Diabetic Foot: Saving Soles

Uma Malhotra, MD, FIDSA

Infectious Diseases & Wound care, Virginia Mason Franciscan Health

Clinical Professor of Medicine, University of Washington

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Disclosures

No financial disclosures

Amputation rates for diabetic foot are staggering. It is estimated that 85% of amputations could be prevented with optimal patient-provider partnerships and multidisciplinary team care.

Outline

- Epidemiology and pathophysiology of diabetic foot ulcers
- Promoting wound healing, foot care & off loading
- Diagnosis and treatment of infection
- Assessment & management of vascular disease
- Adjunct modalities/role for hyperbaric treatment

Some of the slides are courtesy my colleagues at VM: Dr. Pilar Almy, Podiatry; Dr Carlos Pineda, Vascular Surgery; and Dr Nick Bird, Hyperbaric Medicine.

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Epidemiology of Diabetic Foot Ulcers

- 537 million adults worldwide with diabetes (2021)
- 37.3 million adults with diabetes in the US (2023)
- 25% lifetime risk of developing a diabetic foot ulcer
- 20% with a foot ulcer require an amputation
- 70% of patients with amputations die within 5 years

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Amputations in Diabetes

- Worldwide > 1 million/year
- US 154K/year, 2023 >350/day
- 70% of all amputations are caused by diabetic foot ulcers
- Higher rates in men, racial/ethnic minorities

- Costly, $60K/amputation
- >2 Billion dollars/year total costs

National Diabetes Statistics Report, CDC 2023

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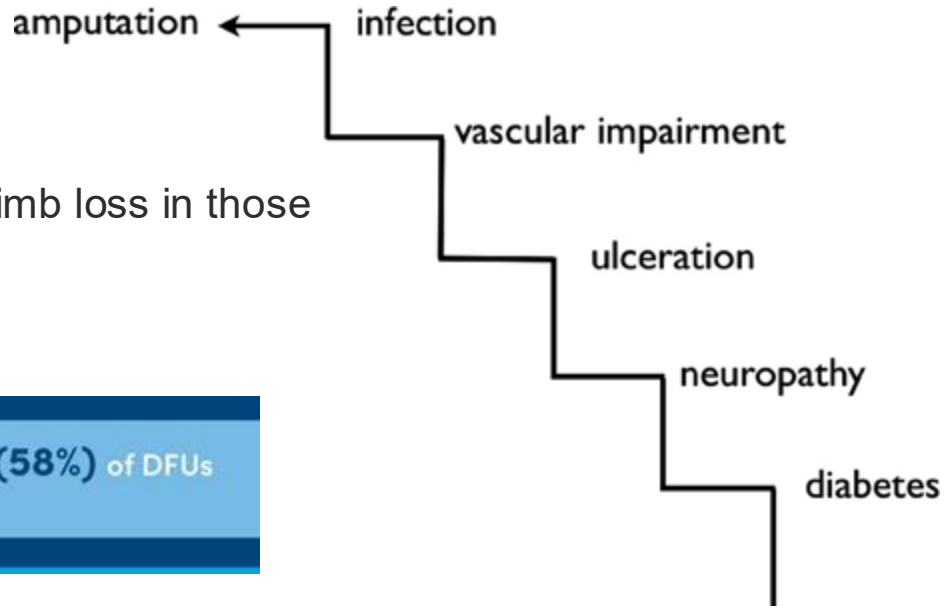
Stairway to Amputation

Compounding steps leading to limb loss in those with diabetes.



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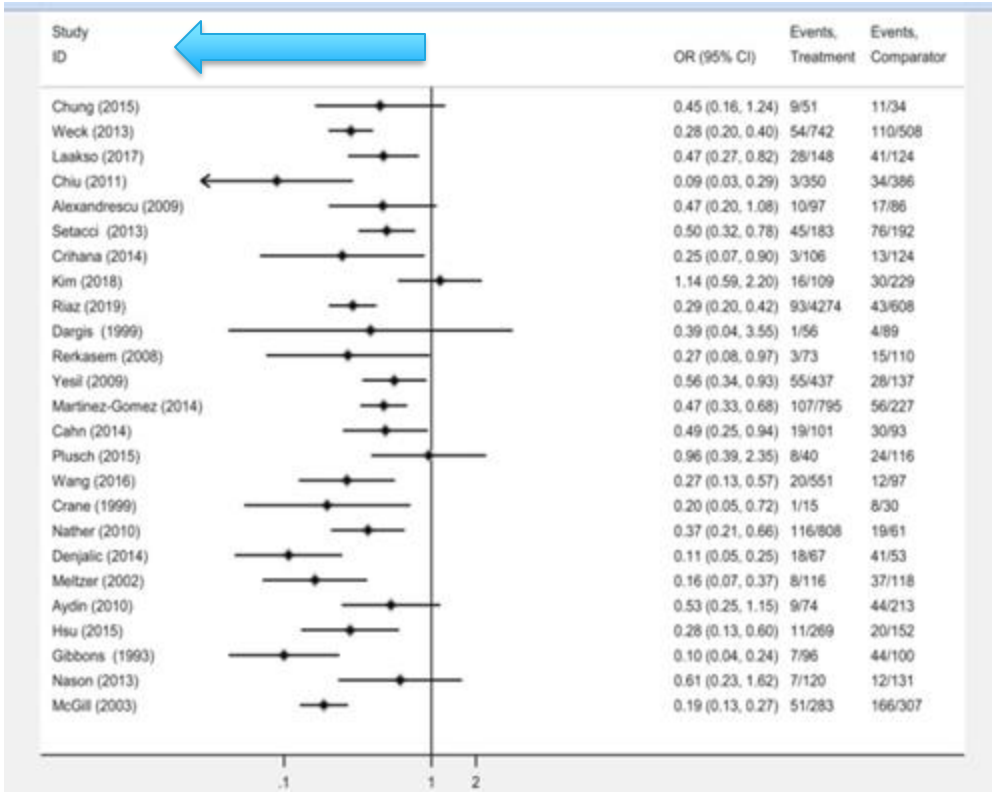
Journal of Vascular Surgery, Volume 52, Issue 3, 23S - 27S

Decreased Incidence of Major Amputations with Multidisciplinary Care for Diabetic Foot Ulcers

Favors Multidisciplinary Care-

Pooled Odds Ratio of 0.4



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Journal of Vascular Surgery, 2020-04-01

Multidisciplinary Diabetic Foot Ulcer Care at VM

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Different mechanisms may dominate in the pathogenesis

N Engl J Med 2000;343:787-793

Risk Factors for Ulceration

Intrinsic

- Previous ulcer/ amputation
- Peripheral neuropathy
- Poor glycemic control, DM duration
- Vascular disease
  - Macrovascular, microvascular
- Structural foot deformity
- Advanced age, limited joint mobility
- Blindness/ partial sight
- Callus

Extrinsic

- Minor mechanical trauma
  - High plantar pressure, shoe pressure
- Thermal injury
  - Hot soaks, frostbite
- Bathroom surgery
  - Nail trimming, callus carving
- Poor knowledge of diabetes
- Cigarette smoking
- Living alone

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Clinical Evaluation: History

- Global history
  - DM duration
  - Glycemic management/control
  - CV, renal, ophthalmic evaluations
  - Other comorbidities
  - Social habits
  - Previous hospitalizations/ surgeries
- Foot-specific history
  - General pain/ problems
  - Daily activity
  - Footwear
  - Occupational trauma
  - Callus formation
  - Deformities
  - Previous foot surgery
  - Neuropathic symptoms
  - Ischemic symptoms

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- Wound/ Ulcer history
  - Location and duration
  - Inciting event or trauma
  - Recurrences
  - Infections
  - Hospitalizations
  - Wound care/ off-loading methods
  - Patient compliance/ wound care response
  - Previous or active charcot joint

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Foot Examination

- Vascular: DP, PT pulses, doppler
- Neurologic: vibratory sensation, protective threshold (Semmes-Weinstein monofilament), temperature sensation, sharp/dull, reflexes
- Dermatologic: temperature, turgor, color, dryness, hair growth, nail condition, edema, erythema, ecchymosis, fungus, calluses
- Musculoskeletal: digital contractures, bony prominences, joint mobility, foot deformity.
- Shoe Gear: wear patterns, fit, stability, cushion, orthotics
- Gait: antalgia, balance, limb length inequality

Assessment of Foot Ulcers

- General extremity assessment
- Ulcer evaluation
  - Determine etiology
  - Neuropathic, ischemic or both?
  - Size and depth
  - Describe margins, base, location
  - Probe all but the most superficial wounds
  - Note odor and exudate, and obtain deep culture if clinical signs of infection

