The Current Pattern of Surgical Bypass in the Context of a Limb Preservation Practice

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Abstract

Background: The pattern of surgical bypass has affected practice in the context of a multidisciplinary limb preservation program. As bypass may be required for limb preservation, such a practice would involve more frequent bypass and increased complexity of bypass performed due to the lack of an autogenous conduit and suitable target artery ("desert foot"), and patients with prior failed endovascular interventions. We investigated this change in the pattern of bypass performed in the context of our limb preservation program. **Methods:** Infrainguinal bypasses performed on patients being managed in a limb preservation program were analyzed and compared with the bypass experience of patients being managed in the time prior to the formalization of such a program. Our institutional Vascular Quality Initiative (VQI) database, with outsourced data entry, was queried from 2016 to 2022. The limb preservation program was formalized in 2018. Earlier case volumes were evaluated based on data from a previously used non-VQI database extending to 2010. All procedures were performed for chronic limb-threatening ischemia, which was defined as rest pain or tissue loss. Bypasses were categorized by conduit and anastomotic configuration as well as outflow target artery: below-knee popliteal, anterior tibial/dorsalis pedis, posterior tibial/plantaris pedis, or peroneal. **Results:** After a limb preservation program was formally initiated in 2018, 103 surgical bypasses were performed, representing 28% of lower extremity revascularization procedures. The number of bypasses revealed an increasing trend from 21% in 2018 to 37% in 2022, which was the highest percentage since 2010. Bypass anatomy included the tibial arteries in 81 patients and the below-knee popliteal in 22. A venous conduit was used in 21% of the patients, with a prosthetic conduit used in 79% due to the lack of autogenous conduit. The prosthetic conduit was heparin-bonded expanded polytetrafluoroethylene with anastomotic adjuncts in 88% of the patients: distal vein patch (57%), distal arteriovenous fistula (12%), and deep vein arterialization (19%). **Conclusions:** Revascularization in the context of a limb preservation program involves an increasing trend in the need for surgical bypass with added bypass complexity. Tibial bypass is usually required, often with the use of a prosthetic conduit and anastomotic adjuncts. Mastery of advanced bypass techniques is important to provide optimal revascularization for healing and amputation prevention in the context of a limb preservation practice.

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The role of endovascular therapy has evolved, with many providers advocating a strict endovascular-first approach. This has changed the landscape of lower extremity revascularization.[1] The recent publication of 2 prospective, randomized clinical trials (BEST-CLI and BASIL-2) has stimulated renewed discussion on the role of bypass for lower extremity revascularization.[2,3] However, a review or comparison of BEST-CLI and BASIL-2 is not the focus of this manuscript and beyond the scope of this analysis. This analysis approaches the question form another viewpoint: the pattern and complexity of surgical bypass in the context of participation in a limb preservation program.

A multidisciplinary team approach to limb preservation has been shown to be critical to optimizing the outcome of amputation prevention.[4] Surgical bypass in the context of such an approach to limb preservation increases the complexity of surgical bypass due to many factors, including the frequent lack of a venous conduit and challenging target arteries, especially after failed prior attempts at revascularization, whether endovascular or surgical. Advances and innovations in bypass technique have been developed to address these challenges and are critical to the current bypass options offered for limb preservation. We sought to characterize current lower extremity bypass patterns and techniques employed for revascularization within such a multidisciplinary limb preservation practice.

Methods

Data analysis was based on the Society of Vascular Surgery-sponsored Vascular Quality Initiative (VQI) database. Our institution has enhanced the VQI database with outsourced, external data entry to optimize accuracy and minimize any data entry bias. This institutional database was queried for all surgical bypasses and endovascular procedures performed from 2016 to 2022. Earlier case volumes were based on data from a prior non-VQI database. The limb preservation program, formalized in 2018, was a multidisciplinary effort centered on vascular surgery, podiatry, a wound center system, and ancillary support staff. The indication for revascularization in all patients in this analysis was chronic limb-threatening ischemia (CLTI), which was defined as rest pain or tissue loss in accordance with the Society for Vascular Surgery/European Society for Vascular Surgery Global Guidelines.[5] Procedure analysis was limited to the senior author, who was the predominant surgeon involved in the limb program, to minimize inter-provider variability.

