Treatment of the diabetic foot poses a challenging clinical dilemma to all practitioners. While often overlooked, foot disorders are a major cause of morbidity to patients with diabetes, as well as cost to the health care delivery system. The patient with diabetes that is complicated by peripheral neuropathy and/or peripheral arterial disease is at high risk for diabetic foot ulcer, diabetic foot infection, and potential amputation. All practitioners that treat diabetic patients should be acutely aware of foot-related complications in this delicate patient population to avoid morbidity, mortality, and limb loss. It is the responsibility of all providers who care for diabetic patients to help prevent such instances through proper examination, education, preventative measures and appropriate treatment.

This lecture will focus on disorders that affect the foot in diabetic patients. The attendee will learn how to properly examine the diabetic foot and stratify patient risk, how to recognize the at-risk diabetic foot, how to diagnose and treat diabetic foot ulcers and infections, and how to diagnose and treat Charcot neuroarthropathy. Real-life case scenarios will be provided to enhance learning and promote discussion.
Diabetic Foot Disorders

Nicholas J. Lowery, DPM
UPMC Podiatric Surgical Residency Program
Immediate Past Chairman, ADA Special Interest Group, Foot Care

Diabetes and its Complications

• "The era of coma has given way to the era of complications"
  • Elliott P. Joslin

Prevalence of Diabetes in USA is Rising

Diabetes Mellitus in the USA

• Other Facts:
  – Incidence: 1.7 million new cases in 2012
  – Undiagnosed: 8.1 million cases in 2012
  – Seniors: 25.9% age 65 or older
  – Prediabetes: 86 million in 2012
  – Deaths: 7th leading cause of death
    • 69,071 as underlying cause
    • 234,051 as underlying or contributing cause
  • American Diabetes Association

Diabetes Mellitus in the USA

• Diabetes in our YOUTH:
  – 208,000 under age 20
  – 0.25% of under 20 population
  – 2008-2009 – Annual Incidence
    • 18,436 with Type I Diabetes
    • 5,089 with Type II Diabetes

Disclosures

• Soluble Systems - speaker
Diabetes Mellitus in the USA

Percent by Ethnicity
- White 7.6%
- Asian 9.0%
- Hispanic 12.8%
- Non-Hispanic Blacks 13.2%
- American Indian 15.9%

Cost of Diabetes
- Total Cost of Diagnosed Diabetes: 245 Cost In Billions
- Direct Medical Cost: 176
- Reduced Productivity: 69

Diabetes on a Global level

Diabetes at the Local level
- Pittsburgh Metro Area
  - 2.4 Million people
    - 223,000 with DM (9.3%)
    - 17,856 DFU (8%)
    - 4,014 Amputation (1.8%)

Diabetes and the Foot
- Very common
  - Foot ulcers, amputation, Charcot
  - >5% have ulceration – maybe higher
- 85% of amputations are preceded by ulceration
  - Reduce ulceration = reduce amputation

Diabetic Foot Disease – Fact Sheet
- More than 60% of lower extremity amputations are in patients with diabetes
- About 75,000 diabetic related amputations each year in U.S.
- Estimated that somewhere in the world a limb is lost every 20 seconds due to diabetes
- Following an amputation in a patient with DM:
  - 30% will have contralateral limb amputation within 3 years
  - 60% will die within 5 years
Lower Limb Amputation Rates - USA

![Graph of Non-traumatic Lower Extremity Amputations in Diabetic Population (per 1000)]

How do we raise Awareness?

Diabetic Foot is on the Radar

Economic Burden of Diabetic Foot Ulcer

- Per patient with DFU = $33,000
  - 1.5 admissions
  - 14 outpatient visits
- Per patient with LEA = $52,000
  - 2 admissions
  - 12 outpatient visits
- Total direct cost = $9-13 billion

Foot-in-Wallet Disease

- AZ Medicaid eliminates podiatry 2009
- Est. $351,000 saved from $8.7 billion
- Analysis to determine – admissions, charges, length of stay and severe aggregate outcomes
  - Mortality
  - Amputation
  - Sepsis
  - Surgical Complications
- Skrepnek et al Diabetes Care Sept 2014

Foot-in-Wallet Disease

![Bar chart showing percent increase in various categories]
Cost Savings??