Diagnostic Tests

- Laboratory testing
  - As needed: CBC, HbA1c, CRP/ESR, serum chemistries, blood/wound cultures, etc.
- Imaging studies
  - Plain radiographs (initial imaging study): cortical breaks, bony erosions, foreign bodies, gas, fractures, vascular calcifications, Charcot changes
  - CT scan may be helpful for assessment of suspected bone/joint pathology not seen on plain films.
  - MRI

Wagner Grading

Grade	Lesion
0	Intact skin
1	Superficial ulcer of skin or subcutaneous tissue
2	Ulcer extend into tendon, bone, or capsule
3	Deep ulcer with osteomyelitis or abscess
4	Gangrene of toes or forefoot
5	Midfoot or hindfoot gangrene

Hussain, Z. Current Drug Targets. 2017

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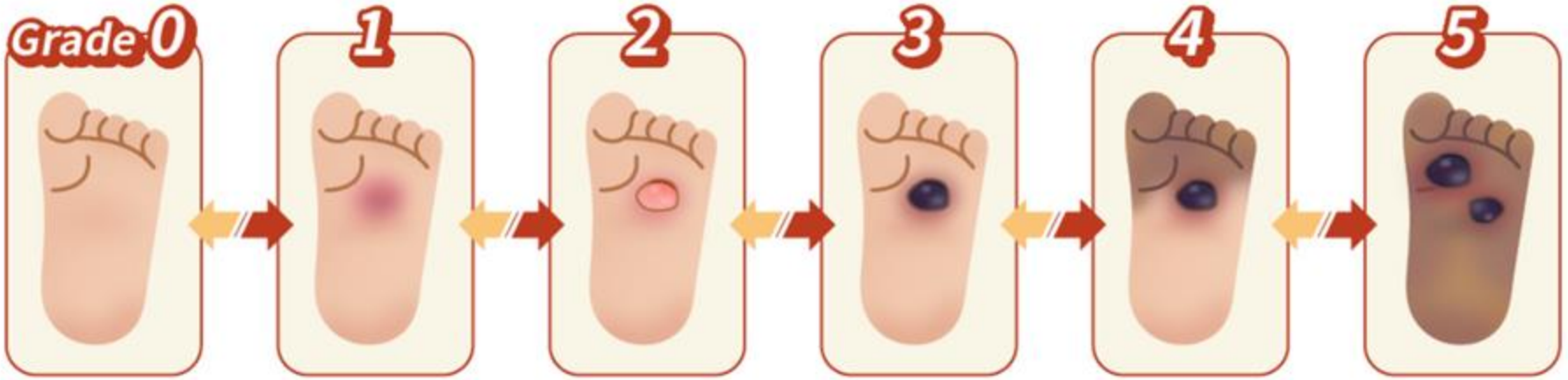
The Wagner Ulcer Classification System for Classifying Diabetic Foot Ulcers



Pre-ulcerative area without open lesion

Superficial ulcers that may penetrate to the dermal tissue

Deep ulcers (reaching ligaments, tendons, joint capsules, or bones) **but without abscess or osteomyelitis**

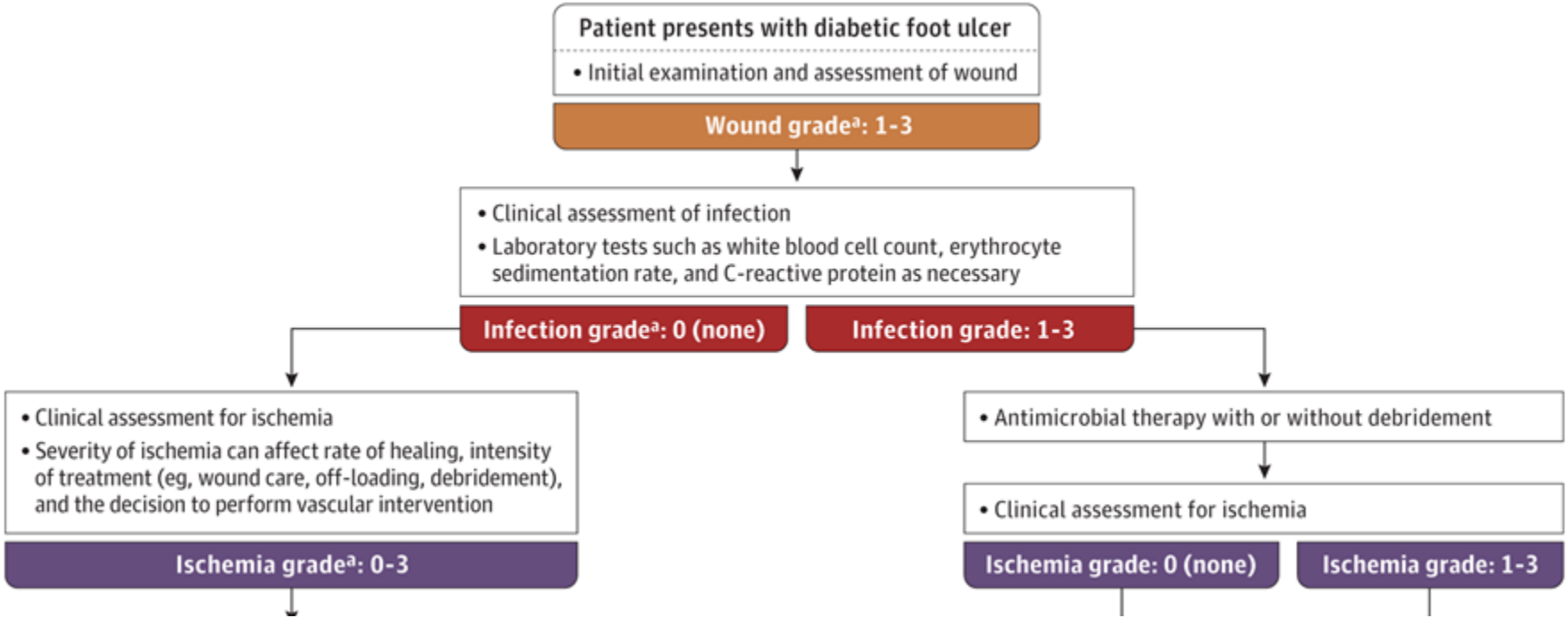
Deep ulcers complicated by the presence of an abscess, osteomyelitis, or joint sepsis

Localized gangrene involving part of the toe or heel

Global foot gangrene

Pay more attention to the wound condition. If it worsens, it would be better to return to the doctor as soon as possible.

Assess for Infection and Ischemia



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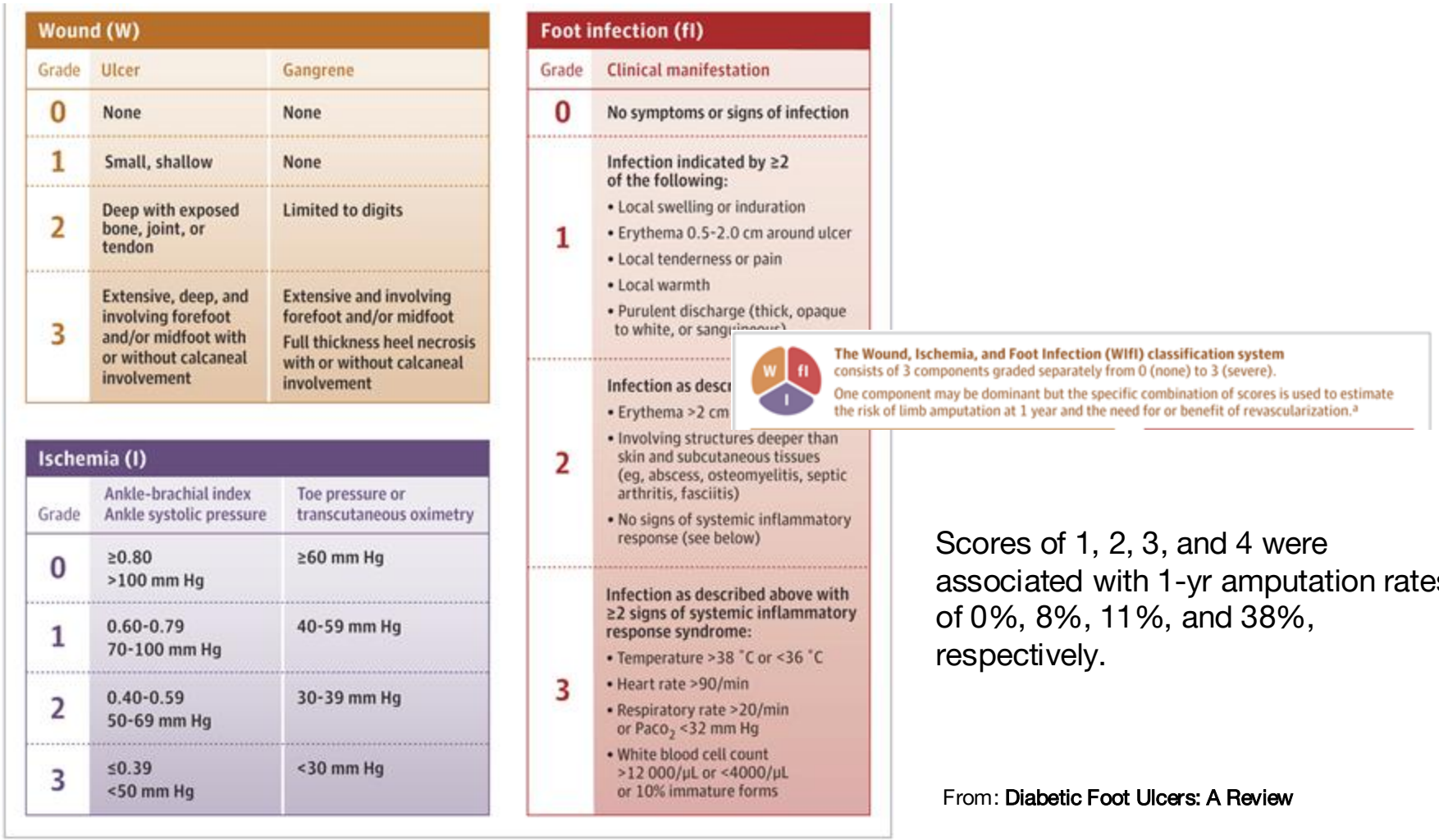
Diabetic Foot Ulcers: A Review JAMA. 2023;330(1):62-75. doi:10.1001/jama.2023.10578



