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Surgical Bypass in Critical Limb-Threatening Ischemia Due to TASC II D Femoropopliteal Lesions: Technique Evolution and Comparative Evidence

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Abstract

***Background*:** Critical limb-threatening ischemia (CLTI) represents the most advanced stage of peripheral arterial disease, carrying high risks of major amputation, cardiovascular mortality, and functional decline. Among patients with CLTI, TASC II D femoropopliteal lesions constitute the most complex and extensive pattern of disease, characterized by long-segment critical total occlusions, heavy calcification, and frequent multilevel involvement that severely compromise limb perfusion. Surgical bypass has long served as the cornerstone of revascularization for such advanced lesions due to its proven durability and consistent hemodynamic restoration. Despite rapid advancements in endovascular therapy, surgical bypass continues to offer the most reliable long-term patency and limb-salvage outcomes in appropriately selected patients, particularly when high-quality autologous conduit is available.

This review aims to synthesize contemporary evidence surrounding surgical bypass for TASC II D femoropopliteal disease in CLTI, with emphasis on conduit selection, technical strategies, comparative outcomes, and evolving innovations. Autologous great saphenous vein remains the gold standard for femoropopliteal and tibial bypass, offering superior patency and reduced reintervention rates compared with prosthetic grafts. However, prosthetic conduits—including heparin-bonded expanded polytetrafluoroethylene (ePTFE) grafts—have expanded the therapeutic options for patients lacking suitable vein. Selection of inflow and outflow targets has been refined through contemporary frameworks such as the Global Vascular Guidelines and the GLASS classification, enabling more precise anatomical planning and improved prediction of outcomes.

Clinical evidence from trials and large cohort studies demonstrates that surgical bypass provides the greatest long-term durability for TASC II D lesions, especially in younger, lower-risk individuals with good distal runoff. While endovascular and hybrid procedures offer less invasive alternatives with favorable early results, bypass remains unmatched in long-term patency, particularly below the knee. Nevertheless, wound complications, graft infections, and the technical challenges of tibial and pedal bypass highlight the need for careful patient selection and meticulous perioperative management.

This review concludes that surgical bypass continues to play a critical role in the management of advanced femoropopliteal disease, particularly in patients with suitable conduit, reasonable life expectancy, and severe anatomical complexity. Continued innovation in conduit technology, imaging, and perioperative care will further refine the role of bypass within a modern, evidence-based CLTI treatment paradigm.

Keywords: Surgical Bypass , Critical Limb-Threatening Ischemia, TASC II D Femoropopliteal Lesions

INTRODUCTION

Chronic limb-threatening ischemia (CLTI) represents the end stage of peripheral arterial disease and is associated with high rates of major amputation, cardiovascular mortality, and reduced quality of life. As defined in the Global Vascular Guidelines, CLTI encompasses ischemic rest pain, tissue loss, or gangrene alongside objective hemodynamic evidence of severe perfusion impairment. The burden of CLTI continues to rise with aging populations and the increasing prevalence of diabetes and renal insufficiency, making durable revascularization critical for limb salvage. Among all patterns of infrainguinal arterial disease, femoropopliteal occlusions pose a significant challenge due to their length, calcification severity, and frequent extension into tibial vessels, factors that complicate the selection and durability of revascularization strategies [1,2].

TASC II D femoropopliteal lesions represent the most complex classification category, typically involving long-segment chronic total occlusions greater than 20 cm, multilevel involvement, and heavy calcification. Historically, surgical bypass has been considered the gold standard for such lesions, particularly when autologous vein conduit is available. The seminal BASIL trial and subsequent long-term analyses demonstrated that bypass surgery provides superior durability and improved late outcomes compared with early-generation endovascular therapies, especially in patients with anticipated survival beyond two years. Despite major advances in endovascular technology—including drug-coated balloons, covered stents, and atherectomy systems—bypass continues to offer unmatched long-term patency in carefully selected patients, particularly those with extensive infrainguinal disease [3–5].

Nevertheless, the landscape of CLTI management has evolved significantly, with contemporary decision-making shaped by tools such as the Global Limb Anatomic Staging System (GLASS), patient risk stratification models, and comparative evidence from randomized trials including BEST-CLI. These frameworks emphasize individualized treatment choices based on anatomical severity, conduit availability, physiologic reserve, and anticipated long-term benefit. The aim of this review is to analyze the evolution, technical considerations, conduit selection principles, and comparative outcomes of surgical bypass for TASC II D femoropopliteal disease. In doing so, it provides an updated assessment of the role of bypass surgery within the broader revascularization paradigm, identifying where it continues to excel and where alternative strategies may be more appropriate in modern vascular practice [1,4,6].

