

Determining Cost-Effectiveness in CLI Therapy

Weighing clinical benefits along with cost when selecting therapies is more important than ever.

BY FIRAS F. MUSSA, MD, MS

Each year, critical limb ischemia (CLI) develops in 500 to 1,000 patients in a Western population of 1 million people. The disease is associated with 5-year mortality rates of $\geq 50\%$ ^{1,2} and an estimated cost of 2.7 billion dollars in 2007.³ Meanwhile, the rapid proliferation of new technologies has left the vascular specialist with an array of potential therapies to treat peripheral arterial disease (PAD), often without rigorous outcome data or cost-effectiveness information to guide responsible treatment decisions.

Endovascular therapy appears to be the least costly in the short term; however, the long-term clinical and economic consequences of these procedures remain unclear.⁴ The current cost-effectiveness data are relatively coarse and tend to lack anatomic information, functional status, and patient-centric outcomes. These issues have gained special relevance since the Patient Protection and Affordable Care Act was signed into law in 2010 in concert with the implementation of other initiatives to bend the curve of rising health care costs. In this context, comparative effectiveness research has received increased attention. The United States Congress has appropriated \$1 billion to support this national initiative and asked the Institute of Medicine to identify priority topics. Lower extremity PAD was identified as one of these priorities.

This report describes the cost-effectiveness of various contemporary CLI management strategies with emphasis on the endovascular-first versus bypass approaches.

COST-EFFECTIVENESS ANALYSIS FOR CLI

Those treating patients with CLI face an unprecedented challenge of providing excellent care with fewer resources. Although the term has been misused in lay and published literature, cost-effective vascular care is defined as care that maintains or further improves patient-centered outcomes,

measured in quality-adjusted life years (QALYs), while minimizing costs (Figure 1).²

Although endovascular procedures appear less costly in the short term, long-term comparison of cost and patient-centered outcomes between catheter-based procedures and open revascularization remains uncertain.⁵ We recently presented that both endovascular-first and bypass-first strategies provide equivalent long-term limb salvage rates in highly selected patients with CLI.⁶ No quality-of-life questionnaires were performed, however, and we did not quantify health utility scores.

In 2011, the Committee on Comparative Effectiveness of the Society for Vascular Surgery published a systematic review of lower extremity arterial revascularization economic analyses.⁷ Only low-quality evidence provided economic data about the relative merits of endovascular and open surgical approaches to the treatment of PAD patients. Barshes et al demonstrated that with an incremental cost-effectiveness ratio (ICER) of \$47,735/QALY, an initial surgical bypass with subsequent endovascular revision(s) as needed was the most cost-effective alternative to local wound care alone (Figure 2).⁵ Endovascular-first management strategies achieved comparable clinical outcomes but at a higher cost (ICER > \$101,702/QALY); however, endovascular management was cost-effective when the initial foot wound closure rate was > 37% or when procedural costs were decreased by > 42%. Primary amputation had less effectiveness and was more costly than wound care alone.⁴

STUDY DESIGNS FOR COST-EFFECTIVENESS ANALYSIS

Three main types of studies have been used to compare treatments and costs: model-based studies, cost-analyses studies, and cost-consequence studies (Table 1).

Model-Based Studies

Model-based studies utilize pooled retrospective data and implement the most robust approaches to sensitivity analyses. They also use long time horizons (5–10 years) and QALY as outcome. No dominant or dominated treatment strategy was found in the pooled studies.⁴ Furthermore, two of the three studies found that the optimal strategy in the ICER was sensitive to indication.^{7,8} In these studies, catheter-based therapy was more cost-effective and provided greater net health benefits in patients with claudication, whereas initial bypass was most cost-effective and provided the greatest limb salvage benefits in patients with CLI. The inconsistency underscores the importance of patient characteristics, lesion anatomy, and degree of ischemia, procedural technique, and perioperative care.

Cost-Analyses Studies

These studies only focus on economic outcomes. In the SVS document, two of the four cost-analysis studies compared endovascular techniques with open surgery, whereas

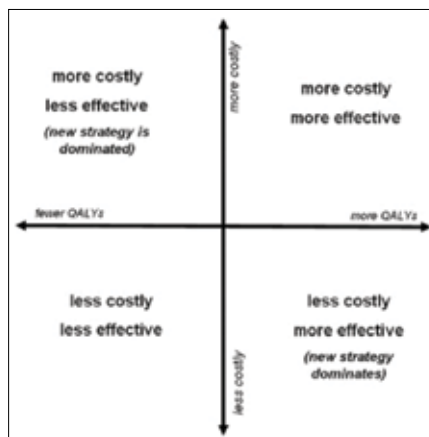


Figure 1. A two-dimensional plane demonstrating the relationship of incremental costs and incremental effectiveness for a reference and a comparator. Reprinted from the *Journal of Vascular Surgery*, Vol. 55, Issue 6, Barshes NR, Chambers JD, Cantor SB, Cohen J, Belkin M, A primer on cost-effectiveness analyses for vascular surgeons, Pages 1794–1800, Copyright 2012, with permission from Elsevier.

the other two included amputation as a third comparator.^{9–13} The main outcome of the cost analyses was consistent across all studies and showed that the endovascular approach was the least costly in the short-term.

