

# Managing Perforations of the Superficial Femoral Artery

How to prevent and treat these endovascular complications.

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Perforations along the superficial femoral artery (SFA) can occur from a variety of causes; if unrecognized or mismanaged, they can result in significant morbidity and even mortality. In the worst cases, uncontrolled bleeding can lead to hemodynamic instability and the need for open surgical management, blood transfusions, and prolonged hospital stays. From a procedural standpoint, perforations can result in prolonged procedure times, incomplete treatment, and tremendous frustration to the operator. This article focuses on SFA perforations related to endovascular interventions, although many of the treatment methods can be applied to other causes of perforation, such as penetrating trauma or crush injury. The prevention of perforations will be discussed first, because the best way to manage any complication is to avoid it altogether. Then, common mechanisms of perforation and the most effective treatment options will be reviewed (see *Common Procedure-Related Causes of SFA Perforations* and *Techniques to Treat SFA Segment Perforations*).

## PREVENTING PERFORATIONS

Preventing SFA perforations during an interventional procedure requires meticulous adherence to good angiographic technique. Almost all SFA guidewire perforations can be avoided by first obtaining a high-quality angiogram and using standard road mapping/overlay features. This is especially important when crossing long-segment, high-grade stenoses. It allows the operator to carefully track the guidewire along the SFA; if the wire deviates from the SFA road map, it becomes clear that a side branch has been entered or the wire has perforated the vessel wall. Similarly, SFA intimal calcifications may provide an informative road map of the vessel lumen. Another way to track along the true lumen of the vessel is to create a small loop at the tip of

### COMMON PROCEDURE-RELATED CAUSES OF SFA PERFORATIONS

- Guidewire perforation
- Angioplasty-induced perforation
- Atherectomy-induced perforation
- Stent fracture pseudoaneurysm

### TECHNIQUES TO TREAT SFA SEGMENT PERFORATIONS

- Balloon tamponade
- Covered stent placement
- Coil embolization or use of other embolics
- External compression
- Reversal of anticoagulation
- Surgical management

the wire above the lesion and then advance it incrementally. Once a stenosis or occlusion is crossed, it is always prudent to verify the wire position distal to the lesion. This is best performed by passing a small catheter across the lesion and performing a gentle hand injection angiogram to confirm positioning in the true lumen rather than in the subintimal space, extravascular space, or vessel side branch.

Once the guidewire is repositioned across the lesion, it is essential to keep track of the wire tip to avoid inadvertent selection of downstream vessel branches. This typically occurs when exchanging long catheters over the wire and can result in serious side branch perforations. Appropriate balloon sizing along the SFA can be challenging, but in gen-

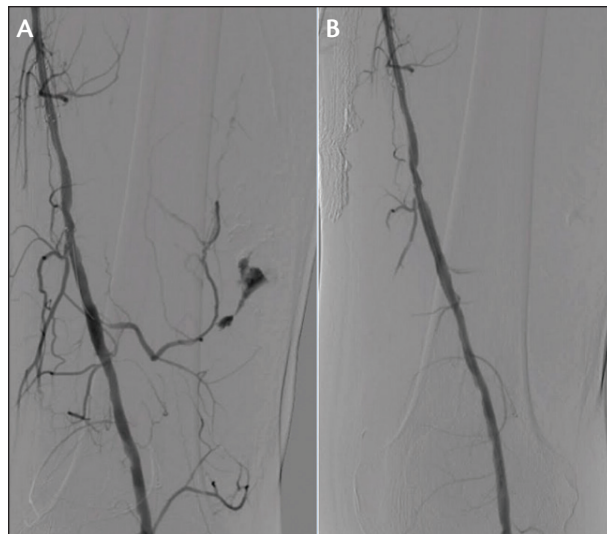
eral, balloon sizes commonly range between 5 and 7 mm in diameter. When heavily calcified high-grade stenoses are encountered, starting with a smaller balloon and then sequentially dilating with a larger balloon may be less traumatic to the vessel. Also, atherectomy may be helpful to prepare the vessel and allow for a lower-pressure angioplasty. Cutting and scoring balloons may also allow for a more controlled lower-pressure angioplasty. If high pressures are absolutely needed, the operator should be prepared to use balloon tamponade or deploy a covered stent if a perforation occurs. Finally, all atherectomy devices should be used cautiously and in accordance with their instructions for use.