- $1 saved = $48 spent by eliminating podiatric services
- $351,000 saved turns into $16 million incurred

Risk Factors for Foot Pathology

- Rarely a single entity
- Neuropathy
- Arterial Disease
- Deformity

The Gift that Nobody Wants = PAIN

- Peripheral Neuropathy
  - THE MOST IMPORTANT cause of ulceration
  - Seven fold increase risk of amputation
  - Sensory loss
  - Musculoskeletal deformity/imbalance
  - Skin changes – autonomic neuropathy

Peripheral Arterial Disease

- Common in Diabetes Mellitus
- Calcification of large vessels
- Affects capillary perfusion
- Typically below the knee

Other Risk Factors

- Foot deformity
- Plantar callus
- Long duration of Diabetes
- Peripheral Edema
- End-stage Renal disease
The Pathway To Ulceration

The Diabetic Foot Exam

- History
  - Type of diabetes and duration
  - History of ulceration/amputation
  - History of neuropathic symptoms
  - History of vascular surgery
  - Renal history
  - Retinal history
  - Cardiac history

Diabetic Foot Exam

- Physical Exam
  - Inspection of Skin
    - Skin condition
    - Sweating
    - Infection
    - Ulceration
    - Calluses

- Musculoskeletal Inspection
  - Deformity
  - Claw/hammertoes
  - Prominent metatarsal heads
  - Charcot Deformity
  - Muscle wasting

- Neurological Assessment
  - Achilles reflexes
  - Semmes-Weinstein Monofilament
  - Vibratory Sensation
  - Light touch Sensation
  - Michigan Neuropathy Screening Instrument

- Vascular Assessment
  - Palpation of pulses
  - Inspection of skin – temperature
  - Ankle/Brachial Index
  - Refer for advanced studies if necessary
Risk Assessment based on Exam

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Definition</th>
<th>Recommendation</th>
<th>Suggested Follow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No LOPS/PAD/Deformity</td>
<td>Patient Education/Advice</td>
<td>Annual</td>
</tr>
<tr>
<td>1</td>
<td>LOPS +/- Deformity</td>
<td>Prescription Shoes, Prophylactic surgery, Education</td>
<td>3-6 Months</td>
</tr>
<tr>
<td>2</td>
<td>PAD +/- LOPS</td>
<td>Prescription Shoes, Vascular consultation</td>
<td>2-3 Months</td>
</tr>
<tr>
<td>3</td>
<td>History of Ulcer or Amputation</td>
<td>Same as 1, consider vascular consultation</td>
<td>1-2 Months</td>
</tr>
</tbody>
</table>

Diabetic Foot Ulcer
- 60 – 85% of Lower Extremity Amputations
- 75,000 Annual
- Following Amputation
  - 30% Contralateral amputation
  - 60% Mortality in 5 years

Normal Wound Healing

Chronic vs. Acute Wounds

Managing the Chronic Wound Bed

- Nonviable Tissue
- Infection/Inflammation
- Moisture Regulation
- Tissue Margins

Wound Bed Preparation and TIME

<table>
<thead>
<tr>
<th>Clinical Observations</th>
<th>Cellular/Molecular Problems</th>
<th>Cellular Actions</th>
<th>Cellular outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue</td>
<td>Debridement</td>
<td>Restoration of wound base, functional ECM</td>
<td>Viable wound base</td>
</tr>
<tr>
<td>Infection</td>
<td>High bacterial load</td>
<td>Remove infection</td>
<td>Bacterial balance, reduced inflammation</td>
</tr>
<tr>
<td></td>
<td>Prolonged inflammation</td>
<td>Topical/systemic ABX</td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>Desiccation, Excessive Fluid</td>
<td>Moisture regulating dressings</td>
<td>Moisture balance</td>
</tr>
<tr>
<td>Edge</td>
<td>Nonmigrating, epithelial margin</td>
<td>Consider advanced therapy</td>
<td>Advancing epithelial margin</td>
</tr>
</tbody>
</table>

Nonviable Tissue

Infection/Inflammation

Moisture Imbalance

Edge – Margin nonadvancing/undermined

Diabetic Foot Ulcer
Diabetes is a Malignant Disease

Diabetic Foot Ulcer

- Neuropathy
  - 2/3 of patients with DFU have neuropathy as etiology
  - Sensory, motor and autonomic components
  - 10% of people with diabetes
  - Nearly half of DM patients with disease > 7 years

