66

Duplex-Guided Interventions

Subhash Banerjee

Contents

Discussion 828
References 829

The development of new catheter-based intravascular interventional techniques has greatly increased the clinician's armamentarium to tackle increasingly complex lesions that require precise placement and manipulation of devices within a blood vessel. While guidewires, catheters, and other devices have continued to evolve, contrast angiography remains the primary mode of vessel and lesion visualization. With the advent of duplex ultrasonography (US) in the 1980s, vascular mapping became widely commercially available for diagnosis of peripheral arterial disease and the concept of US-guided interventions first became clinically feasible [7, 8].

In terms of diagnostic evaluation, US arterial imaging has been well-studied and shown to be a reliable alternative to contrast arteriography in select clinical situations. Several investigations have used it as the primary imaging modality prior to infrainguinal and infrapopliteal bypass procedures [1, 3], where it seems to be most useful in patients with medical comorbidities such as chronic kidney disease and diabetes mellitus, as they are predisposed to contrast-induced nephropathy [12, 15, 18].

Another clear advantage over conventional angiography is the reduced exposure of the patient and medical personnel to ionizing radiation during diagnostic and therapeutic procedures [22]. US visualization may be of special value during infrainguinal endovascular intervention for "flush" occlusions of the superficial femoral artery (SFA). US guidance can allow directional manipulation of a crossing device that is easily visualized under US.

Thus, as the experience with diagnostic evaluation increases, so does the interest in the application of US guidance for peripheral catheter-based procedures. US imaging is unique in that it allows simultaneous visualization of both transverse and longitudinal planes, with detailed vessel and flow characterization at the time of crossing, balloon, and stent expansion. This real-time anatomic and physiologic information can provide immediate feedback after interventions to help guide short-term therapy and may even predict clinical outcomes [8, 13].

S. Banerjee, MD
Division of Cardiology,
VA North Texas Health Care System,
The University of Texas Southwestern Medical Center,
Dallas, TX 75230, USA

R.S. Dieter et al. (eds.), *Endovascular Interventions*,
DOI 10.1007/978-1-4614-7312-1_66, © Springer Science+Business Media New York 2014

Expanding the role of US-guided techniques requires careful consideration of the clinical scenarios where the strengths of this technology will allow for optimal clinical benefits. Peripheral artery lesions that have progressed to TASC C and D categories [9] such as those involving chronic total occlusions (CTO) are of particular interest in this field because crossing them requires prolonged procedure times, increased radiation exposure, larger iodinated contrast loads, and the use of complex subintimal dissection techniques with specialized devices for true lumen reentry [9, 12], all of which represent inherent drawbacks of traditional contrast angiography. US imaging, in turn, allows for detailed vessel wall visualization, plaque morphology characterization, and immediate subintimal flap identification [10, 20] which is especially important when attempting true lumen reentry after crossing these types of lesions. Most notably, vessel and lesion assessment can be repeated as many times as needed without adding to the contrast load or radiation times.

Indeed, complex peripheral vascular lesions are very common (>50 % of all infrainguinal lesions) [21], with low success rates for intervention attempts (50–70 %) [6], so it is in this field where an US-guided approach may offer the most substantial advantages over conventional imaging methods [5].

In 2009, our group published a novel technique for percutaneous endovascular crossing of a long and complex infrainguinal CTO using transcutaneous US-guided blunt microdissection (the “TUG-CTO” technique) [4]. The following case describes the technique in detail.

Case Presentation

The patient is a 52-year-old white male with diabetes mellitus and chronic kidney disease; he was evaluated to have bilateral lower extremity claudication symptoms in Rutherford category 3. The ankle-brachial indices were 0.51 in the right and 0.53 in the left lower extremity.

Prior angiography revealed bilateral patency of the common and external iliacs as well as the common and profunda femoral arteries. The left SFA was noted to be occluded proximally and reconstituted distally at the level of the adductor canal (see Figs. 66.1 and 66.2) with a patent left popliteal and two-vessel infrapopliteal runoff. The length of the occlusion was estimated at 300 mm. His right SFA also had 140-mm CTO with above-the-knee distal reconstitution and two-vessel infrapopliteal runoff. The patient refused to undergo surgical revascularization and requested percutaneous revascularization. Due to the presence of bilateral CTOs and concomitant chronic kidney disease as well as diabetes mellitus, we elected to attempt crossing the left SFA lesion with a transcutaneous US-guided blunt microdissection technique.