Cost-Consequence Studies

Studies conducting a cost-consequence analysis were heterogeneous in their measurement of costs and outcomes. For clinical outcomes, three studies favored surgery, and seven favored endovascular revascularization; two other studies did not report outcomes separately for the two procedures.^{14–25} Using patient-level direct data, all studies found the endovascular approach the least costly.

DISCUSSION

Endovascular therapy appears to be the least costly option in the short

term; however, the long-term clinical and economic consequences remain unclear. The current cost-effectiveness data lacks detailed patient information, anatomic information, functional status, and patient-centered outcomes.

TABLE 1. SUMMARY OF ANALYSIS TYPES, WITH PROS AND CONS

Analysis type	Description	Pros	Cons
Model based	An analytic representation of the problem at hand that uses previously reported data as model inputs	<ul style="list-style-type: none"> Analytic flexibility Less costly/time-consuming than clinical trials All available information can be synthesized together All uncertainty in model inputs can be taken into account simultaneously 	—
Econometric cost analysis	An appraisal that uses quantitative and statistical methods to analyze economic outcomes only and not clinical outcomes together	<ul style="list-style-type: none"> Simple to perform Easily understandable 	<ul style="list-style-type: none"> Does not allow for a complete picture needed for informed decision making
Cost consequences	An appraisal that reports both economic and at least one clinical outcome together	<ul style="list-style-type: none"> Reporting both economic and clinical outcomes allows for the ability to represent potential trade-offs of changing from standard of care to a new approach 	<ul style="list-style-type: none"> Tradeoffs may be abstract and difficult to judge “a good trade”

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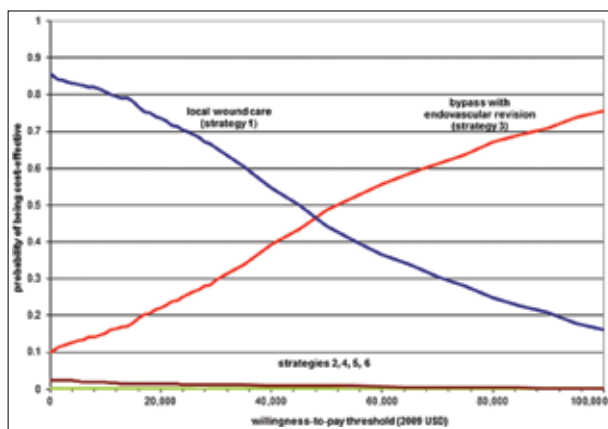


Figure 2. Cost-effectiveness acceptability curves for CLI management strategies compared to local wound care. Surgical bypass with endovascular revision (strategy 4) has a higher probability of being a cost-effective alternative as the willingness-to-pay threshold surpasses \$39,255 per QALY. Reprinted from the *Journal of Vascular Surgery*, Vol. 56, Barshes NR, Chambers JD, Cohen J, Belkin M, Model To Optimize Healthcare Value in Ischemic Extremities 1 (MOVIE) Study Collaborators, Cost-effectiveness in the contemporary management of critical limb ischemia with tissue loss, Pages 1015–1024, Copyright 2012, with permission from Elsevier.

Studies evaluating patients with intermittent claudication should consider medical and exercise therapy in comparison to endovascular interventions or bypass surgery. Studies evaluating patients with CLI need to consider primary amputation as an option. These studies should focus on health-related quality of life and functional capacity (ie, walking distance) in patients with intermittent claudication; and limb salvage, death, and freedom from major adverse limb events in CLI,²⁵ as well as periprocedural events that patients value avoiding (eg severe bleeding, limb loss, cardiovascular events, and death). Furthermore, similar time horizons for both cost and clinical outcomes need to be studied. At present, all studies on cost-effectiveness analysis and CLI differ in providing these data, making systematic reviews of economic analyses problematic.²⁶

Another important consideration in reviewing cost-effectiveness analysis literature is whether sensitivity analysis was performed. Specifically, research performing sensitivity analyses with varying time horizons could help identify interactions between cost-effectiveness and time. This will allow review of treatment by patient and, subsequently, anatomic characteristics could be tailored more appropriately.

CONCLUSIONS

Vascular clinicians should weigh clinical benefits and costs in choosing management strategies, because provid-

ing cost-effective care is in the interest of patients, payers, and health care providers. Future research should focus on patient-centered outcomes, overall quality of life, functional ambulatory measures in claudication, and major adverse limb event-free survival in CLI. The current state of literature mandates that cost and durability be accounted for as new technologies are assessed. ■