The surgical procedures were categorized based on bypass anatomy regarding the outflow target artery: below-knee popliteal, anterior tibial/dorsalis pedis, posterior tibial/plantaris pedis, or peroneal. Bypasses were further analyzed based on the conduit (vein vs prosthetic). Heparin-bonded polytetrafluoroethylene (HePTFE) was the prosthetic conduit used in this patient cohort, with anastomotic adjuncts based on the anatomy and quality of the target artery. This heparin-bonded graft technology has proven beneficial for tibial bypass and is used as the prosthetic conduit for infrainguinal bypass.[6] The anastomotic adjuncts included previously reported techniques of distal vein patch (DVP), DVP with an arteriovenous fistula (DVP-AVF), and DVP with deep venous arterialization (DVP-DVA) (**Figure 1A-C**).[7-9]

Results

A total of 103 surgical bypasses for CLTI (rest pain or tissue loss) were reviewed using the VQI database from 2016 to 2022. A multidisciplinary limb preservation program was formally initiated in 2018. Prior to 2018, the number of surgical bypasses performed were trending in a decreasing manner with a concurrent increase in the number of endovascular procedures performed for CLTI. Following the institution of a limb preservation program, the trend reversed with an increasing number of surgical bypasses (**Figure 2**). Currently, 38% of all revascularization procedures are surgical bypass in the context of the limb preservation program.

All bypasses were performed for CLTI in the form of rest pain or tissue loss. The majority of bypasses were performed in the

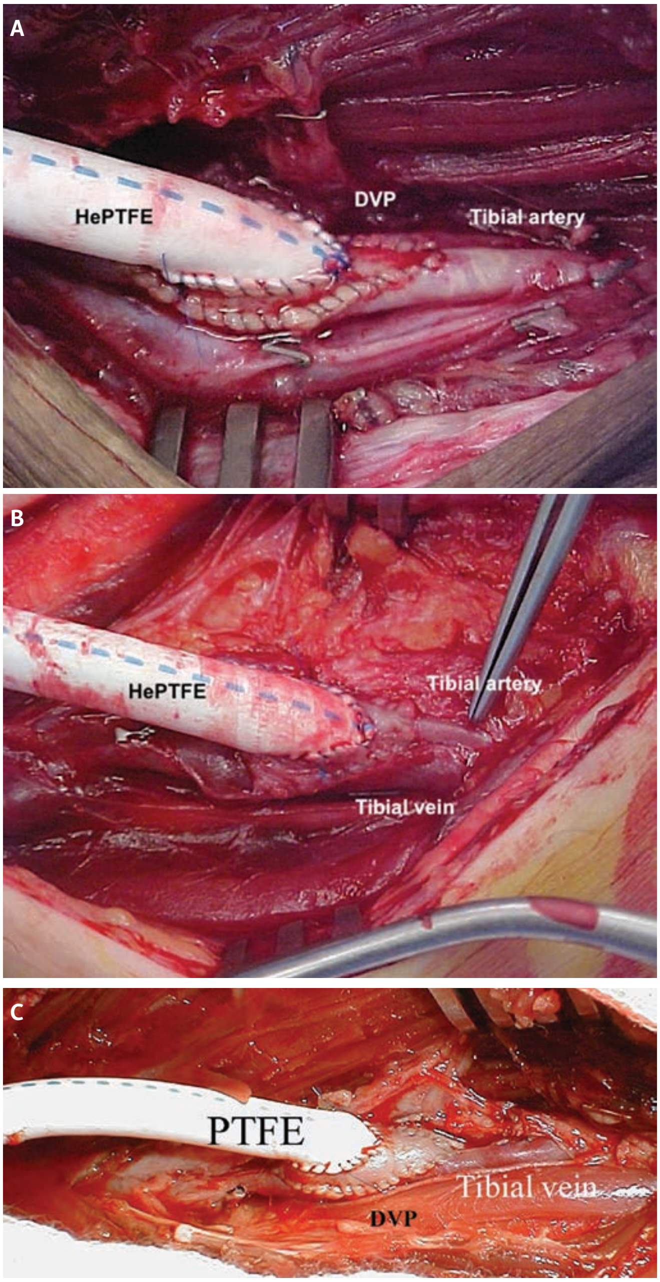

FIGURE 1. Intraoperative images of advances in bypass technique involving anastomotic adjuncts used to enhance prosthetic bypass performed for revascularization in a limb preservation program. **A)** Distal vein patch (DVP). **B)** DVP with arteriovenous fistula. **C)** DVP with deep venous arterialization.

