Objectives

- Identify multiple pathophysiological issues that can lead to diabetic foot disease
- Discuss structural and biomechanical issues contributing to formation of diabetic foot ulcers and recidivism of these wounds
- Describe intervention to create a healing environment for diabetic foot ulcers and to prevent recurrence of these wounds
Ultimate Goal

New Stats on DFU Costs

- DFU pts compared to Non DFU pts-all with DM
- Medicare and privately insured pts
- Results of study
  - DFU pts compared to non-DFU pts
    - Hospital days -↑ 138% Medicare, ↑ 174% private
    - Home health - ↑ 85% Medicare, ↑ 230% private
    - Emergency department - ↑ 40% Medicare, ↑ 109% private
    - Outpatient physician office visits - ↑ 35% Medicare, 43% private
- Conclusions
  - DFU imposes substantial burden on public and private payers
  - From $9-$13 billion above normal diabetes care cost

ADA – Diabetes Care – Nov. 2013
**Good News!!!**
Drop in DM Related Amputation Rates

- CDC - dramatic drop rate of diabetes-related amputations in the U.S.

- CDC
- Diabetes Care: February 2012

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**CDC Reports Amputation Rates**

- **1996**
  - 11 / 1000 with DM

- **2008**
  - 4 / 1000 with DM

↓ 65% Since 1996
Reason for Decrease in Amputation Rates

• Better management of risk factors

• Question: How many of you think risk factors are being better managed and taught to your patients?

Chronic Hyperglycemia
Multi-Organ Dysfunction & Failure

Remember:
• Diabetes is a **Systemic Disease!!!**
• Negative effects on EVERY system of the body
• Several of these systems affect the lower extremity and feet
• Contributing to ulceration and re-ulceration
Road to Ulceration

Complicated

Recurrence Common

Multifactorial

Prevention NOT well reimbursed

#1 Condition leading to Foot Ulcer?

#1 Condition leading to Amputation?

Neuropathy Foot Ulcer
Classic Pathological Triad
Leading to Amputation

Neuropathy  
PAD  
Infection

If your patient has these three components simultaneously they are rapidly headed for an amputation.

Diabetes & Causes of Ulcerations
Multifactorial

- Neuropathy
- PAD
- Musculoskeletal Changes – DM biomechanical disease
  - Equinus deformity
  - Intrinsic foot deformities – muscle atrophy
- Glycosylation of connective tissue (AGE)
- Callus formation
- Infections
- Previous ulcer

Neuropathic Ulcers: Tri-Neuropathy

Sensory
Motor
Autonomic

Peripheral Neuropathy and Ulcerations

• Loss of Protective Sensation (LOPS)
  – Present in 50% of people with DM
  – Present in 80% of people with DFUs
  – 7 Xs increase in ulceration

Sensory/Motor Neuropathy

• Single most common cause of LOPS
• Small fiber – touch, pain, temperature
• Large fiber – intrinsic changes of foot
  – Weakness
  – Musculoskeletal changes in foot/ankle
    • Prominent metatarsal head/fat pad changes
• Leading to high foot pressures


Complications of Chronic Hyperglycemia
Multiple Organ Dysfunction & Failure

Remember:
Diabetes is a Systemic Disease!!!
Remember the Autonomic Nervous System Impairments from Diabetes

Autonomic Neuropathy

• Affected structures: sympathetic parasympathetic ganglions

• S & S:
  – Postural hypotension
  – Cardiorespiratory arrest
  – Anhidrosis
  – Impotency
  – Gastropathy
  – Diarrhea
  – Gustatory sweating
  – Hypoglycemic unawareness
Autonomic Neuropathy Effects on Feet

- Anhidrosis
  - Dry, cracked, fissured skin
- Increased callus formation
- Impaired micro circulation
- Impaired vasodilation
- Impaired normal hyperemic response
- ↑ edema
- ↑ capillary pressure & microvascular sclerosis
- Leads to tissue ischemia
- Lessens protective barrier to injury


Peripheral Arterial Disease

- 2-4X more common in people with DM
- ↑ incidence of infra popliteal and bilateral disease
- Multi segment involvement
  - Tibial, peroneal, small vessels
- Pedal vessels spared
- Autonomic neuropathy causes shunting and microcirculatory malfunction

Neuropathy
• Sensory
• Motor
• Autonomic

Foot Deformity
• Loss of fat pad
• Callus formation

Diabetic Foot Ulcer

Mechanical Trauma

Examine for Structural Changes of Leg & Foot

- Diabetes: a musculoskeletal disease
- Severe consequences on form and function of foot and lower extremity
- Significantly contributing to DFU and recurrence
Advanced Glycosylation of End Products (AGE)

