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RESEARCH ARTICLE

# Comparative Review of Surgical vs. Endovascular Revascularization for Complex Long-Segment Peripheral Arterial Lesions: A Focus on High-Risk Presentations

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**Abstract:** Managing long lesions, especially in peripheral arterial disease, represent a significant clinical challenge in the term of revascularization strategies. Surgical bypass and endovascular therapy (EVT) remain the most important revascularization modalities. With its minimal invasive nature, EVT provides shorter recovery time and lesser perioperative risk, yet it exhibits higher rates of re-stenosis and re-intervention, particularly in lesions longer than 15 cm. Conversely, as surgical bypass is considered being more invasive, it provides superior long-term patency and durability in complex arterial disease. The new advancements like intravascular imaging, drug-coated devices and hybrid procedures are reducing the gap between the two techniques. This review analysis patient-specific factors, safety, efficacy, outcomes and of both surgical and endovascular revascularization and highlighting the ongoing advancement that support a precision medicine approach for managing long arterial lesions.

**Keywords:** Endovascular revascularization; Peripheral arterial disease; Surgery.

## INTRODUCTION

Worldwide, Peripheral arterial disease (PAD) is a major public health issue due to its high risk of death and morbidity, which is linked to cardiovascular disease and adverse limb events [1], particularly impacting elderly and diabetic populations. PAD frequently requires re-interventions after lower extremity revascularization to maintain perfusion [2,3]. Individual evaluation of comorbidities, clinical presentation, and vascular anatomy is necessary for the medical management of individuals with PAD [4]. Long-segment lesions, often located in the femoropopliteal or infrapopliteal regions and often involve chronic total occlusions and multilevel stenoses, have traditionally been managed with surgical bypass. With the evolution of Endovascular therapy, treatment paradigms are shifting [5-7] .

### Endovascular therapy (EVT)

EVT encompasses a broad range of minimally invasive techniques aimed at restoring blood flow in occluded or stenotic peripheral arteries. These approaches include bare-metal stents (BMS), covered stents, sirolimus-coated stents, drug-coated balloons (DCBs), atherectomy devices, and bioresorbable scaffolds offers less invasive treatment, quicker recovery, and has shown increasing durability in the prospective outcomes for patients with PAD [8-12]. Balloon angioplasty remains a fundamental part of EVT. It can involve plain balloon angioplasty (POBA) or drug-coated balloons (DCBs). DCBs deliver anti-proliferative agents (e.g. paclitaxel) directly to the arterial wall to prevent neointimal hyperplasia and decrease the re-stenosis. Several randomized controlled trials (RCTs) have demonstrated that DCBs like Viabahn Endoprosthesis offer superior primary patency rates compared to POBA, particularly in short to intermediate-length lesions [8,9,14]. Additionally, bio resorbable scaffolds and sirolimus coated devices are under consideration with long lesions. Although the results are encouraging, endovascular treatment in long lesions is affected by higher incidence of restenosis ( due to thrombosis and neointimal hyperplasia), stent fracture and target lesion revascularization (14-16).

### Surgical Bypass

Open revascularization using autologous great saphenous vein remains the gold standard for complex and long lesions, mostly in patients with good surgical profiles or life expectancy beyond two years [17,18]. The increased risk of wound infection, multi-month hospital stay, likelihood of graft occlusion, and necessitation of general anesthesia [19,20]. Vein graft restenosis occurs in nearly 30–40% of patients within the first two years post-surgery, necessitating ongoing graft surveillance and potential reintervention [17,21]. This was revealed in the BASIL Trial which underscored the importance of individualized treatment planning, balancing patient comorbidities, life expectancy, and anatomical suitability [17].

### Surgical bypass vs. endovascular therapy

According to the Best Endovascular versus Best Surgical Therapy in Patients with Chronic Limb-Threatening Ischemia (BEST-CLI) trial; the initial surgical bypass was linked to a significantly lower major adverse limb event (MALE) rate than EVT among CLTI patients with a suitable single segment of the great saphenous vein (Cohort 1) who were eligible for both revascularization strategies [22]. These findings highlighted the value of a conduit- and patient-specific approach and emphasized the need for individualized decision-making in managing advanced peripheral arterial disease [23,24]. Meta-analyses and randomized controlled trials showed that limb salvage and mortality outcomes were often comparable between the two approaches. Nevertheless, EVT was associated with a higher rate of re-intervention. For complex lesions, TASC II C and D, the bypass provided superior long-term primary patency, while EVT offered the benefits of lower perioperative morbidity and faster recovery especially in high-risk patients [25,26]. Despite the lower initial morbidity and mortality of EVTs, they did not consistently reduce the rate of major amputations compared to bypass, particularly for the patients with suitable surgical anatomy [27].

