Stress Fractures in the Lower Extremity

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Disclosures

• I have no disclosures.

• There are industry and internet pictures/names used in this presentation, taken for representation purposes without bias.

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Roadmap

• Pathophysiology and Epidemiology
  – Pathophys
  – Intrinsic / Extrinsic Factors
  – Differentials
• The Physical Exam
  – Diagnosis
  – Imaging
• Treatments
• Cases

#GoldfarbCC17
#stressfracture
#osteopenia
#osteoporosis
#vitamind
Why Is this Important?

• 10% of all sports related injuries
  – Up to 30% in some sports (running)
• Incidence
  – 1% of “all” recreational athletes
  – 20% of “elite” athletes
• 90% in the LE’s
  – Tibia = 49.1% (25-75%)
  – Tarsals = 25.3% [Calcaneus (21-28%)]
  – Metatarsals = 8.8% (17-35%)
• Significance of fracture
  – Location, Nature

Mandell JC. Skel Radol, 2017. 28374052
Matheson GO. AmJS M, 1987. 3812860
Robertson AJM. WJO, 2017. PMC5359760
PATHOPHYSIOLOGY & EPIDEMIOLOGY
Getting the Lingo

• **Stress Fracture (SFx)**
  
  – Fracture of *normal* bone exposed to abnormal stress.
    
    • Seen in athletes, military personnel
    • ≈“Fatigue fracture” in orthopaedic literature

• **Insufficiency Fracture (IFx)**
  
  – Fracture of *abnormal* bone exposed to normal stress
    
    • Secondary to untreated Osteoporosis, Infection, Tumor
    • Sedentary lifestyle*
    • MC = Elderly, pelvic
Wolff’s Law
(Julius Wolff, 1836-1902)

• Wolff’s Law = bone responds to stress by continual remodeling to ↑ strengt
  – Greatest amount of bone is laid down in area of greatest applied stress
    • Bone resorption (osteoclasts) ↔ bone synthesis (osteoblasts)

• SFx Triad: Activity that is...
  – New/increased,
  – Relatively strenuous,
  – Repeated
Wolff’s Law

Wolff’s Law

Stress Fracture

Mandell JC. Skel Radol, 2017. 28374052
Pathophysiology

- Subthreshold loading $\rightarrow$ microcracks

- Continue load = crack propagation occurs...
  - Propagation $>$ repair
  - $(t)$ $\rightarrow$ SFx develops
  - Imbalance: bone resorption $\neq$ bone formation

Mandell JC. Skel Radol, 2017. 28374052
Explaining to a patient...

• Medically
  – Fatigue & Overuse \( \rightarrow \)
    Like a muscle strain
  – Intense exercise
    • Bone formation lags behind (\(<\)) bone resproption

• Real world
  – “Paper-clip”
Risk Factors

• **Intrinsic**
  – Metabolic
  – Anatomic

• **Extrinsic**
  – Training regimen
  – Diet
  – Equipment
## Intrinsic Factors

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatomy</td>
<td>- Bone&lt;br&gt;- Muscular strength;&lt;br&gt;- Anatomic alignment</td>
</tr>
<tr>
<td>Gender</td>
<td>- Narrower bones, lower bone mineral density</td>
</tr>
<tr>
<td>Collagen abnormalities</td>
<td></td>
</tr>
<tr>
<td>Metabolic bone disorders</td>
<td></td>
</tr>
<tr>
<td>Vascular supply</td>
<td></td>
</tr>
<tr>
<td>Nutritional</td>
<td>- Vitamin deficiencies;&lt;br&gt;- Diet;&lt;br&gt;- Smoking; Alcohol</td>
</tr>
<tr>
<td>Hormonal imbalance</td>
<td>- Female = estrogen deficiency&lt;br&gt;- Male (athletes) = testosterone → inhibits IL-6, osteoclast production, activity</td>
</tr>
<tr>
<td>Sleep deprivation</td>
<td></td>
</tr>
</tbody>
</table>
Women and SFx

- Female Athlete Triad:
  - Disordered eating
    - Decreased caloric intake
  - Amenorrhoea
  - Osteoporosis

- Risks
  - 5-21% w one symptom
  - 21-30% w two symptoms
  - 29-50% w all three symptoms.