Transcutaneous US-Guided Interventions in the Femoral and Infrapopliteal Arteries:

General Procedure Description

1. US can be used to identify optimal vascular puncture site at the common femoral artery. We recommend using the contralateral site for a “crossover” insertion technique with a 45 or 90 cm destination sheath (described in a previous chapter), as this approach will provide adequate support for chronic occlusions in the femoral and infrapopliteal vessels. An ipsilateral antegrade access approach will also provide enough support for most lesions. In the case of a known CTO or heavily calcified lesion, a 7 Fr sheath size is usually selected to ensure appropriate penetration support.

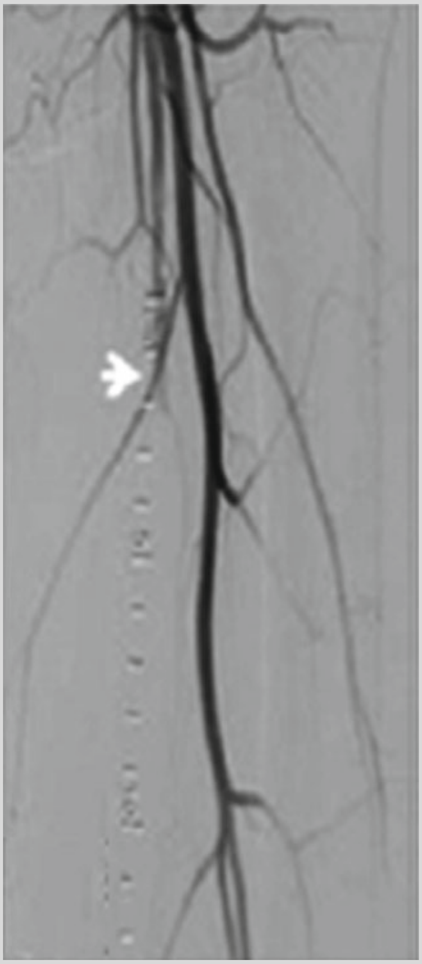

Fig. 66.1 Left SFA angiography showing a proximal CTO (*arrow*)

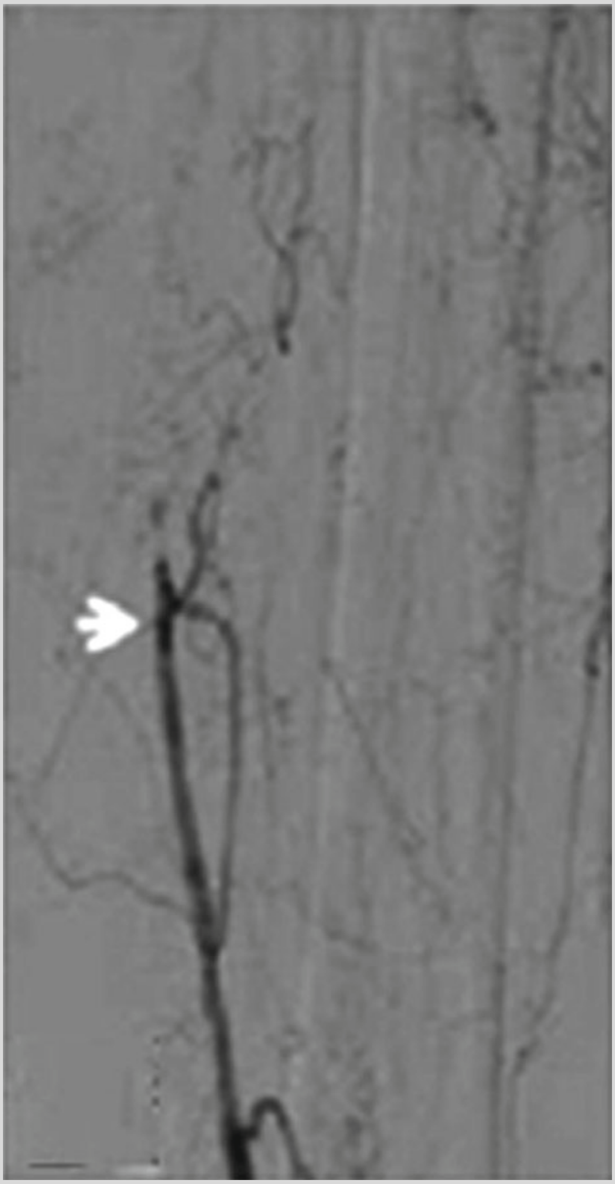

Fig. 66.2 Distal reconstitution (*arrow*)

