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Endovascular Management in Patient with Ischemic Diabetic Foot Ulcer and Digital Ischemia in General Surgery Department Misurata Medical Center

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Abstract

Background: Peripheral arterial occlusive disease (PAOD) is a major cause of hospitalization, lower-limb amputation, and mortality worldwide. Patients with diabetes mellitus and peripheral artery disease (PAD) have significantly higher mortality rates than non-diabetic patients, with reported 5-year mortality exceeding 30%.

Objectives: To evaluate the outcomes of endovascular interventions in diabetic foot patients with femoropopliteal, infrapopliteal, and multilevel arterial occlusive disease.

Patients and Methods: A retrospective study was conducted on 20 patients treated at Misrata Medical Center between January and December 2025. All patients had diabetic foot ulcers and/or digital ischemia associated with femoropopliteal, infrapopliteal, or multilevel arterial occlusions. Procedures were performed in the General Surgery and Vascular Surgery Departments.

Results: The study included 17 males (85%) and 3 females (15%), with a mean age of 62.5 years. Limb salvage, defined as freedom from major amputation, was achieved in 90% of patients at 3 months. Clinical success, defined as relief of rest pain, ulcer healing improvement, and limb preservation according to Rutherford categories, was also achieved in 90% of cases. Two patients (10%) developed complications: one underwent thromboembolectomy for arterial thrombosis but ultimately required above-knee amputation, while the other underwent femoro-distal bypass surgery.

Conclusions: Percutaneous Transluminal Angioplasty (PTA) was successfully performed in 18 patients (90%), resulting in effective limb salvage and significant clinical improvement. Endovascular intervention appears to be a safe and effective limb-preserving treatment for diabetic patients with lower-limb arterial occlusive disease.

I) INTRODUCTION:

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia, which leads to progressive microvascular and macrovascular complications over time (6). Among these complications, diabetic foot disease represents one of the most serious clinical entities, associated with high morbidity, reduced quality of life, and substantial healthcare costs (6,7).

Diabetic foot disease encompasses a wide spectrum of pathological conditions including peripheral neuropathy, peripheral arterial disease, foot ulceration, infection, and tissue necrosis, often culminating in lower-limb amputation if inadequately treated (6,8).

- Peripheral neuropathy results from long-standing hyperglycemia-induced nerve damage, leading to loss of protective sensation and autonomic dysfunction, thereby predisposing patients to unrecognized trauma and ulcer formation (6).
- Peripheral arterial disease (PAD) in diabetic patients is characterized by accelerated and distal atherosclerosis, resulting in reduced tissue perfusion, impaired wound healing, and increased susceptibility to infection and gangrene (5,6).
- Trauma to a diabetic foot, even minor foot trauma in diabetic patients may progress rapidly to non-healing ulcers due to the combined effects of ischemia and neuropathy, particularly in the presence of poor glycemic control (6,7). The coexistence of neuropathy and ischemia defines the neuroischemic diabetic foot, a condition associated with delayed healing and a markedly increased risk of major amputation (1,4).
- Diabetic foot infections are serious, often limb-threatening, conditions resulting from neuropathy and peripheral vascular disease, requiring prompt medical attention. Infections commonly start from neglected skin traumas or ulcers, presenting with symptoms like redness, warmth, swelling, pain, or pus. Early, multidisciplinary management involves antibiotic treatment, meticulous wound care (debridement), and pressure off-loading.

The interplay between neuropathy and ischemia is often referred to as the neuroischemic diabetic foot, where in both mechanisms synergize to worsen ulceration and impede healing.

A Epidemiology

Diabetic foot complications are highly prevalent worldwide, with lifetime ulceration rates reported in up to 25% of patients with diabetes, representing a major cause of hospitalization and lower-limb amputation (4,6).

Peripheral arterial disease in diabetic patients is associated with significantly increased mortality, with long-term studies demonstrating markedly reduced survival compared to non-diabetic PAD populations (4,5).