- Molecular glue - chemical reaction between glucose & proteins
- Cross-linking of proteins irreversible
- Changes in soft-tissue extensibility and joint-capsule mobility - often manifest as decreased ROM
- Clinical marker of DM-related complications
- Any joint can be affected by AGES
- Reduction in ROM may be noticed when it interferes with functional activities including ambulation
- Seen in other areas of body...shoulder-adhesive capsulitis

Musculoskeletal Examination

- Skeletal deformities
- Range of motion
- Muscle strength
- Gait analysis
Range of Motion Examination

• “Limited joint mobility in foot & ankle associated with higher plantar pressures.”
• Hallux Limitus - Limited range of motion in the proximal great toe/Metatarsal-phalangeal joint (MTP)
  – Normal: 50-70° dorsiflexion/extension
• Hallux Rigidus: Absence of ROM in IP joint of great toe

Ankle Equinus

• Equinus- defined as ankle dorsiflexion measured at <0/neutral or less
• Diabetes cohort, 16 of 43 patients (37.2%) equinus
• Compared with 9 of 59 nondiabetic participants (15.3%)
• Threefold risk of equinus in the diabetic population
• Equinus group had a history of ulceration in 52.0% compared with 20.8% of the nonequinus group
• Equinus imparted a fourfold risk of ulceration
• Found 2.8 times ↑risk of equinus in patients with peripheral neuropathy
• CONCLUSIONS:
• “Equinus may be more prevalent in diabetic patients than previously reported. Study found a significant association between equinus and ulceration.”
Ankle Equinus

- Mild Equinus
- Moderate Equinus
- Severe Equinus

Ankle Motion Short of Neutral (NO motion through midfoot!)

Mild Equinus

 Moderate Equinus

Severe Equinus

Ankle Equinus

Limited Ankle Dorsiflexion

- Actively
  - Knee Straight (gastrocnemius)
  - Knee Bent (soleus)

- Lavery L, Armstrong D, Boulton A, Ankle equinus deformity and its relationship to high plantar pressure in a large population with diabetes mellitus JAPMA 92(9) 2002
ROM Needed for Normal Gait Cycle

• Ankle – stance phase
  – 0-10° dorsiflexion
  – 0-20° plantarflexion for push-off
  – 0-5° eversion at subtalar joint
• 1st Metatarsophalangeal joint
  – 50-60° of dorsiflexion during push off
  – (deficiency is cause of shear stress in deep tissue)
• IP joint
  – 10°

Objective ROM Testing

RangeOfMotionVL.flv
Components of Gait Cycle

### Stance
- **60%**
  - Reference foot is in contact with floor
  - 60%
  - Single limb support
    - 40%
    - 1 limb on ground
  - Terminal double limb support
    - 10%
    - Both feet on ground

### Swing
- **40%**
  - Reference foot is not in contact with floor

#### Loading response
- **10%**
  - Initial 13.3%
  - Mid 13.3%
  - Terminal 13.3%

- **Mid-stance** 20%
- **Terminal stance** 20%
- **Pre-swing** 10%

Gait Changes In People With Diabetes

- Slow speed (Brach)
- Prolonged stance
- Short stride
- ↑ step width (Brach)
- ↓ push off due to < ROM MTP jt (hallux)
- Wider base of support
- ↑ shear forces between bone & deep tissue OR between shoe material & skin
Forces Measured by Force Platform During Stance Phase of Gait

- Vertical forces
- Anteroposterior shear
- Mediolateral shear

Shear – what is its effect on deep tissue???

Attribution: Rose Hamm, DPT, CWS
Postural Changes in People with Diabetes

- Balance and postural awareness of body in space impaired
- Due to peripheral neuropathy & gastroc weakness due to ankle hypomobility
- More pronounced with diabetic retinopathy & decreased vision
- Increased sway with eyes open and head forward
- Unstable static balance
- Unstable dynamic balance
- Increased risk for falls

Common Cause of Mechanical Trauma

- Poorly fitting shoes

Attribution: Rose Hamm, DPT, CWS
What to Do???

Therapies to Improve Healing Opportunities in People with Diabetes

- Blood glucose control
- Wound bed preparation
  - Debridement
  - Infection/bioburden management
  - Moisture management
  - Edge
- Dressings – according to the characteristics of the wound
- Advanced wound dressings-collagen, silver, honey
- Offloading
• Large component of BG control is monitoring
• Both capillary and A1C

Adjunctive Technologies for DFUs
• Cellular Tissue Products (CTP) – new CMS language
  – Human cells, tissues & cellular & tissue-based products
• Biophysical agents-electrical modalities
• HBO Therapy
Treatments For DFUs

- Off-loading/pressure redistribution
  - Avoidance/reduction of all mechanical stress on injured extremity, is essential for healing
  - Mechanical stress causes most plantar wounds, and ongoing mechanical stress prevents healing

