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Surgical Management of the Diabetic Foot in End-Stage Kidney Disease: An Integrated Anatomical, Nephrological and Vascular-Surgical Perspective

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Rezumat

Managementul chirurgical al piciorului diabetic în boala renală în stadiu terminal: o perspectivă integrată anatomică, nefrologică și vascular-chirurgicală

Piciorul diabetic la pacienții cu boală renală în stadiu terminal (ESKD) reprezintă rezultatul convergenței neuropatiei periferice diabetice, aterosclerozei accelerate, calcificării arteriale mediale, disfuncției imune uremice şi alterării proceselor de vindecare a plăgilor. Interacțiunea acestor mecanisme determină o rată a amputațiilor de trei până la cinci ori mai mare comparativ cu pacienții diabetici fără uremie, iar mortalitatea la un an după amputația majoră se apropie de 40–50%. Această lucrare de sinteză şi-a propus integrarea dovezilor actuale din domeniile anatomiei, nefrologiei, diabetologiei şi chirurgiei vasculare într-un cadru practic destinat managementului chirurgical al piciorului diabetic la pacienții aflați în program de dializă sau după transplant renal. A fost realizată o analiză narativă a celor mai recente ghiduri internaționale şi documente de consens, incluzând Standards of Care 2025 ale American Diabetes Association (ADA), ghidurile KDIGO 2022 şi 2024, recomandările International Working Group on the Diabetic Foot (IWGDF) din 2023, ghidurile privind boala arterială periferică elaborate de European Society for Vascular Surgery (ESVS) şi Society for Vascular Surgery (SVS), ghidul ACC/AHA 2024 privind boala arterială periferică a membrelor inferioare, Global Vascular Guidelines 2019 pentru ischemia cronică amenințătoare de membru (CLTI), precum şi recomandările KDOQI 2019/2020 referitoare la accesul vascular. Dovezile actuale subliniază că managementul eficient al piciorului diabetic în ESKD necesită o abordare multidisciplinară integrată. Cunoaşterea detaliată a trifurcației tibioperoniere, a ansei plantar-pedale şi a conceptului de angiosom este esențială pentru planificarea revascularizării

membrului. Boala arterială difuză infrapoplitee şi pedală, calcificarea medială extinsă şi anatomia vasculară complexă impun alegerea individualizată între tratamentul endovascular, bypass-ul chirurgical, procedurile hibride şi arterializarea transcateter a venelor profunde la pacienții cu ischemie cronică amenințătoare de membru fără opțiuni convenționale de revascularizare (no-option CLTI). Piciorul diabetic asociat bolii renale în stadiu terminal trebuie considerat o afecțiune sistemică, care necesită un management coordonat din perspectivă anatomică, vasculară, nefrologică, endocrinologică şi chirurgicală, depăşind abordarea limitată la tratamentul local al plăgii. Aplicarea unei strategii multidisciplinare bazate pe ghidurile actuale optimizează deciziile privind revascularizarea, controlul infecției, pregătirea perioperatorie şi alegerea nivelului de amputație, oferind cele mai bune şanse pentru salvarea membrului, în contextul unei morbidități şi mortalități care rămân semnificativ crescute în această categorie de pacienți.

Cuvinte cheie: picior diabetic, boală renală în stadiu terminal, ischemie cronică amenințătoare de membru, revascularizare, calcificare arterială medială, angiosom, arterializare transcateter a venelor profunde, KDIGO, IWGDF, amputație

Abstract

Diabetic foot disease in end-stage kidney disease (ESKD) represents the convergence of diabetic peripheral neuropathy, accelerated atherosclerosis, medial arterial calcification, uremic immune dysfunction and impaired wound healing. The combination yields amputation rates three- to five-fold higher than in non-uremic diabetics and one-year post-amputation mortality approaching 40–50%. In this paper we synthesised the current anatomical, diabetological, nephrological and surgical evidence into a practical framework for the surgeon caring for the dialysis-dependent or kidney-transplant recipient with a diabetic foot. We conducted a narrative review of guidelines and consensus statements from the American Diabetes Association (ADA) Standards of Care 2025, KDIGO 2022/2024, the 2023 inter-societal International Working Group on the Diabetic Foot (IWGDF), European Society for Vascular Surgery (ESVS) and Society for Vascular Surgery (SVS) PAD guideline, the 2024 ACC/AHA Lower-Extremity PAD Guideline, the 2019 Global Vascular Guidelines on chronic limb-threatening ischemia (CLTI), and the KDOQI 2019/2020 vascular access update, supplemented by high-quality reviews published through 2026. Anatomical understanding of the tibioperoneal trifurcation, pedal-plantar loop and the angiosomal territories is now central to revascularization planning; below-the-knee disease in ESKD is diffuse, calcified and pedal-dominant, mandating individualized choice between bypass, endovascular and transcatheter arterialization of the deep veins; perioperative care must integrate dialysis timing, hyperkalaemia control, anaemia and mineral-bone disease management, and ipsilateral vascular-access preservation; the threshold to definitive, well-planned amputation should be lower than in non-uremic diabetics, but only after a structured limb-salvage attempt within a multidisciplinary "toe-and-flow" team.