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- Ramsey SD, et al. Incidence, outcomes, and cost of foot ulcers in patients with diabetes. *Diabetes Care*. 1999;22:382–387.
- Singh N, Armstrong DG, Lipsky BA. Preventing foot ulcers in patients with diabetes. *JAMA*. 2005;293:217–228.
- Rogers LC, Lavery LA, Armstrong DG. The right to bear legs—an amendment to healthcare: how preventing amputations can save billions for the US Health-care System. *J Am Podiatr Med Assoc*. 2008;98:166–168.
- Moriarty JP, Murad MH, Shah ND, et al. Society for Vascular Surgery Committee on Comparative Effectiveness. A systematic review of lower extremity arterial revascularization economic analyses. *J Vasc Surg*. 2011;54:1131–1144.
- Barshes NR, Chambers JD, Cohen J, Belkin M. Model To Optimize Healthcare Value in Ischemic Extremities 1 (MOVIE) Study Collaborators. Cost-effectiveness in the contemporary management of critical limb ischemia with tissue loss. *J Vasc Surg*. 2012;56:1015–1024.
- Moridzadeh R, Kaszubski PA, Rockman CB, et al. Subsequent open surgical revascularization following an initial endovascular approach for critical limb ischemia. Presented at: Annual Meeting of Eastern Vascular Society; September 12–15, 2012; Pittsburgh, PA.
- Hunink MG, Wong JB, Donaldson MC, et al. Revascularization for femoropopliteal disease: a decision and cost-effectiveness analysis. *JAMA*. 1995;274:165–171.
- Muradin GS, Hunink MG. Cost and patency rate targets for the development of endovascular devices to treat femoropopliteal arterial disease. *Radiology*. 2001;218:464–469.
- Eneroth M, Apelqvist J, Troeng T, Persson BM. Operations, total hospital stay and costs of critical leg ischemia. A population-based longitudinal outcome study of 321 patients. [see comment]. *Acta Orthop Scand*. 1996;67:459–465.
- Jansen R, de Vries S, Cullen K, et al. Cost-identification analysis of revascularization procedures on patients with peripheral arterial occlusive disease. *J Vasc Sur*. 1998;28:617–623.
- Myhre H. Socioeconomic costs of limb-threatening critical ischaemia. *Crit Ischaemia*. 1998;8:49–55.
- van Dijk LC, Seerden R, van Urk H, Wittens CH. Comparison of cost affecting parameters and costs of the “closed” and “open” in situ bypass technique. *Eur J Vasc Endovasc Surg*. 1997;13:460–463.
- Moher D, Liberati A, Tetzlaff J, Altman D, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6:e1000097.
- Adam DJ, Beard JD, Cleveland T, et al. Bypass versus angioplasty in severe ischaemia of the leg (BASIL): multicentre, randomised controlled trial. [see comment]. *Lancet*. 2005;366:1925–1934.
- Ballard J, Bergan J, Singh P, et al. Aortic stent deployment versus surgical reconstruction: analysis of outcome and cost. *J Vasc Surg*. 1998;28:94–103.
- Hunink MG, Cullen KA, Donaldson MC. Hospital costs of revascularization procedures for femoropopliteal arterial disease. *J Vasc Surg*. 1994;19:632–641.
- Janne d’Othée B, Morris MF, Powell RJ, Bettmann MAF. Cost determinants of percutaneous and surgical interventions for treatment of intermittent claudication from the perspective of the hospital. *Cardio-vasc Intervent Radiol*. 2008;31:56–65.
- Jeans WD, Danton RM, Baird RN, Horrocks M. A comparison of the costs of vascular surgery and balloon dilatation in lower limb ischaemic disease. *Br J Radiol*. 1986;59:453–456.
- Laurila J, Brommels M, Standertskjöld-Nordenstam CG, et al. Cost-effectiveness of percutaneous transluminal angioplasty (PTA) versus vascular surgery in limb-threatening ischaemia. *Int J Angiol*. 2000;9:214–219.
- Mertens R, Blampain JP, Boly J, et al. Practice variability in the management of subrenal arterial stenoses in seven Belgian hospitals. *Acta Chir Belg*. 2005;105:148–155.
- Singh S, Evans L, Datta D, et al. The costs of managing lower limb-threatening ischaemia. *Eur J Vasc Endovasc Surg*. 1996;12:359–362.
- Stoner MC, Defreitas DJ, Manwaring MM, et al. Cost per day of patency: understanding the impact of patency and reintervention in a sustainable model of healthcare. *J Vasc Sur*. 2008;48:1489–1496.
- Werneck CC, Lindsay TF. Tibial angioplasty for limb salvage in high-risk patients and cost analysis. *Ann Vasc Surg*. 2009;23:554–559.
- Whitling PJ, Gibson M, Torrie EP, et al. Iliac occlusions: stenting or crossover grafting? An examination of patency and cost. *Eur J Vasc Endovasc Surg*. 2000;20:36–40.
- Conte MS, Geraghty PJ, Bradbury AW, et al. Suggested objective performance goals and clinical trial design for evaluating catheter-based treatment of critical limb ischemia. *J Vasc Surg*. 2009;50:1462–73e1–3.
- Pignone M, Saha S, Hoerger T, Mandelblatt J. Cost-effectiveness analyses of colorectal cancer screening: a systematic review for the U.S. Preventive Services Task Force. *Ann Intern Med*. 2002;137:96–104.

COMMENTARY ON COST-EFFECTIVENESS EVALUATION

BY MARY L. YOST, MBA

One of the most striking aspects of Dr. Mussa's review of the research on cost-effectiveness analysis (CEA) of peripheral artery disease (PAD) treatments is that there is so little published research. Furthermore, the published economic literature has been deemed "inadequate for drawing cost-efficacy conclusions."¹

Although numerous studies have evaluated the costs of different management strategies for coronary artery disease and heart failure, this topic is rarely addressed for PAD.²⁻⁴ Yet, there is a significant and growing need for economic and cost data to compare treatments and evaluate new technologies and outcomes in patients with PAD.