Diabetic Foot Ulcer

- Vascular Disease
  - Diabetes – independent risk factor
  - Smoking, hyperlipidemia, hypertension
  - Large and small vessel disease
  - 1/3 of DFU have PAD as etiology
  - 50% of these have neuropathy

Diabetic Foot Infection

- Major contributor to hospitalization and lower extremity amputation among patients with diabetes
- 20-25% of all diabetic related admissions
- Account for large number of hospital bed-days
- Proper evaluation of infected diabetic feet is an essential first step in treatment
**Risk Factors for Diabetic Foot Infection**

- Neuropathy
- Vasculopathy
- Miscellaneous

**Major Risk Factors for Diabetic Foot Infection**

The Diabetic Foot Triad
- Neuropathy
  - Sensorimotor, Autonomic
- Vasculopathy
  - Macrovascular, microvascular
- Immunopathy
  - Miscellaneous
  - Renal failure, CHF, Deformity, Trauma


**Significant Independent Risk Factors for DFI**

- Ulcers that penetrate to bone
- Wound present > 30 days
- Recurrent wounds
- Traumatic wounds
- Peripheral artery disease
- Risk of Hospitalization is 56x
- Risk of amputation is 155x

  - Lavery et al 2006

**Diabetic Foot Evaluation**

- Edelson et al. evaluated 225 consecutively admitted patients with a diabetic foot infection
  - They found the initial evaluation of the patients was critically lacking

**ER and Hospital Records**

- 31% of patients did not have their LE pulses documented
- 60% were not evaluated for presence of protective sensation
- Radiographs were not performed on 1/3 of all patients
- Only 8% of patients had depth, size and description of wound documented, with 57% having no wound description
- 48% of patients did not receive specific instructions for home wound care

**Classification of Diabetic Infection**

- Non Limb Threatening
  - Superficial Infection
  - Less than 2cm from portal of entry/ulcer
  - Minimal or no ischemia
  - Medically stable
  - No constitutional symptoms
Limb Threatening Diabetic Foot Infections

- Cellulitis extending beyond 2cm from initial ulceration
- Constitutional Symptoms
- Lymphangitis
- Hyperglycemia
- Ischemia
- Probes to bone

Charcot Neuroosteoarthropathy

- Non-infectious destruction of bone associated with neuropathy
- Initial recognition can be difficult
- Can be devastating
- Now common in diabetics with neuropathy

Case 1: “Best Case Scenario”

- CC: Swelling and redness of the right foot and ankle
- HPI: 75 y/o female who noted the onset of redness, swelling and mild pain (3 out of 10)
- No history of trauma or increased activity

Past Medical History

- Type II Diabetes Mellitus for 34 years
- Neuropathic pain and numbness in the LE
- Medications
  - Diovan
  - Zocor
  - Amitriptyline
  - HCTZ
  - Insulin

Initial Treatment

- Saw a local physician who injected her foot with steroids
- That did not work so she was prescribed oral steroids
- She was prescribed exercises
- She did not experience any relief
- Referred to foot and ankle specialist

Physical Exam

- 5' 7” tall weighing 176
- WD in No acute distress
- No ulcers or deformity
- Normal pedal pulses but 2+ edema
- Neurological exam
  - Absent sensation with monofilament
  - Decreased vibration
  - Absent Achilles reflexes
Radiographs – Normal!

Initial diagnosis – Stage 0 Charcot
- Walking boot
- Cane
- Further diagnostic workup included an MRI

MRI – Silent Bone Injury

Our Treatment
- Protected weight-bearing in a removable boot for 3 months until inflammation subsided
- Serial radiographs looking for any signs of collapse
- Accommodative insert and shoes

15 Month Follow up – Asymptomatic!

Case 2: “Worst Case Scenario”
- 55 year old female who complains of mild pain and soft tissue swelling, difficulty walking and inability to put her foot in her shoe
- Presents to local ED
- No history of trauma
- Type II DM which is insulin dependent
- End stage renal disease on hemodialysis
- Dialysis three times a week
Initial Presentation - ED

- Mild distress
- Ankle tenderness
- Soft tissue swelling
- Neurological reported as sensation and motor intact
- Extremity was warm and erythematous
- No vascular compromise was noted
- Work up included a negative venous ultrasound
- Radiographs are normal

Initial Radiographs: Normal

[Images of radiographs]

Initial Orthopaedic Evaluation

- Palpable pedal pulses
- Absent sensation
- Unilateral edema with severe valgus deformity
- Subjective complaints of pain

New Radiographs – NOT normal!