2. Once the destination sheath has been positioned, a guidewire or crossing device can be directed into the proximal or distal superficial femoral artery using US guidance (Philips iE33 xMATRIX, Philips Medical Systems, Bothell, Washington).
3. If the anatomy is favorable, we recommend use of a Frontrunner blunt microdissection catheter loaded on a Frontrunner hydrophilic micro-guide (Cordis, Warren, NJ, USA); this device is more echodense than a guidewire and will be easier to visualize and manipulate during US monitoring (Fig. 66.3). However, catheters and guidewires of all types and size can be modified to permit US visualization. The BigBoss™ (Covidien, MA) blunt microdissection CTO crossing catheter may also be used for this purpose.

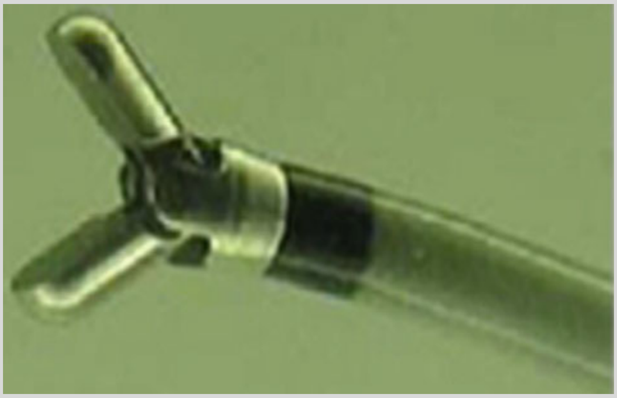

Fig. 66.3 Frontrunner blunt microdissection catheter

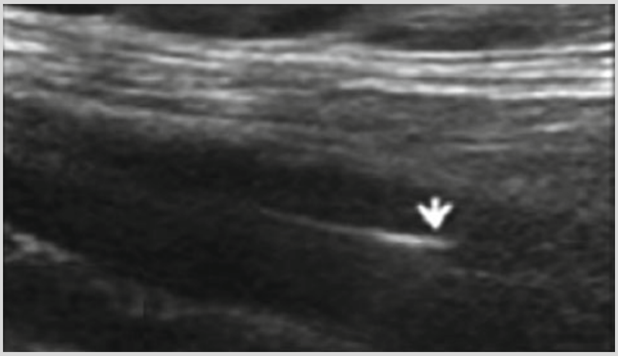

Fig. 66.4 Intraluminal position of the Frontrunner catheter manipulations with closed jaws (*arrow*)

4. Blunt microdissection of the lesion is performed by maneuvering the Frontrunner catheter under US guidance. Penetration of the proximal cap can be performed with closed jaws to advance (Fig. 66.4) and then retraction with open jaws (Fig. 66.5) to create a larger channel for the micro-guide catheter to follow through the lesion. Alternatively, some operators attempt to push the Frontrunner jaws open first so that the device will favor the center of the vessel.
5. If the anatomy is not favorable or a Frontrunner is not available, a 0.035′ hydrophilic J guidewire such as a Glide or Advantage (Terumo, Somerset, NJ, USA) can be used to form a “knuckle” supported by a 2.6 Fr 0.018′ or 4 Fr 0.035′ lumen support microcatheter such as a CXI (Cook Vascular, Vandergrift, PA, USA) (Fig. 66.6). Under US monitoring, the wire is directed toward the origin of the occlusion and away from any side or collateral branches. In this fashion, any resistance is overcome by advancing the catheter/guidewire combination as a unit, which then follows the