## RESULTS AND OBSERVATIONS:

Table 1: comparison between Endovascular Therapy (EVT) and Surgical Bypass

| Parameter | Endovascular Therapy (EVT) | Surgical Bypass | Supporting Studies |
|---|---|---|---|
| Invasiveness | Minimally invasive; percutaneous | Highly invasive; requires open surgery | Bradbury et al., 2005; Farber et al., 2022 |
| Durability / Patency | Lower primary patency in long lesions (>20 cm) | Higher long-term patency, especially with GSV graft | Farber et al., 2022; Bradbury et al., 2005 |
| Suitability for High-Risk Patients | Preferred for elderly or comorbid patients | Higher perioperative risk, limited to fit patients | Members et al, 2016; Bates et al,2024 |
| Restenosis / Reintervention Rate | Higher rate of restenosis, especially in long chronic total occlusion | Lower reintervention rates in good conduit patients | Scheinert et al., 2005; Brodmann et al., 2020 |
| Procedure Flexibility | Repeatable and adaptable with evolving tech | Limited by conduit availability and surgical history | Rocha-Singh et al., 2012 |
| Recovery Time | Shorter recovery, outpatient possible | Longer hospital stay and rehabilitation | Tepe et al., 2008; Rosenfield et al., 2015; |
| Cost and Resources | Typically lower initial cost, fewer ICU needs | Higher upfront cost, longer OR and hospital usage | Tang et al, 2018; Childers et al, 2019 |
| Technological Innovation | Rapidly advancing (e.g., DCBs, sirolimus, lithotripsy, AI) | Innovations mainly in perioperative care and technique | Cassano et al, 2023; Yao et al, 2025 |
| Hybrid Compatibility | Easily combined with open procedures in hybrid approach | Often the anchor for hybrid revascularization | Rossos et al, 2024; Yao et al, 2025 |
| Patient profile | TASC II C/D, high surgical risk, no vein conduit | Good GSV conduit, long life expectancy, low surgical risk | Kluckner et al, 2023; Mumtaz et al, 2025 |

### Complications

EVT complications include: stent fracture or occlusion, distal embolization, access site issues involving **hematomas**, **pseudoaneurysms**, **arteriovenous fistulas**, and **retroperitoneal hemorrhage** ; arterial dissection and perforation, restenosis and reintervention, contrast-induced nephropathy ,radiation exposure, MALE and mortality [28-35]. While surgical complications range from wound complications, infections , graft thrombosis and occlusion, bleeding and hematoma, lymphatic complications, ischemia-reperfusion injury, graft infection to cardiopulmonary events and mortality [30, 36-41]. However, patient selection and procedural planning are critical [*42,43]*.

### Hybrid Revascularization Approaches in Multilevel Peripheral Arterial Disease

Hybrid approaches that integrate **endovascular therapy (EVT) with open surgical procedures** are increasingly employed in the treatment of **multilevel PAD**. These techniques offer **patient-specific solutions**, particularly when implemented in centers with **multidisciplinary expertise**, where procedural planning and execution can be optimized [44,45]. A review of the literature supports the use of **hybrid revascularization** as a **less invasive, durable, and reliable therapeutic strategy**, especially for **high-risk patients** with advanced arterial disease. By combining the advantages of both revascularization modalities, hybrid procedures should be regarded as an essential component of the **contemporary**

**vascular surgeon's armamentarium** [46]. These techniques are particularly effective in the context of **multilevel arterial involvement**, where revascularization of a single level may be insufficient for achieving **wound healing** or **limb salvage**. Performing both interventions in a single session is considered **technically feasible and cost-efficient**, offering comprehensive revascularization tailored to complex clinical presentations [47].

### Advances in Revascularization Techniques

Revascularization is undergoing significant transformation. Driven by advances in technology, patient-specific approaches, and a technological innovations like vessel preparation tools (e.g., lithotripsy), sirolimus-based devices, biodegradable stents, and AI-based planning tools are shaping the future of EVT. Advanced imaging techniques (IVUS and OCT) support procedural accuracy, shifting toward minimally invasive care. One major development is the adoption of sirolimus-based endovascular devices, which are replacing paclitaxel-coated balloons and stents due to sirolimus's antiproliferative effects without the associated late mortality risks [48,50]. **Intravascular Ultrasound (**IVUS) is becoming central in procedural planning, allowing for precise vessel sizing, plaque characterization, and a reduced risk of dissection [51,52]. Adjunctive lesion preparation tools such as orbital and laser atherectomy, as well as scoring balloons, are improving outcomes by minimizing residual stenosis and enhancing drug uptake [53,54]. Despite these advances, surgical bypass remains the gold standard in select younger, low-risk patients with suitable great saphenous vein (GSV), offering superior long-term patency and limb salvage—as reaffirmed by the BEST-CLI trial [55,56]. Hybrid strategies combining open surgical inflow with distal endovascular repair are showing promise, particularly for multilevel or heavily calcified peripheral artery disease (PAD), and may benefit from precision medicine tools like WIfI, GLASS, and AI-based planning [57,58]. Additionally, robotic and AI-assisted interventions are emerging, providing enhancements in imaging analysis, predictive modeling, robotic navigation, potentially improving procedural precision and reducing operator variability [59]. Device innovation continues with the development of drug-eluting technologies, bioresorbable scaffolds, and covered stents such as Viabahn, improving patency even in complex lesions [60]. However, equitable global access remains a critical consideration, as open surgery may still be the only viable option in low-resource settings due to cost constraints and limited endovascular infrastructure.

## CONCLUSION

The management of long lesions in peripheral arterial disease (PAD) presents complex clinical challenges, particularly when selecting between endovascular and surgical revascularization. Both strategies have evolved significantly in the previous years, While endovascular therapy is rapidly gaining ground in long lesion treatment due to innovation and patient-centered benefits, open surgery remains vital—particularly for long tibial lesions and in low-resource settings where endovascular infrastructure may be limited.

Looking forward, the future likely lies in hybrid care, data-driven personalization, and global equity in PAD management. Continued research should prioritize patient-reported metrics, long-term clinical outcomes and cost-effectiveness, while integrating innovations such as drug-eluting devices, bioresorbable scaffolds, and AI-assisted planning tools. Ultimately, optimal treatment should be individualized based on anatomical complexity, patient risk profile, conduit availability, and institutional expertise. Strategic patient selection remains the cornerstone of achieving successful outcomes.

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