### GUIDEWIRE PERFORATIONS

Guidewire perforations of the SFA itself are usually of little consequence because they are typically small and rarely result in significant bleeding. They usually occur when a guidewire is advanced into an occlusion or when the wire inadvertently undermines a plaque and is then manipulated through the vessel wall. It is essential to recognize when a guidewire has perforated the vessel to prevent worsening the situation by advancing a larger catheter or treating with angioplasty. Most of these perforations will resolve spontaneously or can easily be treated with balloon tamponade. Balloon tamponade is performed by selecting a balloon just large enough to obstruct flow along the bleeding segment and inflating to a low pressure (usually 2–4 atm) for a period of 2 to 4 minutes. Reversal of anticoagulation is typically not necessary.<sup>1</sup>

Guidewire perforations of small SFA side branches are often much more problematic. Many times, they are missed during the procedure and are first noticed as a large thigh hematoma in the postprocedure area (Figure 1). When identified during the procedure, the small size of the side branch and distal location of the perforation may preclude treatment with simple balloon tamponade. Furthermore, balloon tamponade alone or placement of a covered stent in the SFA to exclude the origin of the side branch may not entirely stop the bleeding because collateral pathways may continue to perfuse the injured vessel. Side branch perforations are best treated using coil embolization, although more complex perforations can be treated using embolic particles, cyanoacrylate glue, thrombin, and Onyx liquid embolic system (Covidien). These methods are largely derived from well-established transcatheter embolization techniques used to treat trauma-induced bleeding of solid organs and extremities.<sup>2</sup> The same techniques have also been used to treat guidewire perforations of the coronary arteries.<sup>3</sup>

Initially, when a side branch perforation is identified, the bleeding should be controlled. This can be accomplished using balloon tamponade across the origin of the bleeding



**Figure 1.** Frank extravasation of contrast from an SFA side branch due to guidewire perforation (A). The perforation was noted late in the procedure and resulted in a large thigh hematoma. It was treated by prolonged balloon inflation along the SFA and applying external compression with a large blood pressure cuff (B).

side branch. External compressions performed manually or with a large blood pressure cuff can also slow or stop bleeding. These techniques can buy valuable time so that preparations can be made for more definitive treatment with embolization. Embolization is performed by selecting the side branch with a 4- or 5-F catheter and delivering coils or other embolic agents to the site of bleeding. Occasionally, a microcatheter may be needed to reach the source of bleeding.<sup>2</sup>

### ANGIOPLASTY- AND DEVICE-RELATED PERFORATIONS

Angioplasty of SFA stenoses is intended to disrupt the intima and media of the vessel wall in order to increase luminal area. However, when the adventitia is also disrupted, a perforation is created. Hayes et al identified three risk factors for angioplasty-related perforation: diabetes, older age, and critical limb ischemia.<sup>1</sup> They suggest that these risk factors are proxies for decreased vessel wall compliance, which itself leads to higher rates of perforation. In our experience, other predictors of vessel perforation include heavy calcification, high-pressure angioplasty, and oversized balloons. Numerous strategies have been developed to achieve more effective angioplasty and decrease trauma to the vessel wall. These include vessel preparation using a variety of atherectomy devices to debulk plaque and alter compliance, cutting and scoring balloons, and more recently, devices such as the Chocolate balloon (manufactured by

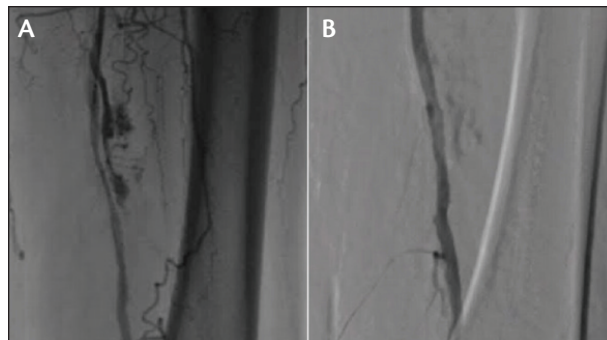


**Figure 2.** Angiogram demonstrating a slow-filling AV communication between the SFA and superficial femoral vein after subintimal angioplasty of the SFA. This finding was not treated and led to no adverse clinical outcome.

TriReme Medical, Inc., distributed by Cordis Corporation), which uniformly distributes the force of the expanding balloon and decreases torsional shear stress.

Atherectomy-related perforations occur due to direct cutting or mechanical disruption of the adventitial layer. Directional atherectomy has a procedural perforation rate of up to 5.3%.<sup>4</sup> Laser atherectomy has a reported perforation rate of 2%.<sup>5</sup> Rotational atherectomy has a perforation rate of 2%, and orbital atherectomy has a perforation rate between 0.5% and 2.2%.<sup>6,7</sup> Although atherectomy-related perforation rates in peripheral arteries are relatively low, they are not insignificant, and operators should have a clear strategy to manage them.