Wound (W)

Grade	Ulcer	Gangrene
0	None	None
1	Small, shallow	None
2	Deep with exposed bone, joint, or tendon	Limited to digits
3	Extensive, deep, and involving forefoot and/or midfoot with or without calcaneal involvement	Extensive and involving forefoot and/or midfoot Full thickness heel necrosis with or without calcaneal involvement

Ischemia (I)

Grade	Ankle-brachial index Ankle systolic pressure	Toe pressure or transcutaneous oximetry
0	≥0.80 >100 mm Hg	≥60 mm Hg
1	0.60-0.79 70-100 mm Hg	40-59 mm Hg
2	0.40-0.59 50-69 mm Hg	30-39 mm Hg
3	≤0.39 <50 mm Hg	<30 mm Hg

Foot infection (fI)

Grade	Clinical manifestation
0	No symptoms or signs of infection
1	Infection indicated by ≥2 of the following: • Local swelling or induration • Erythema 0.5-2.0 cm around ulcer • Local tenderness or pain • Local warmth • Purulent discharge (thick, opaque to white, or sangu
2	Infection as desc • Erythema >2 cm • Involving structures deeper than skin and subcutaneous tissues (eg, abscess, osteomyelitis, septic arthritis, fasciitis) • No signs of systemic inflammatory response (see below)
3	Infection as described above with ≥2 signs of systemic inflammatory response syndrome: • Temperature >38 °C or <36 °C • Heart rate >90/min • Respiratory rate >20/min or $PaCO_2$ <32 mm Hg • White blood cell count >12 000/μL or <4000/μL or 10% immature forms

The Wound, Ischemia, and Foot Infection (WIfI) classification system consists of 3 components graded separately from 0 (none) to 3 (severe).

One component may be dominant but the specific combination of scores is used to estimate the risk of limb amputation at 1 year and the need for or benefit of revascularization.[a]

Scores of 1, 2, 3, and 4 were associated with 1-yr amputation rates of 0%, 8%, 11%, and 38%, respectively.

From: **Diabetic Foot Ulcers: A Review**

JAMA. 2023;330(1):62-75. doi:10.1001/jama.2023.10578

Treatment Principles

- Optimize the wound environment
- Relieve pressure: off-load the ulcer area
- Manage ischemia: vascular surgery consult
- Control infection: I&D, empiric then culture-specific antibiotics, possible ID consult, debride infected tissue/amputation

Optimize the Wound Environment

- Debride necrotic, non-viable or grossly infected material
  - sharp debridement, sometimes amputation
  - enzymatic debriding agents
  - thorough lavage
- Dressings: goals
  - maintain a moist wound environment
  - protect the wound and surrounding skin
  - cost, ease of use, frequency of changes

Diabetic Foot Offloading Devices and Customizable Soles

ADHESIVE FELT OFFLOADING TECHNIQUE

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Customize strategies to patient needs and preferences

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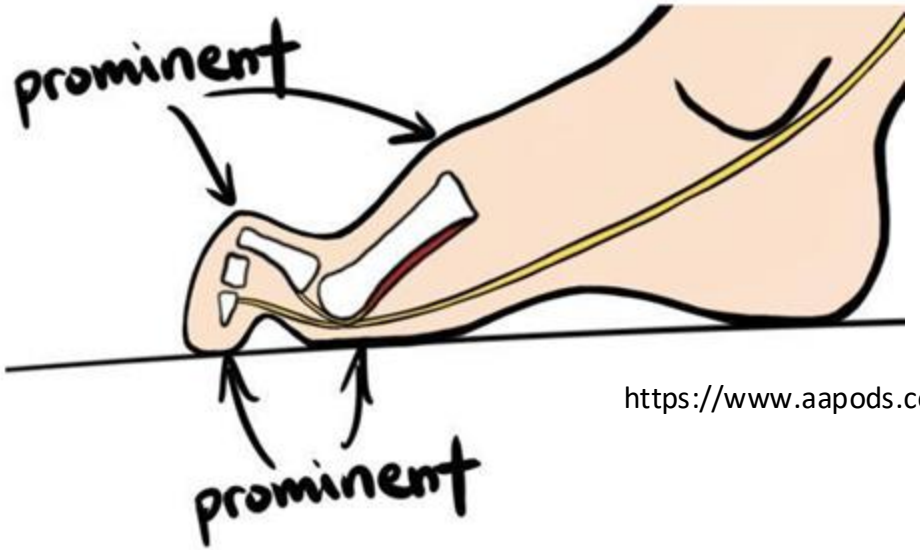
Minimize Internal Pressure Points

Surgical correction of bony prominences can be essential



https://www.aapods.com

Diabetic Foot Infection

- Defined as soft tissue infection and/or osteomyelitis of the foot.
- A diabetic foot ulcer is a common component.
- Most common single factor leading to amputation.
- Response to infection may be altered.

D-FOOT international

How to Classify Diabetic Foot Infection?

	1	2	3
Infection severity	MILD INFECTION (IDSA[a])-PEDIS[b] 2	MODERATE INFECTION (IDSA)-PEDIS 3/3osteomyelitis	SEVERE INFECTION (IDSA)/PEDIS 4/4osteomyelitis
Characteristics	**Presence of at least two of:** ▪ Local swelling or induration ▪ Erythema > 0.5 cm ▪ Local tenderness or pain ▪ Local increased warmth ▪ Purulent discharge	▪ Local infection with erythema >2 cm **OR** ▪ Involvement structures deeper than skin and subcutaneous tissue ▪ No signs of systemic inflammatory response	▪ Temperature >38 °C or <36 °C ▪ Heart rate >90 beats/minute ▪ Respiratory rate >20 breaths/minute or PaCO2 <4.3 kPa (32 mmHg) ▪ White blood cell count >12,000/mm3, or <4,000/mm3, or >10% immature (band) forms
Antibiotics *	Oral agents	Oral or initial parenteral agents	Parenteral agents
Clinical presentation			

** See recommendations of Infection Guideline for empirical antibiotic regimen for diabetic foot infection*

[a] **IDSA**: Infectious Disease Society of America
[b] **PEDIS**: Perfusion, Extent, Depth, Infection and Sensation

Diabetic Foot Infection: Management Principles

- Diagnose infection- presence, severity, extent
- Obtain deep cultures – tissue/bone. Select antibiotic therapy – empiric/definitive
- Determine need for surgery – drainage, debridement, revascularization. Antibiotics and surgical debridement are mainstays of therapy in severe infections.
- Proper wound care and off loading
- Aggressive diabetes care