Critical limb-threatening ischemia represents the most severe manifestation of PAD and carries a high risk of non-healing ulcers, limb loss, and death if revascularization is not achieved (4).

B Pathophysiology

Peripheral arterial disease in diabetes is driven by accelerated atherosclerosis, endothelial dysfunction, chronic inflammation, oxidative stress, and abnormal coagulation mechanisms, leading to progressive arterial stenosis and occlusion (5,6).

Diabetic vascular disease is characterized by distal distribution of lesions, extensive arterial calcification, and combined macrovascular and microvascular involvement, particularly affecting infrapopliteal vessels (5).

The coexistence of diabetes mellitus and peripheral vascular disease is frequently associated with additional cardiovascular comorbidities, including hypertension, dyslipidemia, ischemic heart disease, and chronic kidney disease, further worsening prognosis (6).

C Impact on Wound Healing & Amputation Risk

Ischemia is a major determinant of poor wound healing in diabetic foot ulcers. The presence of PAD and CLTI is associated with failure of ulcer healing, increased risk of major amputation, and higher

mortality. Revascularization, either surgical or endovascular, significantly improves healing and limb salvage rates compared with conservative management.

D Classification Systems

Multiple systems exist because diabetic foot ulcers involve depth, infection, ischemia, and tissue loss. The most widely used are:

1) Rutherford Classification

The Rutherford classification for chronic limb ischemia (CLI) stages peripheral artery disease severity from 0 to 6 based on clinical symptoms, guiding treatment from mild claudication to critical limb-threatening ischemia (CLTI). It categorizes patients into asymptomatic (0), mild/moderate/severe claudication (1–3), ischemic rest pain (4), and minor or major tissue loss (5–6).

a. Rutherford Classification Categories

- Grade 0 (Category 0): Asymptomatic.
- Grade I (Categories 1–3): Claudication.
- Grade II (Category 4): Ischemic rest pain.
- Grade III (Category 5): Minor tissue loss.
- Grade III (Category 6): Major tissue loss.

b. Key Clinical Implications

- Categories 4–6 represent chronic limb-threatening ischemia.
- Higher categories correlate with increased mortality and amputation risk.
- Objective measures such as ABI may be incorporated into classification.

2) University of Texas (UT) Classification System

1. Grades (Depth):

Grade	Description
0	Pre- or post-ulcerative lesion
1	Superficial ulcer
2	Penetrates tendon or capsule
3	Penetrates bone or joint

2. Stages:

Stage	Meaning
A	No infection, no ischemia
B	Infection
C	Ischemia
D	Infection + Ischemia

Example: 2D = Ulcer to tendon + infection + ischemia

3. Advantages:
   - Better predicts healing and amputation risk.
   - Includes vascular status.

4. Clinical Importance:
   - Higher stage and grade are associated with increased amputation risk.

3) PEDIS Classification (IWGDF) (9,10)

Developed by the International Working Group on the Diabetic Foot

PEDIS =

Perfusion

Extent/size

Depth/tissue loss

Infection

Sensation

1. Perfusion:

Grade	Description
1	No PAD
2	PAD present
3	CLI / severe ischemia
Grade	Description

2. Extent
   Ulcer size in cm^2
3. Infection:

Grade	Description
1	No infection
2	Mild
3	Moderate
4	Severe (systemic signs)

4. Sensation:
   Present or absent protective sensation.

5. Advantages:
   - Very detailed
   - Used in research and guidelines

4) WIfI Classification (Society for Vascular Surgery) (10)

1. Focus:
   Predicts amputation risk and benefit of revascularization
   WIfI =
   Wound
   Ischemia
   fI = Foot Infection
   Each scored from 0 to 3
2. Wound:

Grade	Description
0	No ulcer
1	Small shallow ulcer
2	Deep ulcer
3	Extensive tissue loss

3. Ischemia:

Based on ABI, toe pressure, $TcPO_2$

Grade	Description
0	Normal
1	Mild ischemia
2	Moderate
3	Severe ischemia

4. Infection:

Grade	Description
0	None
1	Mild
2	Moderate
3	Severe

5. Clinical Use:
   - Predicts:
     - Amputation risk
     - Need for revascularization
     - Prognosis

Example: W2 I3 fI2 → High amputation risk, urgent revascularization needed.