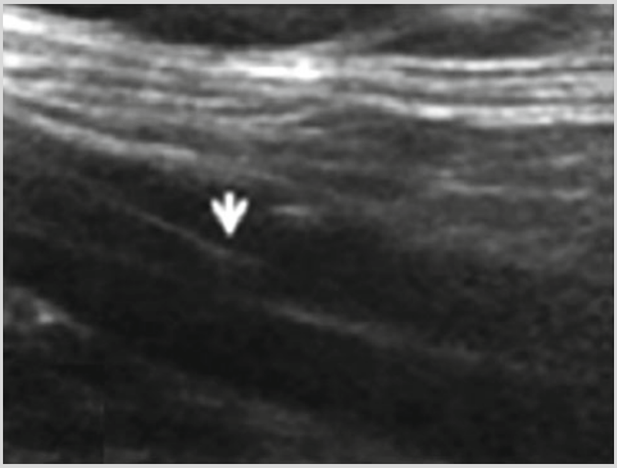

Fig. 66.5 Open jaws (*arrow*)

Fig. 66.6 Hydrophilic, metal-braided, support CXI microcatheters

path of least resistance in a controlled dissection plane.

6. Guidewire visualization with US can be more difficult at the distal SFA segment due to increased soft tissue in some patients, while the Frontrunner device is more echogenic and easier to track.
7. When the Frontrunner or guidewire crosses past the distal edge of the distal segment, reentry techniques (described in a previous chapter) can be performed and parked at the distal SFA, popliteal, or tibioperoneal trunk segments.
8. The lesion is now ready to undergo US-guided balloon angioplasty and stenting with post-dilation flow evaluation. Balloon diameter and length can easily be selected according to arterial measurements obtained by duplex US scan which provides simultaneous transverse and longitudinal axes size. Post-balloon dilation, US can be effective to assess flow, presence of large dissections, and residual lesion diameter. Hemodynamically significant defects causing diameter reductions greater than 50 % and peak systolic velocity ratios greater than 2–2.5 may be considered for stenting, especially in the presence of flow-limiting dissections, with a variety of self-expandable stents under US guidance.
9. Post-intervention US duplex examinations and ankle-brachial indices can be routinely assessed before hospital discharge.

Transcutaneous US-Guided Blunt Microdissection (the "TUG-CTO" Technique): Specific Case Description

1. The patient was brought to the angiography suite and contralateral arterial access was obtained in the right common femoral using manual palpation and US visualization.
2. We then used the "crossover" sheath insertion technique (described in a previous chapter) to place a 7 Fr 45 cm destination sheath at the left common femoral.
3. Next, we used transcutaneous US guidance in addition to intermittent fluoroscopy to engage the occluded proximal left SFA using a Frontrunner catheter loaded inside a hydrophilic micro-guide catheter to perform blunt microdissection of the as previously described (Figs. 66.7 and 66.8).
4. The Frontrunner was eventually advanced across the distal cap of the CTO lesion under constant US visualization; this technique also allowed for immediate confirmation of true lumen position by demonstration of duplex US flow (Fig. 66.9).
5. The micro-guide catheter was advanced past the distal cap over the Frontrunner catheter which was then removed. True lumen position was again confirmed by US visualization of agitated saline injected through the micro-guide catheter and fluoroscopic observation of iodinated contrast injection in the distal segment of the vessel again through the microcatheter.
6. The micro-guide catheter was replaced by a 0.018′, 260-mm-long SV5 guidewire (Cordis, Hialeah, FL, USA). Under US guidance, the guidewire served to pre-dilate the diseased segment with a 5×220-mm Savvy balloon (Cordis) and to stent with overlapping