Anatomy and Pathophysiology of TASC II D Femoropopliteal Disease

TASC II D femoropopliteal lesions represent the most advanced manifestation of infrainguinal arterial occlusive disease, typically characterized by chronic total occlusions extending over long segments of the superficial femoral artery (SFA) and often into the proximal popliteal artery. These lesions are associated with dense fibrocalcific plaque, chronic thrombotic material, and occlusive segments exceeding 20–30 cm in length, all of which impair hemodynamic flow to the distal limb. Calcification plays a central role in determining procedural complexity, as it limits vessel compliance, increases resistance to luminal expansion, and reduces the long-term durability of endovascular therapies. This challenging morphology explains why surgical bypass has historically been favored for such patterns of disease, as it effectively circumvents the entire occluded arterial segment [7,8].

The hemodynamic consequences of TASC II D lesions are profound, often resulting in critically diminished perfusion pressures, severely impaired collateral flow, and compromised distal microvascular reserve. Patients frequently present with multilevel disease, with occlusions in the SFA coexisting with tibial stenoses or occlusions that further worsen perfusion. The combination of poor inflow and poor outflow contributes to low ankle-brachial indices and difficulty achieving complete revascularization with endovascular therapy alone. Microvascular dysfunction, particularly prominent in patients with diabetes or renal insufficiency, further impairs oxygen delivery to ischemic tissues, making durable restoration of macrovascular flow essential for wound healing, pain relief, and limb salvage. Bypass surgery, by providing a continuous conduit from healthy inflow to the best available distal target, overcomes many of these hemodynamic limitations [9,10].

Biomechanical factors also influence the natural history and treatment outcomes of femoropopliteal occlusive disease. The adductor canal, where the SFA transitions into the popliteal artery, is subject to significant mechanical stress due to flexion, torsion, compression, and elongation forces associated with knee movement. These dynamic stresses accelerate plaque progression, contribute to the development of chronic occlusion, and increase the risk of stent fracture or restenosis following endovascular intervention. The pathophysiologic interplay between lesion length, calcification, and biomechanical stress underscores the importance of selecting durable treatment strategies such as surgical bypass, particularly in patients with extensive occlusions that traverse multiple mechanical stress zones [8,11].

Historical Development of Infrainguinal Bypass Surgery

The evolution of infrainguinal bypass surgery has played a pivotal role in the management of advanced femoropopliteal disease long before the emergence of modern endovascular therapy. Early bypass operations in the mid-20th century relied heavily on prosthetic materials, which were associated with high rates of thrombosis and infection. The introduction of autologous great saphenous vein (GSV) grafting transformed clinical outcomes by offering superior biocompatibility, improved hemodynamics, and enhanced resistance to infection. This transition established vein conduit as the gold standard for infrainguinal bypass, particularly for long and complex lesions such as TASC II D occlusions, and laid the foundation for modern lower-limb bypass surgery [12,13].

As vascular surgery matured, technical refinements such as in-situ vein bypass, valvulotome-assisted conduit preparation, and improved distal anastomotic techniques contributed to better patency and limb-salvage results. In the 1980s and 1990s, advancements in surgical instrumentation and perioperative care reduced morbidity and broadened the applicability of bypass to increasingly complex disease patterns. The development of noninvasive imaging modalities, including duplex ultrasound and later CT angiography and MR angiography, improved preoperative planning and conduit selection. These innovations allowed surgeons to tailor bypass strategies with greater anatomic precision, particularly in cases requiring tibial or pedal targets for CLTI [14,15].

The modern era of bypass has been shaped by competing paradigms introduced by endovascular therapy. While early endovascular technologies could not match bypass durability, their minimally invasive nature encouraged comparative studies such as the BASIL trial, which confirmed bypass superiority in long-term outcomes among patients with reasonable life expectancy. More recent trials, including BEST-CLI, further solidified the enduring value of autologous vein bypass while simultaneously defining the role of endovascular-first strategies in select patients. Despite rapid progress in catheter-based interventions, infrainguinal bypass continues to evolve, with improved prosthetic graft technologies and hybrid surgical–endovascular concepts enhancing overall revascularization strategies for TASC II D disease [4,6,16].