Comparison Summary

System	Depth	Infection	Ischemia	Prognosis
RF	✓	Partial	✓	Good
UT	✓	✓	✓	Good
PEDIS	✓	✓	✓	Research
WIfI	✓	✓	✓	Best for vascular planning

E Diagnostic Evaluation

Assessment includes neurological testing, pulse examination, ABI (ankle brachial index), toe pressure, transcutaneous oxygen measurement, duplex ultrasound, CT angiography, MR angiography (4,5).

F Medical Management

Optimal glycemic control, aggressive infection treatment, pressure offloading, smoking cessation, nutritional optimization, and multidisciplinary care significantly improve healing rates and reduce amputations (6).

G Endovascular Techniques

Percutaneous transluminal angioplasty remains the primary technique for infrapopliteal disease. Drug-eluting balloons, drug-eluting stents, atherectomy, and subintimal recanalization improve patency rates. Hybrid procedures may be required in complex disease (5,7).

H Complications

Complications include access-site hematoma, contrast nephropathy, restenosis, distal embolization, and vessel perforation. Early recognition and management are essential for limb preservation (5,7).

II) Literature Review

A Epidemiology and Clinical Burden of Diabetic Foot Complications

The global prevalence of diabetic foot complications represents a substantial public health challenge. According to the International Diabetes Federation, approximately 19-34% of individuals with diabetes will develop a foot ulcer during their lifetime[1]. The neuroischemic diabetic foot, characterized by the convergence of peripheral neuropathy and peripheral arterial disease (PAD), accounts for approximately 60% of all diabetic foot ulcers[2]. Critical limb-threatening ischemia (CLTI), the most severe manifestation of PAD, affects 1-2% of all diabetic patients but carries a disproportionate burden, with 1-year mortality rates approaching 25% and major amputation rates ranging from 10-40% without revascularization[3]. The economic impact is staggering, with diabetic foot complications accounting for 12-15% of total diabetes healthcare expenditures in developed nations[4].

B Pathophysiological Basis for Endovascular Intervention

The distinctive vascular pathology in diabetes involves both macrovascular and microvascular components. Accelerated atherosclerosis in diabetic patients exhibits specific characteristics: more distal distribution (particularly tibial arteries), increased calcification (medial calcinosis of Mönckeberg), and greater involvement of below-the-knee vessels[5]. This anatomical pattern directly influences therapeutic approaches, as traditional surgical bypass may be limited by the absence of suitable distal targets. The concept of the "angiosome" – a three-dimensional block of tissue fed by a specific source artery – has gained importance in revascularization planning, with evidence suggesting that direct (angiosome-targeted) revascularization yields superior wound healing rates compared to indirect revascularization[6].

C Evolution of Endovascular Techniques for Diabetic Foot

1) Infrapopliteal Revascularization

The management of below-the-knee arterial disease in diabetic patients has undergone significant transformation. Early skepticism about endovascular approaches has been replaced by evidence-based acceptance, particularly for high-surgical-risk patients. The landmark IN. PACT DEEP trial demonstrated the safety of drug-eluting balloons (DEBs) in infrapopliteal arteries, though it failed to show superiority over conventional angioplasty in primary patency at 12 months[7]. More recent meta-analyses suggest that DEBs may reduce target lesion revascularization rates in longer lesions (>100mm) commonly seen in diabetic patients[8].