INCREASING DEMAND FOR PAD AND CLI THERAPIES

As baby boomers enter the Medicare system, demand for health care will grow.² Not only is the US patient population aging, but the prevalence of PAD and critical limb ischemia (CLI) is expected to increase.^{2,5,6} This reflects the growing percentage of senior citizens in combination with a greater prevalence of diabetes, particularly in those aged 65 and older.^{2,5} PAD afflicts 30% to 40% of diabetic patients aged ≥ 50 years versus 10% to 20% of those with normal glucose.⁷⁻¹⁴

At \$8,680 per capita, US health care spending is the highest in the world; health care currently accounts for 17.9% of the total gross domestic product (GDP).^{15,16} Over the last 40 years, the 6.7% annual rate of increased federal spending on health care far exceeded the 2.7% growth in GDP.¹⁷ This excess growth is considered unsustainable.^{18,19}

Medicare is the single fastest-growing entitlement program. By 2050, combined Medicare and Medicaid expenditures are projected to reach 13% of the GDP, more than double the current 5.5%.²⁰ Entitlement spending is the main cause of the increasing federal deficit.²⁰ As the federal budget deficit expands, health care resources will become even more constrained.^{17,20}

PAD is expensive to treat, costing as much or even more than coronary artery disease and heart attack.²¹⁻²⁴ In 2010, the annual economic cost of PAD was \$164 to \$290 billion,* with the majority (62%–87%) of these expenditures occurring in the hospital.^{21,24,25} In contrast, hospital costs are only 31% of total US expenditures.²⁶

Treatment costs rise with disease severity. Patients with CLI who are undergoing amputation incur the highest annual costs; asymptomatic patients incur the lowest. It should be noted that costs for asymptomatic patients are similar to those with intermittent claudication.²⁷ Medicare and Medicaid pay approximately 75% of the PAD treatment bill.²⁴

From 2001 to 2005, between 7% to 10% of Medicare patients were treated for PAD.^{22,28} Average per-patient expenditures were \$25,400 to \$62,700* (the higher figure includes long-term care costs).^{22,24,28} At \$63,000, spending on PAD is over six times higher than the \$9,800 spent on the average Medicare beneficiary.²⁴ Notably, above-the-knee amputation is the third most commonly performed procedure, after bypass surgery and endovascular revascularization in patients with PAD.²⁸

COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis (CEA) can be employed to assist in medical decision making and in the allocation of scarce resources.^{4,29} For example, in the treatment of CLI, CEA can be used to decide which of the interventional therapies (endovascular, surgical bypass or primary amputation) are "best" or offer the most value to society. However, the definition of *best* or *optimal therapy* is more of a sociopolitical decision than a medical or scientific one.²⁹

The concept behind CEA is that society is willing to pay up to a specific dollar amount to gain one quality-adjusted life year (QALY) for its citizens. However, there is no scientific justification for any specific dollar amount.²⁹ In the United States, the general convention has been to use a range of \$50,000 to \$120,000 per QALY, with \$50,000 as one of the most frequently employed thresholds.^{3,4,30} In contrast, the United Kingdom's National Institute for Health and Care Excellence (NICE) has set the maximum that society is willing to pay for a new technology at £20,000 or about \$33,000 per QALY gained.⁴

Unless the populace votes on a specific dollar amount, this decision is made by health care policymakers and/or third-party payers such as Medicare and private insurers. In a 2009 commentary on the limits of CEA, Drs. Weintraub and Cohen argued that if \$50,000 is the threshold, it should be a general guideline for understanding value rather than an absolute willingness-to-pay barrier.²⁹

CEA is a model-based tool with limitations.⁴ The conclusions or outputs are only as valid as the inputs or assumptions made.²⁹ For example, in treating CLI with tissue loss, assumptions are made regarding the rate of perioperative mortality, or the frequency and type of revision procedures required after endovascular revascularization.^{2,30} As Dr. Mussa points out, the rate of wound closure and procedure costs are key variables affecting the cost-effectiveness of endovascular treatment versus bypass.

The time frame of the analysis also affects the outcome.⁴ A therapy with higher initial procedure costs might be more cost-effective in the long term if it confers a survival benefit, or if it is associated with fewer revascularizations. In a recent *Circulation* editorial on the FREEDOM trial (Future Revascularization Evaluation in Patients with Diabetes

In an era of increasing scarcity of health care resources, and Medicare and Medicaid footing 75% of the PAD bill, the lack of cost data is problematic.

Mellitus: Optimal Management of Multivessel Disease), Dr. Hlatky argued that clinical effectiveness is the key to cost-effectiveness.³ Clinical effectiveness varies depending on the characteristics of the patient treated, especially the indication for the treatment. A 2012 analysis by Barshes and colleagues focused on CLI patients with tissue loss, Rutherford class V, and found that surgical bypass was more cost-effective than endovascular treatment.³⁰ However, in other PAD patients, such as those with intermittent claudication or CLI patients with rest pain, the outcomes might be different.