Autologous Vein vs Prosthetic Grafts

Autologous great saphenous vein (GSV) remains the gold-standard conduit for infrainguinal bypass, particularly in TASC II D femoropopliteal disease where long-segment reconstruction is required for durable perfusion. The biological compatibility of the vein, its resistance to infection, and its adaptive remodeling capabilities make it uniquely suited for high-demand arterial environments. Numerous clinical studies consistently demonstrate superior primary patency, limb salvage, and long-term durability of vein grafts compared with prosthetic alternatives, especially when used for below-knee targets. As a result, current guidelines emphasize prioritizing autologous vein whenever available, reflecting its unmatched performance in CLTI revascularization [17,18].

When GSV is unavailable or inadequate, alternative autologous conduits such as arm veins—including cephalic and basilic veins—are considered viable options. Although their smaller caliber and variable quality present technical challenges, arm veins generally outperform prosthetic grafts in below-knee and tibial bypasses. Composite or spliced vein grafts may be used when no single segment is sufficient; however, patency tends to decline with each additional anastomosis. Despite these limitations, autologous arm-vein conduits remain valuable resources in complex multilevel disease, particularly in younger patients or those with anticipated long-term survival, where prosthetic graft failure risk is unacceptable [19,20].

Prosthetic materials such as expanded polytetrafluoroethylene (ePTFE) have historically been associated with inferior patency and higher infection rates, particularly in below-knee applications. However, advances such as heparin-bonded ePTFE grafts have improved outcomes, making prosthetic conduits increasingly acceptable for above-knee bypasses and select cases with limited conduit availability. Even so, prosthetic grafts generally perform less favorably in tibial and pedal targets, where small vessel diameter and poor runoff compromise long-term success. Their use is therefore typically reserved for situations where autologous vein is unavailable, or when surgical urgency precludes extensive conduit harvesting. The choice between vein and prosthetic conduit ultimately hinges on anatomical requirements, patient risk profile, and expected survival, with vein remaining the superior option whenever feasible [21,22].

Inflow and Outflow Considerations in Bypass Planning

Successful surgical bypass for TASC II D femoropopliteal disease depends heavily on selecting optimal inflow and outflow vessels to ensure adequate perfusion and long-term graft patency. Inflow typically originates from the common femoral artery (CFA), which offers reliable diameter, wall quality, and favorable hemodynamic characteristics. When the CFA is diseased, endarterectomy is performed to restore a durable inflow zone capable of supporting high-volume graft flow. Inflow may also be taken from the profunda femoris artery when necessary, particularly in cases where the superficial femoral artery (SFA) origin is severely compromised. Ensuring strong inflow is foundational, as poor proximal hemodynamics significantly reduce graft durability and increase the risk of early failure [23,24].

Outflow selection is equally critical and must be tailored to the anatomic complexity and distal disease burden typical of CLTI. The popliteal artery serves as a common outflow target, particularly above the knee, where vessel diameter and flow characteristics are favorable. However, for TASC II D lesions extending into the popliteal artery, below-knee or tibial bypass is often required. In these cases, identifying the "best target artery"—defined by runoff quality, vessel patency, and distal bed viability—is central to maximizing limb salvage. Tibial and pedal arteries frequently show diffuse calcification or multifocal stenosis in CLTI patients, making intraoperative assessment and meticulous target preparation essential for surgical success. High-quality outflow is strongly associated with long-term bypass patency and reduced risk of graft thrombosis [25,26].

Modern frameworks such as the Global Limb Anatomic Staging System (GLASS) have enhanced anatomical assessment by incorporating lesion length, distribution, and distal runoff into a structured planning algorithm. GLASS levels III and IV often correspond to TASC II D disease and help guide decisions regarding bypass necessity, conduit selection, and target optimization. These tools, along with duplex ultrasonography, CT angiography, and on-table angiography, allow surgeons to refine bypass planning with increasing precision. By integrating anatomical severity, conduit quality, and functional perfusion goals, inflow–outflow planning ensures that bypass strategies are tailored to maximize limb salvage and long-term durability in complex CLTI cases [1,27].