HePTFE, heparin-bonded polytetrafluoroethylene.

tibial arteries (n = 81, 79%), with the below-knee popliteal artery also serving as the outflow target (22, 21%). A venous conduit was used in 22 patients (21%), which included 20 tibial and 2 plantaris pedis bypasses. A large saphenous vein, either ipsilateral or contralateral, was the autogenous conduit utilized, with no arm vein or small saphenous vein used. A prosthetic conduit was used if a large saphenous vein (ipsilateral or contralateral) was absent, previously used (cardiac or prior bypass), sclerotic, or varicose. An alternative autogenous conduit, such as an arm vein and small saphenous vein, was not employed in this series due to previously reported success obtained with the DVP bypass technique.[10,11] This approach resulted in a prosthetic conduit used in 81 patients (79%), with 21% using a great saphenous vein (**Figure 3**). Prosthetic bypasses included an HePTFE conduit alone without anastomotic adjuncts in 12% of the patients, and with anastomotic adjuncts in the remaining 88%: DVP (57%), DVP-AVF (12%), and DVP-DVA (19%) (**Figure 4**). Bypass was performed after prior failed attempts at revascularization in 41% of the cases: 33 failed endovascular procedures (often multiple) and 9 failed bypasses.

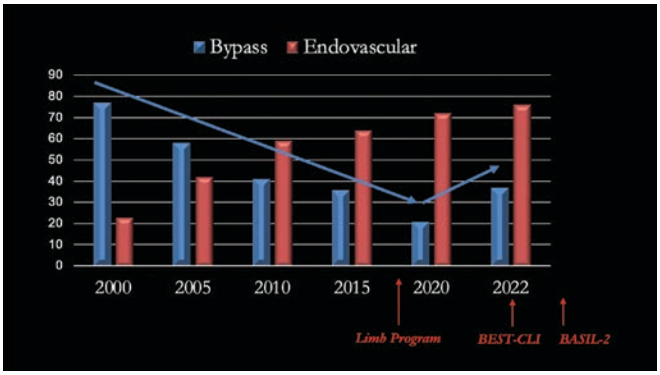

FIGURE 2. Percentage (y axis) of surgical bypass and endovascular interventions before and after the formal institution of a limb preservation program demonstrating a trend of increasing bypass performed.

Discussion

Multidisciplinary programs have been shown to improve outcomes for patients facing nonhealing wounds and possible limb loss.[12,13] This review assesses the pattern of surgical bypass performed in the context of such a multidisciplinary limb program. The goal of this analysis was to assess the impact of a such a program on the frequency of surgical bypass and type of bypass constructed in this complex patient population. The question arises as to whether an endovascular-first approach is increasingly used in a limb program or whether bypasses are performed in a limb program that are different than those performed in standard surgical practices. We have published basic criteria to guide the use of bypass in our limb practice,[14] and these criteria were used as guidelines but not as dogmatic rules in the choice of revascularization type. Additionally, the BEST-CLI and BASIL-2 trials have addressed the issue of bypass vs endovascular therapy, but the timing of the publication of these trials had minimal impact on the time interval involved in this analysis. Although we believe that these trials will have an added impact on the decision-making process, a discussion of BEST-CLI and BASIL-2 is beyond the scope of this manuscript.

Our data noted a reversal in the trend of decreasing bypass frequency after formal initiation of the limb program. Interestingly, there was a corresponding increase in endovascular procedures during the same time interval, indicating an increase in total lower extremity revascularization in the context of the limb program. This increase in the number of surgical bypasses may be related

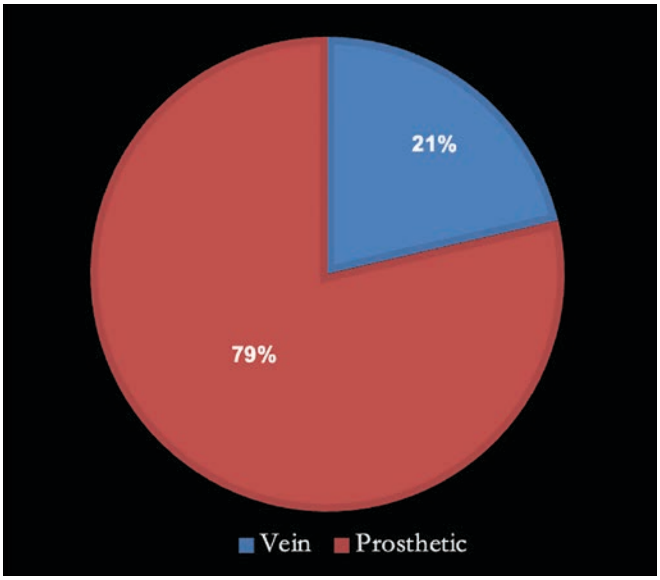

FIGURE 3. Comparison of infrapopliteal bypass conduit revealing a greater number of prosthetic grafts (red) compared with venous grafts (blue), which is opposite of most standard vascular practices, reflecting the complexity of bypass in a limb preservation program.