Another key variable affecting CEA outcomes is the costs included in the model or payer perspective.³⁰ The Barshes analysis also employed a third-party payer perspective (such as Medicare Part A), which calculated endovascular therapy as less costly than bypass. This simulation included only inpatient, interim rehabilitation care, and prosthesis purchase and maintenance costs. In contrast, the initial analysis based on society's perspective—which also included nursing home care and wound care costs—found that surgical bypass was more cost-effective than endovascular intervention.³⁰

PAD CEA should be based on US costs only.² Because of differences in clinical practice, reimbursement systems, and prices and costs of products and services, cost data from other countries are not suitable for comparing the costs of treatment strategies in the United States.^{2,31}

HOW MUCH DO INTERVENTIONAL PAD AND CLI THERAPIES COST?

In quantifying the economic burden of PAD, there are a number of important questions that CEA cannot answer: How much do current PAD and CLI interventional therapies actually cost the hospital? What is the total macroeconomic cost? How much is society willing to pay to treat lower limb atherosclerotic disease?

Primary amputation as a treatment for CLI exemplifies this lack of cost data. In Medicare patients with CLI, primary amputation is frequently the first and only therapy provided. Between 25% and 33% of Medicare patients undergo primary amputation.^{32,33} Sixty percent or more of these amputations occur with no previous attempt at revascularization, and 46% to 73% do not have a diagnostic angiogram.^{32,34,35}

How much do these amputations cost the hospital? Costs, not hospital charges, are the variable of interest. Charges, the amount billed to the patient or payer, are poorly correlated with actual resources consumed.⁴ Total costs include not just the initial procedure cost but also the cost of perioperative morbidity, mortality, and in-hospital revisions.³⁶⁻⁴³ However, other than our consulting research and one recent case report authored by Jindeel and Narahara, which examined amputation costs at Harbor-UCLA Medical Center, hospital cost data are lacking.⁴⁴

How much does primary amputation for CLI cost society? The 2005 Dillingham article is the only recent US research that we could locate that contains data suitable for estimating the macroeconomic cost of CLI amputations. Dillingham estimated that in 1996, amputation cost Medicare \$4.3 billion.⁴⁵ Since 1996, major amputations have declined, but medical care costs, especially inpatient hospital costs, have increased considerably.⁴⁶⁻⁴⁹ Inflating the Dillingham per-patient cost data to 2010 dollars, we calculated that the annual costs of major amputation exceed \$10 billion.^{*50}

WITHOUT COST DATA, REIMBURSEMENT MAY BE DENIED

In an era of increasing scarcity of health care resources, and Medicare and Medicaid footing 75% of the PAD bill, the lack of cost data is problematic. Treatment will be denied as “not cost-effective” or because of “insufficient evidence.” Denial of treatment (rationing) will take the form of Medicare not reimbursing a procedure or a new technology.⁶ The recent US Preventative Services Task Force (USPSTF) draft statement on screening with ankle-brachial index is a case in point. The USPSTF continues to recommend against screening because “the evidence is insufficient.”⁵¹

If clinicians who treat PAD and CLI patients do not develop the data, then governmental agencies, health care policy makers, or third-party payers will.⁴ The outcomes of CEA depend on assumptions and inputs, and treating physicians are the most capable of providing accurate and current data.

**All reported costs have been inflated to 2010 dollars.*

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1. Moriarty JP, Murad MH, Shah ND, et al. A systematic review of lower extremity arterial revascularization economic analyses. *J Vasc Surg*. 2011;54:1131-1144.

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What are your tips and tricks for crossing long CTOs that start in the SFA and reconstitute in the distal tibial arteries in patients with ischemic ulcers?



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Most cases of long occlusions of the superficial femoral artery (SFA) can be recanalized using either an intraluminal crossing technique or the subintimal technique. Actually, most cases end up using partial intraluminal and partial subintimal passages. The problem with all of these kinds of lesions is re-entering the true lumen at a point where the artery is patent again and not to extend the dissection too far distally. Typically, re-entry devices are used to make a controlled re-entry at a pre-established level. Due to the bulky nature of the re-entry devices, they cannot be used in the smaller tibial vessels.

To achieve re-entry in the tibial vessels, I typically downsize a Glidewire device (Terumo Interventional Systems, Inc., Somerset, NJ) from 0.035 to 0.032 inch because the lesser stiffness of the guidewire tip will allow for formation of a loop with a smaller radius, which provides easier re-entry. When re-entry is needed very distally, I choose an even smaller guidewire size (0.014 or 0.018 inch) with a Glidewire-like tip. In those cases, I will support the guidewire with a support catheter (QuickCross, Spectranetics Corporation, Colorado Springs, CO; CXI, Cook Medical, Bloomington, IN; or similar).

When these measures fail, I resort to retrograde recanalization from a distal access site. In those cases, proximal re-entry is usually not an issue, and after proximal wire pick-up, the procedure can be completed from above. In cases

when it is not possible to create a connection between the antegrade and retrograde channel, balloon dilatation at the level where the guidewires meet may crack the intima, thus establishing a connection between the two lumina.



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Diabetic patients with ischemic foot ulcers (Rutherford class 5–6; University of Texas Wound Classifications 2C, 3C, 2D, and 3D) could often (27%) present with multilevel disease involving SFA, popliteal tract, and below-the-knee (BTK) vessels. Treating a long occlusion of the SFA, starting at its origin and extending to the popliteal artery and trifurcation with rehabilitation of a single BTK artery in the distal tract, is usually a challenging situation.