Most perforations are easily identified on an angiogram as frank extravasation, a persistent blush, or an arteriovenous (AV) communication. Although there is no formal grading system for peripheral arterial perforation, as there is for coronary artery perforation,<sup>8</sup> it is important to discern the severity of the perforation once it is seen. Frank extravasation is the most severe finding and should be dealt with promptly. An extravascular blush that persists beyond the venous phase typically represents a smaller, more contained perforation, which should also be dealt with promptly. It is important to distinguish these perforations from contrast blush along the adventitia of the vessel that slowly dissipates; this finding can be misinterpreted as a perforation, when it actually represents more benign disruptions of the vaso vasorum or non-flow-limiting dissections in the subintimal space. AV communications, which are often seen after



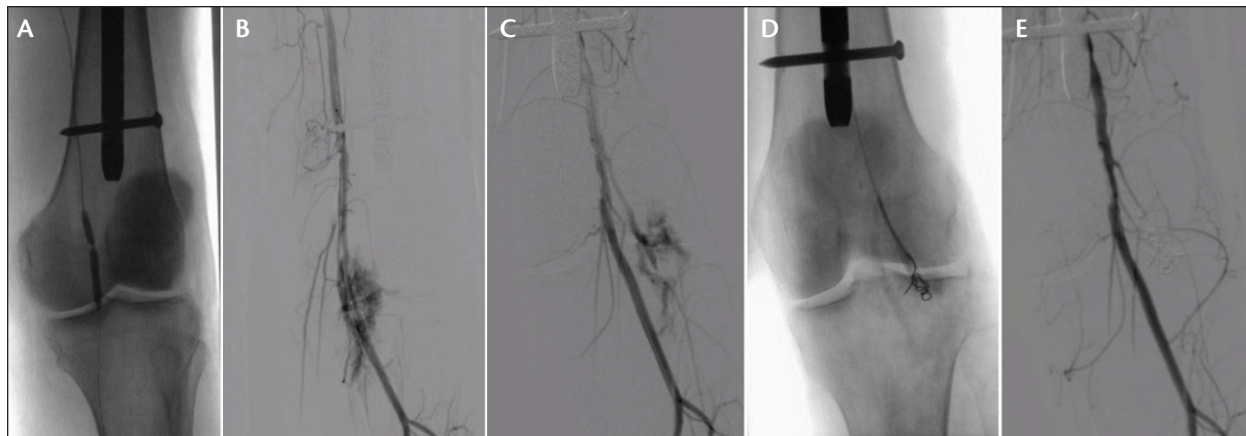
**Figure 3.** Frank extravasation of contrast from a focal SFA perforation after angioplasty (A). This was successfully treated using a Viabahn covered stent (B).

subintimal angioplasty, are the least concerning. Slow-filling, irregular AV communications usually represent a series of microperforations between the artery and adjacent vein, which tend to resolve spontaneously and have little clinical consequence (Figure 2). Larger, well-defined AV communications with brisk flow should be considered for repair, because they are more likely to persist over time.

The first step to controlling bleeding is to position a balloon just large enough to occlude the vessel across the perforation and inflate it a low pressure (usually 2–4 atm) for 2 to 4 minutes. Balloon tamponade stops the bleeding and allows for initiation of the coagulation cascade to seal the perforation. This is followed by a repeat angiogram to determine if the perforation has adequately resolved. If not, balloon tamponade can be repeated several more times.<sup>2</sup> Reversal of anticoagulation is commonly listed as part of the treatment for perforations, but based on our experience, anticoagulation should rarely be reversed during the intervention to control and treat the perforation, as this may lead to additional complications related to thrombosis and may limit the operator's ability to definitively treat the perforation and complete the procedure.

In the case that balloon tamponade is not sufficient, consideration can be given to treating with a covered stent (Figure 3). Because of the mechanical forces inherent to the SFA such as bending and stretching, a self-expanding covered stent should be used. Two examples are the Viabahn stent graft (Gore & Associates) and the Fluency Plus stent graft (Bard Peripheral Vascular). The Viabahn stent graft is preferred because stent sizes commonly used in the SFA can be delivered through a 6- to 7-F sheath compared to the Fluency stent graft, which requires an 8- to 9-F sheath. The diameter of the stent graft should be sized one-to-one to the diameter of the vessel, and the length of the stent should be selected to cover the entire extent of the perforation.