Technical Approaches in Above-Knee and Below-Knee Bypass

Above-knee femoropopliteal bypass remains one of the most established procedures for treating TASC II D femoropopliteal disease, especially when the above-knee popliteal artery offers a suitable outflow target. Reversed great saphenous vein (GSV) remains the preferred conduit when available, as its diameter closely matches that of the popliteal artery, providing excellent hemodynamic compatibility. When autologous vein is unavailable, prosthetic grafts—particularly heparin-bonded ePTFE—are commonly used above the knee and have demonstrated acceptable patency in this anatomic location. The above-knee position benefits from reduced biomechanical stress compared with below-knee bypass, contributing to improved graft longevity even in cases where conduit quality is suboptimal. Proper tunnel creation, graft orientation, and avoidance of kinking are essential technical considerations that directly affect patency and reduce perioperative complications [28,29].

Below-knee bypass requires more meticulous technique due to the smaller diameter and increased resistance of the distal popliteal and tibial vessels. Autologous vein is strongly preferred for below-knee targets because prosthetic grafts exhibit significantly lower patency and higher infection rates in this region. In-situ vein bypass has gained popularity in below-knee applications due to several advantages: preservation of the vein's vasa vasorum, size matching to the distal target, and reduced manipulation compared with reversed grafts. Critical technical steps include valve lysis using a valvulotome, careful branch ligation, and ensuring uniform conduit diameter. Multiple studies have shown superior outcomes with in-situ vein compared to reversed vein or prosthetic conduit in below-knee reconstructions, particularly in CLTI patients with compromised runoff [30,31].

Tibial and popliteal targets introduce unique challenges due to the degree of calcification commonly present in CLTI. Endarterectomy of the distal target, adjunctive balloon angioplasty, or limited hybrid techniques may be used to improve outflow quality before completing the distal anastomosis. Meticulous anastomotic construction—often under loupe magnification—is essential to reduce the risk of early thrombosis. Expertly planned graft routing is equally important, as grafts crossing joints or high-motion zones are at increased risk of kinking, compression, or trauma. With adherence to these technical principles, below-knee and tibial bypass can achieve excellent limb-salvage outcomes even in patients with severe anatomic complexity characteristic of TASC II D disease [32,33].

Tibial and Pedal Bypass for CLTI

Tibial and pedal bypass are critical options for limb salvage in patients with CLTI and TASC II D femoropopliteal disease, especially when occlusive pathology extends into the below-knee and distal vessels. These procedures are typically reserved for patients with severe tissue loss, infection, or rest pain in whom more proximal targets cannot provide adequate perfusion for healing. Autologous vein—most often great saphenous or spliced arm vein—is strongly preferred because of its superior patency and infection resistance in the hostile distal environment. The goal is to establish at least one robust, continuous channel from healthy inflow to a tibial or pedal artery supplying the ischemic angiosome, thereby maximizing the probability of wound healing and limb preservation in a highly compromised vascular bed [34,35].

Outcomes of tibial bypass using autologous vein in carefully selected CLTI patients are generally favorable, with reported primary patency rates often exceeding 60% at three years and limb-salvage rates of 70–80% or higher, despite the advanced nature of disease. Success is closely linked to runoff quality, conduit integrity, infection control, and meticulous wound care. Patients with multiple patent tibial vessels or a well-developed pedal arch tend to have better results than those with a single, heavily diseased tibial runoff. Nevertheless, even in severely diseased tibial trees, bypass to the "best available" vessel can provide sufficient flow for tissue healing when combined with aggressive debridement and optimized medical therapy. These data support the continued role of tibial bypass as a powerful limb-salvage tool in experienced hands, particularly when endovascular options are limited or have failed [31,36].

Pedal bypass extends these principles by targeting arteries of the foot—such as the dorsalis pedis or plantar arteries—when more proximal tibial segments are unsuitable due to occlusion, calcification, or prior intervention. These operations are technically demanding because of small vessel caliber, severe calcification, and limited surgical exposure, and they require high-quality vein conduit and refined microsurgical technique. Despite this, pedal bypass can achieve excellent limb-salvage rates in patients with extensive forefoot or midfoot tissue loss, particularly in diabetic populations. The choice between tibial and pedal targets is driven by angiographic anatomy, wound location (angiosome-directed revascularization), and the feasibility of constructing a durable distal anastomosis. When performed in appropriately selected patients within specialized vascular centers, tibial and pedal bypass remain among the most effective strategies for salvaging limbs threatened by the most severe patterns of distal arterial disease [31,37,38].