Accommodative Dressing (Birke)
Biophysical Agents for Wound Closure/Healing

- E-Stim
- Low Level Light Therapy
- Negative Pressure Wound Therapy
- Ultraviolet C
- Low Frequency Ultrasound
- Electro Magnetic Energy Fields

Pressure Ulcer in Patient; Diabetes & PAD

**ABI=.51**

Treatment
- Debridement
- ES- stocking electrode
- PDGF
- Infrared light

69y/o male with h/o type 2 diabetes, previous fem/pop bypass to foot; developed pressure ulcer on heel while in hospital for amputation of all 5 R-toes. Complete wound healing in 6 weeks.
• 49 y/o with DM
• 7- year hx CVI ulcers
• Treatment:
  • Compression
  • Infrared light
• Complete wound healing 3 months

Preventing Recurrence
Diabetes Education

• 3X increase in amputations without diabetes self-management education

ROM as Close to Normal as Possible

• Non-invasive methods to increase ROM
  – Stretching:
    • Active
  • Passive
    – Assisted stretching
    – Sustained-splinting
    – Earth shoe – puts sustained stretch on Achilles tendon and gastroc muscle
### Achilles Tendon Lengthening

- TCC 29 / 33 (88%) ulcers in healed (41=/- 28 days)
- Achilles Lengthening 30/30 ulcers (100%) healed (58+/− 47 days) (p >0.050)
- Recurrence of ulcer a 7 months (p = 0.001)
  - 16/27 (59%) in the total-contact cast group
  - 4/27 (15%) in the Achilles tendon lengthening group
- 2 year follow-up Ulcer recurrence
  - 21/26 (81%) total-contact cast group
  - 10/26 (38%) Achilles tendon  (p = 0.002)

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### Footwear and Assistive Devices

![Image of a foot wearing a black shoe and a leg in a cast]

**Attribution:** Greg Bohn, MD


**Courtesy:** Rose Hamm, DPT, CWS
Management of Post-Healing Foot

• Medicare Therapeutic Shoe Bill
  – Pays for diabetic shoes and inserts
  – Patient must have diabetes, previous amputation, ulceration, pre-ulcerative calluses, foot deformities, or poor circulation
  – Must be under care of physician who is managing diabetes

Ensure Patients Get Shoes & Inserts

• Only small percentage of patients eligible for therapeutic shoes and insoles receive them
• Shoes and inserts decrease pressure, friction & shear
• Growing body of basic science work supports important role of friction and shear in ulcer development in insensate feet
• Patients wearing shear-reducing insoles had fewer foot ulcers than patients with standard prevention therapy
• More research needed
Purpose of Footwear and Orthotics

• Redistribute pressure
• Optimize patient function
• Provide stability during gait/transfers

Is Shoe Gear Important???

• Studies:
  – 1st study: Patients in neuropathic group received therapeutic and custom shoes
    • 26% had reulceration
    • 83% reulceration - wore their own footwear
  – 2nd study: Randomized clinical trial of single style of shoe and insert for men and women was conducted in persons with prior foot ulcer at 2 study sites in Italy
    • After 1 year, reulceration occurred in 28% of the therapeutic footwear group vs 58% in those wearing their own footwear.
Educate Patients Exactly How to Perform a Self-Foot Exam

• Use adult learning principles
  – Show - visual
  – Tell - auditory
  – Practice - kinesthetic

• Provide follow-up education
• Time for return demonstration

Evaluate Patient’s Ability to Perform Self-Foot Exams

1. Assess knowledge of the self-exam
2. Assess vision
3. Assess flexibility
4. Assess skill using tools
  1. Mirror
CONCLUSIONS—Infrared temperature home monitoring, in serving as an “early warning sign,” appears to be a simple and useful adjunct in the prevention of diabetic foot ulcerations.

ADA Guidelines for Foot Care in Patients With Diabetes

- Annual foot examination to identify high-risk conditions and assess:
  - foot structure, biomechanics, vascular status, protective sensation, and skin integrity
- Evaluate more often those with, or having a history of, high-risk foot conditions, including:
  - peripheral neuropathy, history of ulcers, PVD, bony deformity, altered biomechanics, signs of increased pressure, severe nail pathology
- Persons with neuropathy should have visual foot exam at every visit with healthcare professionals

ADA. Diabetes Care. 2005;28(suppl 1):S4-S36.
Is Physician / Healthcare Provider Important??

- This study suggests that careful attention to foot care by health care professionals may be more important than therapeutic footwear.
- But does not negate the possibility that special footwear is beneficial in persons with diabetes who do not receive such close attention to foot care by their health care providers or in individuals with severe foot deformities.

A Component for Preventing Recidivism / Recurrence Screen For Depression

• Studies show increased incidence of depression in people with diabetes
• Depression often causes decrease self-care strategies
• Decreased self-care creates increase incidence in complications including foot ulcers

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