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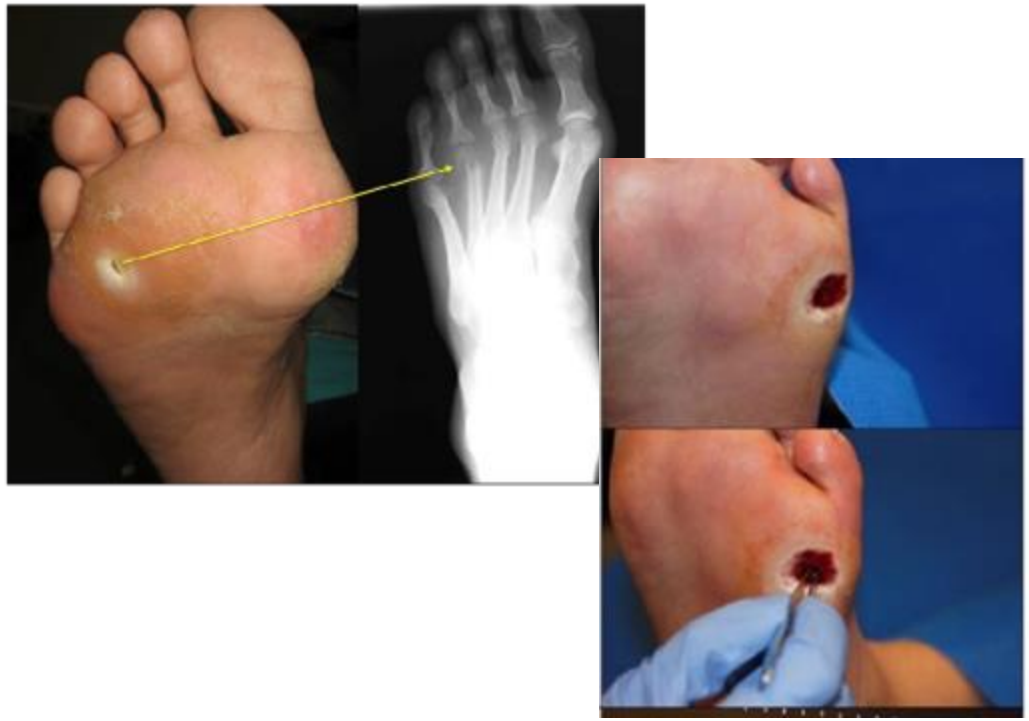
IWGDF/IDSA guidelines recommend hospitalizing all persons with a DFI in the severe category or if the category of moderate infection when there are key co-morbidities

The International Journal of Lower Extremity Wounds. 2023;0(0).

Diabetic Foot Osteomyelitis

- Frequent complication of DFU
- Contiguous focus most common
- Can be difficult to diagnose

- Probe to bone
- Inflammatory markers
- Imaging – plain x-rays, MRI



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Imaging for Diagnosis of Diabetic Foot Osteomyelitis

Modality	N	Sensitivity	Specificity
Probe-to-bone or exposed bone	288	0.60 (0.46-0.73)	0.91 (0.86-0.94)
Radiography	177	0.54 (0.44-0.63)	0.68 (0.53-0.80)
MRI	135 421	0.90 (0.82-0.95) 0.93 (0.82-0.97)	0.79 (0.62-0.91) 0.75 (0.63-0.84)
Bone scan	185	0.81 (0.73-0.87)	0.28 (0.17-0.42)
Leukocyte scan	269	0.74 (0.67-0.80)	0.68 (0.57-0.78)

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Dinh MT, Abad CL, Safdar N. Clin Infect Dis 2008; 47:519-527. Lauri C, Tamminga M, Glaudemans AWJM.. Diabetes Care 2017; 40: 1111-1120.

Pathogens Associated with Diabetic Foot Infection

Foot-infection syndrome	Pathogens
Cellulitis without an open skin wound	β-Hemolytic streptococcus[a] and *Staphylococcus aureus*
Infected ulcer and antibiotic naive[b]	*S. aureus* and β-hemolytic streptococcus[a]
Infected ulcer that is chronic or was previously treated with antibiotic therapy[c]	*S. aureus*, β-hemolytic streptococcus, and Enterobacteriaceae
Ulcer that is macerated because of soaking[c]	*Pseudomonas aeruginosa* (often in combination with other organisms)
Long duration nonhealing wounds with prolonged, broad-spectrum antibiotic therapy[c,d]	Aerobic gram-positive cocci (*S. aureus* , coagulase-negative staphylococci, and enterococci), diphtheroids, Enterobacteriaceae, *Pseudomonas* species, nonfermentative gram-negative rods, and, possibly, fungi
"Fetid foot": extensive necrosis or gangrene, malodorous[c]	Mixed aerobic gram-positive cocci, including enterococci, Enterobacteriaceae, nonfermentative gram-negative rods, and obligate anaerobes

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Guidelines for Diabetic Foot Infections. CID 2004;39:885-910

Antibiotic Selection

- Mild DFI, antibiotic naïve coverage of aerobic GP organisms, Staph/Strep
- Moderate and severe cases include coverage for MRSA and Pseudomonas
- Extensive necrosis/malodorous include anaerobic coverage
- Obtain deep tissue/abscess cultures for soft tissue infection and bone cultures for osteomyelitis

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Typical Duration of Antibiotic Therapy

Degree and Management of Foot Infection	Duration
Osteomyelitis, managed nonoperatively	6 weeks
Osteomyelitis, following debridement (but not curative amputation)	3–6 weeks
Soft tissue infection without osteomyelitis	10–21 days
Soft tissue infection and/or osteomyelitis, following curative amputation	0–48 hours

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Role for Oral Antibiotics in Rx of Osteomyelitis

- Noninferiority demonstrated in 8 RCTs
- Most notable was the Oral Vs. IV Abx for bone and joint infection (OVIVA) trial
- OVIVA showed no difference in long-term cure between all-IV vs. rapid transition to PO antibiotics.

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Oral vs. intravenous antibiotics for bone and joint infections. NEJM 2019; 380:425-36

Indications for Surgery

- Urgent surgical debridement is indicated for deep or extensive abscess, extensive bone or joint involvement, necrosis, gangrene, necrotizing fasciitis, compartment syndrome.
- Prior to surgery, vascular evaluation should be performed if there is concern for peripheral artery disease.
- Early surgical debridement for severe diabetic foot infection may decrease the risk of amputation.

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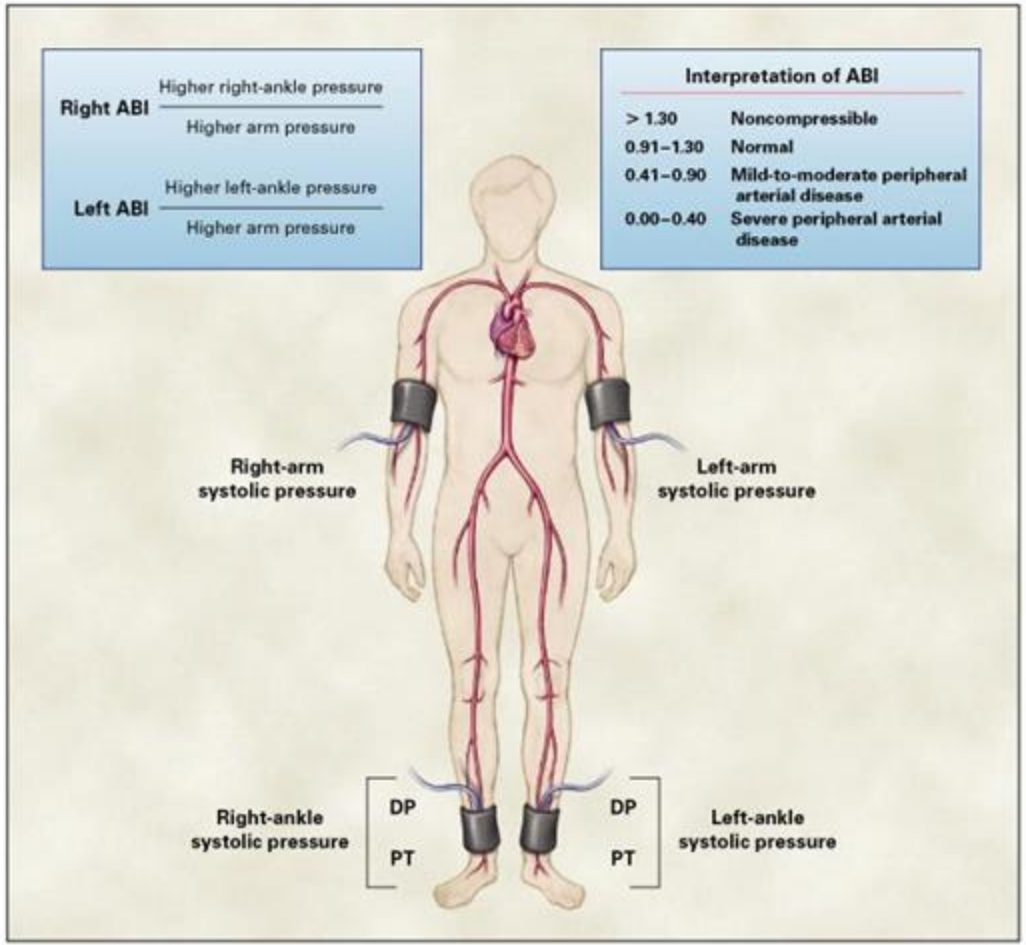
The role of early surgical debridement and revascularization in patients with diabetes and deep foot space abscess: retrospective review of 106 patients with diabetes. J Foot Ankle Surg. 2006; 45(4):220–226.