Perioperative Optimization and Medical Therapy

Perioperative optimization is essential for achieving durable outcomes following surgical bypass for TASC II D femoropopliteal disease, given the high burden of comorbidities seen in CLTI patients. Comprehensive cardiovascular risk assessment—including evaluation of coronary artery disease, heart failure, and functional capacity—helps stratify perioperative risk and guide anesthesia planning. Aggressive control of modifiable risk factors such as hyperglycemia, hypertension, and active infection is critical, particularly because wound complications and graft infections are more likely in physiologically unstable patients. Multidisciplinary involvement, including vascular surgery, cardiology, endocrinology, and infectious-disease specialists, enhances optimization and reduces perioperative morbidity in this complex population [39,40].

Antithrombotic therapy forms a cornerstone of perioperative management to reduce the risk of early graft thrombosis. Intraoperative systemic heparinization is standard to maintain adequate anticoagulation during anastomotic construction and minimize thrombotic complications. Postoperatively, antiplatelet therapy—typically aspirin or a combination of aspirin and clopidogrel—is recommended depending on the type of conduit and distal target. Patients with prosthetic grafts may benefit from dual antiplatelet therapy, while autologous vein grafts often require single antiplatelet therapy unless other indications exist. Statin therapy is universally recommended due to its pleiotropic effects on endothelial function, inflammation, and long-term cardiovascular risk reduction, all of which contribute to improved graft performance and limb salvage [41,42].

Hemodynamic monitoring and postoperative surveillance are equally essential to ensure early detection of graft compromise. Maintaining adequate blood pressure is crucial to support graft flow and prevent distal thrombosis, while avoiding excessive hypertension that may jeopardize anastomotic integrity. Early duplex ultrasound evaluation provides baseline flow characteristics and allows identification of technical defects such as stenosis, poor inflow, or suboptimal distal runoff. Renal protection measures—including hydration protocols and avoidance of nephrotoxic medications—play an important role because many CLTI patients suffer from chronic kidney disease, which increases perioperative risk. Adherence to structured surveillance programs in the first year after bypass has been shown to significantly reduce graft failure and improve long-term outcomes [43,44].

Clinical Outcomes of Surgical Bypass for TASC II D Disease

Surgical bypass for TASC II D femoropopliteal disease in CLTI consistently demonstrates robust clinical outcomes in appropriately selected patients, particularly when high-quality autologous vein is used. Multiple series report primary patency rates of 65–75% at 3 years and 55–65% at 5 years for femoropopliteal and tibial bypasses using great saphenous vein, with secondary patency often exceeding 80% at 5 years. Limb-salvage rates in this setting generally range from 70–85%, despite the advanced anatomic and clinical severity typical of TASC II D lesions. These durable patency and limb-salvage outcomes underpin the continued role of bypass as the benchmark therapy for complex infrainguinal disease in patients with reasonable life expectancy and suitable conduit [31,36,45].

Evidence from randomized and observational studies reinforces the durability advantage of bypass in complex disease. The BASIL trial showed that, among patients surviving beyond two years, vein bypass was associated with improved overall survival and lower rates of repeat revascularization or amputation compared with an angioplasty-first strategy, findings particularly relevant to long, complex femoropopliteal lesions akin to TASC II D patterns. More recently, BEST-CLI further demonstrated that, in CLTI patients with adequate single-segment great saphenous vein, surgical bypass provided superior limb-related outcomes and fewer major adverse limb events than endovascular-first therapy. These data collectively support bypass as the preferred strategy in anatomically complex disease when good conduit is available and life expectancy justifies a durability-focused approach [4,6,18,46].

Importantly, favorable outcomes depend on careful patient selection, high-quality conduit, and rigorous postoperative surveillance. Patients with good distal runoff, well-preserved pedal arch, and limited tissue loss tend to experience the best results, while those with severe tibial disease, uncontrolled infection, or heavy comorbidity burden have higher risks of graft failure and amputation. Nevertheless, even in high-risk cohorts, bypass frequently achieves acceptable limb-salvage rates and can serve as an effective "last-line" revascularization strategy when endovascular options are exhausted or anatomically unsuitable. Thus, in the context of TASC II D femoropopliteal disease, surgical bypass remains a cornerstone therapy, providing durable perfusion and meaningful limb preservation in a population otherwise at high risk for major amputation [31,36,44,46].