Keywords: diabetic foot, end-stage kidney disease, chronic limb-threatening ischemia, revascularization, medial arterial calcification, angiosome, transcatheter arterialization of deep veins, KDIGO, IWGDF, amputation

Introduction

The diabetic foot ulcer (DFU) remains the most visible somatic manifestation of systemic diabetic vasculopathy and neuropathy, and ESKD is its most lethal modifier (1). Approximately 50% of people with diabetes and a foot ulcer have concomitant peripheral artery disease (PAD), and PAD substantially increases the risk of non-healing, infection and major amputation (2). When PAD is layered on uremia, the picture changes qualitatively rather than quantitatively: the medial arterial calcification of CKD–mineral and bone disorder (CKD-MBD) renders ankle pressures unreliable, distal targets disappear, and the immunological, nutritional and haematological milieu of dialysis dismantles the wound-healing cascade (3).

This article frames the diabetic foot in ESKD as an integrated anatomical-surgical problem. We trace the diabetic injury along its anatomical course, from the glomerular capillary and the renal microvasculature, through the aorto-iliac and infrainguinal axis, into the tibial and pedal arteries that perfuse the angiosomes of the foot, and correlate each level with the operative decisions that flow from it: vascular access creation, revascularization, debridement, amputation, perioperative care and, where applicable, simultaneous or sequential kidney/kidney–pancreas transplantation. Current direction-of-care statements from the ADA Standards of Care 2025 (4), KDIGO 2022 Diabetes-in-CKD (5), KDIGO 2024 CKD (6), and the 2024 ACC/AHA Lower-Extremity PAD Guideline (7) provide the contemporary scaffolding for the recommendations that follow.

Anatomical and Pathophysiological Correlations

Renal microvascular anatomy and the diabetic nephron

Diabetic kidney disease (DKD) begins in the glomerular capillary, where hyperglycaemia-driven glycation of the glomerular basement membrane, podocyte effacement, mesangial expansion and nodular Kimmelstiel-Wilson glomerulosclerosis culminate in proteinuria and progressive nephron loss (8). The afferent-efferent arteriolar hyalinosis that accompanies DKD is not confined to the kidney: the same medial smooth-muscle apoptosis, elastin fragmentation and hydroxyapatite deposition characterise arterioles throughout the body, including the digital and pedal vessels (8). The KDIGO 2024 CKD framework re-emphasises classification by cause, GFR category (G1-G5) and albuminuria category (A1-A3), and prognostication via the heat-map, because each cell in that map carries a distinct cardiovascular and limb-event risk (6).

Vascular anatomy relevant to the diabetic limb

The arterial supply of the lower limb is conventionally segmented into inflow (aorto-iliac), outflow (femoropopliteal) and runoff (infrapopliteal/pedal). In diabetes, and especially in ESKD, the disease is disproportionately infrapopliteal and pedal, sparing the iliac and common femoral segments (9). The popliteal artery bifurcates into the anterior tibial artery, which crosses the interosseous membrane to become the dorsalis pedis, and the tibioperoneal trunk, which divides into the posterior tibial and peroneal arteries (10). The posterior tibial artery, behind the medial malleolus, divides into the medial and lateral plantar branches that form the plantar arch; the peroneal sends anterior and posterior communicating branches that may, in advanced disease, become the sole inflow to the foot (11).

The angiosome concept (Taylor & Palmer; refined for the foot by Attinger) divides the foot into six three-dimensional tissue blocks each supplied by a source artery: three from the posterior tibial (medial calcaneal, medial plantar, lateral plantar), two from the peroneal (lateral calcaneal, anterior perforating) and one from the anterior tibial/dorsalis pedis (11). Direct revascularization of the angiosome containing the wound (when feasible) is associated with higher wound-healing and limb-salvage rates, although indirect revascularization via the pedal-plantar loop remains an acceptable alternative when direct targeting is not anatomically possible (2,12).

