Ultrasound Techniques to Enhance Our Understanding of Below-the-Knee Outcomes

Tips for using extravascular ultrasound guidance to evaluate below-the-knee disease and select the proper tools for treatment.

BY FRANCESCO LIISTRO, MD

Critical limb ischemia (CLI) is one of the most complex scenarios in vascular medicine due to the high morbidity and mortality associated with this disease, as well as the relevant socioeconomic impact.[1] Diabetes mellitus is the main cause of lower limb atherosclerotic disease, particularly in the below-the-knee (BTK) area, where the disease generally affects more than one vessel, with long and calcified occlusions responsible for CLI occurrence. Despite the advances in endovascular techniques, which have significantly increased the acute success of tibial vessel angioplasty, vessel reocclusion occurs in more than half of the treated lesions as a result of residual mechanical defects (flow-limiting dissection, plaque recoil, or acute thrombosis) or restenosis (intimal proliferation with positive or negative vessel remodeling).[2,3] Due to the anatomic aspects of BTK atherosclerotic disease (long calcified occlusions), implantation of drug-eluting stents in a "full metal jacket" fashion is not advised. The use of stents is limited to < 5% of cases with proximal short tibial occlusions.[4] Thus, the aim of every interventionist performing BTK revascularization is to achieve an optimal balloon angioplasty result, which is mainly defined by digital subtraction angiography as a residual stenosis < 30% as measured by quantitative vascular angiography without flow-limiting dissection.

However, several factors may lessen the value of this definition. The presence of calcification and the extent of the atherosclerotic disease alter the accuracy of quantitative vascular angiography to detect the minimal luminal diameter and reference vessel diameter (RVD). The diagnostic accuracy is even lower in cases of residual dissection, which is very common in BTK angioplasty and often a product of the initial interventional strategy (subintimal recanalization), the evaluation of which is mainly done by visual examination without proven efficacy.

USE OF EVUS TO GUIDE BTK THERAPY

As reported in coronary settings, anatomic and functional assessment by intravascular ultrasound (IVUS) and fractional flow reserve may improve the immediate and long-term results of balloon angioplasty and stent implantation.[5-7] Although IVUS and fractional flow reserve could also be used during BTK angioplasty, extravascular ultrasound (EVUS) may provide similar advantages at a lower cost while offering the possibility of continuous vessel patency monitoring during follow-up.[8] EVUS guidance during BTK procedures ensures correct sizing of the balloon for dilatation according to the real RVD (measured from media to media) (Figure 1). On the other hand, the lumen size detected by angiography usually tends to cause undersizing of the balloon diameter,[9] particularly in BTK vessels, which often have a large burden of atherosclerosis (Figure 2).[10]

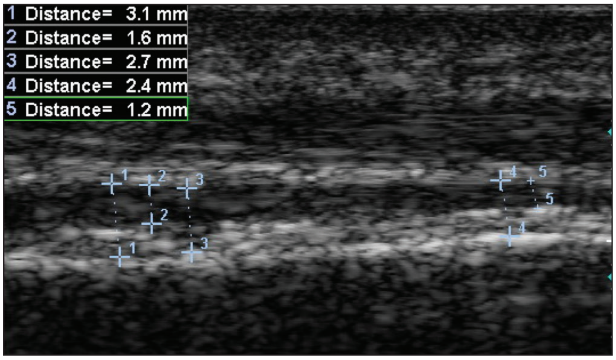

Figure 1. RVD measured by EVUS from media to media (distance measurements 1, 3, and 4) in the proximal segment of an anterior tibial artery. The luminal diameter (distance measurements 2 and 5) is significantly smaller than the RVD due to the large burden of atherosclerosis.

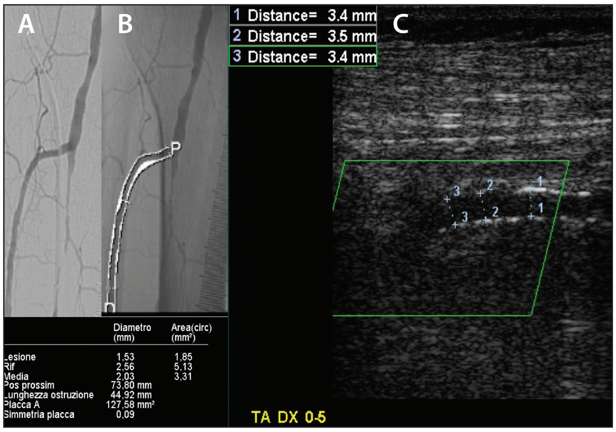

Figure 2. The proximal segment of a right anterior tibial artery (A) with analysis of quantitative vascular angiography (B). EVUS evaluation of RVD (C) measured from media to media. The RVD detected by angiography is notably smaller than that reported by EVUS.

