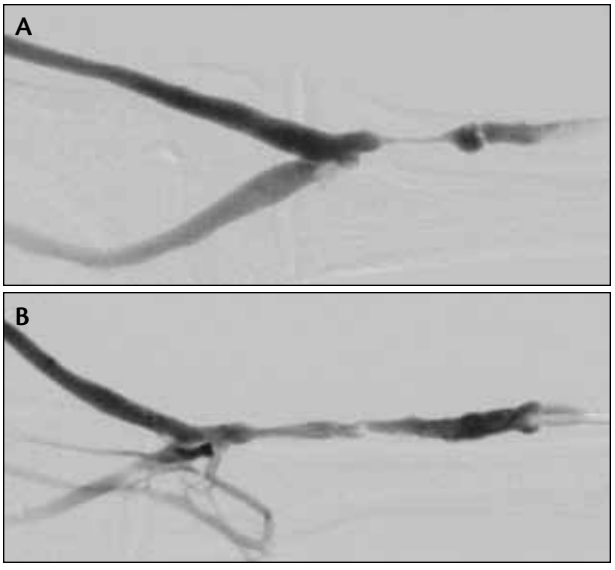

Figure 2. Very severe stenosis involving the cephalic vein near the left elbow joint (A). Anatomic failure after angioplasty (B). There is minimal improvement in the luminal diameter of the vein after angioplasty.

not required for publication of a clinical study; it is a colloquial term. Some authors report technical success, and others do not.

After initial angiographic evaluation of the patient's vascular access, the operating physician determines whether an angioplasty procedure is needed. If it is, but the operating physician cannot advance a guidewire across the stenosis, then the angioplasty procedure would be considered a technical failure. Another reason for technical failure is the inability to fully inflate the angioplasty balloon (Figure 1). If a second balloon achieves full inflation, then the procedure is a technical success. If the angioplasty balloon bursts during inflation, it may still be a successful procedure. If a second balloon achieves full inflation, then the procedure would be a technical success. However, bursting of an angioplasty balloon will often cause rupture of the adjacent blood vessel. If there is rupture of the vascular wall, then the angioplasty procedure is a technical failure with a complication.

Complications

One additional criterion defines a successful angioplasty procedure: the absence of a complication. Successful angioplasty requires anatomic success and clinical success without complications. For example, dilatation of a stenosis may cause acute rupture of the blood vessel at the site of angioplasty. Such an injury can be managed using a stent graft, resulting in both anatomic success and clinical success. However, the successful outcome of the procedure is attributed to deployment of the stent graft and not the angioplasty—the angioplasty was unsuccessful and caused a complication.

MANAGEMENT OF FAILED ANGIOPLASTY

Technical Failure

The inability to fully inflate the angioplasty balloon should be an uncommon cause of technical failure (Figure 1). The majority of high-pressure angioplasty balloons have a rated burst pressure of 20 atm, which is sufficient to dilate the majority of stenoses.[5,6] If necessary, ultra-high-pressure angioplasty balloons can be used to attain inflation pressures exceeding 30 atm.[5] Alternatively, a cutting balloon can be used to create multiple longitudinal microincisions along the inner lumen of the stenosis.[7] These incisions may release fibrous tissue and allow complete expansion of the stenosis. Of note, the inability to fully inflate an angioplasty balloon at the site of stenosis is a relative contraindication to placement of a stent or stent graft. Recalcitrant, fibrotic stenoses can be resistant to ultra-high-pressure angioplasty balloons and cutting balloons. Such rigid stenoses cannot be opened by a metal stent or stent graft. A rigid stenosis will likely pinch and partially occlude both devices.

Anatomic Failure

Anatomic failure is defined as > 30% residual stenosis after the angioplasty procedure (Figure 2). Immediate anatomic failure is often due to venous spasm or acute elastic recoil of the blood vessel wall. Inflation of a correctly sized angioplasty balloon is intended to overexpand a stenosis and cause disruption of both the intimal and medial layers of the blood vessel wall. Disruption of the vein wall allows enlargement of luminal diameter and initiates a vascular remodeling process that will reshape the inner dimensions of the blood vessel. It is important to remember that angioplasty is intended to cause significant damage to the blood vessel at the site of stenosis. Therefore, contact with normal blood vessels adjacent to the stenosis should be avoided. Correct sizing and positioning of the angioplasty balloon is important.

Blood vessels are composed of elastic fibers that allow stretching and contracting of the vessel wall in response to changes in blood pressure. These elastic fibers are located within the tunica media layer of the blood vessel wall. Inflation of an appropriately sized angioplasty balloon should significantly stretch the elastic fibers within the stenosis. The intent is to disrupt and tear the restrictive elastic fibers and enlarge the inner lumen of the blood vessel. The angioplasty procedure may fail if there is not sufficient disruption of the elastic fibers in the medial layer.

Angioplasty may incite contraction of the elastic fibers causing immediate (acute) narrowing and restenosis at

the site of dilatation. This phenomenon is called *acute elastic recoil*. The degree of residual stenosis is variable, and elastic recoil can occur immediately or minutes to hours after an angioplasty procedure. Further treatment of the residual stenosis is determined by the specific clinical circumstances. Reinflation of the angioplasty balloon, or use of a larger-diameter angioplasty balloon, may break the elastic contraction and achieve anatomic success. If reinflation of the angioplasty balloon provides no improvement, then a metal stent or stent graft can be used to treat elastic recoil. However, the majority of currently available devices are not approved for this indication. Importantly, full inflation of an appropriate-size angioplasty balloon is required prior to placement of a stent or stent graft.

