

Hybrid Revascularization for TASC II D Femoropopliteal Disease: Contemporary Outcomes and Evolving Strategies in Critical Limb-Threatening Ischemia

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Received: 13 March 2024, **Accepted:** 17 April 2024, **Published:** 20 May 2024

ABSTRACT

Background: Critical limb-threatening ischemia (CLTI) is the most advanced manifestation of peripheral arterial disease and is associated with significant morbidity, mortality, and risk of major amputation. Among patients with CLTI, TASC II D femoropopliteal lesions represent the most complex anatomic subset, characterized by long-segment occlusions, heavy calcification, and frequent multilevel involvement. These lesion characteristics have historically made open surgical bypass the preferred revascularization method due to its durability. However, the past decade has witnessed rapid advancement in endovascular technologies and the increasing adoption of hybrid strategies that combine open and endovascular interventions in a single setting. Hybrid revascularization has emerged as a viable and often preferred option in anatomically complex or physiologically fragile patients, particularly when inflow or outflow optimization is required to achieve durable patency and limb salvage. The aim of this review is to synthesize the current evidence regarding hybrid revascularization for TASC II D femoropopliteal disease in CLTI, emphasizing patient selection, technical approaches, clinical outcomes, and evolving innovations. Despite the increasing use of hybrid procedures, there remains a lack of consolidated literature evaluating their relative effectiveness compared with pure endovascular interventions and traditional open bypass surgery. This review addresses that gap by examining contemporary studies, device developments, and outcome registries that report on patency, limb-salvage rates, perioperative risk, and long-term durability. Hybrid techniques offer theoretical and practical advantages, including improved inflow through common femoral endarterectomy, enhanced outflow through tibial interventions, and the ability to treat multilevel disease with reduced physiological stress compared with full open surgery. Early and mid-term outcomes have demonstrated promising patency rates, acceptable complication profiles, and favorable limb-salvage results in properly selected patients. However, challenges remain, including restenosis, wound complications at surgical access sites, operator-dependent variability, and limited long-term comparative data. This review concludes that hybrid procedures represent a pivotal evolution in the management of TASC II D femoropopliteal disease, offering a balanced approach for advanced CLTI patients who require both durability and reduced surgical morbidity. Continued research, prospective trials, and device innovation are essential to refine patient selection algorithms, optimize technical strategies, and determine the long-term role of hybrid revascularization within contemporary CLTI management paradigms.

Keywords: *Hybrid Revascularization, TASC II D Femoropopliteal Disease, Contemporary Outcomes, Critical Limb-Threatening Ischemia*

INTRODUCTION

Critical limb-threatening ischemia (CLTI) represents the most severe stage of peripheral arterial disease and is associated with high rates of major amputation, cardiovascular death, and diminished quality of life. The Global Vascular Guidelines emphasize the need for timely, durable revascularization to restore perfusion, particularly in patients presenting with tissue loss or rest pain. Femoropopliteal disease is especially complex in CLTI due to multilevel involvement, long critical occlusions, severe calcification, and impaired microvascular reserve. These anatomical and physiological challenges highlight the importance of individualized revascularization strategies aimed at maximizing limb salvage and functional outcomes [1,2].

TASC II D femoropopliteal lesions represent the most challenging anatomic category, typically defined as critical total occlusions exceeding 20 cm, frequently involving multiple arterial segments and often extending into the popliteal artery. Historically, TASC II recommendations favored open surgical bypass as the gold standard for such complex lesions due to its superior long-term patency in comparison with earlier-generation endovascular therapies. However, advances in endovascular technology—including drug-coated balloons, covered stents, intravascular imaging, and atherectomy devices—have substantially expanded the therapeutic landscape. These developments have sparked increasing interest in hybrid revascularization, which combines targeted open surgical interventions with advanced endovascular techniques to address multilevel disease within the same procedure [3,4]. There remains a notable research gap regarding the comparative effectiveness of hybrid procedures specifically for TASC II D lesions in CLTI. While registries and institutional series suggest favorable perioperative outcomes and promising limb-salvage rates, high-level evidence directly contrasting hybrid strategies with pure endovascular treatment or conventional open bypass remains limited. Furthermore, patient selection criteria, optimal technical sequencing, and inflow–outflow optimization strategies vary considerably among institutions. The aim of this review is to analyze contemporary evidence surrounding hybrid revascularization for TASC II D femoropopliteal disease, highlighting clinical outcomes, technical considerations, and evolving device innovations, while identifying areas where future research is required to guide standardized best practice [2–5].