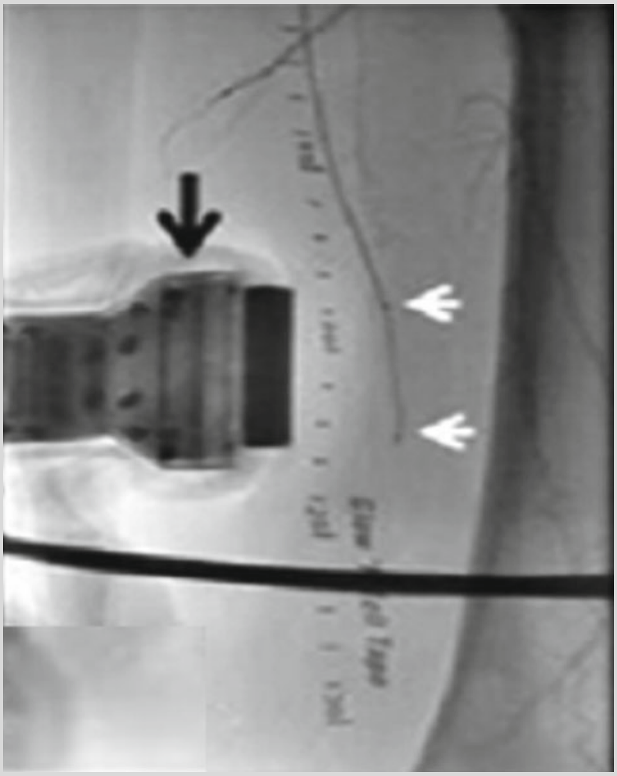

Fig. 66.7 US probe monitoring the advance of the Frontrunner (*white arrows*) across the occluded arterial segment. *Black arrow* designates the US probe placed transcutaneously on the left thigh

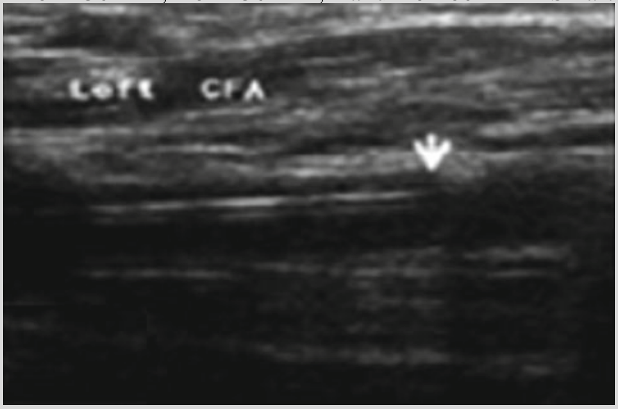

Fig. 66.8 Frontrunner catheter shaft and its engagement of the occluded left SFA lesion

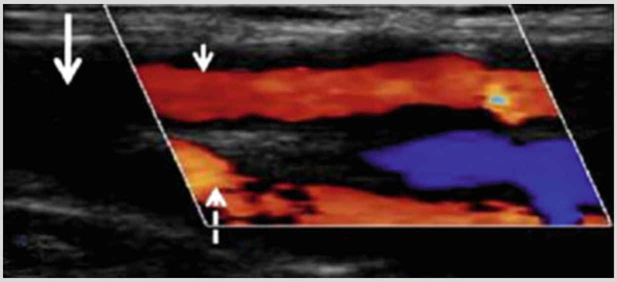

Fig. 66.9 Duplex US assessment of left SFA after successful recanalization of CTO: *Short solid arrow* indicates flow through mid-left SFA. *Long white arrow* shows left common femoral artery. *Short hatched arrow* shows left profunda artery. *Red color* is for arterial flow and *blue color* is right common femoral venous flow