It could be very difficult to identify and reconstitute the trifurcation, as there could be a mild risk of distal embolization in the only patent vessel, and the duration of the procedure could be very long, with an exponential rise in the risk of potential complications.

A treatment strategy should therefore be planned after evaluating the following:

- Grade of calcifications;
- The risk of compromising collateral refilling distal to the occlusion;
- Presence or absence of a landing zone, possibly related to the wounded area.

If there is calcification present, antegrade ultrasound-guided access of the common femoral artery and an intra-

luminal attempt with loaded tip wires (0.018 inch) directly supported by a balloon or dedicated catheters should be considered first. I try to alternate the use of loaded wires with navigation wires, especially when tortuosities and curves are present. Devices for crossing chronic total occlusions (CTOs) can also sometimes help.

When crossing failures occur, shifting to a subintimal technique could be considered, being mindful of the collaterals refilling the distal zone. Dissection should not extend beyond the vessel reconstitution by collaterals, and a few prudent attempts to achieve re-entry into the true lumen should be performed with a 4-F Berenstein type 2 catheter (Cordis Corporation, Bridgewater, NJ).

A re-entry device could be useful in the popliteal area, but not for BTK vessels. The landing zone could be difficult to re-enter, and dissection must be stopped before the collateral level. If I am still in the subintimal space after a reasonable number of attempts with the tip of different properly shaped wires, a retrograde approach should be considered. This way, we have the ability to select the artery related to the wound in order to achieve a direct, straight inline flow when two or three BTK distal vessels are still patent.

In my experience, it is better to consider a retrograde approach immediately after the first re-enter failure rather than engaging in prolonged attempts; these procedures are time and energy consuming for us and the patients! The retrograde approach through the distal tract of the anterior tibial artery is usually the easiest, whereas a posterior tibial distal puncture, especially around the malleolar area, could be a little more difficult. With a retrograde distal peroneal puncture, it is not possible to perform manual compression in case of failure, and compartment syndrome is always possible, which can cause severe complications.

Hemostasis is achieved in the peroneal artery with antegrade inflation of a low-pressure balloon. If there is an absence of calcifications, my first choice is a direct subintimal dissection performed with a 0.018-inch stiff wire supported again by a 4-F Berenstein catheter.



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As always, you have to be specifically trained in doing these kinds of procedures. First, you must start with relatively simple cases, and once you have mastered those, you can

proceed to the more difficult ones. Second, it is very important to be closely familiar with all of the devices you are using, especially in knowing the specific quirks of the guidewires and catheters. Third, you should have a good portfolio of devices on hand, so that if one does not work, you can quickly switch to another one. You also need a lot of patience to continue trying different techniques until you are successful. It is crucial that you are able to realize when the first device is not going to be successful and switch to another one, so that you do not continue pursuing the wrong approach.



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Long CTOs starting in the SFA and reconstituting in a distal tibial vessel may be the most challenging endovascular intervention scenario. Successful recanalization of these long CTOs can be deeply satisfying and essential to ulcer healing in CLI patients. In terms of my approach to these challenging lesions, I largely rely on some of the fundamental wire and catheter techniques. I typically approach all of my endovascular cases with contralateral femoral access. I use a 6-F Ansel sheath (Cook Medical), which I will sometimes bury in the origin of the SFA to help facilitate "pushability" of my crossing catheters.

Although there is a plethora of crossing devices, catheters, and wires that have specific application for crossing CTOs, I find that the most reliable approach is with a combination of the Glidewire and a catheter. Specifically, for the SFA segment, I will use a 0.035-inch, hydrophilic, angled Glidewire supported by a 0.035-inch QuickCross catheter. A stiff 0.035-inch wire can be used for added support in lesions with bulky calcification.

Within the proximal SFA, I form a small J-tip, which I then use to facilitate wire propagation through the CTO. The wire is advanced and followed closely with the QuickCross support catheter while maintaining a short, tight J-tip. I will generally continue this approach to the level of the below-the-knee popliteal, at which point, I transition to a 0.014-inch system. I employ a similar technique for the below-the-knee popliteal segment to the reconstituted vessel.

One of the greatest challenges here is in getting some directionality to the target tibial vessel. A directional catheter, such as the angled CXI or Glide catheter (Terumo Interventional Systems, Inc.), can help to direct the wire to

the tibial target. Once I think that I am oriented toward the target, I use a 0.014-inch Pilot wire (Abbott Vascular, Santa Clara, CA) with a 0.14-inch QuickCross for support. The two techniques I employ here are with a J-tip technique or as a "piggyback" with the pilot wire exposed 1 to 2 mm and followed with close support of the QuickCross catheter. In this latter piggyback technique, the wire and catheter are advanced simultaneously. In cases of dense calcification or with particularly troublesome lesions, I may also employ a heavier 0.014-inch wire, such as an 18- or 25-g Approach CTO wire (Cook Medical).

However, when the antegrade approach fails to succeed, as it often does for these long CTOs, it is important to have an alternative approach. In these CLI patients, in whom an antegrade approach has failed and there are no bypass options, I feel very comfortable employing retrograde access techniques via the target tibial vessel. In my approach to retrograde tibial access, I exclusively use a 0.014-inch platform. I start with a 0.14-inch micropuncture needle and wire using fluoroscopic guidance. Once I have wire access, I advance the microsheath dilator only as initial catheter support. I will then use a 0.014-inch Pilot wire and 0.014-inch QuickCross catheter as support, employing some of the same techniques I previously described. I like to keep the size of the retrograde tibial access as small as possible and avoid using sheaths.