Pathophysiology and Anatomical Complexity of TASC II D Lesions

TASC II D femoropopliteal lesions represent the highest grade of complexity within the TASC II classification, generally involving long critical total occlusions (CTOs) often extending from the superficial femoral artery (SFA) to the proximal or mid-popliteal segment. These lesions are frequently

multilevel and associated with significant calcific burden, which affects luminal compliance and makes wire crossing, balloon expansion, and stent deployment technically challenging. In addition, occlusions in TASC II D disease often reflect longstanding atherosclerotic progression, producing dense fibrotic caps and intraluminal thrombotic material that further complicate endovascular recanalization. The interplay between calcification, length, criticality, and vessel tortuosity forms the core pathophysiologic basis underlying procedural complexity in these patients [6,7].

An essential component of the pathophysiology is the impaired hemodynamic reserve observed in advanced femoropopliteal disease. Long-segment occlusions significantly reduce collateral circulation, and in many CLTI patients, tibial runoff is simultaneously compromised by extensive infrapopliteal disease. Poor distal runoff is strongly linked to lower patency and higher failure rates following both open and endovascular interventions, which is particularly relevant in TASC II D lesions where multilevel involvement is the rule rather than the exception. Furthermore, critical ischemia at the microvascular level contributes to endothelial dysfunction, decreased capillary density, and impaired tissue oxygen diffusion, limiting the limb's ability to recover even after successful revascularization [8,9].

The anatomical complexity is further influenced by biomechanical stresses along the femoropopliteal segment, especially around the adductor canal and popliteal artery, where torsion, flexion, and compression forces are pronounced during knee motion. These forces predispose the vessel—and any implanted stent—to deformation, fatigue, and restenosis. The dynamic loading environment contributes to accelerated neointimal hyperplasia following intervention and remains a significant factor in the variable durability of endovascular treatments in long, complex lesions. The combination of mechanical stress, plaque morphology, and multilevel arterial insufficiency explains why hybrid strategies often target both inflow and outflow to maximize long-term perfusion and procedural success [7,10].

Evolution of Hybrid Revascularization Techniques

Hybrid revascularization techniques emerged as a response to the limitations of isolated open or endovascular strategies in managing complex multilevel arterial disease, especially in patients with CLTI. Early experience in the late 1990s and early 2000s demonstrated that combining common femoral endarterectomy (CFE) with iliac or femoropopliteal endovascular interventions could achieve hemodynamic improvements superior to either modality alone. This approach offered the advantage of surgically restoring durable inflow while simultaneously addressing more distal lesions with less physiological stress. As endovascular tools became more advanced and reliable, hybrid procedures gained traction as an integrated solution capable of treating anatomically extensive disease in a single operative setting [11,12].

The evolution of these techniques accelerated with improvements in endovascular imaging, guidewire technology, drug-coated balloons, and nitinol stents, enabling more predictable success in crossing and treating long-segment occlusions. Hybrid strategies evolved from simple inflow correction combined with angioplasty to more sophisticated combinations, including sequential multi-level endovascular treatment, adjunctive atherectomy, and the use of covered stents to improve patency in long femoropopliteal lesions. The technical shift mirrored a broader paradigm change in vascular surgery, with surgeons increasingly expected to integrate open and endovascular skills. Consequently, hybrid operating suites were developed to support both modalities in a single environment, optimizing workflow and patient safety [13,14].

In addition to technological advancements, the indications for hybrid revascularization expanded as evidence accumulated demonstrating its value in high-risk surgical candidates. Studies showed that physiologically fragile patients—who might not tolerate extensive open procedures—experienced improved outcomes when treated with hybrid combinations involving limited incisions and shorter operative times. This has been particularly impactful in the elderly, those with severe cardiopulmonary comorbidities, and individuals with renal dysfunction or diabetes, who often compose a large proportion of the CLTI population. Hybrid approaches therefore emerged not only as a technical innovation but also as a strategy aligned with the principles of individualized, risk-adapted revascularization emphasized in contemporary guidelines [15,16].