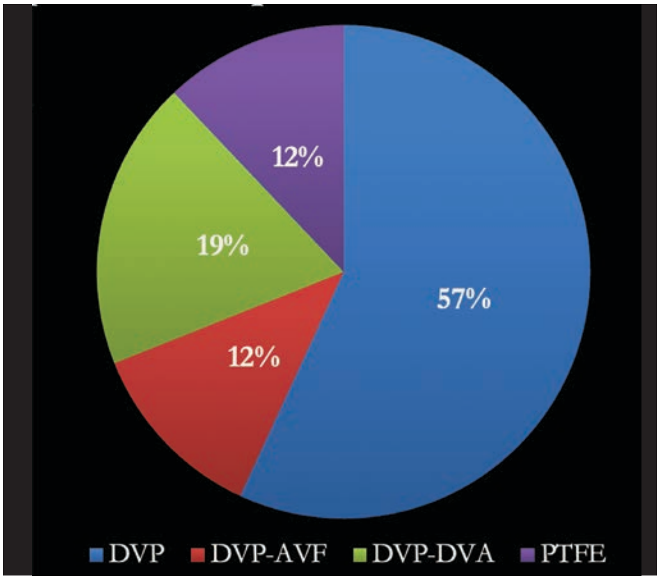

FIGURE 4. Experience with the use of anastomotic adjuncts for revascularization by bypass in a limb preservation program. DVP, distal vein patch; DVP-AVF, distal vein patch with arteriovenous fistula; DVP-DVA, distal vein patch with deep venous arterialization; PTFE, polytetrafluoroethylene.

to an increased complexity of the revascularization required due to the tertiary (often quaternary) referral patterns involved with such a limb preservation program, as well as many patients having had failed attempts at revascularization prior to referral.

The type of bypass performed was also different in the limb program cohort compared with prior experience in a standard vascular practice. The saphenous vein has long been the gold standard autogenous conduit to treat CLTI.[15] Tibial bypass surpassed popliteal bypass, and the use of prosthetic grafts with anastomotic adjuncts was increased based on a frequent lack of saphenous vein conduit due to prior lower extremity bypass, coronary bypass, varicose veins, or phlebitic veins. When an autogenous conduit is not available, it has been our practice to use HePTFE with appropriate anastomotic adjuncts as described. If a distal tibial artery is available as an outflow target for bypass, the DVP technique is used. This configuration alters the compliance mismatch between the diseased artery and the prosthetic graft, and offsets the hyperplastic response to the suture line between the graft and vein patch, thereby minimizing hyperplasia in the runoff tibial artery.[16] Additionally, surgeons find the patch technically easier to suture to the diseased artery, often a calcified tibial artery, as compared with the larger, stiff prosthetic material. If the distal tibial target artery is suboptimal in terms of caliber or lack of inline runoff, an arteriovenous fistula is added to the DVP technique. This reduces outflow resistance and maintains graft velocity above the critical thrombotic threshold.[17,18] Recently, DVA has been added to the bypass armamentarium through the DVP technique (DVP-DVA). This technique is an option for patients with a “desert foot” lacking an outflow target as well as an available venous conduit.[4] Our experience with deep venous revascularization by DVP bypass is ongoing and a subject for future analysis.