Medial arterial calcification and the unreliability of ankle pressures

Mönckeberg medial sclerosis, driven in CKD by hyperphosphataemia, elevated FGF-23, low Klotho, vitamin-K deficiency and osteoblastic transdifferentiation of vascular smooth-muscle cells, produces non-compressible tibial arteries (2). Ankle–brachial index (ABI) is therefore frequently spuriously normal or supra-normal (>1.3) in ESKD (7). The 2023 IWGDF/ESVS/SVS guideline (2) and the 2024 ACC/AHA Lower-Extremity PAD guideline (7) both recommend complementing ABI with toe-brachial index (TBI), pedal Doppler waveform analysis and, where available, transcutaneous oximetry ($TcPO_2$) or skin perfusion pressure (13). A toe pressure ≥ 30 mmHg increases pre-test probability of healing by approximately 30%; values < 30 mmHg, or $TcPO_2$ < 30 mmHg, identify a limb at high risk of major amputation (2).

The Wound, Ischemia, foot Infection (WIfI) staging system

The SVS WIfI classification, endorsed by the 2019 Global Vascular Guidelines and retained in the 2023 IWGDF intersocietal document, integrates wound depth, ischemia grade and infection severity into four clinical stages (1-4) that estimate one-year amputation risk and the expected benefit of revascularization (12). In ESKD cohorts, every WIfI stage carries an excess amputation hazard, and WIfI-4 limbs in dialysis patients can have one-year major-amputation rates exceeding 60%, a figure that should temper enthusiasm for prolonged salvage attempts (14).

Diabetic neuropathy, autonomic dysfunction and uremic neurotoxicity

Sensorimotor distal symmetric polyneuropathy, autonomic neuropathy and uremic neurotoxicity act additively. Loss of protective sensation eliminates the protective withdrawal reflex; intrinsic-muscle atrophy from motor neuropathy creates claw-toe and equinus deformities that concentrate plantar pressure; and autonomic sympathetic denervation causes anhidrosis with fissuring, paradoxical arteriovenous shunting and impaired vasoregulation. In dialysis patients, β2-microglobulin amyloidosis and accumulation of uremic toxins compound the deficit (15).

Increased intracellular glucose activates the polyol, hexosamine, and glycolytic pathways, generating sorbitol accumulation, advanced glycation end-products, reactive oxygen species, and electron transport chain overload. In parallel, dyslipidaemia promotes oxidized LDL, free fatty acid accumulation, and receptor-mediated inflammatory signalling through

RAGE, LOX1, and TLR4 (16). In the diabetic foot, these mechanisms help explain the anatomical and surgical phenotype of neuropathy, endothelial dysfunction, impaired tissue perfusion, poor resistance to infection, delayed wound healing, and reduced success of conservative limb-salvage procedures (17).

Epidemiology and Prognosis

Metabolic and inflammatory pathways linking hyperglycaemia, dyslipidaemia, neuropathy, and tissue failure in the diabetic foot is shown in *Fig. 1.*

The lifetime risk of DFU in unselected diabetes is 19-34%, and approximately 20% of moderate-to-severe diabetic foot infections culminate in some level of amputation (19). In ESKD, ulceration prevalence on dialysis approaches 25-40%, and the relative risk of major amputation is three- to five-fold higher than in non-uremic diabetics, with reported one-year mortality after major lower-extremity amputation in this population in the 40-50% range. Survival after revascularization in dialysis-dependent patients is similarly inferior, with one-year all-cause mortality in contemporary series often reported between 20% and 40% (20).

Independent prognostic variables consistently identified across registries and meta-analyses include: dialysis vintage, serum albumin < 3.0 g/dL, haemoglobin < 10 g/dL, C-reactive protein elevation, severe coronary disease, WIfI stage at presentation, absence of an auto-