[Images of radiographs]

Lateral Radiographs

[Images of radiographs]

Treatment - BKA

[Images of treatment procedure]
Lessons Learned

- Early diagnosis
- Early offloading before deformity develops
- Excellent functional outcome can result
- Better than any surgical outcome

The common denominator = Neuropathy

“The absence or decrease in pain sensation in the presence of uninterrupted physical activity”

Diabetes  
Leprosy  
Myelomeningocele or Spina Bifida  
Chronic Alcoholism  
Transplant patients  
Chemotherapy  
Tabes dorsalis  
Syringomyelia  
Congenital insensitivity to pain  
Spinal Cord Injury  
Peripheral Nerve Inj.  
Idiopathic neuropathy

Today’s Unified Theory

RANKL-OPG Balance

Renal Osteodystrophy
Who is at risk?

- 55-60 years old (mean 57)
- Obese (mean BMI 33)
- Longer duration of DM (15)
- 80% have diabetes for 10 yrs
- Sensory neuropathy is always present
- Relationship between bone mineral density is unclear
- H/o transplant surgery

Diagnosis of Charcot

- Must have a high index of suspicion
- Be wary of diabetic patient who is able to walk on a foot that looks like this
- If you elevate the LE for 5 minutes you may resolution of erythema

“The Perils of Procrastination”

- Nearly 80% of cases misdiagnosed, most being labeled as sprains
- Additional imaging (MRI, CT and Bone Scans) facilitate early diagnosis
- Early utilization of advanced imaging can prevent extended foot fractures and deformity
- Chantelau. Diabetes Medicine 2005

The Perils of Procrastination

- Ankle sprain (6)
- Cellulitis (4)
- Osteomyelitis (3)
- Gout (3)
- Septic arthritis (2)
- Plantar fasciitis (2)
- DVT (2)

“The Consequences of Complacency”

- 20 patients with Stage 0 Charcot
- Initial diagnosis missed 19/20
- Less complications in those that did not collapse
  - 14% vs 66%
- Surgery required in 50%
- No amputations
  - Wukich et al, Diabetes Med, 2011

ADA-APMA Task Force 2011

- Convened in Paris in 2011
  - Definition
  - Pathogenesis
  - Diagnosis
  - Treatment
- Published in Diabetes Care
Treatment Algorithm for Charcot — Task Force Recommendations

Conservative Treatment for Charcot

- Stage 0 Charcot: Immobilize Immediately!!
- Stage I Acute Charcot
  - Immobilize in TCC
  - CAM walker
  - Wait until signs of inflammation cease

Conservative Treatment Progression

Goals for Surgical Intervention

- Plantigrade foot
- Stable
- Shoeable/Braceable
- Heal any ulcers
- Prevent recurrences
- Decrease or eliminate pain
- Avoid amputation
- Maintain ambulation

Do We Make a Difference?

- Each $1 invested in care by a podiatrist for people with diabetes results in $27 to $51 of healthcare savings. (JAPMA 2010)
- Podiatric medical care in patients with a history of ulceration can reduce high level amputation by 65-80% (Gibson, Int Wound Journal, 2013)
- Instituting a structured diabetic foot program can yield a 75% reduction in amputation rate and four-fold reduction in inpatient mortality (Weck, Cardio. Diabetology, 2013)

Case Studies
1. Standard Issue DFU

- Confirm – good pulses/inflow
- Confirm – well managed DM
- Confirm – No radiographic infection
- Confirm – No clinical infection/healthy wound bed

2. “Minor” deformity = “Major” problem?