The difference between luminal diameter and vessel diameter is particularly important when using drug-coated balloons (DCBs), as their goal is to deliver an antiproliferative drug directly into the vessel wall. To ensure correct drug delivery, the operator must be sure that the balloon touches and presses the vessel wall, and only EVUS guidance can reduce the risk of balloon undersizing. As previously mentioned, optimal balloon angioplasty is the main goal of BTK intervention, with or without the use of drug-eluting therapy. Thus, EVUS may reveal significant residual stenosis (peak systolic velocity ratio [PSVR] > 2.4) where angiography does not (Figure 3). Ending a procedure after achieving a suboptimal tibial angioplasty result, with or without additional DCB use, is associated with a higher risk of reocclusion at the site of the residual stenosis (Figure 3).

TIPS FOR OPTIMAL EVUS USE

The correlation between residual stenosis and restenosis with the use of DCBs was reported in a recent article by Siablis et al,[11] which showed that even though DCBs achieved a lower rate of late lumen loss compared to drug-eluting stents, the restenosis rate was higher due to the higher residual stenosis left at the end of the procedure. In order to properly address significant residual narrowing in tibial vessels, EVUS should prompt the use of a larger balloon diameter or the use of dedicated materials such as debulking devices or stents in those cases where simple balloon angioplasty failed to achieve an optimal result (Figure 4). The possibility of increasing one's accuracy when defining optimal balloon angioplasty as evaluated

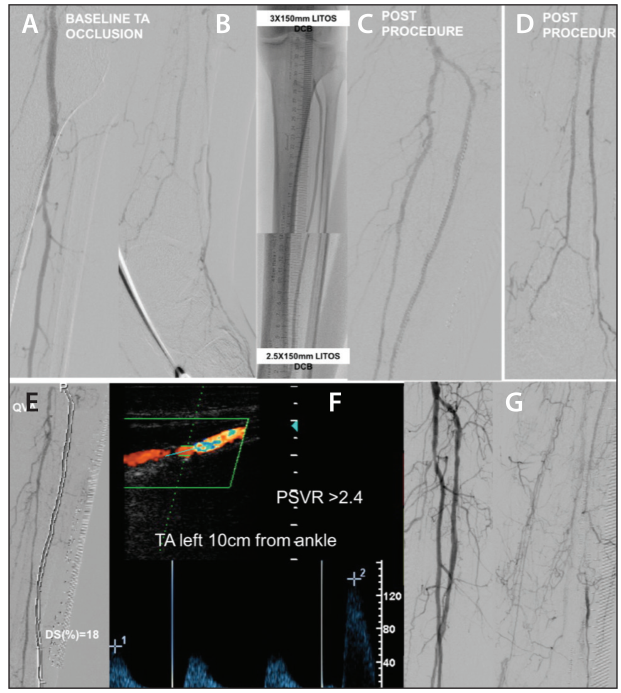

Figure 3. Long blunt occlusion of the left anterior tibial artery with reperfusion 10 cm from the ankle (A, B). Dilatation with a 3- X 150-mm DCB from the ostium to the mid-segment of the artery and with a 2.5- X 150-mm DCB from the mid-segment to the ankle (C). Final angiographic result showing vessel patency with a nonsignificant residual stenosis on quantitative vascular angiography (C–E). Duplex evaluation of the final result showing a significant increase in flow velocity 10 cm from ankle (F). Four-month angiogram showing good vessel patency in the proximal and mid-segment but vessel reocclusion at the point of residual distal stenosis on the previous angiogram (G).

by EVUS is extremely important and could be utilized in randomized trials evaluating new devices for tibial interventions. In fact, only with concomitant anatomic and functional assessment of the final result can we truly compare "apples to apples" and limit the impact of residual mechanical defects on the study outcome, which could translate into device failure.