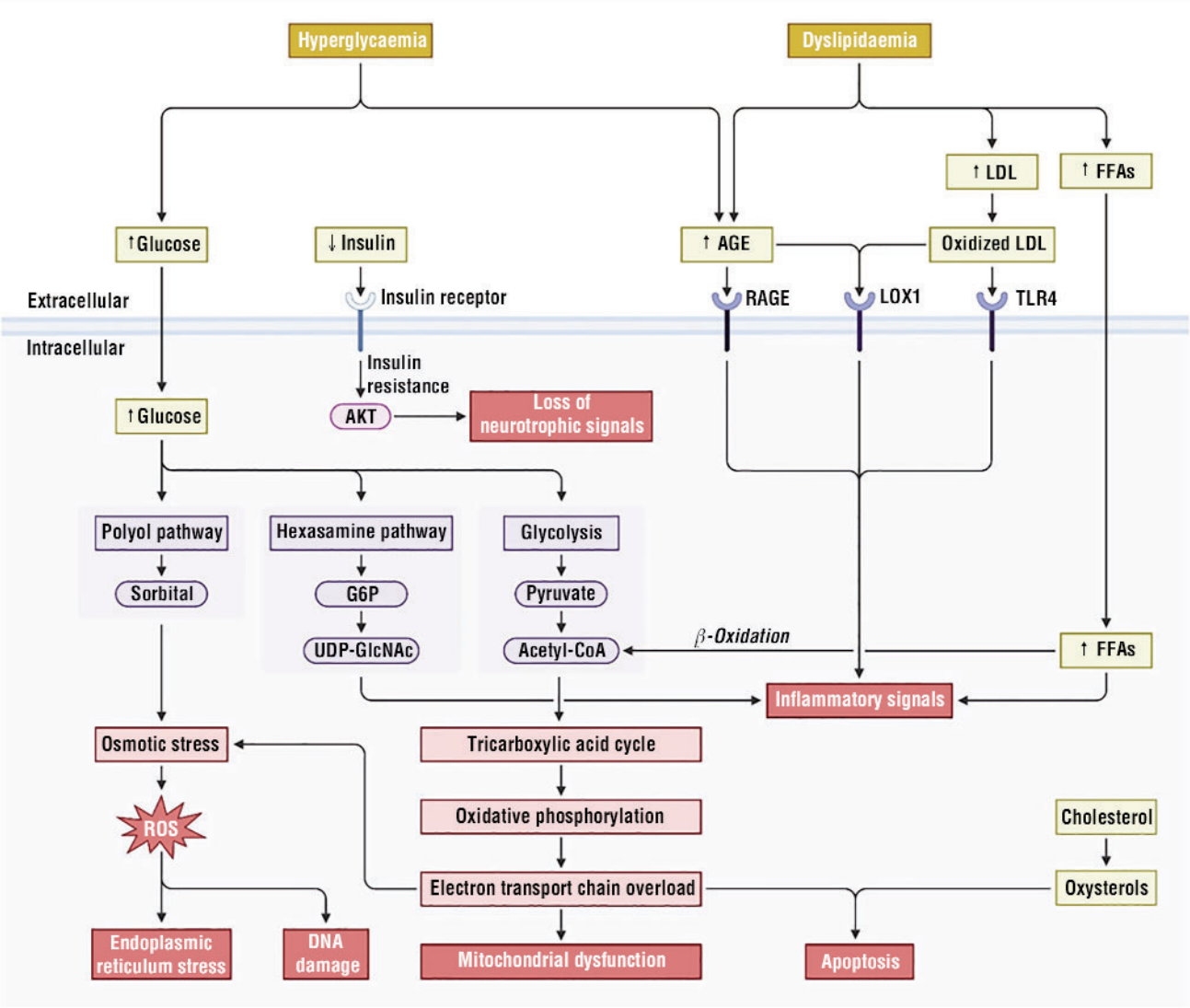

Figure 1. Metabolic and inflammatory pathways linking hyperglycaemia, dyslipidaemia, neuropathy, and tissue failure in the diabetic foot. Image created in Biorender (18)

genous bypass conduit, and the inability to achieve direct angiosomal revascularization (21). These variables, rather than the technical feasibility of an operation, should drive the salvage-versus-primary-amputation conversation (22).

Contemporary Diagnostic Workup

Foot and neurological examination

Per ADA 2025 Section 12, every person with diabetes should receive an annual comprehensive foot examination including inspection, palpation of dorsalis pedis and posterior tibial pulses, 10-g monofilament testing and at least one additional neurological modality (vibration with 128-Hz tuning fork, pinprick, ankle reflexes, or vibration perception threshold), with risk stratification (IWGDF risk 0-3) determining follow-up frequency (ADA 2025).

Vascular assessment in calcified vessels

In a person with diabetes and a foot ulcer, the IWGDF/ESVS/SVS 2023 guideline (2) recommends evaluation of pedal Doppler waveforms combined with ABI and TBI; when wounds are present, toe pressure and $TcPO_2$ are particularly informative because they bypass the falsely elevated ankle pressures caused by medial calcification. Cross-sectional imaging of the entire lower-extremity arterial tree from aorta to foot, by CT angiography (taking into account contrast-related risk in residual renal function) or, increasingly, contrast-enhanced MR angiography or duplex-guided strategies, is recommended whenever revascularization is contemplated (IWGDF 2023).

Infection assessment, osteomyelitis and microbiology

The 2023 IWGDF/IDSA Diabetic Foot Infection guideline (19) classifies infection severity (uninfected, mild, moderate, severe) and recommends probe-to-bone testing plus plain radiography as the initial imaging step, with MRI as the gold standard for soft-tissue and bone involvement when diagnostic uncertainty persists. Bone biopsy with culture and histology remains the diagnostic standard for osteomyelitis. Empirical antibiotics should be narrowed by deep tissue culture; in dialysis patients, every dose must be reviewed for renal adjustment and dialysability (23).