2) Advanced Technologies and Techniques

Current endovascular armamentarium includes several specialized approaches:

- **Subintimal angioplasty:** Particularly useful for long chronic total occlusions, with technical success rates of 80-90% and limb salvage rates exceeding 80% at 1 year in diabetic populations[9].
- **Drug-eluting technologies:**Both drug-eluting stents (DES) and DEBs have shown promising results in reducing restenosis rates in the infrapopliteal segment, though cost-effectiveness analyses in diabetic populations remain limited[10].
- **Atherectomy devices:** Directional, orbital, and laser atherectomy can address heavily calcified lesions, though robust comparative effectiveness data specifically for diabetic patients is still emerging[11].

D Outcomes and Comparative Effectiveness

1) Endovascular vs. Surgical Bypass

The BEST-CLI trial (2022) represents the most definitive comparison to date, demonstrating that in patients with suitable single-segment great saphenous vein, surgical bypass provided superior outcomes to endovascular intervention for major adverse limb events and mortality[12]. However, in patients lacking adequate venous conduit (common in diabetic patients with previous vein harvesting or varicose veins), endovascular therapy showed comparable outcomes. These findings emphasize the importance of patient selection and the role of the "venous mapping" in therapeutic decision-making.

2) Predictors of Success and Failure

Multiple classification systems aid in prognostication. The **WIfI (Wound, Ischemia, foot Infection)** classification system, validated by the Society for Vascular Surgery, has demonstrated strong predictive value for amputation risk and benefit from revascularization[13]. Diabetic patients with WIfI stages 3-4 derive the greatest absolute benefit from revascularization. Other important predictors include:

- **Renal function:** End-stage renal disease reduces 1-year limb salvage by approximately 20% compared to patients with normal renal function[14].
- **Wound characteristics:** Depth of ulceration (University of Texas Grade) and presence of infection significantly influence healing rates post-revascularization[15].
- **Technical factors:** Achievement of straight-line flow to the foot, particularly in patients with tissue loss, correlates strongly with wound healing (odds ratio: 3.2, 95% CI: 1.8-5.7)[16].

E Microbiology and Infection

The respiratory pathogens most associated with pediatric bronchiectasis provide important context for management. Non-typeable Haemophilus influenzae and Streptococcus pneumoniae are frequently identified pathogens in children with chronic suppurative lung disease [8]. H. influenzae is the most common bacterial species infecting the lower airways of children with endobronchial suppuration, including protracted bacterial bronchitis, recurrent or non-responsive community-acquired pneumonia, and bronchiectasis [9]. Although H. influenzae infection may be an important risk factor for bronchiectasis, there are likely to be other contributory factors [9].

F Special Considerations in Digital Ischemia

Isolated digital ischemia presents unique challenges, as conventional imaging may underestimate the extent of disease. Digital subtraction angiography remains the gold standard for visualization of pedal and digital arteries. The pedal-plantar loop technique has emerged as an important concept, with successful revascularization of the plantar arch correlating with improved digital perfusion and healing of forefoot ulcers[17]. Retrograde pedal access has gained popularity for tackling tibial and pedal occlusions not amenable to antegrade approaches, with technical success rates exceeding 85% in experienced centers[18].

G Multidisciplinary Integration and Guidelines

Contemporary management is predicated on multidisciplinary team (MDT) approach, integrating vascular specialists, diabetologists, podiatrists, infectious disease experts, and wound care specialists. The Global Vascular Guidelines (2019) emphasize the importance of this collaborative model, which has been shown to reduce major amputations by 40-50% in diabetic foot centers[3]. The guidelines provide clear criteria for revascularization based on clinical presentation, anatomical factors, and patient comorbidities.