Assess perfusion

Increase if insufficient



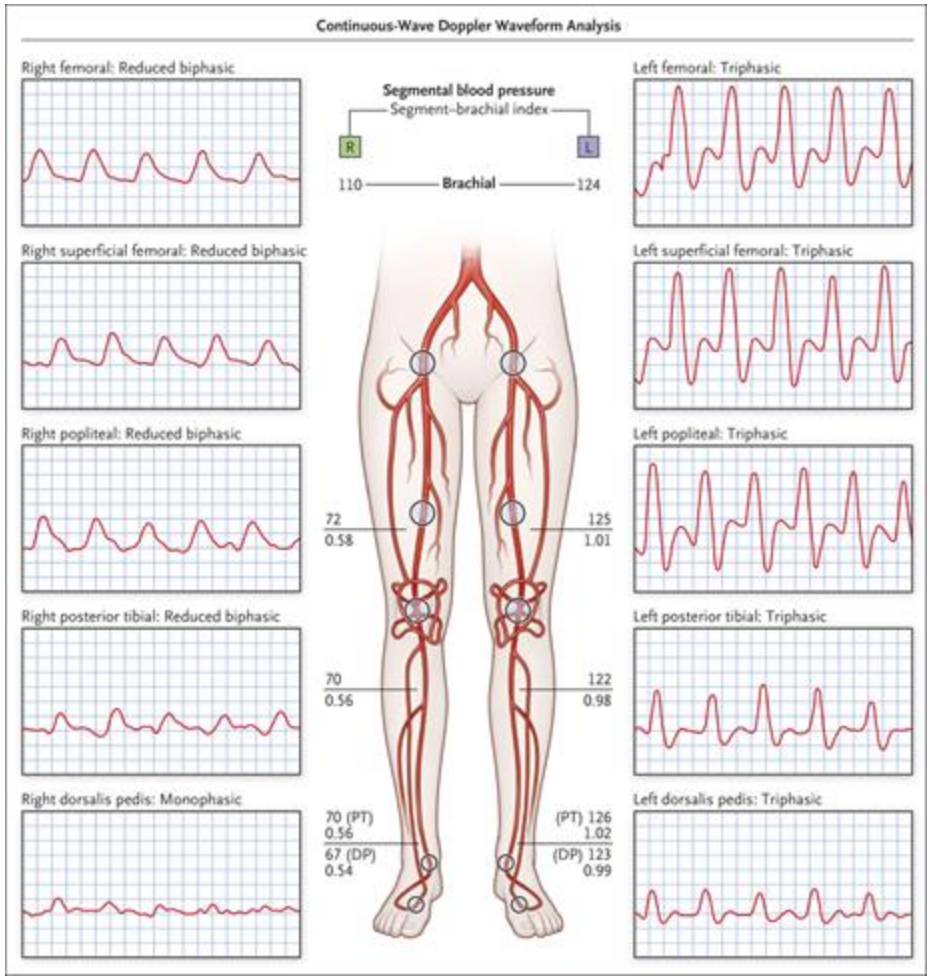
NEJM Volume 344 • Number 21 • May 24, 2001

Measurement of the Ankle–Brachial Index (ABI)

- PAD is considered to be present when the resting ABI is 0.90 or less.
- Patients with claudication typically have ABI values 0.41 to 0.70, and those with critical leg ischemia have values of 0.40 or less.
- A ratio >1.30 suggesting a noncompressible, calcified vessel. Additional tests are required to diagnose PAD.

- Toe Pressures: More accurate measurement >60 mmHg is required for wound healing.

- Continuous-wave Doppler waveforms analyzed to assess arterial blood flow.



Full Leg Pressures

Measurement of segmental pressures/ indexes and continuous-wave Doppler exam.

- Generally a drop in the blood pressure >20 mm Hg between two adjacent locations indicates a hemodynamically significant stenosis.
- Normally, a triphasic or biphasic response is present, whereas a reduced biphasic or monophasic signal indicates a hemodynamically significant stenosis.

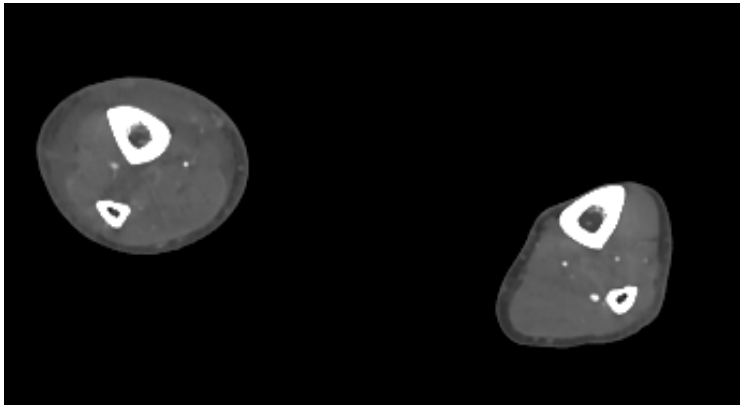
NEJM, **Volume 374 • Number 9 • March 3, 2016**

Vascular Imaging

Arterial duplex ultrasound (velocities and flow)

CT angiogram

MR angiogram



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Perfusion Assessment: Arteriogram

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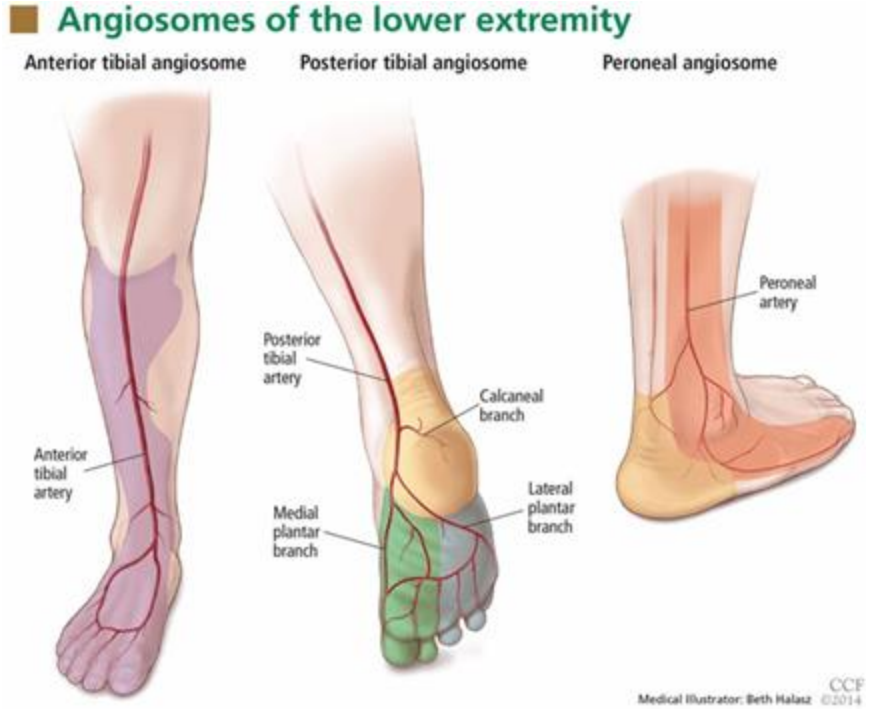

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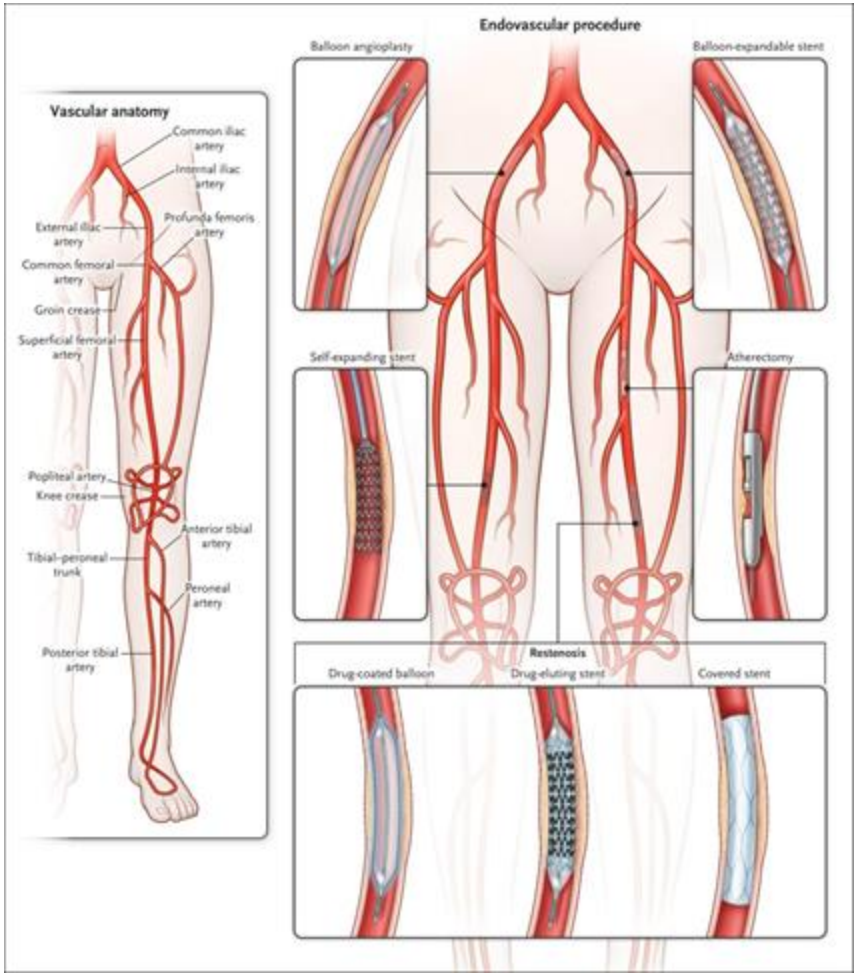
Endovascular Procedures for Treatment of PAD