Medical Optimisation Before, During and After Surgery

Glycaemic management in CKD and on dialysis

KDIGO 2022 (5) endorses individualised HbA1c targets between 6.5% and 8.0% on dialysis, with continuous glucose monitoring (CGM) as the preferred glycaemic-monitoring modality because of HbA1c distortion from anaemia, iron therapy, erythropoiesis-stimulating agents and carbamylation. Metformin is contraindicated below an eGFR of 30 mL/min/1.73 m². Sodium–glucose co-transporter-2 (SGLT2) inhibitors are recommended for adults with type 2 diabetes, CKD and an eGFR ≥ 20 mL/min/1.73 m² (continued until kidney replacement therapy initiates) because of robust kidney- and cardiovascular-protective effects; signals of increased lower-extremity amputation with canagliflozin from CANVAS have not been replicated with empagliflozin or dapagliflozin in CKD trials, but vigilance for active foot pathology before initiation remains prudent (24). The non-steroidal mineralocorticoid-receptor antagonist finerenone is recommended in T2D with CKD and persistent albuminuria despite maximally tolerated renin-angiotensin-system blockade, on the basis of FIDELIO-DKD and FIGARO-DKD. GLP-1 receptor agonists are recommended for additional glycaemic and cardiovascular benefit, and, based on the FLOW trial (semaglutide), now also for renal endpoints (25).

Anaemia, iron and mineral-bone disorder

Optimisation of haemoglobin (typically 10–11.5 g/dL on dialysis, individualised) with erythropoiesis-stimulating agents and iron supplementation improves oxygen delivery to healing tissues (26). Hypoxia-inducible-factor prolyl-hydroxylase inhibitors (HIF-PHI) are now available in many jurisdictions. Phosphate and parathyroid-hormone control reduce ongoing vascular calcification (27).

Cardiovascular and antithrombotic care

The 2024 ACC/AHA Lower-Extremity PAD guideline recommends single antiplatelet therapy (aspirin or clopidogrel) for symptomatic PAD; combination low-dose rivaroxaban 2.5 mg bid plus aspirin (the COMPASS/VOYAGER regimen) is reasonable in selected high-risk patients after revascularization, with bleeding risk individualised, particularly relevant in ESKD where bleeding risk is elevated (7). High-intensity statin therapy is recommended regardless of LDL-C in symptomatic PAD (7).

Nutritional support and protein-energy wasting

Protein intake on maintenance haemodialysis is targeted at 1.0-1.2 g/kg/day (28). Albumin < 3.5 g/dL is one of the strongest single predictors of wound failure and post-operative mortality (28). Pre-operative nutritional consultation is no longer optional.