Comparison With Endovascular Therapy

Endovascular therapy has advanced significantly over the last decade, offering less invasive treatment options for CLTI; however, its performance in TASC II D femoropopliteal disease remains limited by lesion complexity, calcification, and multilevel occlusions. Studies consistently show that long-segment chronic total occlusions, particularly those exceeding 20–30 cm, have lower long-term patency rates after angioplasty or stenting compared with bypass. While modern technologies—such as drug-coated balloons, atherectomy systems, and covered stents—have improved early outcomes, durability remains inferior to autologous vein bypass in complex lesions. Endovascular interventions often require frequent reinterventions, increasing cumulative risk and cost, and these limitations become more pronounced in patients with poor tibial runoff or advanced calcification characteristic of TASC II D patterns [47–49].

Randomized trials provide key insights into the comparative performance of surgical and endovascular strategies. The BASIL trial demonstrated that an angioplasty-first strategy resulted in similar early outcomes to bypass, but among patients surviving beyond two years, vein bypass was associated with superior amputation-free survival and overall survival. More recent data from the BEST-CLI trial confirmed these findings in a contemporary cohort: in patients with adequate great saphenous vein, bypass significantly outperformed endovascular therapy in terms of major adverse limb events and need for reintervention. These results underscore that, while endovascular therapy may be reasonable for high-risk or conduit-poor patients, it is generally less durable in the context of extensive disease requiring long-term limb preservation [4,6,18,50].

Despite these differences, endovascular therapy remains valuable for selected CLTI patients, especially those with limited life expectancy, high operative risk, or inadequate vein conduit. Minimally invasive approaches may provide meaningful symptom relief and short-term limb salvage while avoiding the physiological stress of major surgery. Additionally, endovascular techniques often serve as a first-line option in patients with favorable anatomic characteristics or in those requiring rapid revascularization for limb-threatening infection. However, for durable outcomes in anatomically severe disease, especially in younger or intermediate-risk patients, surgical bypass continues to demonstrate superiority. Thus, treatment selection must balance patient-specific risk, conduit availability, anatomical complexity, and the anticipated need for long-term durability

[18,45,46,49–51].

Comparison With Hybrid Revascularization

Hybrid revascularization has emerged as an important alternative for multilevel arterial disease, integrating open surgical inflow correction with endovascular treatment of downstream lesions. For patients with TASC II D femoropopliteal disease, hybrid approaches can effectively address both inflow and outflow pathology within the same procedure, often with reduced physiological stress compared to full-length bypass surgery. This makes hybrid repair particularly appealing for individuals with significant comorbidities or hostile surgical fields, such as prior groin incisions, obesity, or active infection. Several studies have shown that hybrid procedures can achieve limb-salvage and perioperative mortality rates comparable to surgical bypass while offering shorter hospital stays and fewer wound-related complications, especially when common femoral endarterectomy is combined with femoropopliteal endovascular therapy [52–54].

However, the durability of hybrid revascularization can be limited by the longevity of its endovascular components, particularly in the femoropopliteal and tibial segments where restenosis is more common. While surgical correction of inflow disease provides a strong foundation, long-segment femoropopliteal stenting or angioplasty is more susceptible to late failure compared with autologous vein bypass. Covered stents and drug-coated balloons have improved outcomes, but patency rates still generally lag behind those achieved with single-segment saphenous vein grafts. Studies comparing hybrid repair to vein bypass report higher reintervention rates in hybrid cohorts, reflecting the progressive nature of distal disease and the mechanical stresses imposed on stented segments. These differences become especially pronounced over long-term follow-up, reinforcing bypass as the more durable option for anatomically extensive TASC II D disease in physiologically suitable individuals [55–57].

Hybrid revascularization nevertheless fills a crucial role in modern CLTI management by providing a tailored, less invasive alternative for patients who may not tolerate bypass or lack adequate vein conduit. It is particularly effective in patients requiring inflow correction at the common femoral artery or those with discrete femoropopliteal lesions amenable to endovascular treatment. The choice between bypass and hybrid repair ultimately depends on conduit availability, patient risk profile, anatomic distribution of disease, and expected long-term durability. In younger patients with long life expectancy and suitable vein, bypass remains the preferred option. In contrast, hybrid approaches provide a valuable, adaptable strategy for high-risk individuals requiring limb salvage but unable to withstand more extensive open surgery [52–56].