- Balloon angioplasty, stenting, and atherectomy are common endovascular procedures.
- Drug-eluting or covered stents and drug-coated balloons are being evaluated to reduce the rate of restenosis.

NEJM, **Volume 374 • Number 9 • March 3, 2016**



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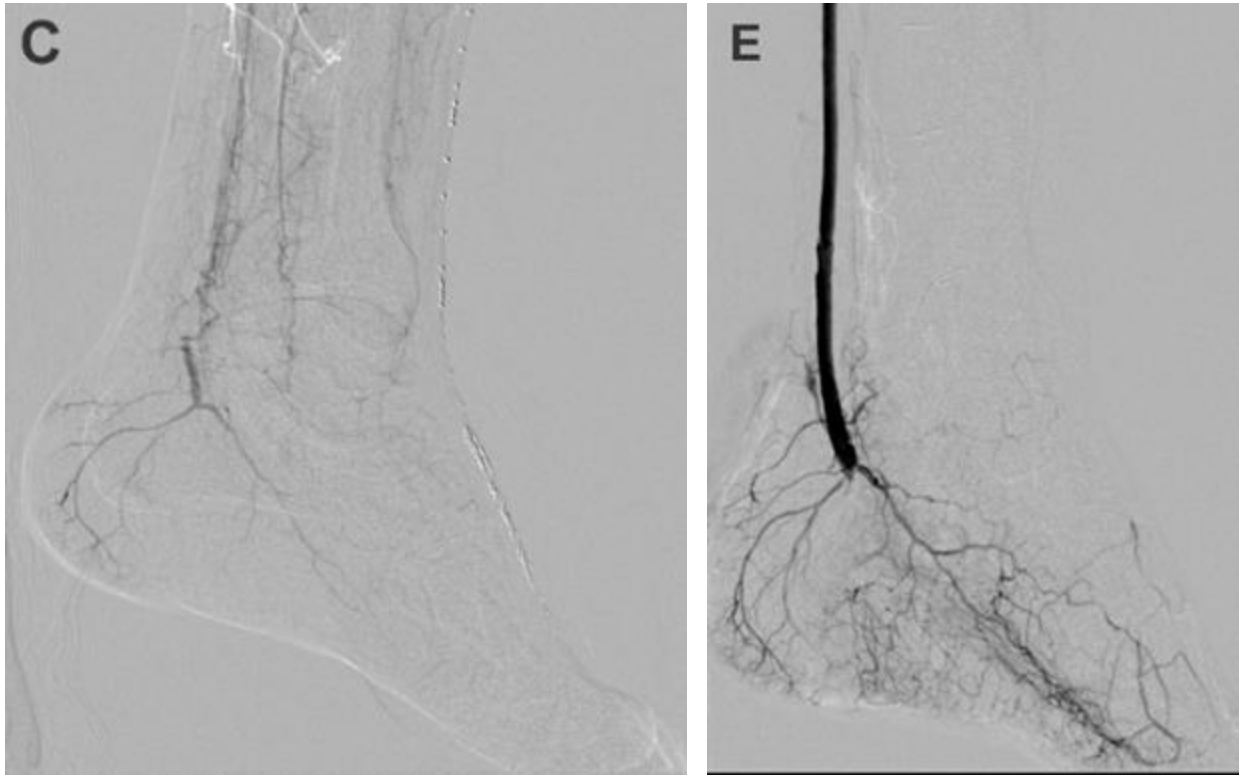
Lesion too long/unable to cross and target present

Bypass

Old school

It works!



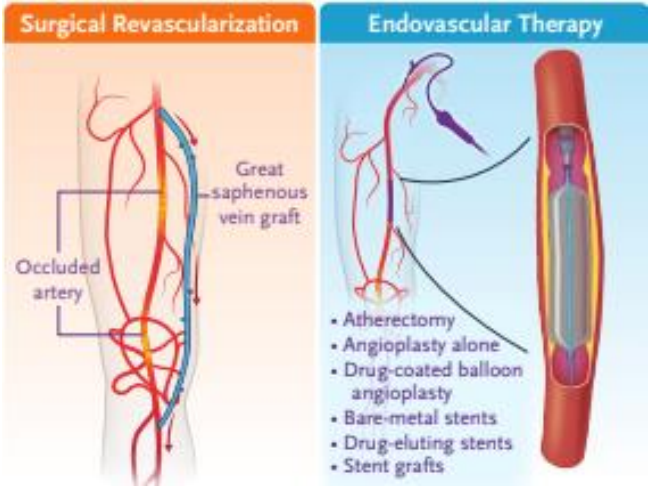
Gomez-Sanchez CM (JVS CIT, 2022)

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 DECEMBER 22, 2022 VOL. 387 NO. 25

Surgery or Endovascular Therapy for Chronic Limb-Threatening Ischemia

A. Farber, M.T. Menard, M.S. Conte, J.A. Kaufman, R.J. Powell, N.K. Choudhry, T.H. Hamza, S.F. Assmann,* M.A. Creager, M.J. Cziraky, M.D. Dake, M.R. Jaff, D. Reid, F.S. Siami, G. Sopko, C.J. White, M. van Over, M.B. Strong, M.F. Villarreal, M. McKean, E. Azene, A. Azarbal, A. Barleben, D.K. Chew, L.C. Clavijo, Y. Douville, L. Findeiss, N. Garg, W. Gasper, K.A. Giles, P.P. Goodney, B.M. Hawkins, C.R. Herman, J.A. Kalish, M.C. Koopmann, I.A. Laskowski, C. Mena-Hurtado, R. Motaganahalli, V.L. Rowe, A. Schanzer, P.A. Schneider, J.J. Siracuse, M. Venermo, and K. Rosenfield, for the BEST-CLI Investigators†



CONCLUSIONS: Among patients with CLTI who had a great saphenous vein adequate for surgical revascularization, clinical outcomes with an initial treatment of surgery were superior to those with endovascular therapy.

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After revascularization

Typically on dual antiplatelet therapy (4-6 weeks)

Foot may get warm, swollen, and painful (reperfusion)

OK to proceed with debridement/amputation

Surveillance imaging at 1-, 3-, 6-, 12 months

Decrease in TBI/increase in velocities → threatened revascularization

When to Call Hyperbaric Medicine

- **>30d** of wound care w/o improvement
- Wagner grade $\geq$ **3**
- Optimized macrovascular flow
- Infection control
- Blood sugar control
- Offloading (internal / external)
- **Logistical ability** to get to/from HBO_2 for 30-40 treatments

When in doubt…just give us a call

206-583-6543 or 206-341-0144

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HBO2: Goals and Expectations

- Preserve as much tissue as possible
  - Lose a toe(s), but save a foot
- Re-establish sufficient microvascular supply to achieve and sustain healing
- Preserve ambulatory ability for as long as possible
- Psychological transition time to accept amputation