Patient Selection for Hybrid Interventions

Optimal patient selection is critical to the success of hybrid revascularization, particularly in the setting of TASC II D femoropopliteal disease where both anatomical complexity and clinical severity dictate individualized treatment strategies. Hybrid procedures are most frequently selected in patients with multilevel disease involving both inflow and outflow segments, where open correction of critical inflow pathology—such as common femoral artery stenosis or occlusion—is necessary to provide durable perfusion. Endovascular treatment of downstream femoropopliteal and tibial segments can then be performed with reduced physiological burden. Current guidelines emphasize tailoring revascularization based on anatomical complexity, hemodynamic status, and patient-specific risk factors, making hybrid procedures particularly appealing in anatomically extensive CLTI cases [17,18].

Comorbidity burden remains a major determinant when choosing between hybrid, purely open, or purely endovascular approaches. Patients with significant cardiac disease, critical obstructive pulmonary disease, advanced age, or renal impairment often face elevated perioperative risk from prolonged open bypass surgery. Hybrid revascularization offers an opportunity to minimize surgical trauma through limited incisions and shorter operative times. Evidence from large observational cohorts shows that hybrid-treated patients often represent higher-risk groups who would otherwise

have limited options for durable limb salvage. Despite these challenges, studies consistently report acceptable perioperative morbidity and mortality in hybrid-treated CLTI populations, suggesting that these patients may benefit from the balance between durability and reduced physiological stress [19,20].

Runoff quality and infra-popliteal involvement also play a pivotal role in selecting candidates for hybrid interventions. Many TASC II D lesions coexist with below-the-knee disease, which strongly influences patency and limb-salvage outcomes. Hybrid strategies allow for targeted endovascular treatment of tibial vessels concurrently with open inflow procedures, thus optimizing both proximal and distal hemodynamics in a single session. Patients with heavy calcification, poor tibial runoff, or compromised distal microcirculation often require such combined approaches to ensure adequate perfusion restoration. Therefore, selection criteria incorporate lesion severity, distal target quality, and anticipated durability, reinforcing the value of hybrid procedures in patients with advanced multilevel disease where a single-modality strategy may be insufficient [21,22].

Technical Approaches in Hybrid Femoropopliteal Revascularization

Hybrid femoropopliteal revascularization combines open surgical correction of critical inflow disease with endovascular treatment of downstream occlusions, creating a comprehensive multilevel strategy tailored to the complexity of TASC II D lesions. A foundational component involves common femoral endarterectomy (CFE), which restores durable inflow and provides an optimal platform for subsequent endovascular intervention. Through the same groin incision, the surgeon gains arterial access for guidewire introduction, allowing seamless transition between open and endovascular phases. This integrated workflow eliminates the need for multiple staged procedures and reduces exposure to contrast and anesthesia. The approach is particularly suited for long-segment femoropopliteal occlusions, where restoring inflow is essential for achieving adequate distal perfusion and long-term patency [23,24].

There are several technical variations in hybrid procedures, including open-first and endovascular-first sequences. Inflow-first strategies are commonly employed when CFE is required for heavily diseased or occluded common femoral arteries. After plaque removal, retrograde or antegrade access is obtained to treat femoropopliteal occlusions with angioplasty, drug-coated balloons, or stent placement depending on disease morphology. In certain cases, endovascular-first sequencing is favored, particularly when remote access through the radial or contralateral femoral artery is used to cross a challenging occlusion before exposing the groin. This approach minimizes operative time and reduces the risk of embolization during open dissection. Choice of sequencing depends on plaque morphology, lesion crossing predictability, and surgeon expertise, emphasizing the individualized nature of hybrid interventions [25,26].

Adjunctive techniques enhance the versatility of hybrid revascularization. Atherectomy devices may be used to debulk heavily calcified or resistant plaque, improving luminal gain and stent expansion. Covered stents, such as heparin-bonded endoprotheses, have demonstrated improved patency in long-segment femoropopliteal disease and are increasingly incorporated into hybrid strategies when adequate landing zones are available. Tibial and pedal artery interventions are frequently performed in the same session to optimize outflow, especially in CLTI patients with poor tibial runoff. Advanced imaging guidance, including IVUS, enables accurate assessment of vessel sizing and lesion morphology, further refining technical decision-making. Collectively, these interventional tools enhance the precision, efficacy, and adaptability of hybrid procedures in addressing extensive multilevel disease [27,28].