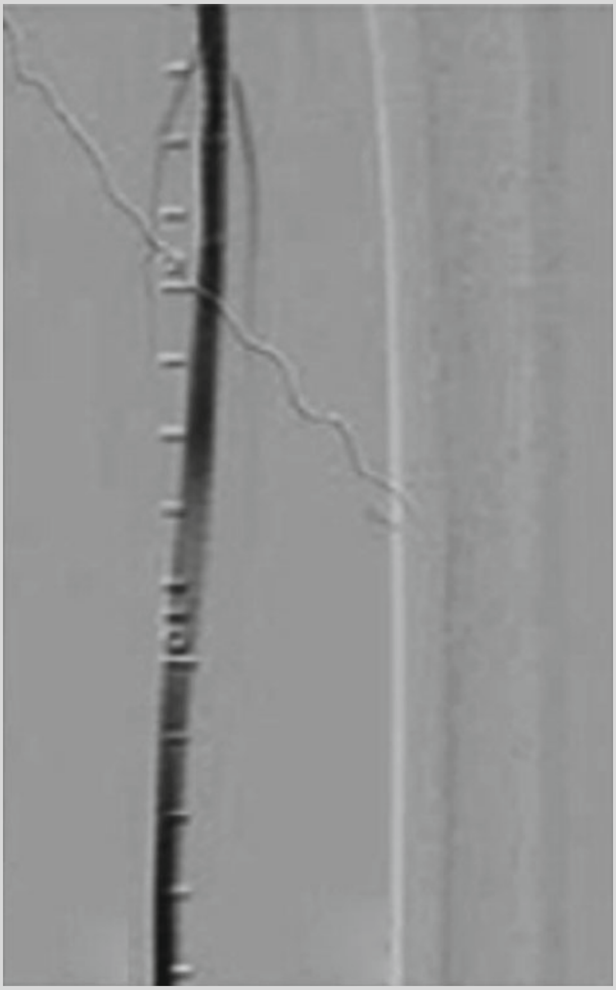

Fig. 66.10 Angiography after balloon angioplasty and self-expanding nitinol stent placement implantation shows excellent angiographic result

6×150-mm, 6×150-mm, and 6×60-mm Smart Control (Cordis) self-expanding nitinol stents which were post-dilated with the 5×220-mm Savvy balloon.

7. Final result was evaluated to be excellent by angiography (Fig. 66.10) and duplex US visualization with low duplex peak systolic velocities (Fig. 66.11). The procedure was performed with 23 min of fluoroscopy time and 80 ml of iodinated contrast.

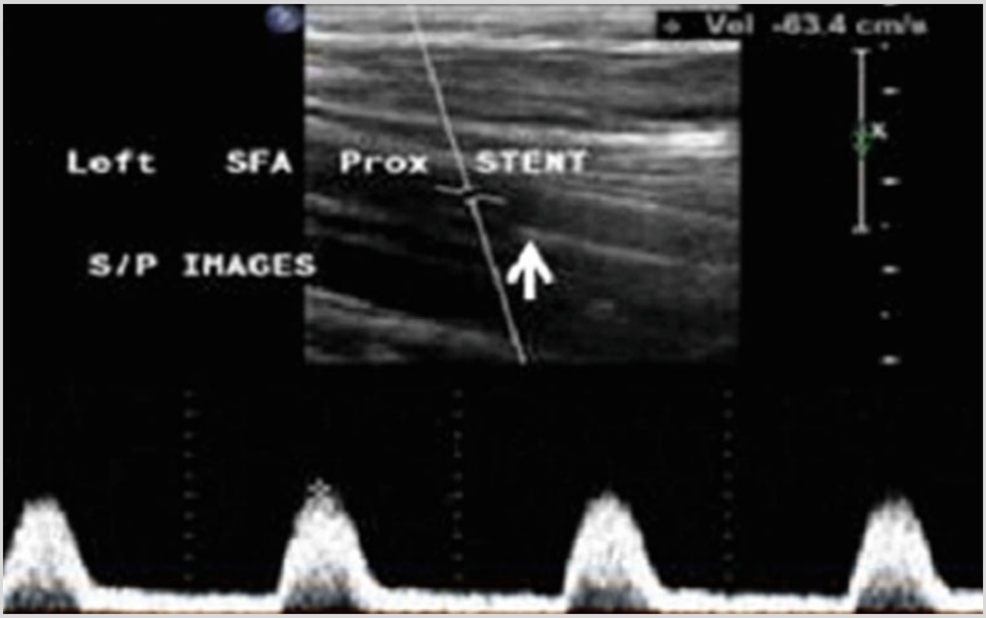

Fig. 66.11 Widely patent, well-visualized stents post-procedure, with low duplex peak systolic velocities in the proximal SFA

8. The patient was brought back 1 week after for elective intervention of the right SFA occlusion using the same TUG-CTO blunt microdissection technique. His renal function was not affected and he reported significant improvements in walking distance and ABIs post-procedure.