3. It takes a village

- 56 year old male
- Type I DM
- Peripheral neuropathy
- History of deep abscess left foot
- Had multiple debridements
- NPWT
- Other advanced therapies
- HBOT
- Now scheduled for 1st Ray Amputation

Clinical Presentation

- Medial 1st MPJ exposed through 4.5x2.5 cm wound
- No acute signs of infection
- No gross deformity/instability

Physical Exam

- Vascular:
  - Palpable Pedal pulses, biphasic DP/PT with doppler
  - ABI 1.09 LLE, Non-invasives normal
  - CFT intact to digits
- Neurologic:
  - Absent protective sensation
  - Absent vibratory sensation
  - Absent Achilles reflex
Initial Labs/Cultures

- WBC: 8.1
- ESR: 97
- CRP: 3.5
- HbA1C: 7.2

OR Bone Cultures:
- MSSA from 1st metatarsal
- On Cefazolin 2G IV Q8 for 6 weeks with PICC

Radiographs

Initial Treatment Plan

- Return to OR
- Full thickness excisional debridement of wound, bone
- Application of Advanced Skin Substitute
- Application of NPWT

Clinical Presentation

- 12/17/12
- Taken to OR, wound debridement, application of skin substitute and wound VAC
- First PO visit – 1 week later
Clinical Presentation

1 week return to wound center

Skin Substitute #2 applied at 4 weeks

Clinical Presentation

Two weeks s/p 2nd Skin Substitute

Progressive Improvement

Healed

Ultimately healed in 12 weeks after OR debridement

Two applications of Skin substitute

#4. Insurmountable Deformity

Patient is a 56 year old female with non-healing ulcer of her left foot.

Ulcer is under lateral foot, present for 9 months

Local wound care provided, including offloading, local products, Skin Substitute application x8

No pain — history of neuropathy

Referred due to nonhealing ulcer, consider operative management
Past Medical History

- Type II Diabetes Mellitus with known peripheral neuropathy
- Back surgery x3, tethered cord
- MRSA
- History of brain injury – cause “from spinal cord stimulator, MRSA clot”
- Chronic left leg pain/deformity
- Partial vision loss after clot incident
- SH: Denies smoking, EtOH, Drug use

Physical Examination

- Vascular: Pedal pulses palpable 2/4 bilateral, CFT intact to all digits, skin temperature warm
- Neurologic: Absent vibratory sensation and Absent monofilament exam. Achilles reflexes absent.
- Musculoskeletal: Muscle strength left – 4/5 for eversion, inversion, plantarflexion. 2/5 dorsiflexion. Equinovarus deformity noted, unable to correct to neutral.
Labs
  • WBC 5.8
  • HbA1c 6.7
  • Glucose 122
  • ESR 28
  • CRP 1.2

Diagnosis
  • Non-healing diabetic foot ulceration
  • No radiographic/MRI/lab evidence of osteomyelitis
  • Chronic Equinovarus deformity left lower extremity

Treatment Options??

Treatment Plan
  • Tibialocalcaneal Arthrodesis with intramedullary fixation
    – Obtain cultures intraoperative from bone
  • Debridement of wound
  • Application of skin substitute

Post Op Radiographs

Follow up visit – 9/11/13
Healed – 12/04/13

Radiographs – 5/14

Successful result

• Now ambulating in custom shoes, last follow up 5/15
• Recognition of Biomechanical forces that cause pressure
• Combine deformity correction with local/advanced wound care

#5. Severe Diabetic Foot Infection

• 68 year old male in ICU – sepsis
• Unable to obtain history
• Severe diabetic foot infection right foot
• Ulcers sub 2 and sub 5, passively draining purulent discharge
• Ulcer medial foot, passively draining as well
• Fluctuance dorsal right foot

Severe Diabetic Foot Infection

• Vitals
  – Temp: 100.1
  – BP: 126/86
  – Resp: 20
  – Pulse: 102
• Labs
  – WBC: 22.7
  – ESR: 120
  – Glucose: 326

- 56 year old female complains of redness and swelling right ankle
- Painful, difficult to ambulate
- Type 2 Diabetes Mellitus
- Peripheral Neuropathy
- History of left second digit amputation
Follow up

- Redness/swelling unresolved
- Right ankle remains painful
- Now feels unstable
- Non-healing arthroscopic portal
- Cultures growing VRE

Radiographs 1/25/11

Treatment

First Step – Stabilize and treat infection

Next step – TTC fusion with Ex Fix

3 Months – TCC
6 months – WB with CROW

12 months – WBAT with AFO

One Day With Diabetes:

- 5000 Diagnosed
- $670 million
- 280 Lives
- 200 Limbs
- We Can Do Better. Today.

- ADA 2014