Inflow Procedures Combined with Endovascular Repair

Common femoral endarterectomy (CFE) remains the cornerstone inflow procedure in hybrid revascularization, particularly for patients with severe common femoral artery (CFA) stenosis or occlusion accompanying TASC II D femoropopliteal disease. CFE provides durable inflow restoration by removing heavily calcified plaque that is not amenable to endovascular therapy, and its long-term patency rates consistently exceed those of stenting in this segment. By re-establishing robust inflow, CFE enhances the hemodynamic success of downstream endovascular interventions and reduces the risk of early restenosis or graft failure. Contemporary studies demonstrate that combining CFE with femoropopliteal angioplasty or stenting leads to excellent limb-salvage outcomes in CLTI, underscoring why this hybrid approach is preferred in the presence of complex multilevel disease [29,30].

Another essential inflow strategy within hybrid procedures involves iliac artery reconstruction, particularly when proximal disease contributes to impaired perfusion. Balloon angioplasty, bare-metal stents, or covered stents may be deployed to treat common or external iliac artery stenosis, often through the same access used for femoral exposure. Iliac disease frequently coexists with long-segment femoropopliteal occlusions, and failure to correct proximal inflow can compromise the durability of distal interventions. Evidence shows that treating both inflow and outflow in a single hybrid setting increases overall procedural success and reduces the need for reintervention. Combining iliac repair with CFE and subsequent femoropopliteal intervention provides a comprehensive multilevel reconstruction that improves limb salvage in high-risk CLTI patients [31,32].

Beyond morphological correction, inflow optimization also improves technical feasibility during endovascular portions of hybrid procedures. Adequate proximal flow enhances guidewire navigation, reduces catheter instability, and facilitates controlled device deployment, particularly in long or calcified occlusions. Furthermore, restored inflow reduces hemodynamic turbulence and shear stress, mitigating the risk of distal embolization during intervention. The synergy between open inflow repair

and endovascular outflow treatment results in improved perfusion pressure gradients, promoting better wound healing and tissue oxygenation in ischemic limbs. This integrative approach is especially beneficial in TASC II D lesions, where both proximal and distal arterial segments are compromised, necessitating a holistic revascularization strategy to achieve optimal outcomes [33,34].

Outflow Optimization and Distal Interventions

Outflow optimization constitutes a central component of successful hybrid revascularization, particularly in CLTI patients with TASC II D femoropopliteal disease where multilevel occlusive pathology frequently extends into the tibial and pedal arteries. Poor tibial runoff is one of the strongest predictors of procedural failure and diminished patency following both open and endovascular interventions. Hybrid procedures allow surgeons to combine open inflow correction with targeted endovascular treatment of tibial arteries—often using balloon angioplasty or atherectomy—to restore at least one straight-line flow to the foot. Achieving robust distal perfusion is essential for wound healing, minimizing ischemic pain, and improving limb-salvage rates in patients with advanced tissue loss [35,36].

Endovascular tibial interventions in hybrid procedures are facilitated by improved proximal hemodynamics after inflow correction, enabling better wire control, vessel visualization, and balloon expansion. Techniques such as pedal loop reconstruction, multi-vessel tibial angioplasty, or retrograde pedal access may be employed when antegrade crossing is not feasible. Several studies have demonstrated that aggressive outflow optimization performed concurrently with inflow repair leads to superior outcomes compared with treating femoropopliteal disease alone, particularly in those with severe tissue loss or infection. By addressing both proximal inflow and distal outflow in the same session, hybrid strategies yield improved hemodynamic recovery and reduce the likelihood of early restenosis or occlusive failure [37,38].

The importance of outflow optimization extends beyond immediate procedural success and significantly influences long-term durability. Tibial disease is often associated with diabetes, renal dysfunction, and heavy medial arterial calcification, all of which contribute to higher restenosis rates. The hybrid approach enables focused treatment of these calcified distal vessels using adjunctive tools such as low-profile balloons, specialty scoring balloons, or atherectomy systems adapted for infrapopliteal arteries. When combined with durable inflow repair, these strategies enhance limb-salvage potential while minimizing the need for staged or repeated procedures. Sustained outflow patency correlates strongly with wound healing and amputation-free survival, reinforcing its role as a key determinant in the overall success of hybrid revascularization for CLTI [39,40].