EVUS should be performed in the entire treated vessel, recording the color flow and a sample of flow velocity every 5 cm. Due to the high rate of obesity among diabetic foot patients, a 15-MHz transducer may be helpful to fully detect the vessel wall, particularly the tibioperoneal trunk and the peroneal arteries, which have a deeper course in the leg. It is very important to detect the pattern of flow velocity in the third segment of the popliteal artery before scanning the tibials. The presence of monophasic and dampened flow in the popliteal may limit the accuracy of

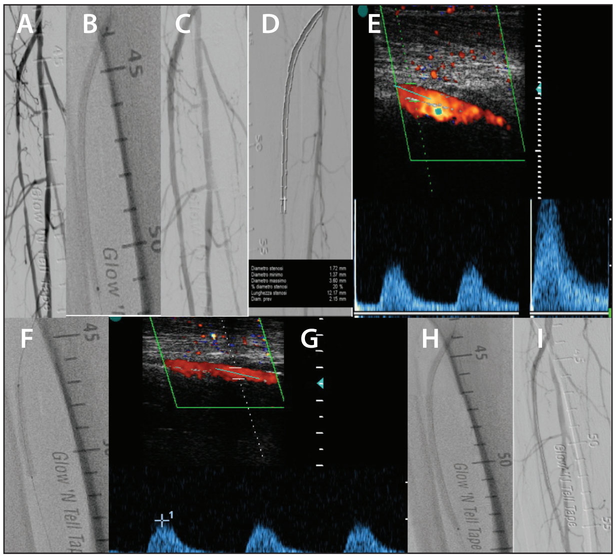

Figure 4. Ultrasound guidance of tibial angioplasty. Long tandem stenosis in the proximal anterior tibial artery segment (A) treated with a 3- X 80-mm balloon (B) with a good angiographic result (C, D) but a significant residual gradient on duplex evaluation (E), which disappeared after use of a 3- X 40-mm noncompliant balloon inflated to 22 atm (F, G). Final dilatation with a 3- X 80-mm DCB with an optimal result (H, I).

EVUS in detecting significant residual stenosis in the tibial arteries. Moreover, with sequential stenosis, the impact of the last stenosis on flow velocity is lower and may be underestimated.[12] At my center, we consider a PSVR > 2.4 the diagnostic criteria for significant stenosis. In residual dissection, measurement of PSVR along the entire dissected segment is crucial.

APPLYING FINDINGS FROM EVUS

The absence of significant flow acceleration may define a non–flow-limiting dissection, whereas an increase in PSVR suggests a flow-limiting dissection (Figure 5) that requires further intervention (long balloon inflations or bailout stenting) before we consider the procedure finished. A pattern of triphasic flow at the level of the ankle is the optimal functional result to aim for in tibial interventions, but it is very rare to achieve this outcome due to the high burden of atherosclerotic disease in diabetic patients with foot ulcers who often show a concomitant inflow (superficial femoral/popliteal artery segments) and outflow (pedal circulation) disease with relevant vessel calcification. However, the demonstration of a stable and unchanging flow pattern along the treated tibial without a significant increase in PSVR due to residual significant angiographic stenosis is, in the author's opinion, suggestive of an optimal result.

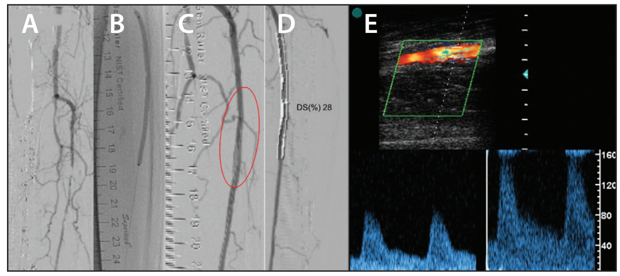

Figure 5. A short anterior tibial artery occlusion treated with a 2.5- X 80-mm balloon (A, B) with a residual dissection (C). A quantitative vascular angiogram of the dissected segment showed a nonsignificant residual narrowing (D). However, duplex evaluation showed a significant gradient among the dissected segment typical of a flow-limiting dissection (E).

CONCLUSION

EVUS guidance in BTK interventions is important to assess the real RVD and, consequently, balloon sizing, to detect flow-limiting dissection, as well as guide device escalation until an optimal result is achieved. ■

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