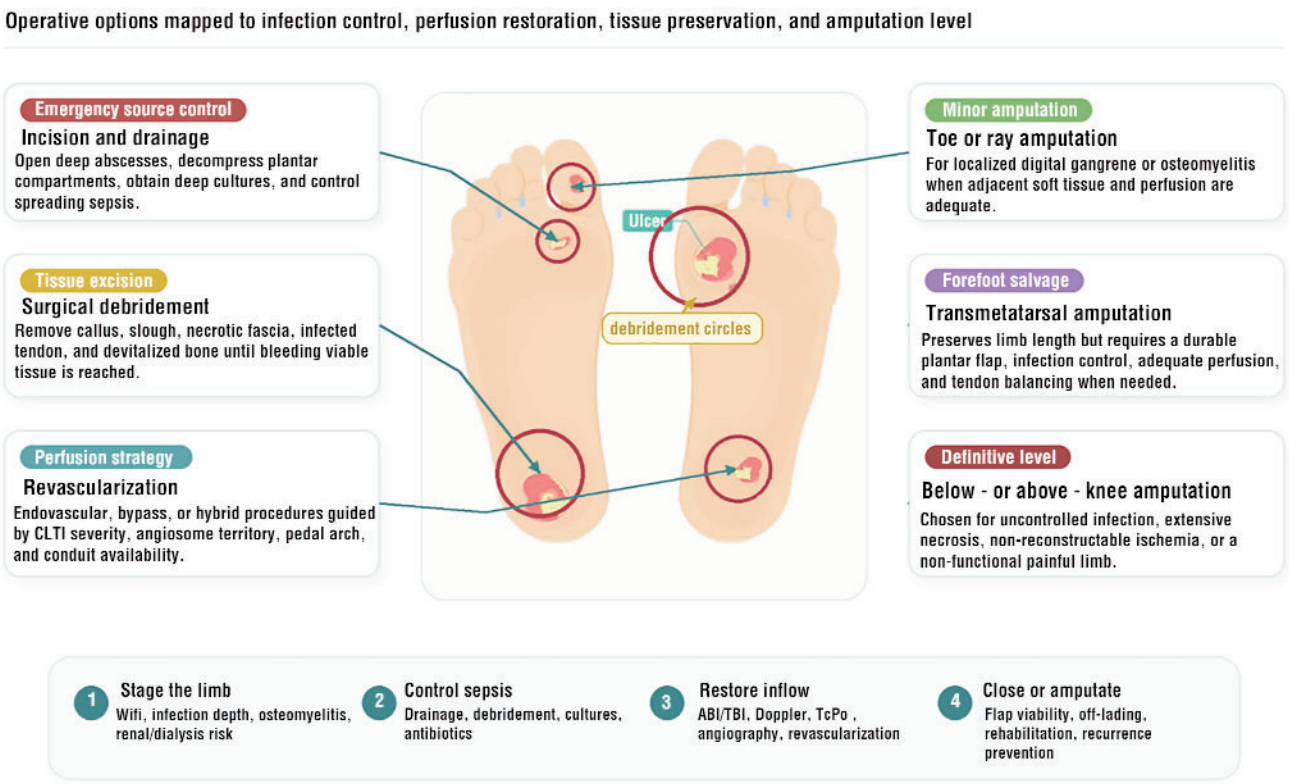

Figure 2. Comprehensive surgical strategies in diabetic foot management

Surgical Management

Fig. 2 summarizes the major surgical approaches used in the management of diabetic foot complications, emphasizing the balance between infection control, limb preservation, and restoration of tissue perfusion. Emergency procedures such as incision and drainage are performed to control deep infections and prevent the progression of sepsis, while surgical debridement removes necrotic and infected tissues to promote wound healing. Evidence from other surgical specialties further supports the value of minimally invasive approaches in diabetic patients, demonstrating reduced postoperative complications, faster recovery, and improved long-term outcomes whenever anatomically and clinically feasible (29).

Revascularization techniques, including endovascular or bypass procedures, aim to restore adequate blood flow in patients with critical limb ischemia. Depending on the extent of tissue destruction and vascular status, operative management may progress from limited toe or ray amputations to transmetatarsal amputations for forefoot salvage, or to major below- or above-knee amputations in cases of uncontrolled infection or nonviable limbs. The lower panel highlights the stepwise therapeutic approach involving limb staging, sepsis control, restoration of arterial inflow, and definitive closure or amputation, illustrating the multidisciplinary and individualized nature of diabetic foot surgery.

Debridement: principles and operative technique

Debridement is the foundational surgical act of diabetic foot care. Sharp surgical debridement, favoured over enzymatic, autolytic or biological methods in the surgical patient, should achieve removal of all non-viable tissue down to bleeding, healthy dermis, fascia, tendon or bone (30). In ESKD the surgeon must balance aggressive necrosectomy against the limited perfusion reserve: every millimetre of viable tissue is precious because the angiogenic and reparative capacity to regenerate it is impaired (31).

Anatomical landmarks matter. The plantar aponeurosis tethers infection along the central, medial and lateral compartments of the foot; pus tracks proximally along the long flexor tendons through the

tarsal tunnel into the deep posterior compartment of the leg, and along the dorsal subaponeurotic space (32). Compartment release in necrotising plantar-space infections must address all three plantar compartments and the interosseous spaces. Failure to follow the tendon sheath proximally is a common cause of recurrent sepsis (33,34).

Per the 2023 IWGDF/IDSA infection guideline, negative-pressure wound therapy (NPWT) is not routinely recommended for DFI as a stand-alone infection-control measure but is widely used after source control to promote granulation; protein loss into NPWT effluent should be measured in dialysis patients and replaced (19).

Revascularization: when, what and how

Indications and timing

Per the IWGDF/ESVS/SVS 2023 guideline (2), revascularization should be considered in any person with diabetes, a foot ulcer and clinical findings of ischemia (absent pulses, monophasic/absent pedal Doppler, ankle pressure < 100 mmHg or toe pressure < 60 mmHg) and pursued urgently when ABI < 0.4, ankle pressure < 50 mmHg, toe pressure < 30 mmHg, $TcPO_2$ < 30 mmHg, or pedal Doppler is monophasic/absent. The "time-to-revascularization" target after admission for severe limb threat is widely adopted at < 14 days, and earlier in the presence of tissue loss with infection.

Open infrainguinal bypass

Where an adequate (≥ 3.0-3.5 mm), single-segment great saphenous vein is available, the 2023 IWGDF intersocietal guideline (2) and the BEST-CLI 2022 trial (35) favour open bypass over endovascular therapy for suitable patients with infrainguinal disease and a target distal artery. Distal targets in diabetes are frequently the dorsalis pedis, plantar arteries or the peroneal at the ankle. In ESKD, however, the perioperative cardiovascular risk, wound-healing problems at the groin and leg incisions, and the higher risk of graft thrombosis qualify the recommendation - patient selection becomes paramount (35). Prosthetic conduits perform poorly in the presence of infection and uremia and should generally be avoided.