Perioperative management plays a crucial role in the success of hybrid revascularization for TASC II D femoropopliteal disease, with hemodynamic stability, antithrombotic therapy, and optimized

cardiovascular status forming the foundation of good outcomes. CLTI patients typically exhibit a high burden of comorbidities—including diabetes, renal insufficiency, and coronary artery disease—that predispose them to perioperative complications. Preoperative evaluation includes cardiac risk assessment, renal function optimization, infection control, and glycemic management to minimize postoperative morbidity. Contemporary vascular guidelines emphasize individualizing perioperative planning based on physiological risk and anatomical disease distribution, underscoring the need for multidisciplinary care in hybrid intervention candidates [41,42].

Antiplatelet and anticoagulation strategies are essential to maintain vessel patency during and after hybrid procedures. Intraoperative systemic heparinization is routinely administered to prevent thrombotic events, particularly when transitioning between open and endovascular phases. Postoperatively, dual antiplatelet therapy (DAPT) is commonly employed following stent placement, typically consisting of aspirin and a P2Y₁₂ inhibitor for a defined duration depending on the devices used and patient bleeding risk. Drug-coated balloon (DCB) interventions may require shorter courses of DAPT, while covered stents generally mandate longer regimens. Evidence suggests that adherence to optimized antithrombotic protocols significantly reduces early restenosis and enhances long-term patency, especially in complex multilevel reconstructions [43,44].

Hemodynamic monitoring and perfusion optimization extend into the postoperative period, where maintaining adequate distal flow is vital for limb salvage and wound healing. Immediate postoperative duplex ultrasound or angiography may be used to confirm technical success and identify residual stenosis, dissection, or flow-limiting lesions requiring revision. Blood pressure control is essential to avoid excessive hypertension that can compromise suture lines or endarterectomy sites, as well as hypotension that may jeopardize distal perfusion. Adequate hydration and renal protection strategies are implemented to mitigate contrast-induced nephropathy, which is particularly relevant for CLTI patients who frequently have critical kidney disease. Close surveillance in the early postoperative phase allows timely identification of complications such as access-site bleeding, thrombosis, or distal embolization, directly influencing short- and long-term procedural success [45,46].

Clinical Outcomes of Hybrid Revascularization

Clinical outcomes of hybrid revascularization for TASC II D femoropopliteal disease have consistently demonstrated promising results, particularly in high-risk CLTI patients who may not tolerate extensive open surgery. Early studies reported technical success rates exceeding 90%, with significant improvements in ankle-brachial index (ABI) and relief of ischemic symptoms. Contemporary series show primary patency rates ranging from 65% to 80% at one year, depending on tibial runoff status, lesion severity, and device selection. Importantly, hybrid procedures achieve limb-salvage rates of 80–90% in most CLTI cohorts, outcomes that compare favorably with both open bypass and endovascular-

only strategies in similar anatomical contexts. These findings highlight the value of hybrid therapy in achieving competitive durability while minimizing operative stress [47,48].

Long-term outcomes show that secondary patency rates after hybrid revascularization remain robust, often exceeding 85% at three years when inflow is surgically optimized and outflow interventions are performed adequately. A key advantage of hybrid procedures is the ability to correct multilevel disease that would otherwise require staged or repeated procedures. This integrated approach reduces the cumulative risk of restenosis and occlusion by stabilizing hemodynamics across the entire limb. Studies demonstrate that durability improves further when covered stents or drug-coated technologies are used in the femoropopliteal segment, particularly in long-segment occlusions typical of TASC II D lesions. These results underscore how modern device evolution has synergized with hybrid techniques to enhance mid- and long-term outcomes [49,50].