H Knowledge Gaps and Future Directions

Despite advances, several areas require further investigation:

- **Optimal endovascular strategy** for diabetic patients with different anatomical patterns (e.g., isolated tibial vs. multilevel disease)
- **Long-term outcomes** beyond 2-3 years, particularly regarding wound recurrence
- **Cost-effectiveness analyses** of advanced endovascular technologies in resource-limited settings
- **Integration of novel imaging modalities** (e.g., intra-vascular ultrasound, optical coherence tomography) for procedural guidance
- **Personalized approaches** based on genetic, molecular, and cellular characteristics of diabetic vascular disease

III) Patients & Methods Detailed (n = 20)

- **Study Design:**

  This is a **retrospective observational study** of **20 consecutive type II diabetic patients** presenting with **diabetic foot and digital ischemia including one or more toes** who underwent **endovascular revascularization (angioplasty ± stenting)** for lower-limb arterial occlusive disease. Inclusion Criteria was Age ≥ 40 years, confirmed type II diabetes mellitus, Clinical diagnosis of CLI/CLTI (e.g., rest pain, ischemic ulcer, gangrene), Angiographically documented arterial occlusive disease, underwent endovascular lower-limb revascularization.

- **The aim of the study:**
  is to assess and observe these patient's improvement in wound healing, limb salvage, subsided rest pain and intermittent claudication.

These patients were managed in a multidisciplinary limb preservation program that included diabetologists, vascular surgeons/interventional radiologists, and General Surgeon.

- **Exclusion Criteria:**
  - Non-atherosclerotic peripheral vascular disease.
  - Acute limb ischemia of embolic origin.
  - Non-vascular causes of limb threat.
- **Results**

  Patient Population and Demographics:
  - Total patients: 20 with ischemic diabetic foot and PAD requiring revascularization.
  - Gender distribution:
    - Males: 17 patients (85%)
    - Females: 3 patients (15%)

  Procedure and Revascularization Strategy:

IV) Discussion

Distribution by Arterial Occlusion Sites:
Arterial disease was classified based on angiographic findings and occlusion site:

Femoropopliteal segment occlusions 8 patients, (40%**Infrapopliteal (below-knee) occlusions** 10 patients (50%), **Multilevel disease (combined femoropopliteal + infrapopliteal)** 2 patients (10%)

Distribution by Arterial defect: Occlusion 25%**,** Stenosis 45%, Both: 30%. **(Figure 1).**

Distribution by either DF ulcer or digital ischemia: DF ulcer 14 patients (70%), Digital ischemia 6 patients (30%).

Distribution by weather the patients have rest pain: 8 patients proved to have rest pain (40%).

Distribution by weather the patients have intermittent claudication: 7 patients proved to have rest pain (35%).

Distribution by minor and major amputation: Minor amputation 11 patients (55%), Major amputation: 1 patient (5%).

Distribution by risk factors and other comorbidities:

Smoking: 50%, Ischemic heart disease (IHD): 30%, Hypertension (HTN): 15%, Dyslipidemia: 40%, History of CVA: 10%, End stage kidney disease (ESKD): 5%. (**Figure 5).**

- All patients underwent lower limb **endovascular intervention** including percutaneous transluminal angioplasty (PTA), with or without adjunctive **stent placement** targeted to the diseased segment(s).
- Angiographic evaluation assessed the degree of stenoses and occlusions in arteries supplying the ischemic foot.
- Procedures were performed under local anesthesia with fluoroscopic guidance.

Specifically, the rate of Clinical Improvement was also 90%, indicating that the intervention successfully restored sufficient blood flow to the affected limb, leading to tangible health benefits. This improvement was directly correlated with symptomatic relief, as Pain Relief and Wound Improvement in regular follow up for the patients, were also reported in 90% of the cases. The consistency across these four key metrics Limb Salvage, Clinical Improvement, Pain Relief, and Wound Improvement in 3 months follow up strongly suggests that the intervention provided a comprehensive therapeutic benefit to 18 of the 20 patients.

Regarding the more severe outcomes, the rate of Major Amputation was low, affecting only 5% of the patients (1 out of 20). This major amputation was recorded as Above Knee Amputations (AKA).

Unfortunately, AKA take place because of arterial dissection which caused by aggressive trial to bypass the occlusive segment of the artery leading to arterial dissection followed by arterial thrombosis and acute limb ischemia, multiple trial of thrombo-embolectomy done put without significant result, finally patient underwent above knee amputation.