Discussion

As mentioned earlier, there is considerable interest in expanding the role of US when performing interventions in the infrainguinal vasculature; case reports from Mossop et al. [17] and Kawarada et al. [11] represent examples of how US monitoring can reliably assist the crossing of an SFA CTO lesion using guidewires supported by microcatheters. The largest case series reports the use of duplex US scanning to guide 253 balloon angioplasty attempts across all categories of TASC infrainguinal lesions [2]. In this study, authors utilized US guidance for vessel cannulation, guidewire monitoring, and selection of balloons and stents according to arterial measurements. Lesions with diameter reductions greater than 30 % and peak systolic velocity ratios greater than two were stented also under duplex US guidance. Their reported overall technical success was 93 % (236/253 cases); however, the success rate for TASC D lesions (CTOs of the femoral/popliteal vessels) was lower at 73 % (25/34). Overall, they concluded that US-guided angioplasty and stenting was safe and effective with some notable advantages being direct visualization of the puncture site, improved selection of balloon and stent sizes, as well as confirmation of the adequacy of the technique by hemodynamic and imaging parameters, along with decreased use of radiation exposure and contrast material.

While angioplasty TASC C or TASC D lesions are not routinely attempted as first-line therapy, these reports illustrate how US imaging can be used to improve the success rate and safety of infrainguinal endovascular interventions, particularly for CTOs in patients with significant comorbidities predisposing to contrast-induced nephropathy [12, 18]. Transcutaneous US monitoring assists complex lesion crossing by simultaneously visualizing both the intraluminal space of occluded arterial segments and the crossing device. In this way, movement of the device toward the wall can be detected and corrected before subintimal dissection occurs. The Frontrunner catheter is particularly well-suited for US guidance as it is more echo-reflective than guidewires and offers excellent directional control [17, 23]. Even if dissection occurs, adequate imaging of the vessel wall and subintimal flap usually allows for true lumen reentry.

An important caveat mentioned in these case reports is the high difficulty in crossing heavily calcified vessels with a guidewire and microcatheter, as well as the poor visualization of wires at the ostial SFA segment in obese patients and in distal SFA lesions below the adductor canal. These anatomically challenging locations are also the sites where difficult guidewire manipulation is typically encountered, which can lead in turn to straying into the subintimal space and difficult reentry attempts. It should be noted that this problem persists despite the high quality visuals provided by current generation US scanners.

Nevertheless, transcutaneous US guidance provides immediate identification of successful lesion crossing either by color Doppler US imaging (which shows blood flow beyond the distal catheter tip) or by injection of agitated saline (which serves as a type of US contrast). These strategies can practically void the need for contrast injection under fluoroscopy altogether, which is desirable not only for the reduction in dye and radiation loads but in the case of subintimal crossing attempts to avoid staining of the vessel wall in the event of an unsuccessful cross [16].

Duplex US guidance also allows for unlimited, repeated imaging of the entire treated segment and may detect residual stenoses that require additional treatment [7, 19]. US can also assess distal lower extremity flow during bent-leg maneuvers crucial to the diagnosis and treatment of stent fractures, especially in the SFA distribution. Other reported applications for US monitoring in peripheral arterial disease include prediction of outcomes such as probability of lumen reentry based on lesion characterization [13] and intraoperative/postoperative surveillance of infrainguinal bypass grafts [14].

In summary, duplex US represents a simple, safe, and widely available technology that has the potential to greatly enhance the safety and success of peripheral endovascular interventions. Its advantages over conventional angiography are more likely to be evident in the management of complex or chronically occluded infrainguinal lesions which carry higher complication rates and lower success probability.