Despite favorable patency and limb-salvage outcomes, reintervention remains common in CLTI patients due to the progressive nature of atherosclerosis and the complexity of multilevel disease. Reported reintervention rates range from 20% to 35% within the first two years, largely driven by restenosis in tibial or femoropopliteal segments. Nevertheless, most reinterventions can be performed endovascularly, preserving the initial hybrid reconstruction and maintaining limb salvage. Importantly, perioperative mortality for hybrid procedures remains low—typically 1% to 3%—despite the high comorbidity burden in treated populations. These results collectively indicate that hybrid revascularization offers an effective balance of safety, durability, and anatomical versatility, positioning it as a valuable strategy in managing complex TASC II D CLTI [51,52].

Complication Profile and Risk Mitigation

Complications in hybrid revascularization for TASC II D femoropopliteal disease arise from both the open and endovascular components, making comprehensive risk assessment essential. Access-related issues such as hematoma, pseudoaneurysm, and arterial dissection remain among the most common adverse events, particularly at the common femoral artery, where surgical exposure and percutaneous manipulation often occur simultaneously. The presence of heavy calcification characteristic of CLTI patients increases the difficulty of vascular closure and predisposes to bleeding or vessel trauma. Large series have reported access-site complication rates of 5–10%, comparable to isolated open or endovascular procedures, but vigilance is crucial given the fragility of this patient population. Ensuring meticulous surgical technique and appropriate sheath selection remains central to minimizing these risks [53,54].

Restenosis and thrombosis represent significant medium- and long-term complications following hybrid femoropopliteal interventions. The combination of biomechanical forces in the adductor canal, plaque morphology, and multilevel involvement predisposes patients to intimal hyperplasia, leading to progressive luminal narrowing. Tibial vessels, often treated in the same hybrid session, are particularly

prone to restenosis due to small caliber and calcification. Surveillance with duplex ultrasound enables early detection of flow abnormalities and timely reintervention, which has been shown to improve secondary patency and limb salvage. Pharmacologic optimization—particularly adherence to antiplatelet therapy—also plays a key role in reducing restenosis risk, as demonstrated in multiple CLTI cohorts [55,56].

Surgical-site complications such as wound infection, lymphatic leak, or seroma may occur at the groin incision used for common femoral endarterectomy. These complications are more common in diabetic or obese patients and those with tissue edema from advanced ischemia. Deep groin infections, though infrequent, carry significant morbidity and may jeopardize inflow repair. Risk mitigation strategies include meticulous dissection, limited incision size, prophylactic antibiotics, and careful lymphatic control. Some centers have adopted minimally disruptive techniques or adjunctive negative-pressure wound therapy to reduce wound-related complications. Overall, while complication risk is real, outcomes remain favorable when hybrid procedures are performed in specialized vascular centers with robust perioperative protocols and structured surveillance programs [57,58].

Hybrid vs Pure Endovascular Approaches

Pure endovascular approaches have evolved considerably over the past decade, offering minimally invasive options for high-risk CLTI patients. However, in TASC II D femoropopliteal disease, purely endovascular techniques may be limited by heavy calcification, long-segment occlusions, and the frequent need for durable inflow correction. Multiple studies show that endovascular-only interventions in such complex lesions result in lower primary patency and higher reintervention rates compared with less complex disease patterns. Although advancements such as drug-coated balloons, atherectomy devices, and covered stents have improved technical success, these modalities cannot fully compensate for the hemodynamic benefits achieved through surgical inflow repair. Consequently, hybrid approaches often outperform pure endovascular methods in anatomically extensive disease where mixed morphology requires both structural and luminal correction [59,60].

When comparing clinical outcomes, hybrid procedures have demonstrated superior limb-salvage rates and longer patency in patients with multilevel disease requiring inflow correction. Pure endovascular interventions frequently fail to adequately treat common femoral artery lesions, which are best managed surgically because stenting in this segment carries increased risks of stent fracture and occlusion due to flexion forces. Hybrid procedures circumvent this challenge by performing common femoral endarterectomy while simultaneously addressing distal lesions endovascularly. Evidence from observational studies and meta-analyses shows that hybrid procedures yield patency rates equivalent to or better than endovascular-only approaches, with significant reductions in procedural failure linked to untreated inflow disease [61,62].