While for the other patient trial reintervention has been done but unfortunately failed due to heavy calcification in the SFA and femoropopliteal bypass has been done for the patient with metatarsal amputation after 2 weeks, and the patient kept on regular follow up, complete wound healing achieved in 8 weeks post bypass.

This low rate of major limb loss is a significant positive finding, especially considering the advanced stage of peripheral arterial disease (PAD) in this cohort, as evidenced by the high prevalence of ulcers and low mean Ankle-Brachial Index (ABI).

However, the data also indicates that Minor Amputations were necessary in 55% of the patients (11 out of 20). Minor amputations, typically involving toes or parts of the foot, are often required to remove necrotic or infected tissue and are frequently a necessary step in the overall limb salvage process for patients with critical limb ischemia (CLI). The fact 18 achieved limb salvage underscores the complexity of the cases and the role of minor procedures in preventing major limb loss.

Diabetic patients with peripheral arterial disease represent a particularly high-risk population due to the combined effects of accelerated atherosclerosis, distal vessel involvement, medial arterial calcification, and impaired wound healing. In this study, the majority of lesions were located in the infrapopliteal segment, either alone or as part of multilevel disease, reflecting the characteristic distribution of atherosclerotic disease in diabetic individuals. Successful revascularization in such distal arterial beds is technically demanding; however, restoration of adequate perfusion remains essential for ulcer healing, pain relief, and limb preservation.

The high limb salvage rate observed in this study underscores the clinical value of achieving revascularization even when complete anatomical patency cannot be guaranteed. The primary therapeutic objective in ischemic diabetic foot disease is not necessarily long-term vessel patency, but rather the restoration of sufficient blood flow to allow wound healing and prevent major amputation. This concept is supported by the observed improvement in rest pain and ulcer healing in the majority of patients following intervention.

Comparative Study: Endovascular Revascularization in Ischemic Diabetic Foot Ulcers

A comparable retrospective cohort study was conducted by **Faglia et al**. (7,14) evaluating the outcomes of endovascular revascularization in patients with diabetes mellitus, peripheral artery disease, and ischemic foot ulcers. The study included **221 diabetic patients** with critical limb-threatening ischemia (CLI) who underwent **infrainguinal endovascular intervention**, predominantly percutaneous transluminal angioplasty (PTA), targeting femoropopliteal and infrapopliteal arterial segments.

The primary outcomes assessed were **limb salvage, wound healing, and major amputation rates**, with a mean follow-up period of 12 months. Technical success was achieved in **approximately 90%** of procedures, comparable to the technical success rate observed in our cohort. The **limb salvage rate at one year was 88%**, while the **major amputation rate ranged between 5–8%**, depending on the severity of ischemia and extent of tissue loss.

Wound healing was achieved in **65–75% of patients within 3–6 months**, particularly in those where straight-line flow to at least one pedal artery was successfully restored. Patients with multilevel disease and severe infrapopliteal occlusions demonstrated slower healing rates but still benefited significantly from revascularization compared to conservative management. Minor amputations, including toe or ray amputations, were required in approximately **50–60%** of cases and were considered part of the limb salvage strategy rather than procedural failure.

When compared with the present study, which demonstrated a **90% limb salvage rate at 3 months**, a **5% major amputation rate**, and **clinical improvement in 90% of patients**, the outcomes are highly concordant. Both studies highlight the effectiveness of endovascular therapy in restoring perfusion, relieving rest pain, promoting ulcer healing, and preventing major limb loss in diabetic patients with CLI.