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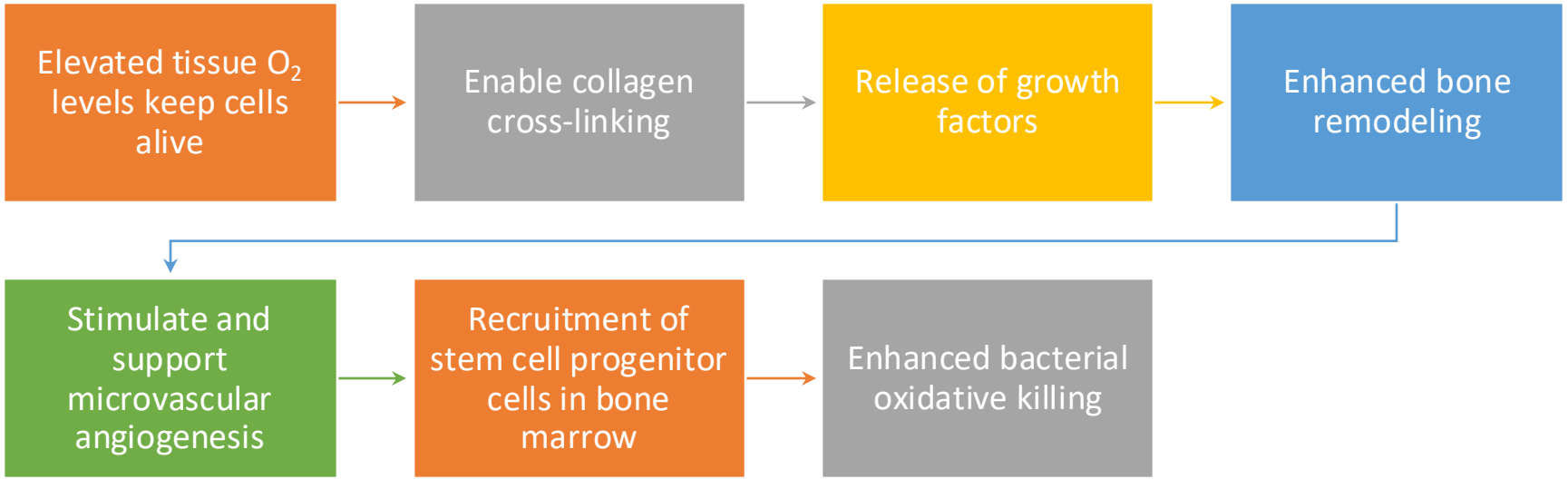
Primary Mechanisms Of Hyperbaric Oxygen



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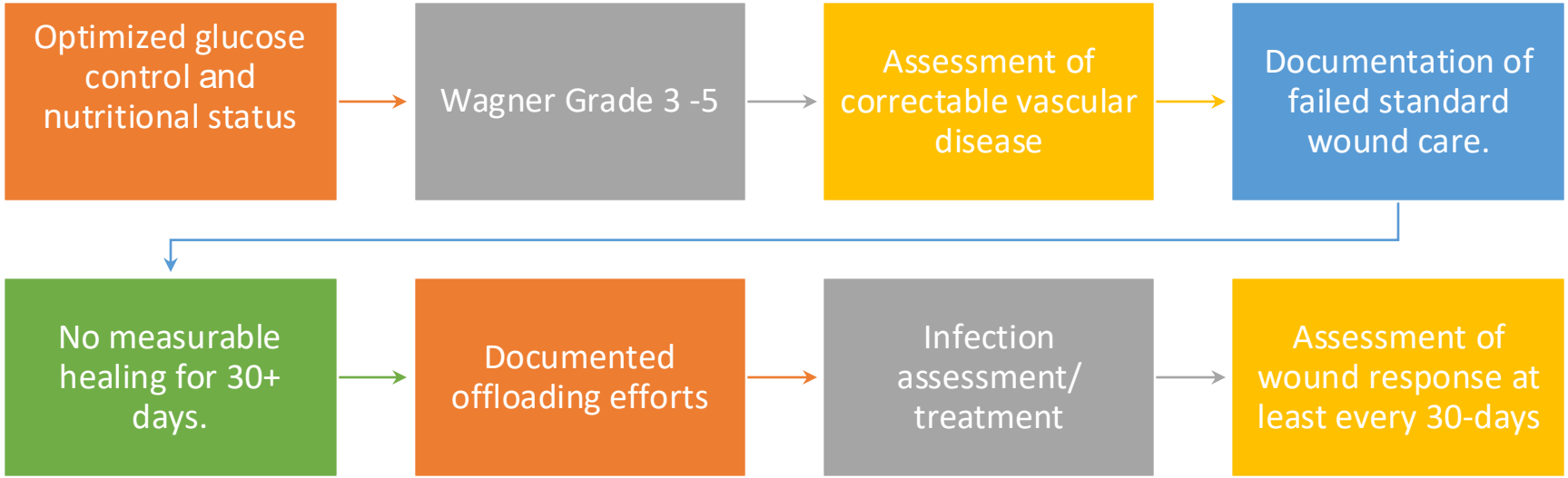
CMS Criteria for Hyperbaric Oxygen



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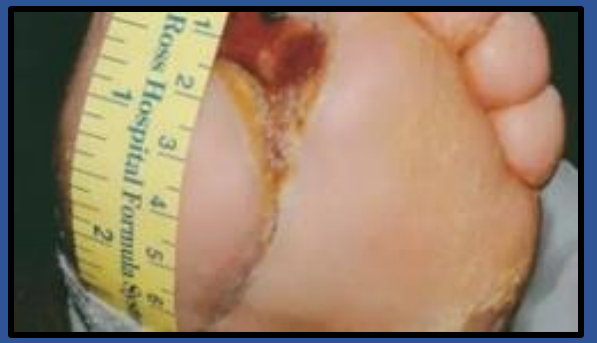
Collaborative Approach

When we maintain a person's ambulatory ability, we affect their dignity, autonomy, and productivity

Pre-HBO_2

Photos by Kenneth Stoller, MD



26 HBO_2 Treatments

50 HBO_2 Treatments

Beckman, R. VA Press Release. 2023

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Collaboration and Coordination

- Wagner 3-4, BKA and AKA are associated with high 5-year mortality.
- Practice experience: approx. 70% of patients achieve wound healing with a collaborative approach.
- A structured team approach resulted in 91% healing at ½ the 1st-year costs of amputation.

Eggert, JV. UHMJ vol 43. 2016

72% Favorable Outcomes

Wound classification	n	Number of sessions
Complete wound healing	74 (36)	43 (33–57)
≥80% wound healing	75 (36)	56 (40–60)
<80% wound healing	25 (12)	45 (8–58)
Wound deteriorated	5 (2)	28 (12–45)
Minor amputation	12 (6)	24 (16–38)
Major amputation	15 (7)	10 (8–19)
Total	206 (100)	42 (28–58)

Values are median (Q1–Q3) or n (%); Number of patients with ≥30 sessions=152 (74%)

J Wound Care vol 30. 2021

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72 year old female with left great toe ulcer, DM, HTN, and peripheral neuropathy

Plain films show lytic destruction of distal phalanx

55yo diabetic man with left heel wound for 1 month.

h/o poorly controlled diabetes, peripheral neuropathy, retinopathy, ESRD s/p KT

ABI. Bilateral lower extremity ABI incalculable due to vessel Incompressibility. Toe pressures reduced bilaterally.

Wound cultures MRSA

Angio - Single-vessel lower extremity runoff via the anterior tibial. Tibioperoneal trunk stenosis. Peroneal artery diminutive.

Amputation risk based on Wound-Ischemia-foot Infection system

Wound grade (0-3)	Ischemia grade (0-3)	foot Infection grade (0-3)			
		0	1	2	3
0	0	VL	VL	L	M
1	0	VL	VL	M	M
0	1	VL	L	M	H
1	1	VL	L	M	H
0	2	L	L	M	H
1	2	L	M	H	H
0	3	L	M	M	H
1	3	M	M	H	H
2	0	L	L	M	H
3	0	M	M	H	H
2	1	M	M	H	H
3	1	M	M	H	H
2	2	M	M	H	H
3	2	H	H	H	H
2	3	H	H	H	H
3	3	H	H	H	H

Adapted from: Mills JL, Conte MS, Armstrong DG, et al. The Society for Vascular Surgery Lower Extremity Threatened Limb Classification System: Risk stratification based on Wound, Ischemia, and foot Infection. J Vasc Surg 2014; 59:220.. 2025 UpToDate