Endovascular therapy

Endovascular techniques, including plain-balloon angioplasty, drug-coated balloons, atherectomy, intravascular lithotripsy and selective stenting, have become first-line in many ESKD patients given comorbidity (36). Long-segment infrapopliteal occlusions, heavy calcification and pedal-vessel disease limit durability, and reintervention should be anticipated. Intravascular lithotripsy is a mechanically rational adjunct for the heavy medial calcification of CKD; drug-eluting devices below the knee remain an area of active evidence development (37).

Hybrid procedures and the pedal-plantar loop

Hybrid procedures, e.g. iliac stenting plus femoral endarterectomy and distal bypass, allow the operator to address inflow and outflow lesions in a single sitting. The pedal-plantar loop technique (retrograde recanalisation across the deep and superficial plantar arch when antegrade access fails) is now a routine bail-out for the foot in expert centres (38).

No-option CLTI and transcatheter arterialization of deep veins

In patients without a target artery for direct revascularization ("no-option" CLTI), percutaneous deep-vein arterialization (pDVA), diverting arterial inflow into the deep venous system of the foot via a covered stent and ablation of competing venous outflow, emerged from PROMISE I/II as a viable salvage strategy. 1-year amputation-free survival in PROMISE II was approximately 66% in a cohort otherwise destined for major amputation, with sustained benefit at extended follow-up (39). Approximately one-third of patients in PROMISE II were on dialysis, a population in which the technique should be considered before committing to a major amputation when standard options have been exhausted (39).

Amputation: levels, technique and decision-making

Minor (foot-sparing) amputations

Toe (ray), transmetatarsal (TMA), Lisfranc (tarsometatarsal) and Chopart (midtarsal) amputations preserve weight-bearing surface and ambulation. Anatomical pearls: a successful TMA requires preservation of tibialis anterior insertion or formal tendon-balancing (percutaneous tendo-Achilles lengthening, posterior tibial transfer) to avoid equinovarus and recurrent forefoot ulceration; in Lisfranc/Chopart disarticulations, equinus deformity is the rule and must be addressed (40). In ESKD, the failure rate of minor amputations is markedly higher than in nonuremic diabetics; perfusion must be either intact or restored before commitment to a foot-sparing level (41).

Below-knee (transtibial) amputation

BKA at the junction of the proximal and middle thirds of the tibia is the workhorse major amputation. A posterior myocutaneous flap (Burgess) is standard (42).

The tibia is transected 12–15 cm distal to the medial joint line; the fibula is shortened 1–2 cm shorter than the tibia. Beveling of the anterior tibial crest reduces prosthetic-related pressure necrosis. Successful BKA preserves the knee joint, dramatically improving prosthetic rehabilitation potential, but in ESKD, the energy cost of ambulation and frailty often preclude functional prosthetic use, and primary stump failure is common (43).

Above-knee (transfemoral) amputation

AKA heals more reliably than BKA in severe proximal ischemia and in frail, non-ambulatory patients, but eliminates the knee joint and roughly doubles the metabolic cost of ambulation. In the very frail ESKD patient who will not regain ambulation, primary AKA may be the most humane choice (44).

Knee disarticulation

Knee disarticulation, often underused, preserves the distal femur as an end-bearing stump and the long lever arm of the femur for transfers, and may be preferable to AKA in non-ambulatory bedridden patients with limited rehabilitation potential (45).

Vascular Access and Transplantation: Surgical Decisions That Outlive the Foot

Protecting and planning vascular access

In any ESKD patient with a diabetic foot, the surgeon must remember that an arm vein saved today is a fistula tomorrow. The KDOQI 2019 Vascular Access guideline (46) endorses an individualised, "ESKD Life-Plan" approach with patient-specific access selection rather than a rigid "fistula-first" mandate, while still emphasising autogenous arteriovenous fistula (AVF) where appropriate. Operative pearls relevant to the foot surgeon: avoid peripheral IV cannulation in the non-dominant arm; do not place arterial lines in radial arteries planned for AVF; counsel the anaesthetic team about brachial-vein preservation (47). Steal syndrome of a brachial AVF can itself precipitate digital ischemia of the hand, and analogous physiology underlies why an ipsilateral fistula does not "steal" from the leg but can complicate fluid management around lower-limb revascularization (48).