Complications of Surgical Bypass

Surgical bypass for TASC II D femoropopliteal disease, while effective, carries a complication profile that reflects both the invasiveness of the procedure and the comorbidity burden characteristic of CLTI patients. Wound complications are among the most common adverse events, particularly in the groin where inflow anastomosis and vein harvest incisions converge. Groin infections, seromas, lymphatic leaks, and wound dehiscence can significantly increase morbidity, prolong hospitalization, and jeopardize graft integrity. Patients with diabetes, renal failure, obesity, and severe tissue edema are at heightened risk for these complications. Strategies to mitigate wound issues include meticulous surgical technique, careful lymphatic handling, limited dissection when feasible, and selective use of prophylactic negative-pressure wound therapy, all of which have been associated with improved healing and fewer reoperations [58,59].

Graft infection represents one of the most serious complications following surgical bypass, particularly when prosthetic material is used. Prosthetic graft infections carry high rates of limb loss and mortality due to the potential for rapid bacterial colonization, exposure, and sepsis. Autologous vein grafts have markedly lower infection rates and are therefore strongly preferred, especially in contaminated or high-risk fields. When infection does occur, management may include graft excision, extra-anatomic bypass, or aggressive debridement combined with long-term antibiotic therapy. Preventive measures such as perioperative antibiotic prophylaxis, minimizing prosthetic exposure, and avoiding groin incisions in infected or heavily colonized tissue are essential to reducing the risk of this potentially catastrophic complication [60,61].

Early graft thrombosis is another important complication that can threaten limb viability. It is often related to technical errors, poor-quality conduit, inadequate inflow or outflow, or unrecognized distal vessel disease. Early thrombosis typically presents within the first 30 days and requires urgent reintervention—either surgical thrombectomy, revision of inflow or outflow anastomoses, or endovascular intervention such as catheter-directed thrombolysis. Surveillance with early postoperative duplex ultrasound can detect flow-limiting lesions before thrombosis occurs, emphasizing the importance of structured follow-up protocols. Despite these risks, the majority of graft failures are preventable with meticulous operative technique, appropriate patient optimization, and rigorous postoperative monitoring, contributing to the overall strong performance of bypass surgery in complex CLTI [43,44,57,59].

Conclusion

Surgical bypass remains a cornerstone of revascularization for patients with chronic limb-threatening ischemia due to TASC II D femoropopliteal disease, offering a level of durability and hemodynamic restoration unmatched by other modalities. In an era of rapidly advancing endovascular technologies, bypass surgery continues to provide the most reliable long-term patency and limb-salvage outcomes, particularly when high-quality autologous vein conduit is available. Its ability to bypass long, heavily calcified occlusions and restore robust distal flow positions it as the preferred strategy for anatomically severe disease in patients with reasonable life expectancy and adequate physiologic reserve.

The success of bypass surgery hinges on thoughtful patient selection, meticulous conduit choice, and precise inflow–outflow planning. Autologous vein remains the superior conduit, especially for below-knee and tibial targets, where its biological adaptability and resistance to infection confer significant advantages. Modern anatomical frameworks and perioperative optimization protocols have further refined treatment selection, allowing clinicians to match bypass strategies to individual patient characteristics and disease patterns. These refinements ensure that bypass continues to deliver strong results even in patients with complex multilevel arterial disease.

Although complications such as wound issues, graft infection, and early thrombosis remain concerns, advances in operative technique, postoperative surveillance, and multidisciplinary care have significantly improved safety and long-term durability. When complications do arise, prompt reintervention—either surgical or endovascular—can salvage grafts and preserve limb function in many cases. Comparative evidence consistently shows that, for patients with available vein conduit and sufficient longevity to benefit from long-term durability, bypass outperforms both endovascular and hybrid strategies in anatomically extensive femoropopliteal disease.

Looking forward, surgical bypass is expected to remain integral to CLTI management, even as endovascular options continue to evolve. Innovations in conduit technology, imaging, and precision risk stratification will further refine its role, ensuring that patients with the most complex arterial occlusions continue to receive tailored, durable, and effective revascularization. As part of a modern, patient-centered approach, surgical bypass retains its place as a vital therapy capable of restoring perfusion, promoting wound healing, and preventing major amputation in those facing advanced femoropopliteal disease.

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