The presence of a multidisciplinary program may alleviate some reluctance for such referrals from other vascular providers, as the patient is referred for treatment of both soft tissue wounds as well as persistent ischemia. Such referrals to the limb preservation program often involve cases with failed prior attempts at revascularization. This increases the complexity of subsequent revascularization, especially in the form of a surgical bypass. In our experience, 41% of the bypass procedures were performed after a prior failed revascularization: endovascular (33) and prior bypass (9). Failed endovascular therapy can lead to an alteration of the target artery, or a more distal location on the target than would have been required with an initial bypass prior to endovascular failure.[19,20] The BASIL-1 trial demonstrated that bypass was less successful after failed balloon angioplasty.[21] Prior failed bypass also increases subsequent bypass complexity through prior utilization of an autogenous conduit and available target arteries. Finally, up to 20% of patients in a limb-threatening situation present with a paucity of any suitable distal arterial targets, or the so-called “desert foot”.[22] The cohort of patients treated in a limb preservation program can involve the difficult scenario that compounds several complex factors: lack of an autogenous conduit, prior failed revascularization, and a disadvantaged target artery. Therefore, alternative conduits and anastomotic adjuncts have been utilized to overcome these challenges in an attempt to prevent amputation. The need for surgical bypass as a significant revascularization option in the context of the limb preservation program is important and seems to stimulate an upward trend in terms of bypass frequency.

There are certainly limitations to this data. The analysis was performed at a single institution with bypasses performed by a single surgeon; this inherently leads to practice bias. The number of bypasses performed after a failed endovascular therapy may demonstrate bias in patient selection, as patients with more complex pathologies and surgical history are more likely be referred to a limb preservation center compared to a standard surgical practice. As such, this data should be seen as an observation, stimulating further characterization or future trends in lower extremity revascularization after establishment of an endovascular-first/only approach in many centers treating CLTI for amputation prevention. Additionally, this study did not analyze outcomes of the techniques or effect of patient comorbidities. However, surgical bypass, often with a prosthetic conduit and anastomotic adjuncts, was observed to fill a significant role in revascularization in the context of a limb preservation program. It will be important to master these techniques so that revascularization can continue to be offered to patients for healing and amputation prevention. Establishment of a limb preservation program requires technical competence in all forms of revascularization; therefore, communication between interventionalists and surgeons to choose the appropriate strategy of revascularization in such a program is critical for success.

Conclusion

Revascularization in the context of a limb preservation program involves an increasing trend in the need for surgical bypass with added complexity. The role of bypass has received new interest based on publication of the BEST-CLI and BASIL-2 trials and the recognized importance of multidisciplinary limb programs to prevent amputation. In such programs, tibial bypass is more often required as opposed to the “fem-pop” bypass of old. Additionally, the use of a prosthetic conduit and anastomotic adjuncts is important in such a limb program. Mastery of advanced bypass techniques is important to offer optimal revascularization for healing and amputation prevention in the context of a limb preservation practice.

References

1. Goodney PP, Beck AW, Nagle J, Welch HG, Zwolak RM. National trends in lower extremity bypass surgery, endovascular interventions, and major amputations. *J Vasc Surg*. 2009;50(1):54-60. doi:10.1016/j.jvs.2009.01.035

2. Farber A, Menard MT, Conte MS, et al; BEST-CLI Investigators. Surgery or endovascular therapy for chronic limb-threatening ischemia. *N Engl J Med*. 2022;387(25):2305-2316. doi:10.1056/NEJMoa2207899

3. Bradbury AW, Moakes CA, Popplewell M, et al; BASIL-2 Investigators. A vein bypass first versus a best endovascular treatment first revascularisation strategy for patients with chronic limb threatening ischaemia who required an infra-popliteal, with or without an additional more proximal infra-inguinal revascularisation procedure to restore limb perfusion (BASIL-2): an open-label, randomised, multicentre, phase 3 trial. *Lancet.* 2023;401(10390):1798-1809. doi:10.1016/S0140-6736(23)00462-2

4. van den Berg JC, Driver VR, Holden A, et al; CLI Global Society. Modern multidisciplinary team approach is crucial in treatment for critical limb threatening ischemia. *J Cardiovasc Surg (Torino).* 2021;62(2):124-129. doi:10.23736/S0021-9509.21.11725-2

5. Conte MS, Bradbury AW, Kolh P, et al; GVG Writing Group for the Joint Guidelines of the Society for Vascular Surgery (SVS), European Society for Vascular Surgery (ESVS), and World Federation of Vascular Societies (WFVS). Global vascular guidelines on the management of chronic limb-threatening ischemia. *Eur J Vasc Endovasc Surg*. 2019;58(1S):S1-S109.e33. doi:10.1016/j.ejvs.2019.05.006

6. Begovac PC, Thomson RC, Fisher JL, Hughson A, Gällhagen A. Improvements in GORE-TEX vascular graft performance by Carmeda BioActive surface heparin immobilization. *Eur J Vasc Endovasc Surg*. 2003;25(5):432-437. doi:10.1053/ejvs.2002.1909

