An increasing percentage of interventionists treat patients with symptomatic femoropopliteal occlusive disease with a “percutaneous intervention-first” approach. This is particularly so in patients deemed to be at high risk for surgical procedures and is based on the results of recent reports showing reduced morbidity and mortality with an intraluminal or subintimal endovascular approach to these lesions.

These patients generally have an increased risk of cerebral and cardiovascular comorbidities. Many patients also prefer endovascular treatment because of reduced cost and shorter hospital stay.

The BASIL trial substantiated essentially no difference in long-term outcomes between percutaneous and surgical revascularization in patients suitable for either form of treatment. If the patient’s arterial occlusion cannot be crossed by percutaneous techniques, the patient will necessarily be relegated to a surgical procedure or, worse, amputation, depending on the arterial anatomy and patient comorbidities. Currently, there is evidence that even the most extensive TASC II D femoropopliteal lesions can be approached percutaneously with a reasonable expectation of hemodynamic and limb salvage success.

Although the observation has been made that all femoropopliteal lesions can be safely and effectively managed with endovascular therapy, the more complex lesions have a lower primary and primary-assisted patency rate.

Crossing femoropopliteal chronic total occlusions (CTOs) remains a particularly challenging endeavor for the interventionist. Generally accepted factors that contribute to procedural success can be divided into patient-specific and lesion-specific criteria. Worsening degrees of critical limb ischemia, such as rest pain or tissue loss, are generally associated with poor outcomes.

Patients with symptomatic infraginguinal atherosclerosis on hemodialysis are identified as a particularly high-risk subset for procedural failure and limb loss.

Lesion characteristics associated with unsuccessful or limited patency rates include: (1) increasing lesion length, (2) more advanced TASC II classification, (3) increasing severity of calcification noted on fluoroscopy, and (4) flush occlusions at the superficial femoral artery origin. Most studies also show that at least one tibial vessel needs to be patent for long-term procedural success. It is generally accepted that the greater the number of tibial runoff vessels present, the greater the opportunity for long-term patency due to increased flow rates across the intervened segment.

The most common way to address CTOs currently is to choose either an intraluminal (IL) or subintimal (SI) approach. Until the recent introduction of crossing catheters, the fallback position for failed initial guidewire crossing of the CTO by IL technique was SI angioplasty. This technique was first popularized by Bolia et al. Others have subsequently validated this technique in published reports, with or without adjunct stent placement.

Both IL and SI techniques have their proponents. Generally, the enthusiasm for a particular technique is based on training and personal experience. A review of the literature reveals very little comparative data of SI versus IL lesion crossing. Comparative trials of these two procedures for procedural success and long-term paten-
The specific composition and characteristics of the occluded lumen are really what guides the wire. Soft plaque or IL thrombus generally allow for IL wire passage, whereas more fibrotic or calcific plaque tend to cause a more difficult central channel crossing. This may necessitate an SI approach as the wire progress is impeded and then deflected to a less resistant SI channel.

If an IL position can be maintained throughout the length of the CTO, the guidewire typically exits into the true lumen. If an SI approach has been employed, the looped guidewire will likely reenter spontaneously through the thin dissection flap near the reentry point. Reentry devices, such as Outback (Cordis Corporation, Bridgewater, NJ) or Pioneer (Medtronic, Inc., Minneapolis, MN), are required in 10% to 15% of SI CTO crossings to regain distal true lumen. Care needs to be taken not to propagate the SI dissection flap too far distally to preserve collaterals as well as possible distal targets for bypass if required later.

**INTRALUMINAL TECHNIQUE**

The IL technique is the classic approach used by most interventionists to cross CTOs. A 0.014-, 0.018-, or 0.035-inch hydrophilic wire is frequently used in combination with a support catheter. Much of this technique relies on tactile feedback as well as operator perception as to the course of the vessel. In addition to support catheters, a balloon catheter can be sequentially advanced with the wire and inflated in an attempt to stay in the true lumen. Angioplasty of the proximal segments can also decrease catheter friction that is sometimes experienced with a "tight" CTO. Some proponents also use laser ablation and sequentially advance the laser catheter along the wire to ablate IL debris for this same purpose.