- BMI
  - RF w BMI <19-21kg/m²

- Menstruation Abnormalities
  - Low bone mineral density
    - Exercise induced
    - Pre/Menopause

Matzkin M. JAAOS, 2015. 26111876
Extrinsic Factors

- Type of sport
- Training regimen
  - Schedule / Recovery (?)
  - Posture, gait, foot strike
  - Loads
- Training surfaces / environment
- Poor equipment (shoe gear)
- Iatrogenic
Differential Diagnosis

- MTSS / “Shin Splints” (PM shaft pain)
- Stress reaction / marrow edema
- Growth arrest lines
- Periostitis
- Infection (Chronic OM)
- Avulsion injury / muscle strain
- Tendinopathy
- Bursitis
- Neoplasm (osteoid osteoma; osteosarcoma)
- Exertional compartment syndrome
- Nerve / Artery Entrapment

NOTE: Differentials based on either presenting symptoms, physical exam, or imaging modality evaluation.
THE PATIENT EXAM / EXPERIENCE
“Chief Complaint”

• **Focal / pin-point pain** or tenderness to a particular location (66-81%)

• **Edema** (18-44%)
  – Pain/edema increases with time (day), duration on feet, increased activity

• **Exertional** pain

• **Aching** pain
Playing Detective

• History of un-acclimated / un-conditioned and repeated activity, limited rest.
  – Training: ↑ in volume / intensity; change in technique/surface; alteration of footgear; change in season sport (surface / footgear).

• Sequence / Evolution = pain after exercise > pain during exercise > pain without exercise.
  – Load related pain.

• General health, medications, diet, menstrual history (females).
Diagnosis

Physical Exam

- Bone tenderness
  - Long Bone = Direct palpation
  - Calcaneus = Squeeze
- Pain w bone “bending”
  - Metatarsals
    - MTPJ ROM DFX/PVX → placing bone under compression/tension and strains → cx pain
- Pain w tuning fork test
- Localized swelling
  - Tissue edema; bone callus

Biomechanical Evaluation

- LLD
  - 70% incidence w LE SFx
- Joint ROM / Stability
- Muscle Strength / Flexibility
- Alignment
  - Limb
  - Foot
- Gait analysis
- Shoe analysis
Imaging Modalities – XRs

• Very specific IF a SFx is seen
  – Periosteal bone formation, horizontal / obl linear sclerosis/scar, endosteal callus, frank fx line

• However, XRs can be false(-) for up to 3 months after symptom onset.
  – Early XR (1-3wk) are often normal w detection as low as 10-15% and serial XRs are diagnostic in 50% cases.
    • Lagging effect to symptom and perceived diagnosis ~ 10-21d
    • s/p 3 wk sensitivity = 30-70%
Imaging Modalities – MRI

• Able to detect abnormalities weeks before XR lesion presents
  – Similar sensitivity, greater specificity to bone scan
• Identifies concurrent muscular or ligamentous injury or strain
• Best w T2/STIR to identify bone marrow edema, (the hallmark of SFx)
  – Periosteal and BM Edema
  – Intracortical signal changes
  – Intramedullary fracture lines
• Rec’d as secondary imaging and gold standard by ACR
Imaging Modalities

• CT
  – Detect cortical fractures
  – For: Navicular, Diaphyseal bone

• Bone Scan
  – Tc-99m = inc uptake all 3 phz
    • Soft tissue injuries = inc uptake in phz 1-2, not 3
  – Lacks specificity
  – Detects osteoblastic activity associated w remodeling
# MRI – Radiological Grading

<table>
<thead>
<tr>
<th>Grade</th>
<th>Radiograph</th>
<th>Bone Scan</th>
<th>MR Imaging†</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>Mild uptake confined to one cortex</td>
<td>Positive STIR image</td>
<td>Rest for 3 weeks</td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>Moderate activity; larger lesion confined to unicortical area</td>
<td>Positive STIR and T2-weighted images</td>
<td>Rest for 3-6 weeks</td>
</tr>
<tr>
<td>3</td>
<td>Discrete line (+/-), periosteal reaction (+/-)</td>
<td>Increased activity (&gt;50% width of bone)</td>
<td>No definite cortical break; positive T1- and T2-weighted images</td>
<td>Rest for 12-16 weeks</td>
</tr>
<tr>
<td>4</td>
<td>Fracture or periosteal reaction</td>
<td>More intense bicortical uptake</td>
<td>Fracture line; positive T1- and T2-weighted images</td>
<td>Rest for 16+ weeks</td>
</tr>
</tbody>
</table>