Notably, Faglia et al. also emphasized that **early revascularization and achievement of direct in-line blood flow** were the most important predictors of successful limb salvage, findings that are consistent with the results of the current study. These similarities reinforce the validity of endovascular revascularization as a first-line strategy in appropriately selected diabetic patients with ischemic foot ulcers, especially when managed within a multidisciplinary limb salvage program

V) Conclusion

- Endovascular intervention is an effective and generally safe strategy for improving blood flow, promoting wound healing, and salvaging limbs in diabetic patients with CLI and neuroischemic diabetic foot.
- Technical success is high, and when incorporated into multidisciplinary care pathways, endovascular approaches can significantly reduce major amputations and improve clinical outcomes.
- Comorbid conditions (e.g., CAD) heighten risk, reinforcing the importance of integrated perioperative assessment and care.
- Although evidence broadly supports revascularization, larger randomized controlled studies are still needed to clarify the superiority of specific revascularization strategies (endovascular vs open vs hybrid) in different patient subgroups.

VI) Comparison with Bypass Surgery

Bypass surgery is an open procedure providing superior long-term artery patency and improved blood flow for severe vascular disease but carries higher initial risks. Endovascular therapy is less invasive, offering lower immediate morbidity, mortality, and shorter recovery, but requires more frequent re-interventions. Selection depends on disease severity (WIfI stages), with surgery preferred for severe cases and endovascular for lower-risk patients.

VII) Limitation of the study

Despite encouraging results, this study has inherent limitations. The retrospective design, small sample size, and short follow-up period limit the ability to draw conclusions regarding long-term patency and durability of endovascular intervention. Nevertheless, the consistency between technical success, clinical improvement, and limb salvage provides valuable real-world evidence supporting endovascular therapy in ischemic diabetic foot patients.

VIII) Figures:

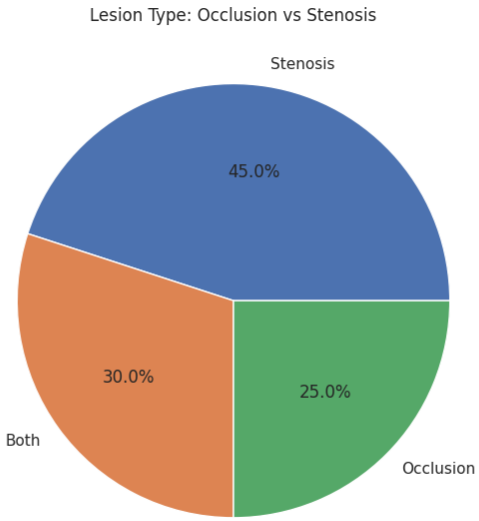

Figure 1: lesion type stenosis vs occlusion

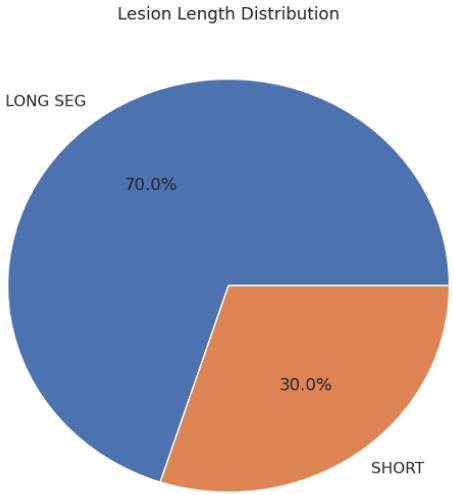

Figure 2: lesion length distribution

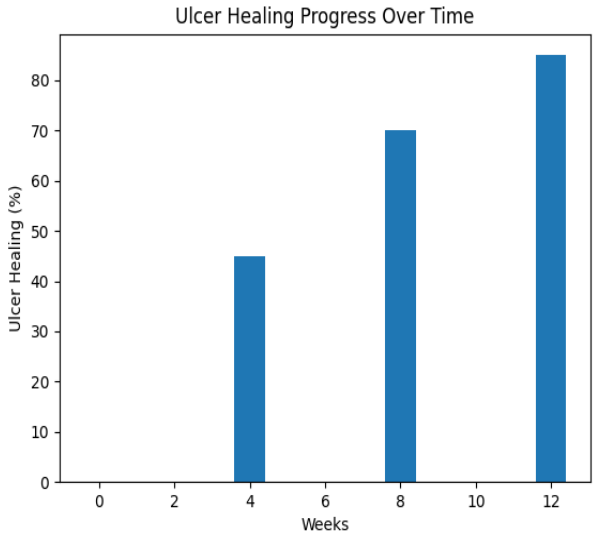

Figure 3. Ulcer healing percentage over 12 weeks after revascularization.