Inflation of an angioplasty balloon with overstretching of a normal blood vessel can cause muscular contraction along the blood vessel wall, resulting in vascular spasm. Vascular spasm typically appears as a long, smoothly tapered stenosis involving a previously normal blood vessel adjacent to the site of angioplasty. Vascular spasm can be differentiated from acute elastic recoil by local administration of a vasodilator drug, such as nitroglycerin. Venous spasm will often resolve, whereas a residual stenosis caused by acute elastic recoil will persist.

Venous Rupture

Venous stenoses associated with hemodialysis fistulas and grafts are notoriously resistant to dilatation and often require high inflation pressures to fully inflate an angioplasty balloon. Balloon inflation pressures of 15 to 20 atm are often needed to achieve full inflation of the balloon. It is not surprising that these tremendous forces can damage or tear a vascular wall.

A venous rupture is a deep tear that extends through all three layers of the vascular wall, causing hemorrhage into the perivascular tissue. This complication has been reported to occur during 2% to 4% of hemodialysis access-related angioplasty procedures.[8] A venous rupture may also occur if the angioplasty balloon bursts during inflation.[9]

A venous rupture is fluoroscopically identified as extravasation or leakage of x-ray contrast material beyond the margins of the vessel wall with delayed washout or persistent staining.[8] Continued hemorrhage can produce a perivascular hematoma that can compress the adjacent vein and thereby obstruct blood flow through the vascular access. Such compression of the outflow vein will increase the pressure within the vascular access and accentuate further extravasation from the rupture site. A perivascular hematoma will often cause pain, and it may be palpable on physical examination.

The options for percutaneous management of venous rupture include manual compression, balloon tamponade, insertion of a stent or stent graft, or intentional thrombosis of the vascular access. The effectiveness of these techniques is dependent upon the hemodynamic status of the vascular access at the time of vascular injury. If the fistula or graft is thrombosed and the injury occurs before restoration of blood flow, any bleeding may be controlled by manual compression. However, if there is blood flow through the vascular access, then balloon tamponade is the preferred technique. The presence of a distal stenosis will often potentiate the vascular injury. A distal stenosis increases the endoluminal pressure within the vascular access, which accelerates the rate of hemorrhage. In the event of a vascular tear, any untreated downstream stenosis should be dilated using angioplasty as soon as possible.

Manual compression of the injury site is a simple and rapid method to treat a venous rupture. In most instances, the venous injury is in a superficial location that can easily be compressed by the physician or an assistant. Moderate compression is applied over the site of injury for 5 to 10 minutes. Upon release of compression, fistulagraphy should be performed to reevaluate the site of venous rupture and verify that bleeding has ceased.

A common method to treat venous rupture is balloon tamponade.[9] It is generally believed that balloon tamponade is more effective than manual compression. In the event of a vascular tear, the angioplasty balloon should be repositioned across the site of injury and reinflated to tamponade the hemorrhage and "tack up" the damaged vascular wall.

Metal stents and stent grafts can be used to treat venous ruptures and dissections.[10] These devices are widely available, easy to insert, and may provide a more durable repair of a venous injury. It is important to note that many of the currently available stents and stent grafts have not received US Food and Drug Administration approval for use in hemodialysis fistulas and grafts.

Typically, the diameter of the stent or stent graft should be 20% larger than the diameter of the blood vessel at the site of deployment. The correct stent length should be determined so that the device completely covers the site of injury but minimizes the amount of stent that extends into the adjacent normal blood vessel. Ideally, the stent should not extend more than 10 mm into the normal vein.

Insertion of a stent graft can provide rapid treatment of acute venous rupture. A stent graft provides an occlusive fabric patch that effectively seals the site of vascular

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injury and prevents further bleeding. The endoluminal radial force exerted by the stent graft can resist extrinsic compression by a perivascular hematoma and thereby maintain blood flow through the vascular access. Furthermore, as the underlying vascular injury heals, the fabric layer serves as a barrier to encroachment of neointimal hyperplasia. Metal stents and stent grafts are not designed for repeated needle puncture. Frequent cannulation of these devices with a large-diameter needle can cause substantial damage to a stent or stent graft.

CONCLUSION

Angioplasty procedures can fail for a variety of reasons. Vascular stenoses associated with hemodialysis fistulas and grafts are often resistant to angioplasty and may require adjunctive techniques or devices to open the stenotic blood vessel. These stenoses are also prone to elastic recoil and vascular spasm, both of which can cause immediate restenosis at the site of angioplasty.

The criteria that define successful angioplasty are similar to those for a failed angioplasty, so knowledge of these criteria is important. Technical success and anatomic success should be determined at the time of the angioplasty procedure. Hemodynamic success and clinical success are usually determined at the patient's hemodialysis treatment center. Ideally, each patient's vascular access is monitored over time, and a coordinated vascular access management plan is implemented as needed. ■

Thomas M. Vesely, MD, is with Vascular Access Services, LLC in St. Louis, Missouri. He has disclosed that he is a consultant for W.L. Gore & Associates. Dr. Vesely may be reached at (314) 995-7081; tmvesely@gmail.com.

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