## Table 1 – Grading of stress fracture: MRI and plain radiography

<table>
<thead>
<tr>
<th>Grade</th>
<th>STIR signal change</th>
<th>T2 signal change</th>
<th>T1 signal change</th>
<th>Plain x-ray film</th>
<th>Average time to return to play (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Present</td>
<td>None</td>
<td>None</td>
<td>Negative</td>
<td>3.3</td>
</tr>
<tr>
<td>2</td>
<td>Present</td>
<td>Present</td>
<td>None</td>
<td>Negative</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Periosteal reaction</td>
<td>11.4</td>
</tr>
<tr>
<td>4</td>
<td>Present</td>
<td>Fracture line (or on T1)</td>
<td>Fracture line (or on T2)</td>
<td>Periosteal reaction or fracture line</td>
<td>14.3</td>
</tr>
</tbody>
</table>

# Fredericson Classification
(MRI Tibial Grading)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Illustration</th>
<th>Grade</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grade 0:</strong> Normal MR</td>
<td><img src="image1" alt="Grade 0 Illustration" /></td>
<td><strong>Grade 3:</strong> Moderate bone marrow edema seen on both T2-weighted images and T1-weighted images; return to sport in mean 39-44 days</td>
<td><img src="image2" alt="Grade 3 Illustration" /></td>
</tr>
<tr>
<td><strong>Grade 1:</strong> Periosteal edema only</td>
<td><img src="image3" alt="Grade 1 Illustration" /></td>
<td><strong>Grade 4a:</strong> Cortical signal abnormality, not linear in morphology; return to sport in mean 39-44 days</td>
<td><img src="image4" alt="Grade 4a Illustration" /></td>
</tr>
<tr>
<td><strong>Grade 2:</strong> Mild bone marrow edema seen on T2-weighted images only</td>
<td><img src="image5" alt="Grade 2 Illustration" /></td>
<td><strong>Grade 4b:</strong> Linear cortical signal abnormality; return to sport in mean 71 days</td>
<td><img src="image6" alt="Grade 4b Illustration" /></td>
</tr>
</tbody>
</table>

*Return to sport in mean 39-44 days.*
MRI
(fibula Sfx)
XR v MRI
Imaging: Directing the Treatment

• OV 1 = XRs
  – Positive = Treat at SFx
  – Negative, with high suspicion = Treat as SFx
  – AND return in 2-3 weeks

• OV 2 = XRs
  – Positive = Treat at SFx
  – Negative = MRI to confirm a pathology

• NOTE: MRI may be warranted at OV1 if:
  – High level athlete;
  – High Risk SFx
Determining Optimal Management

1. Optimal Imaging Modality
2. High Risk v Low Risk
3. Conservative (v) Surgical
   3a. Conservative → Rehab Schedule?
   3b. Surgical → Best Technique?
4. When To RTS?
5. Preventable Programs?

Robertson GAJ. WJO, 2017. PMC5359760
Low vs. High Risk SFx

- Low-risk stress fractures
  - posteromedial tibia (24-73%)
  - 2nd/3rd metatarsals (17-35%)
  - calcaneus (21-28%)
  - distal fibula
  - cuboid
  - cuneiforms

- High-risk stress fractures
  - anterior tibial cortex
  - medial malleolus
  - navicular
  - talus
  - base of fifth metatarsal
  - base of second metatarsal
  - hallux sesamoids

Mandell JC. Skel Radol, 2017. 28343329
Treatment Options

Low Risk

- Heal well with activity modification, maintain WBing.
- Treat w 1-6 wks → trans
- “Compressive” Forces
  - MC
    - Tibia – Post-Med Distal
    - Calcaneus
    - Metatarsals (1-4)
  - LC
    - Distal fibula
    - Cuboid, Cuneiforms

High Risk

- Predilection for progression to complete fx, delayed or non-union
- Treat as acute fxs
- “Tensile” Forces ± Poor Vascularity
- Includes:
  - Tibia – Anterior Cortex*
  - Medial Malleolous
  - Talus
  - Navicular*
  - 5th MT base*; 2nd MT neck
  - Hallux Sesamoids
Good Read(s)