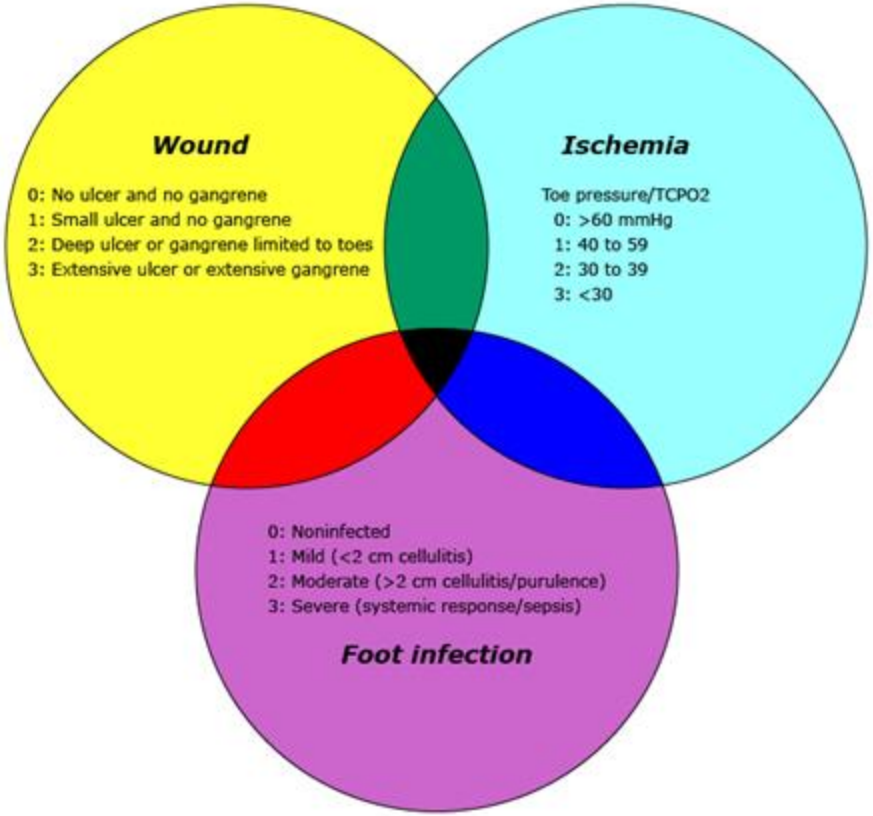
55yo diabetic man with left heel wound for 1 month.

h/o poorly controlled diabetes, peripheral neuropathy, retinopathy, ESRD s/p KT

1, Wound care
2. Antibiotics
3. Left tibioperoneal artery and peroneal artery angioplasty
4. Off loading
5. Glycemic control

Summary: Interaction between the main factors that contribute to wound/tissue loss

- Ask, "Which factor or combination of factors contributes most to the wound?" Helps determine initial wound management priorities.
- Frequent reassessment is important since the wound environment is dynamic.



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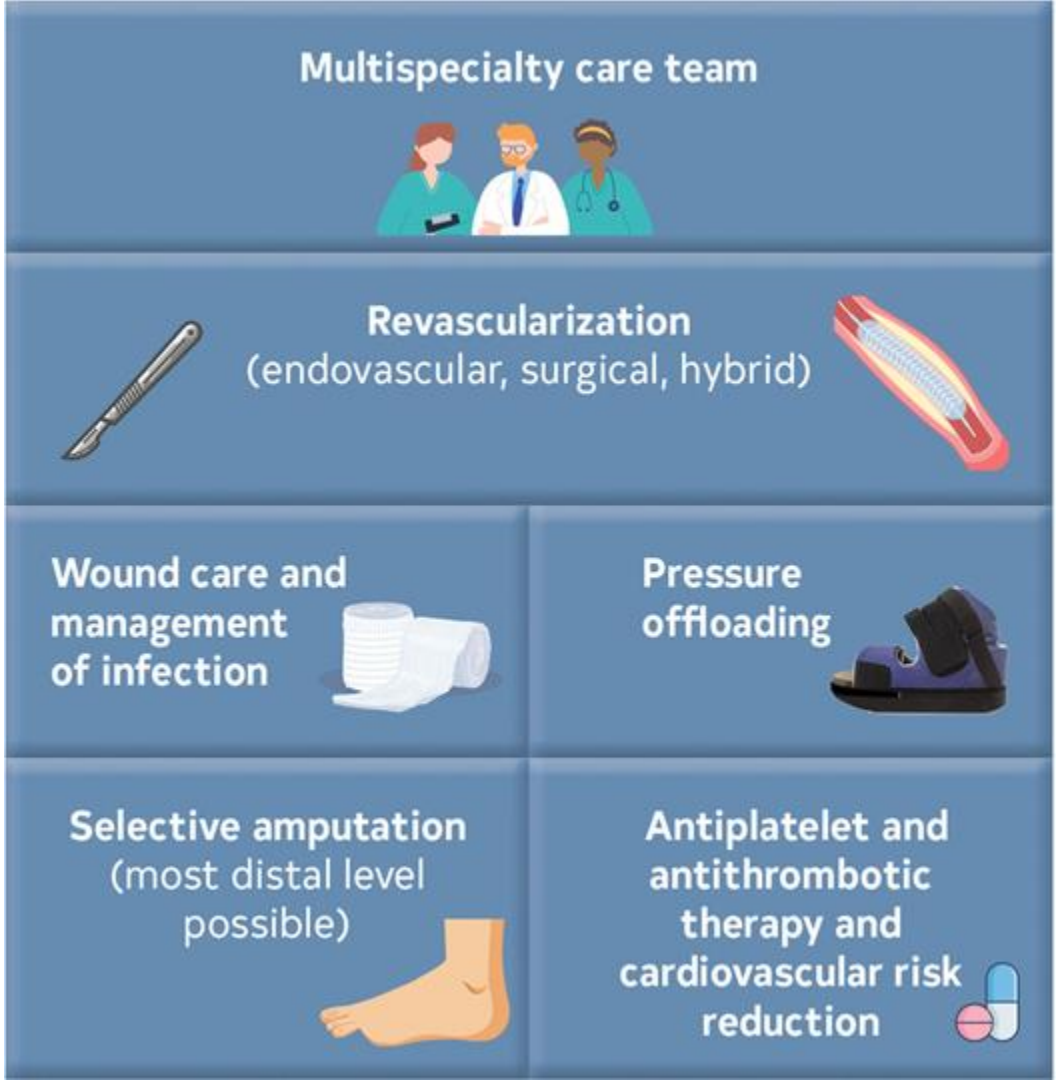
- *Adapted from: A Wound Medicine 2013; 1:13., Journal of Vascular Surgery 2015; 61:939., Journal of Vascular Surgery 2014; 59:220.*

It takes a village



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Saving Soles: Take Home Points

- Counsel patients on well-fitting shoes and daily foot inspection
- Annual provider exams with optimal diabetes control
- In patients with foot ulcers- evaluate for ischemia and infection. Assess need for wound care/off loading, antibiotics, and revascularization.
- Link with Podiatry, Vascular Surgery, Wound Care.
- Hospitalize for urgent surgical intervention, IV antibiotics, or medical stabilization.

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Clinical Infectious Diseases
IDSA GUIDELINES

IWGDF/IDSA Guidelines on the Diagnosis and Treatment of Diabetes-related Foot Infections (IWGDF/IDSA 2023)

Éric Senneville,[1,2] Zaina Albalawi,[3] Suzanne A. van Asten,[4] Zulfiqarali G. Abbas,[5] Geneve Allison,[6] Javier Aragón-Sánchez,[7] John M. Embil,[8] Lawrence A. Lavery,[9] Majdi Alhasan,[10] Orhan Oz,[11] Ilker Uçkay,[12] Vilma Urbančič-Rovan,[13] Zhang-Rong Xu,[14] and Edgar J. G. Peters[15,16,17]

[1]Gustave Dron Hospital, Tourcoing, France; [2]Univ-Lille France, Lille, France; [3]Department of Medicine, Division of Endocrinology, Memorial University, St. John's, Newfoundland and Labrador, Canada; [4]Department of Medical Microbiology, Leiden University Medical Centre, Leiden, The Netherlands; [5]Abbas Medical Centre, Muhimbili University of Health and Allied Sciences, Dar es Salaam, Tanzania; [6]Department of Medicine, Tufts Me[illegible] Infectious Diseases, University of Manitoba, Winnipeg, Health-Midlands, Columbia, South Carolina, USA; [11]U[illegible] Medical Centre, University of Ljubljana, Ljubljana, Slov Infectious Diseases, Amsterdam, The Netherlands; [16]A Infectious Diseases, Amsterdam, The Netherlands

The International Working Group or prevention of diabetes-related foot c diagnosis and management of foot i

Clinical Infectious Diseases
STATE OF THE ART REVIEW

Evaluation and Management of Diabetes-related Foot Infections

Nicolas W. Cortes-Penfield,[1,6] David G. Armstrong,[2] Meghan B. Brennan,[3] Maya Fayfman,[4,5] Jonathan H. Ryder,[1] Tze-Woei Tan,[2] and Marcos C. Schechter[5,6]

[1]Division of Infectious Diseases, University of Nebraska Medical Center, Omaha, Nebraska, USA; [2]Department of Surgery, University of Southern California, Los Angeles, California, USA; [3]Division of Infectious Diseases, University of Wisconsin, Madison, Wisconsin, USA; [4]Division of Endocrinology and Metabolism, Emory University, Atlanta, Georgia, USA; [5]Department of Medicine, Grady Memorial Hospital, Atlanta, Georgia, USA; and [6]Division of Infectious Diseases, Emory University, Atlanta, Georgia, USA

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Thank you.

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