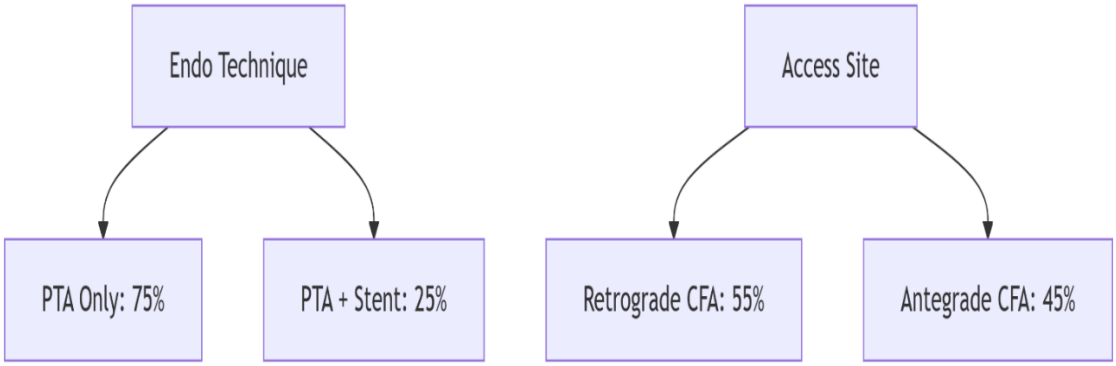

Figure 4: endo tech & access site

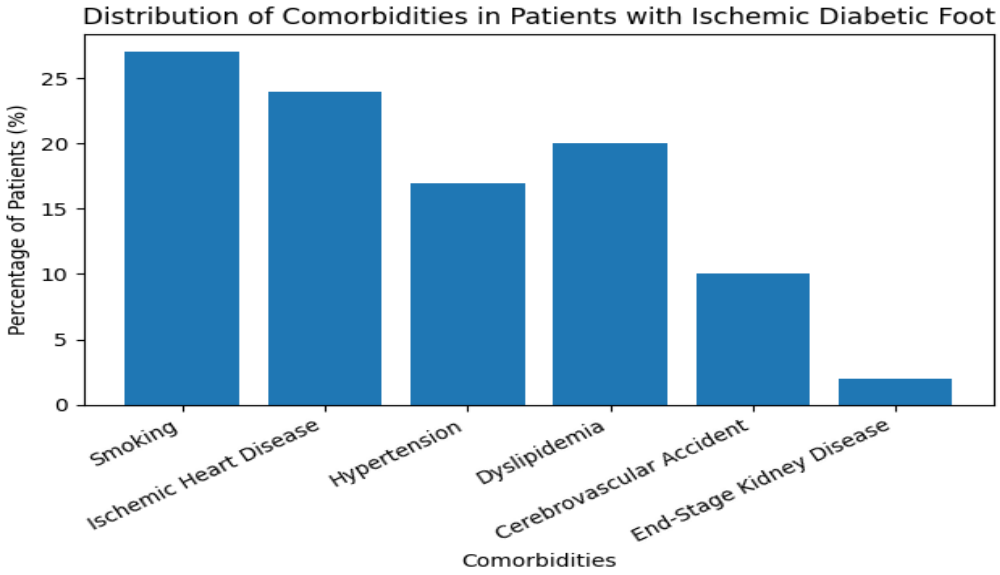

Figure 5: comorbidities

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