**Stress fractures of the foot and ankle, part 1: biomechanics of bone and principles of imaging and treatment**

Jacob C. Mandell, Bharti Khurana, Stacy E. Smith

Received: 20 January 2017 / Revised: 22 February 2017 / Accepted: 13 March 2017

PMID: 28374052 & 28343329

**Stress Fractures: Diagnosis, Treatment, and Prevention**

Deepak S. Patel, M.D., Rush-Copley Family Medicine Residency, Aurora, Illinois

Matt Roth, M.D., The Toledo Hospital Primary Care Sports Medicine Fellowship, Toledo, NEHA KAPIL, M.D., Rush-Copley Family Medicine Residency, Aurora, Illinois

American Family Physician www.aafp.org/afp Volume 83, Number 1 • January 1, 2011

PMID: 21888126

**World Journal of Orthopedics**

Submit a Manuscript: http://www.wjgnet.com/wjo/
DOI: 10.5312/wjo.v8i3.242

Lower limb stress fractures in sport: Optimising their management and outcome

Greg A J Robertson, Alexander M Wood

PMID: PMC5359760

PMID: PMC219443
Treatment – Bone Specific

**Fibula**
- Location:

**Medial Malleolus (HR)**
- Rare, 0.6-4%
- Athletes: run/jump sport
Treatment – Bone Specific

Fibula
• Location:

Talus (HR)

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Treatment – Bone Specific

**Navicular (HR)**
- Location: Central 3rd
- Pain (av) 6mth b/f dx

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Stress reaction; signal change on MRI noted, but stress fracture not imaged on CT</td>
</tr>
<tr>
<td>1</td>
<td>Dorsal cortical fracture on coronal image</td>
</tr>
<tr>
<td>2</td>
<td>Fracture extends into navicular body on coronal image</td>
</tr>
<tr>
<td>3</td>
<td>Complete propagation of fracture to second cortex (medial, lateral or plantar) on coronal image</td>
</tr>
</tbody>
</table>

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging. Adapted from Saxena et al (4) and Saxena and Fullem (16).

**Calcaneus**
- Location:
  - Posterior/tuber (56%)
  - Middle (18%); Anterior (26%)
- Conservative care:
  - Immobilization
  - Restriction of activity

Saxena A. JFAS, 2017. 17144953
Mandell JC. Skel Radol, 2017. 28343329
Treatment – Bone Specific

**Sesamoids (HR)**
- <4% F&A, < 1% running injuries
- Location: Tib > Fib
- Treatment:
  - Acute = 6 wks NWB w cast extending to toe top, prevents dfx
  - Long Term = Mortons extension; dancers padding
  - Sx = pain < 6mths
    - Sesamoidectomy

**Metatarsals**
- Location:
  - 2\textsuperscript{nd} (52%); 3\textsuperscript{rd} (35%); 1\textsuperscript{st} (8%)
  - 2\textsuperscript{nd}-4\textsuperscript{th} (diaphyseal)
  - Dancers = bases
- Risk:
  - LR = 2-4 diaphyseal
  - HR = 5MT “Jones”
- Conservative Care:
  - Immobilization
  - Restriction of activity
  - RTS once tenderness resolves
    - Modify...?
- Sx reserved for:
  - Converted Fx with dp/angle
  - Symptomatic non-union
Treatment Options – CRH

• **Metatarsal**
  
  – OV#1 = XR; WBAT CAM/SxShoe, RTC 3-4 wks
  
  – OV#2 = Re-eval w XR/PE. Goal 80% improvement to transition to sneaker. 1-2 wks ADLs b/f slow RTS
  
  • If not met goal (80%), WBAT CAM x2 wks and RT (continue until reach goal)
  
  • “Let pain be your guide.”
Treatment Options – CRH

• Gradual build up to activities/sport
  – *Gradual return to normal after immobilization
  – Reduced SFx risk w reduce stride length, running speed, and mileage

• Strengthen muscles in LE
  – Role of muscles = muscle fatigue, concentrating forces to localized areas
  – Muscle action function to dissipate energy and reduce tensile bone stress

• Maintain health diet

• Vitamins? (D, Ca)
  – SUN!
Additional Considerations – Females

- Women
  - SF related to activity? Age?
  - Osteoporosis? “Fragility Fracture”? 
  - If ~50yo w no DEXA, refer to PCP 
  - Vitamin D, Ca, Mg, Phos labs? 
  - Hormone replacement therapy? 

- H/O stress fractures? Fragility fractures (hip, femur)? 