7. Neville RF, Tempesta B, Sidawy AN. Tibial bypass for limb salvage using polytetrafluoroethylene with a distal vein patch. *J Vasc Surg*. 2001;33(2):266-271; discussion 271-272. doi:10.1067/mva.2001.113131

8. Neville RF, Dy B, Singh N, DeZee K. Distal vein patch with an arteriovenous fistula: a viable option for the patient without autogenous conduit and severe distal occlusive disease. *J Vasc Surg*. 2009;50(1):83-88. doi:10.1016/j.jvs.2008.12.052

9. Lauria AL, Propper B, Neville RF. Surgical deep vein arterialization; adding to the armamentarium of complex limb salvage. *Ann Vasc Surg*. 2022;87:198-204. doi:10.1016/j.avsg.2022.03.036

10. Neville RF, Capone A, Babrowicz J, Amdur R. A single center experience comparing tibial bypass with heparin bonded ePTFE versus saphenous vein. *J Vasc Surg.* 2010;52(6):1746-1747. doi: 10.1016/j.jvs.2010.10.037

11. Neville RF, Lidsky M, Capone A, Babrowicz J, Rahbar R, Sidawy AN. An expanded series of distal bypass using the distal vein patch technique to improve prosthetic graft performance in critical limb ischemia. *Eur J Vasc Endovasc Surg*. 2012;44(2):177-182. doi:10.1016/j.ejvs.2012.04.014

12. Sumpio BE, Armstrong DG, Lavery LA, Andros G, SVS/APMA writing group. The role of interdisciplinary team approach in the management of the diabetic foot: a joint statement from the Society for Vascular Surgery and the American Podiatric Medical Association. *J Vasc Surg*. 2010;51(6):1504-1506. doi:10.1016/j.jvs.2010.04.010

13. Krishnan S, Nash F, Baker N, Fowler D, Rayman G. Reduction in diabetic amputations over 11 years in a defined U.K. population: benefits of multidisciplinary team work and continuous prospective audit. *Diabetes Care*. 2008;31(1):99-101. doi:10.2337/dc07-1178

14. Neville RF. CLI revascularization advice from a surgeon who performs distal bypass. *Endovascular Today*. 2019;18(5):74-76.

15. Veith FJ, Gupta SK, Ascer E, et al. Six-year prospective multicenter randomized comparison of autologous saphenous vein and expanded polytetrafluoroethylene grafts in infrainguinal arterial reconstructions. *J Vasc Surg*. 1986;3(1):104-114. doi:10.1067/mva.1986.avs0030104

16. Neville RF, Elkins CJ, Alley MT, Wicker RB. Hemodynamic comparison of differing anastomotic geometries using magnetic resonance velocimetry. *J Surg Res*. 2010;169(2):311-318. doi:10.1016/j.jss.2009.12.008

17. Strandness DE. *Hemodynamics for Surgeons*. Grune and Stratton; 1975.

18. Kreienberg PB, Darling RC III, Chang BB, Paty PS, Lloyd WE, Shah DM. Adjunctive techniques to improve patency of distal prosthetic bypass grafts: polytetrafluoroethylene with remote arteriovenous fistulae versus vein cuffs. *J Vasc Surg*. 2000;31(4):696-701. doi:10.1067/mva.2000.104597

19. Sandford RM, Bown MJ, Sayers RD, London JN, Naylor AR, McCarthy MJ. Is infrainguinal bypass grafting successful following failed angioplasty? *Eur J Vasc Endovasc Surg*. 2007;34(1):29-34. doi:10.1016/j.ejvs.2007.01.020

20. Joels CS, York JW, Kalbaugh CA, Cull DL, Langan EM III, Taylor SM. Surgical implications of early failed endovascular intervention of the superficial femoral artery. *J Vasc Surg*. 2008;47(3):562-565. doi:10.1016/j.jvs.2007.11.044

21. Adam DJ, Beard JD, Cleveland T, et al; BASIL trial participants. Bypass versus angioplasty in severe ischaemia of the leg (BASIL): multicentre, randomised controlled trial. *Lancet.* 2005;366(9501):1925-1934. doi:10.1016/S0140-6736(05)67704-5

22. Yost ML. *Critical Limb Ischemia Vol I, U.S. Epidemiology, 2016 Supplement*. The Sage Group; 2016.

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