Of course, when all else fails, there is nothing better than a good old-fashioned bypass to get the blood flowing. ■

(Continued from page 57)

2. Barshes NR, Belkin M. A framework for the evaluation of "value" and cost-effectiveness in the management of critical limb ischemia. *J Am Coll Surg*. 2011;213:552-566.
3. Hlatky MA. Effectiveness is the key to cost-effectiveness. *Circulation*. 2013;127:764-765.
4. Barshes NR, Chambers JD, Cantor SB, et al. A primer on cost-effectiveness analyses for vascular surgeons. *J Vasc Surg*. 2012;55:1794-1800.
5. Yost ML. Critical limb ischemia Volume I. United States epidemiology. Atlanta (GA): The Sage Group. 2010.
6. Taylor SM, Kalbaugh CA, Blackhurst DW, et al. Determinants of functional outcome after revascularization for critical limb ischemia: an analysis of 1000 consecutive vascular interventions. *J Vasc Surg*. 2006;44:747-756.
7. Barzilay JL, Gottdiener JS, Spiekerman CF, et al. Prevalence of clinical and isolated subclinical cardiovascular disease in older adults with glucose disorders. *Diabet Care*. 2001;24:1233-1239.
8. Mackaay AJ, Beks PJ, Dur AH, et al. The distribution of peripheral vascular disease in a Dutch Caucasian population: comparison of type II diabetic and non-diabetic subjects. *Eur J Vasc Endovasc Surg*. 1995;9:170-175.
9. Beach KW, Strandness DE Jr. Arteriosclerosis obliterans and associated risk factors in insulin-dependent and non-insulin-dependent diabetes. *Diabetes*. 1980;29:882-888.
10. Lange S, Diehm C, Darius H, et al. High prevalence of peripheral arterial disease but low antiplatelet treatment rates in elderly primary care patients with diabetes. *Diabet Care*. 2003;26:3357-3358.
11. Faglia E, Caravaggi C, Marchetti R, et al. Screening for peripheral arterial disease by means of the ankle-brachial index in newly diagnosed type 2 diabetic patients. *Diabet Med*. 2005;22:1310-1314.
12. Nilsson SE, Nilsson JE, Frostberg N, Emilsson T. The Kristianstad Survey II. *Acta Med Scand*. 1967;Suppl 469:1-42. Quoted in Palumbo PJ, Melton LJ. Peripheral vascular disease and diabetes. In: *Diabetes in America*. 2nd ed. Bethesda (MD): National Diabetes Data Group of the National Institute of Diabetes and Digestive and Kidney Diseases; 1995. NIH Publication No. 95-1468. p. 401-408.
13. Brandle M, Burke R, Zhou H, et al. The direct medical cost of type 2 diabetes. *Diabet Care*. 2003;26:2300-2304.
14. Norman PE, Davis WA, Bruce DG, Davis TME. Peripheral arterial disease and the risk of cardiac death in type 2 diabetes. *Diabet Care*. 2006;29:575-580.
15. NHE fact sheet. Historical NHE including sponsor analysis, 2011. Centers for Medicare & Medicaid Services. [Internet.] Available at: <http://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NHE-Fact-Sheet.html>.
16. OECD (2011). Health at a Glance 2011: OECD Indicators. OECD Publishing. [Internet.] Available at: http://dx.doi.org/10.1787/health_glance-2011-en.
17. Silver N. What is driving growth in government spending? [Internet.] *The New York Times* 2013, Jan 16. Available at: <http://fivethirtyeight.blogs.nytimes.com/2013/01/16/what-is-driving-growth-in-government-spending/>.
18. The unsustainable cost of healthcare. Social Security Advisory Board 2009. Available at: http://www.ssab.gov/documents/TheUnsustainableCostofHealthCare_508.pdf.
19. The economic case for healthcare reform. Executive Office of the President. Council of Economic Advisers. Available at: http://www.whitehouse.gov/assets/documents/CEA_Health_Care_Report.pdf.
20. Federal Budget in pictures 2012. Entitlements chart 3. The Heritage Foundation. Available at: <http://www.heritage.org/federalbudget/entitlements>.
21. Mahoney EM, Wang K, Cohen DJ, et al. One-year costs in patients with a history of or at risk for atherothrombosis in the United States. *Circ Cardiovasc Qual Outcomes*. 2008;1:38-45.
22. Jaff MR, Cahill KE, Yu AP, et al. Clinical outcomes and medical care costs among Medicare beneficiaries receiving therapy for peripheral arterial disease. *Ann Vasc Surg*. 2010;24:577-587.
23. Migliaccio-Walle K, Caro JJ, Ishak KJ, O'Brien JA. Costs and medical care consequences associated with the diagnosis of peripheral arterial disease. *Pharmacoeconomics*. 2005;23:733-742.
24. Yost ML. The real cost of peripheral artery disease. Atlanta (GA): The Sage Group; 2011.
25. Margolis J, Barron JJ, Grochowski D. Health care resources and costs for treating peripheral artery disease in a managed care population: results from analysis of administrative claims data. *J Manag Care Pharm* 2005;11:727-734.