Despite these advantages, pure endovascular treatment retains an important role in selected CLTI patients, particularly those with prohibitive surgical risk or limited life expectancy. Pure endovascular approaches are associated with shorter hospital stays, reduced physiological stress, and fewer wound-related complications—an important consideration in frail patients. However, when anatomy is unfavorable or long-term durability is prioritized, hybrid revascularization provides a balanced solution that leverages the strengths of both modalities. The prevailing evidence suggests that for TASC II D lesions requiring robust inflow-outflow optimization, hybrid techniques offer a clear advantage in durability, limb salvage, and overall procedural success, reinforcing their growing role in contemporary vascular practice [63,64].

Hybrid vs Open Bypass in TASC II D Disease

Hybrid revascularization and open surgical bypass represent two complementary strategies for managing TASC II D femoropopliteal disease in CLTI, with choice driven by anatomy, conduit availability, and patient risk profile. Historically, autologous vein bypass has been considered the most durable option for long, complex femoropopliteal occlusions, a view supported by randomized data such as the BASIL trial and subsequent meta-analyses showing superior late outcomes of bypass in patients surviving beyond two years compared with a balloon-angioplasty-first strategy [18,65]. However, many CLTI patients present with significant comorbidities, limited conduit, or hostile groins, making full-length bypass less attractive. Hybrid procedures aim to bridge this gap by combining durable inflow correction—most often with common femoral endarterectomy—with less invasive endovascular treatment of long femoropopliteal segments, thereby reducing operative trauma while preserving satisfactory patency and limb-salvage potential [14,52,66].

Comparative studies evaluating hybrid procedures against traditional bypass in multilevel infrainguinal disease suggest broadly similar early limb-salvage and survival outcomes, with some series reporting shorter hospital stay and fewer major wound complications in the hybrid cohorts. Propensity-matched analyses of large databases have shown that hybrid CFE plus endovascular therapy can achieve perioperative mortality and systemic complication rates comparable to vein bypass, while often reducing deep surgical-site infection and reoperation for wound issues, particularly when prosthetic grafts would otherwise be required [22,38,67]. At the same time, autologous vein bypass continues to demonstrate superior long-term patency in carefully selected patients with good distal targets and reasonable life expectancy, particularly in more diffuse GLASS III–IV or TASC II D patterns where extensive stenting would be required [11,18,69]. Thus, current evidence supports a nuanced, anatomy- and risk-based approach: hybrid revascularization is especially advantageous in high-risk patients with multilevel disease and inflow lesions requiring CFE, whereas open bypass remains the benchmark for younger, fitter patients with good conduit and long projected survival. [14,18,22,38,65–69]

Conclusion

Hybrid revascularization has established itself as a central strategy in the management of TASC II D femoropopliteal disease, offering a balanced approach that leverages the durability of open surgery and the minimally invasive benefits of endovascular therapy. By combining surgical inflow restoration—most commonly through common femoral endarterectomy—with targeted endovascular treatment of long femoropopliteal and tibial occlusions, hybrid procedures provide comprehensive multilevel revascularization in a single operative setting. This synergistic approach addresses the complex anatomical and hemodynamic challenges inherent to CLTI, improving perfusion, enhancing wound healing, and supporting high limb-salvage rates while reducing overall physiological stress.

The evolution of endovascular technologies, including drug-coated devices, covered stents, atherectomy systems, and advanced imaging tools, has further strengthened the performance and durability of hybrid interventions. These advances have expanded the suitability of hybrid procedures to more anatomically complex lesions that previously required open bypass alone. Nevertheless, hybrid revascularization is not intended to replace open surgery outright; rather, it offers an adaptable middle ground for patients who lack optimal surgical fitness, have limited conduit, or present with multilevel disease patterns poorly suited to a single-modality intervention. As a result, hybrid therapy fits naturally into contemporary decision-making frameworks that emphasize patient-specific risk, anatomical severity, and expected long-term benefit.

Looking ahead, the continued integration of technological innovation with refined patient-selection models will further strengthen hybrid approaches in CLTI management. Future prospective comparative trials, improved surveillance strategies, and deeper understanding of restenosis mechanisms will help define the precise role of hybrid therapy relative to evolving endovascular and open surgical techniques. With rising global rates of diabetes, renal disease, and advanced PAD, hybrid revascularization is poised to remain a cornerstone of lower-extremity limb-preservation strategies. Its ability to combine durability, flexibility, and reduced perioperative risk makes it a highly valuable approach for achieving optimal outcomes in patients with the most challenging femoropopliteal disease profiles.

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