- Referral to either rheumatology, osteoporosis, or bone health clinic
Additional Considerations – Athletes

• Identify and correct predisposing factors
• Identify and correct training errors (MC)
  – Physical therapy and sport-specific trainers
    • Video-monitoring technique $\rightarrow$ correct
    • Force-plate weight distribution $\rightarrow$ correct
    • Posture $\rightarrow$ correct
  – Cross-Train
• Education
• “Get fit quick” programs
• Assess shoegear = type and condition
  – Insoles? Viscoelastic = dampening forces
  – Change every 3-6 months (cheap EVA foam, compacts, lose shock absorption quality)
CASE EXAMPLES
Case 1 – RDT (45♀)

- History of 9 days of acute foot pain, moderate in level, gradually increasing and sharp with WBing. Localized about the base of the 2nd toe. Relieved with rest.
- PMH = hypertension
- PSxH = n/a
- Social = ØT/A/D
- FH = n/a
- Meds = Amlodipine, Sertraline
- BMI = 22.14 kg/m²
  - 5’4, 129 lbs
Case 1 – RDT (45♀)

- OV #1 (9/29/16)
- Physical Exam =
  - No obvious findings.
  - Acute tenderness to the 2nd metatarsal neck/head region on bone palpation.
- Dx = L-2nd met neck stress fx
- Tx =
  - Sx shoe WBAT, rest;
  - Labs = Vit D, Ca, Mg, Phos;
  - RT 3-4 wks.
Case 1 – RDT (45♀)

• OV #2 (10/17/16)
  – Reports no pain to foot after 3 wks WBAT Sx Shoe.
  – Did not get labs.
  – Phys Exam = mild tenderness to 2\textsuperscript{nd} met neck
  – Tx =
    • Cont’d Sx Shoe WBAT 2-3 wks w sneaker transition as tol
Case 1 – RDT (45♀)

• OV #3 (11/16/16)
  – Reports min sorenes after sneaker transition, but improving qd.
  – Phys Exam = mild tenderness; palpable callus.
  – Tx = Cont’d sneaker WBAT 2-3 wks, then slow as tol, activity inc.
  – Discharged.
Case 1 – RDT (45♀)
Case 2 – SJ (38♀)

- Patient initially presented for plantar fasciitis, was treated twice over 4 weeks and told to follow up in 6 wks.
- Presents 2 weeks later with acute lateral forefoot pain of 1 week duration after her PF was improving, and returned to her cardio activities.

- PMH = hypothyroid
- PSxH = appendectomy
- Social = ØT/D, min EtOH
- FH = AS (brother)
- Meds = Synthroid
- BMI = 32.45 kg/m²
  - 5’5, 195 lbs
Case 2 – SJ (38♀)

- OV #1 (9/15/16)
- Physical Exam =
  - No obvious findings.
  - Acute tenderness to the 4th metatarsal neck/head region on bone palpation.
  - Pain with PFX 4th MTPJ in PFX
- Dx = L-4th met neck stress fx
- Tx =
  - CAM Boot WBAT, rest;
  - Labs = Vit D, Mc, Ca, Phos;
  - RT 3-4 wks.
Case 2 – SJ (38♀)

- OV #2 (10/20/16)
  - Reports min/no pain to foot after 4 wks CAM WBAT, and no pain WBAT w/o CAM at home. No physical activity to date
  - Vit D3 = 35.3
  - Ca = 9.6 / Mg = 2.0 / P = 3.5 (all wnl)
  - Phys Exam = mild tenderness to 4th met neck w/ no pain on 4th MTPJ ROM
  - Tx =
    - Cont’d CAM WBAT 1 wk w sneaker transition as tol
    - Vitamin D3 = 2-5k U/qd
Case 2 – SJ (38♀)

- OV #3 (11/17/16)
  - OOB to sneaker w min pain; reports 60-70% overall improvement
  - Vit D3 = 35.3
  - Ca = 9.6 / Mg = 2.0 / P = 3.5 (all wnl)
  - Phys Exam = mild tenderness to 4th met neck w/ no pain on 4th MTPJ ROM
  - Tx =
    - Cont’d transition to activity as tol;
    - Cont’d supplement.
  - Discharged
Any questions?
References

• Bakalar N. Yogurt may be good for the bones. NYTimes. 16 May 2017. Online.
• Robertson GAJ. Lower limb stress fractures in sport: optimizing their management and outcome. WJO. 2017. 8(3): 242-255.
• NOTE – References listed throughout presentation as:
  – Name. Journal, Year. PMID
Thank you

Question?
Contact me at:
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#GoldfarbCC17 #stressfracture #osteopenia #osteoporosis #vitamind