26. Health Care Costs 101. Oakland (CA): California HealthCare Foundation; 2011, May. Available at: <http://www.chcf.org/publications/2011/05/health-care-costs-101>.
27. Mahoney EM, Wang K, Keo HH, et al. Vascular hospitalization rates and costs in patients with peripheral artery disease in the United States. *Circ Cardiovasc Qual Outcomes*. 2010;3:642-651.
28. Hirsch AT, Hartman L, Town RJ, Virnig BA. National health care costs of peripheral arterial disease in the Medicare population. *Vasc Med*. 2008;13:209-215.
29. Weintraub WS, Cohen DJ. The limits of cost-effectiveness analysis. *Circ Cardiovasc Qual Outcomes*. 2009;2:55-58.
30. Barshes NR, Chambers JD, Cohen J, et al. Cost-effectiveness in the contemporary management of critical limb ischemia with tissue loss. *J Vasc Surg*. 2012;56:1015-1024.
31. Tennvall GR, Apelqvist J. Health-economic consequences of diabetic foot lesions. *Clin Infect Dis* 2004;39(suppl 2):S132-S139.
32. Henry AJ, Hevelone ND, Belkin MB, Nguyen LL. Socioeconomic and hospital-related predictors of amputation for critical limb ischemia. *J Vasc Surg*. 2011;53:330-9.e1.
33. Baser O, Verpillat P, et al. Prevalence, incidence, and outcomes of critical limb ischemia in the US Medicare population. *Vasc Dis Mgmt*. 2013;10: E26-36.
34. Allie DE, Hebert CJ, Litzman MD, et al. Critical limb ischemia: a global epidemic. A critical analysis of current treatment unmasking the clinical and economic costs of CLI. *EuroIntervention*. 2005;1:60-69.
35. Goodney PP, Travis LL, Nallamothu BK, et al. Variation in the use of lower extremity vascular procedures for critical limb ischemia. *Cardiovasc Qual Outcomes*. 2012;5:94-102.
36. Hasanadika R, McLafferty RB, Moore CJ, et al. Predictors of wound complications following major amputation for critical limb ischemia. *J Vasc Surg*. 2011;54:1374-1382.
37. Belmont PJ, Davey S, Orr JD, et al. Risk factors for 30-day postoperative complications and mortality after below-knee amputation: a study of 2,911 patients from the national surgical quality improvement program. *J Am Coll Surg*. 2011;213:370-378.
38. Aulivola B, Hile CM, Hamdan AD, et al. Major lower extremity amputation: outcome of a modern series. *Arch Surg*. 2004;139:395-399.
39. Stone PA, Flaherty SK, Hayes JD, et al. Lower extremity amputation: a contemporary series. *W V Med J*. 2007;103:14-18.
40. Taylor SM, Kalbaugh CA, Cass AJ, et al. "Successful outcome" after below knee amputation: an objective definition and influence of clinical variables. *Am Surg*. 2008;74:607-612.
41. Toursarkissian B, Shireman PK, Harrison A, et al. Major lower-extremity amputation: contemporary experience in a single Veterans Affairs institution. *Am Surg*. 2002;68:606-610.
42. Yeager RA, Moneta GL, Edwards JM, et al. Deep vein thrombosis associated with lower extremity amputation. *J Vasc Surg*. 1995;22:612-615.
43. Zickler RW, Gahtan V, Matsumoto T, Kerstein MD. Deep venous thrombosis and pulmonary embolism in bilateral lower-extremity amputee patients. *Arch Phys Med Rehabil*. 1999;80:509-511.
44. Jindeel A, Narahara KA. Nontraumatic amputation: incidence and cost analysis. *Int J Lower Extrem Wounds*. 2012;11:177-179.
45. Dillingham TR, Pezzin LE, Shore AD. Reamputation, mortality, and health care costs among persons with dysvascular lower-limb amputations. *Arch Phys Med Rehabil*. 2005;86:480-486.
46. Consumer price index (CPI). All urban consumers 12 month price change. Medical Commodities CPI. Series ID CUUR0000SAM1, CUUS0000SAM1. Available at: <http://www.bls.gov/cpi/data.htm>.
47. Consumer price index (CPI). All urban consumers 12 month price change. Hospital Services CPI. Series ID CUUR0000SEMD01. Available at: <http://www.bls.gov/cpi/data.htm>.
48. Jones WS, Patel M, Dai D, et al. Geographic variation of lower extremity amputation in patients with peripheral artery disease: results from U.S. Medicare 2000-2008. *J Am Coll Cardiol*. 2012;59(13s1):E1670.
49. Belatti DA, Phisitkul P. Declines in lower extremity amputation in the US Medicare population, 2000-2010. *Foot Ankle Int*. In press.
50. Yost ML. The economic cost of dysvascular amputation. Atlanta (GA): The Sage Group; 2013. In press.
51. U.S. Preventive Services Task Force. Screening for peripheral artery disease and cardiovascular disease risk assessment with ankle brachial index in adults: U.S. preventive services task force recommendation statement (draft). Washington, DC: 2013. Available at: <http://www.uspreventiveservicestaskforce.org/uspstf12/pad/paddraftrec.htm>.