Recanalization of chronic SFA occlusions often involves angioplasty or atherectomy along a subintimal plane, which



**Figure 4.** Angioplasty of what was thought to be the popliteal artery (A). A subsequent angiogram shows extravasation of contrast from the region of angioplasty (B). An oblique angiogram shows that the extravasation is actually arising from a sural branch off of the popliteal artery and indicates that the sural artery was inadvertently treated, rather than the popliteal artery (C). The ruptured sural artery was then selected with a 4-F catheter and embolized using two Nester coils (Cook Medical) (D), resulting in resolution of extravasation (E).

can result in perforation. In these cases, the perforation can sometimes be treated by shifting intravascular plaque to seal the site of extravasation. First, the bleeding should be controlled using balloon tamponade. Next, a second guidewire can be used to cross the diseased segment through a different subintimal plane; angioplasty along the new subintimal plane will often shift plaque to a position that will seal the perforation. Another possible method is to rewire the occlusion from a retrograde tibio pedal or popliteal access through either the true lumen or a different subintimal channel and then perform angioplasty.

The majority of angioplasty- or device-related SFA perforations can be managed with balloon tamponade and covered stent placement. However, more extensive bleeding can occur from inadvertent angioplasty of a side branch using a balloon intended for the SFA (Figure 4). These can be difficult to control because the vessel rupture is often due to longitudinal tears. These cases typically require coil embolization of the side branch, as previously described. Additionally, because the injury may involve the side branch origin or SFA itself, concomitant placement of an SFA covered stent across the side branch origin may also be needed.

In rare cases of extreme bleeding that cannot be controlled by the previously described methods, external compression should be applied in order to transition the patient to surgery for definitive repair. Reversal of anticoagulation should be considered in these situations.

## COMPLICATIONS RELATED TO SFA PERFORATION

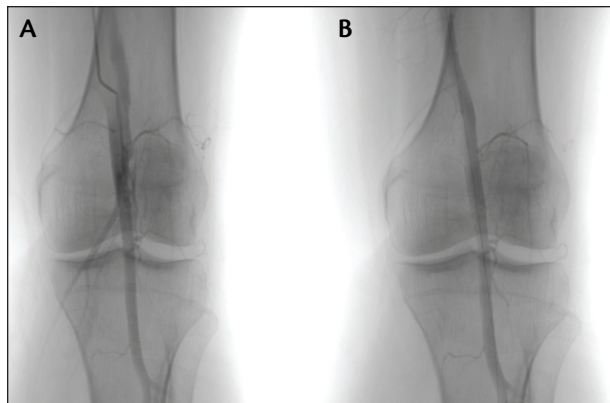
*Compartment syndrome* refers to a situation in which the pressure in one or more of the myofascial compart-

ments of the lower extremity exceeds the arterial perfusion pressure and the local tissue no longer receives blood and oxygen. Although compartment syndrome is a well-known complication in the calf, it can also occur in the thigh due to vessel perforation in rare instances. We have not seen compartment syndrome as a complication of SFA intervention, but in our experience, the majority of cases that result in severe thigh hematomas have occurred from side branch perforations that are not identified during the procedure. The development of thigh compartment syndrome is characterized by increasing pain in the thigh and associated neurologic symptoms, which will manifest first in the foot. Measurement of compartment pressures may be helpful in the diagnosis, but if compartment syndrome is strongly suspected, fasciotomy should be considered to avoid limb loss or permanent dysfunction.<sup>9,10</sup>

A pseudoaneurysm is a collection of blood that forms adjacent to a vessel perforation and is contained by surrounding tissues. SFA pseudoaneurysms are often identified days, weeks, or months after an intervention and can be a result of all of the aforementioned perforations: guidewire perforation, angioplasty-related perforation, and device-related perforation.<sup>11,12</sup> Stent fractures in which the fractured struts penetrate the vessel wall and cause a perforation are another source of late SFA pseudoaneurysm formation.<sup>13</sup> Most pseudoaneurysms of the SFA itself are readily treated with a covered stent, and those occurring in vessel side branches are typically treated with coil embolization.

AV fistulae occur as a result of a perforation of both the artery and adjacent vein. If the communication persists over time, it can become quite large and eventually arte-





**Figure 5.** An angiogram performed over a year after a distal SFA/upper popliteal intervention shows an AV fistula between the upper popliteal artery and vein (A). Because the patient was symptomatic (with chronic left leg swelling), the AV fistula was repaired by placing a Viabahn covered stent in the popliteal artery (B).

rialize the draining vein. Similar to a pseudoaneurysm, AV fistulae can result from any of the aforementioned types of perforations. Most small, asymptomatic SFA AV fistulae do not require treatment. However, symptomatic or large AV fistulae should be considered for repair and are easily treated by covering the arterial perforation with a covered stent (Figure 5). Cases in which there is an inadequate landing zone for a covered stent to create a seal should be considered for surgical repair. The use of coil embolization of the fistula track has been described, but requires a high level of technical experience with embolization.<sup>14</sup>

## CONCLUSION

Most SFA perforations can be prevented by using good angiographic technique. When an SFA perforation is encountered, the overwhelming majority can be treated effectively using endovascular techniques. ■

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