Kidney and simultaneous pancreas-kidney transplantation

For dialysis-dependent type 1 diabetics, simultaneous pancreas-kidney (SPK) transplantation restores euglycaemia and renal function, and longitudinal data show stabilisation or regression of microvascular complications and reduced amputation rates compared with kidney-alone or dialysis (49). For type 2 diabetics, kidney-alone transplantation remains the standard. After transplantation, immunosuppression (corticosteroids, calcineurin inhibitors, mTOR inhibitors) impairs wound healing and increases infection risk; tacrolimus also worsens insulin sensitivity (50). Diabetic foot ulcers in post-transplant patients can be particularly indolent and severe, and have been associated with graft loss and patient mortality in cohort studies (50). Surgical planning in the transplant recipient must therefore include immunosuppression review, infection prophylaxis and graft-function protection (contrast minimisation, NSAID avoidance (51).

Perioperative Care of the Dialysis Patient

Dialysis timing, fluid and electrolytes

Elective surgery should be scheduled the day after haemodialysis, with the patient euvolaemic, normokalaemic and free of residual heparin. Same-day dialysis predisposes to intra-operative hypotension and bleeding (52). Pre-operative potassium $\leq$ 5.5 mmol/L is generally recommended; phosphate, calcium and acid-base balance should be corrected. For peritoneal-dialysis patients, the abdomen should be drained immediately before general anaesthesia (53).

Anaesthetic considerations

Regional anaesthesia (popliteal block, ankle block, neuraxial) is attractive for foot surgery in ESKD because it avoids the haemodynamic instability of general anaesthesia and reduces opioid requirement, but coagulopathy, residual heparin from dialysis, and active infection at the puncture site limit its use (54). Drug dosing, especially of opioids (morphine and its active metabolite M6G accumulate), gabapentinoids, NSAIDs (avoid) and antibiotics, must be renally adjusted (55).

Antibiotics in the dialysis patient

Empiric coverage must address methicillin-resistant Staphylococcus aureus (MRSA) in moderate-to-severe DFI and gram-negative/anaerobic pathogens in chronic, previously treated wounds (56). Vancomycin, aminoglycosides, β-lactams and fluoroquinolones all require dose adjustment; ceftriaxone, linezolid, daptomycin (with renal adjustment), ertapenem and metronidazole are workhorses. Tailor therapy to deep-tissue cultures and bone biopsy whenever possible (57).

Multidisciplinary "toe-and-flow" model

The integrated "toe-and-flow" service, bringing together vascular surgery, podiatric/orthopaedic foot surgery,

infectious disease, endocrinology/diabetology, nephrology, vascular access surgery, plastic surgery, prosthetics and rehabilitation, has repeatedly been associated with reductions in major amputation, in keeping with IWGDF and ADA recommendations. ESKD patients benefit at least as much as non-uremic diabetics from this model, though absolute outcomes remain worse (58).

Future Directions

Three vectors are likely to shape the next decade: 1. Pharmacological - broader uptake of SGLT2 inhibitors, finerenone and GLP-1 receptor agonists in the CKD population, with renal- and limb-event reduction translating into fewer presentations of CLTI; 2. Interventional - refinement of below-the-knee techno-logy (intravascular lithotripsy for medial calcification, drug-eluting devices for the tibial and pedal vessels, and pDVA for no-option CLTI); 3. Biological and regenerative - mesenchymal stromal cells, exosome-based therapies, bioengineered skin substitutes, topical growth factors and acellular dermal matrices, alongside refined offloading and patient-centred care pathways. Across all three, integration will produce most of the gain. The future of surgery is increasingly shifting toward personalized, biomarker-guided treatment strategies that optimize patient selection and improve clinical outcomes (59).

Conclusion

The diabetic foot in ESKD is the somatic endpoint of a long anatomical journey that begins in the glomerular capillary and ends in the pedal angiosome. For the surgeon, this means that no debridement is local, no revascularization is purely vascular, and no amputation is purely orthopaedic. Each operation is performed in a body whose immune system, haematology, metabolism, fluid balance and mineral homeostasis have been re-written by uremia and diabetes. Contemporary guidelines from ADA, KDIGO, IWGDF/ESVS/SVS, ACC/AHA and KDOQI now provide a coherent scaffold: stratify with WIfI, image the entire arterial tree from aorta to foot, attempt direct angiosomal revascularization where feasible, escalate to pDVA in no-option CLTI before major amputation, anticipate medial arterial calcification, schedule surgery around dialysis, and operate within a multidisciplinary "toe-and-flow" service. The honest acknowledgement that this population suffers worse outcomes despite our best technical efforts must coexist with a disciplined application of those best efforts, including the willingness to choose a well-timed, well-planned amputation when salvage no longer serves the patient.

Conflicts of Interest

The authors declare no conflict of interest. All authors contributed equally and share collective authorship.

Ethical Statement

All procedures performed in this study were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments. Given the retrospective nature of the study and the absence of any experimental interventions, approval from an ethics committee was not required.

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