**SUBINTIMAL TECHNIQUE**

The SI technique creates a neolumen between the intimal and adventitial layers of the arterial wall, displacing the atheromatous and calcified intimal and medial layers to the contralateral side of the vessel lumen and produc-
ing a relatively smooth flow lumen. Generally, a 0.035-inch hydrophilic guidewire is advanced with a hydrophilic support catheter to the CTO origin. The guidewire tip is directed toward the arterial wall at the site of the occlusion. There is generally little resistance after entering the SI space. A wire loop is formed and the SI space dissected. Caution should be taken to maintain a relatively narrow wire loop, which perforates spontaneously back into the true lumen in the majority of cases.

**PROS AND CONS OF INTRALUMINAL TECHNIQUE**

IL CTO crossing is an easily acquired skilled set and is the most commonly used CTO crossing method (Table 1). It is an easy transition from crossing highly stenotic lesions and a well-understood translation for the interventionist. Furthermore, the procedural costs are quite low and limited to a standard guidewire and crossing catheter. Problems associated with the IL technique are that it is not uniformly successful and may require conversion to SI angioplasty to achieve a technically successful crossing. Without concurrent imaging, it is also difficult to know whether CTO crossing remains truly IL and that the guidewire does not veer off segmentally into SI channels. Because of the amount of IL material, there is a frequent need to add adjunctive therapy other than a standard angioplasty balloon. This may require the addition of atherectomy devices or scoring balloons to debulk or modify the plaque. Stents may also be required to maintain an adequate flow channel.

**PROS AND CONS OF SUBINTIMAL TECHNIQUE**

The SI technique is also a low-cost procedure in that it only requires a guidewire and hydrophilic support catheter, and multiple studies have documented its high technical procedural success rate (Table 2). Limb salvage rates are substantial in patients who present with critical limb ischemia. The technique, however, is somewhat difficult to assimilate, with a steeper learning curve compared to IL techniques. There remains a 10% to 15% need for reentry devices. Many investigators will not use atherectomy in an SI space for the concern of vessel perforation of the thin subadventitial layer. It appears that technical success and patency rates are positively affected with stenting. Some proponents of SI techniques routinely line the channel with stents, especially to ensure luminal gain at the proximal cap and distal reentry sites.

Complications common to either the SI or IL technique include vessel perforation, distal embolization, or occlusion of collateral vessels. Rarely, however, do these complications lead to the need for emergent open repair, and they can usually be managed with percutaneous techniques. Prolonged balloon inflation at lower dilation pressures as well as covered stents are typically effective at managing complications of vessel perforation.

**RECENT TRIALS AND FUTURE DIRECTION**

Despite high procedural success crossing rates with both IL and SI techniques, the outcomes are not uniformly successful. The medical device industry continues to attempt to address this problem with different device types. The corporate rationale behind these efforts is to improve crossing rates that allow for subsequent delivery of therapeutic devices (angioplasty balloons, atherectomy catheters, cryoplasty, lasers) to the target lesion. Other goals include decrease in crossing times and allowing for more consistent distal reentry.

Devices such as the Crossover (Bard Peripheral Vascular, Tempe, AZ) and Wildcat (Avinger, Redwood City, CA) CTO catheters validate the clinical need for a device that consistently crosses through the true lumen. The recently completed CONNECT (Chronic Total Occlusion Crossing with the Wildcat Catheter) study is a prospective, multicenter, nonrandomized trial documenting the safety and efficacy profile of the Wildcat catheter in crossing femoropopliteal CTOs. The catheter demonstrated an 89% crossing rate with minimal associated morbidity. This trial was the basis for US Food and Drug Administration clearance of the Wildcat as a CTO crossing catheter in August 2011.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Low-cost device and procedure</td>
<td>Advanced interventional skill set required</td>
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<tr>
<td>High technical success rate</td>
<td>Steep learning curve</td>
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<tr>
<td>High limb salvage rate in critical limb ischemia</td>
<td>10% to 15% need for reentry device</td>
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<tr>
<td>Does not preclude or jeopardize surgical bypass options</td>
<td>Substantial need for adjunctive stenting</td>
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**TABLE 2. SI TECHNIQUE: PROS AND CONS**
It is still unclear as to whether procedural patency and limb salvage rates are affected by the specific technique used for CTO crossing. A comparative trial of these techniques appears warranted to better define any advantages of IL versus SI CTO crossing. An important part of such a trial would necessitate the use of high-quality intravascular ultrasound or optical coherence tomography to ensure that crossing was through an SI or true IL channel. Until a clear advantage of one technique over the other is established, it is likely that interventionists will continue to use the technique they consider most efficacious based on their experience.

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