References

1. Ascher E, Hingorani A, et al. Lower extremity revascularization without preoperative contrast arteriography: experience with duplex ultrasound arterial mapping in 485 cases. Ann Vasc Surg. 2002;16(1):108–14.
2. Ascher E, Marks NA, et al. Duplex-guided endovascular treatment for occlusive and stenotic lesions of the femoral-popliteal arterial segment: a comparative study in the first 253 cases. J Vasc Surg. 2006;44(6):1230–7; discussion 1237–1238.
3. Ascher E, Mazzariol F, et al. The use of duplex ultrasound arterial mapping as an alternative to conventional arteriography for primary and secondary infrapopliteal bypasses. Am J Surg. 1999;178(2): 162–5.
4. Banerjee S, Das TS, et al. Transcutaneous ultrasound-guided endovascular crossing of infrainguinal chronic total occlusions. Cardiovasc Revasc Med. 2010;11(2):116–9.
5. Banerjee S, Master R, et al. Intravascular ultrasound-guided true lumen re-entry for successful recanalization of chronic total occlusions. J Invasive Cardiol. 2010;22(12):608–10.
6. Bosch JL, Hunink MG. Meta-analysis of the results of percutaneous transluminal angioplasty and stent placement for aortoiliac occlusive disease. Radiology. 1997;204(1):87–96.
7. Cluley SR, Brener BJ, et al. Transcutaneous ultrasonography can be used to guide and monitor balloon angioplasty. J Vasc Surg. 1993; 17(1):23–30; discussion 30–21.
8. Cluley SR, Brener BJ, et al. Ultrasound-guided balloon angioplasty is a new technique for vascular surgeons. Am J Surg. 1991;162(2): 117–21.
9. Hirsch AT, Haskal ZJ, et al. ACC/AHA guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American associations for vascular surgery/society for vascular surgery, society for cardiovascular angiography and interventions, society for vascular medicine and biology, society of interventional radiology, and the ACC/AHA task force on practice guidelines (writing committee to develop guidelines for the management of patients with peripheral arterial disease)–summary of recommendations. J Vasc Interv Radiol. 2006;17(9):1383–97; quiz 1398.
10. Kakkos SK, Nicolaides AN, et al. Effect of zooming on texture features of ultrasonic images. Cardiovasc Ultrasound. 2006;4:8.
11. Kawarada O, Yokoi Y, et al. Chronic total occlusions in the superficial femoral artery: a novel strategy using a 1.5 mm J-tip hydrophilic guidewire with an over-the-wire balloon catheter under ultrasound guidance. Catheter Cardiovasc Interv. 2005;65(2):187–92.
12. Lautin EM, Freeman NJ, et al. Radiocontrast-associated renal dysfunction: a comparison of lower-osmolality and conventional high-osmolality contrast media. AJR Am J Roentgenol. 1991;157(1): 59–65.
13. Marks NA, Ascher E, et al. Gray-scale median of the atherosclerotic plaque can predict success of lumen re-entry during subintimal femoral-popliteal angioplasty. J Vasc Surg. 2008;47(1):109–15; discussion 115–106.
14. Marks NA, Hingorani AP, et al. Duplex guided balloon angioplasty of failing infrainguinal bypass grafts. Eur J Vasc Endovasc Surg. 2006;32(2):176–81.
15. Martin-Paredero V, Dixon SM, et al. Risk of renal failure after major angiography. Arch Surg. 1983;118(12):1417–20.
16. Met R, Van Lienden KP, et al. Subintimal angioplasty for peripheral arterial occlusive disease: a systematic review. Cardiovasc Intervent Radiol. 2008;31(4):687–97.
17. Mossop P, Cincotta M, et al. First case reports of controlled blunt microdissection for percutaneous transluminal angioplasty of chronic total occlusions in peripheral arteries. Catheter Cardiovasc Interv. 2003;59(2):255–8.
18. Parfrey PS, Griffiths SM, et al. Contrast material-induced renal failure in patients with diabetes mellitus, renal insufficiency, or both. A prospective controlled study. N Engl J Med. 1989;320(3):143–9.
19. Ramaswami G, al-Kutoubi A. Duplex controlled angioplasty. Eur J Vasc Surg. 1994;8(4):457–63.
20. Sabetai MM, Tegos TJ, et al. Reproducibility of computer-quantified carotid plaque echogenicity: can we overcome the subjectivity? Stroke. 2000;31(9):2189–96.
21. Smith FB, Lee AJ, et al. Variation in cardiovascular risk factors by angiographic site of lower limb atherosclerosis. Eur J Vasc Endovasc Surg. 1996;11(3):340–6.
22. Walsh SR, Cousins C, et al. Ionizing radiation in endovascular interventions. J Endovasc Ther. 2008;15(6):680–7.
23. Whitbourn RJ, Cincotta M, et al. Intraluminal blunt microdissection for angioplasty of coronary chronic total occlusions. Catheter Cardiovasc Interv. 2003;58(2):194–8.