How Can I Get This Bone to Heal

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Fracture Healing

• Patient Factors
  • Age
  • Smoking
  • DM

• Fracture Environment
  • Open fractures
  • Bone loss
  • Osteopenia/porosis

• Fracture Stability
  • Surgical/Non surgical treatment
Bone Composition

• Cells
  • Osteocytes
  • Osteoblasts
  • Osteoclasts

• Extracellular Matrix
  • Organic (35%)
    • Collagen (type I) 90%
  • Inorganic (65%)
    • Primarily hydroxyapatite $\text{Ca}_5(\text{PO}_4)_3(\text{OH})_2$
Osteoblasts

- Derived from mesenchymal stem cells
- Line the surface of the bone and produce osteoid

Picture courtesy Gwen Childs, PhD.
Osteocytes

- Osteoblasts surrounded by bone matrix
  - trapped in lacunae
- Function poorly understood
  - regulating bone metabolism in response to stress and strain

Picture courtesy Gwen Childs, PhD.
Osteocyte Network

Network probably facilitates response of bone to mechanical and chemical factors
Osteoclasts

• Multinucleated cells whose function is bone resorption

• Parathyroid hormone activates osteoclastic bone resorption

Picture courtesy Gwen Childs, PhD.
Prerequisites for Bone Healing

- Adequate blood supply
- Adequate mechanical stability
Blood Supply

- Long bones have three blood supplies
  - Nutrient artery (intramedullary)
  - Periosteal vessels
  - Metaphyseal vessels

Figure adapted from Rockwood and Green, 5th Ed
Vascular Response in Fracture Repair

• Fracture stimulates the release of growth factors that promote angiogenesis and vasodilation
• Blood flow is increased substantially to the fracture site
  • Peaks at two weeks after fracture
Mechanical Stability

- Early stability promotes revascularization
- After first month, loading and interfragmentary motion promotes greater callus formation
Mechanical Stability

• Mechanical load and small displacements at the fracture site stimulate healing

• **Inadequate stabilization** may result in excessive deformation at the fracture site interrupting tissue differentiation to bone (soft callus)

• **Over-stabilization**, however, reduces periosteal bone formation (hard callus)
Stages of Fracture Healing

• Inflammation
• Repair
• Remodeling
Inflammation

• Tissue disruption results in hematoma at the fracture site
• Local vessels thrombose causing bony necrosis at the edges of the fracture
• Increased capillary permeability
  • Release of Osteoinductive growth factors
• Periosteal callus forms along the periphery of the fracture site

• Intramedullary callus forms in the center of the fracture site

• Chemical and mechanical factors stimulate callus formation and mineralization
Remodeling

- Woven bone is gradually converted to lamellar bone
- Medullary cavity is reconstituted
- Bone is restructured in response to stress and strain (Wolff’s Law)
Local (chemical) Regulation of Bone Healing

- Growth factors
- Cytokines
- Prostaglandins/Leukotrienes
- Hormones
- Growth factor antagonists
Growth Factors

• Transforming growth factor

• **Bone morphogenetic proteins**
  • Fibroblast growth factors
  • Platelet-derived growth factors
  • Insulin-like growth factors
Clinical Use of BMP’s

• Osteo**inductive** proteins
• Used at doses between 10x & 1000x native levels
• Negligible risk of excessive bone formation
• rhBMP-2
• BMP-7 approved for use in nonunions
Hormones

• **Estrogen**
  • Stimulates fracture healing through receptor mediated mechanism

• **Thyroid hormones**
  • stimulate osteoclastic bone resorption

• **Glucocorticoids**
  • Inhibit calcium absorption from the gut causing increased PTH and therefore increased osteoclastic bone resorption
Hormones (cont.)

• Parathyroid Hormone
  • Intermittent exposure stimulates
    • Osteoblasts
    • Increased bone formation

• Growth Hormone
  • Increases callus formation and fracture strength
Local Anatomic Factors That Influence Fracture Healing

• Soft tissue injury
• Interruption of local blood supply
• Bone death caused by radiation, thermal or chemical burns or infection
Systemic Factors That Decrease Fracture Healing

• Malnutrition
  • Reduces activity and proliferation of osteochondral cells
  • Decreased callus formation

• Smoking
  • Cigarette smoke inhibits osteoblasts
  • Nicotine causes vasoconstriction diminishing blood flow at fracture site

• Diabetes Mellitus
  • Associated with collagen defects

• Anti-Inflammatory Medications
  • Cause (at least a temporary) reduction in bone healing
Bone Stimulator
Electromagnetic Field

• Electromagnetic (EM) devices are based on Wolff’s Law that bone responds to mechanical stress: In vitro bone deformation produces piezoelectric currents and streaming potentials.

• Exogenous EM fields may stimulate bone growth and repair by the same mechanism

• Clinical efficacy very controversial
  • No studies have shown PEMF to be effective in “gap healing” or pseudarthrosis
Summary

• Fracture healing is influenced by many variables
  • mechanical stability
  • electrical environment
  • biochemical factors
  • blood flow
Osteoporosis - Scope of the Problem

• 50% Caucasian Women will Fracture
• Most Serious Outcome - Hip Fracture
• 10-20% Excess Mortality at 1 year
• 25% Long Term NH Care
• Only 1/3 Regain Independence
• Psychological and Social Issues
• ↓ Quality of Life
Definitions

- **Insufficiency Fracture**
  Bone Fails with Normal WB

- **Fragility Fracture**
  Fall from a Standing Height or Less
Diagnosis - DEXA BMD

- Relationship (SD) to Norms
- **T-Score** - Reference Standard
  - Comparison to “young normal” adult same sex
- **Z-Score**
  - Comparison to age matched adult same sex
Orthopaedic Diagnosis - Osteoporosis

• **Clinical Presentation**
  • Presence of Insufficiency or Fragility Fracture

• **Bone Mineral Density (BMD)**
  • **2.5 SD** Below the Young Adult Average Value (T)
Further Diagnosis - Osteoporosis

• **Labs** Can Help R/O Secondary Causes
  - CMP, Serum Thyrotropin, Protein Electrophoresis, PTH, Vitamin D, Urine Calcium, Cortisol

• Clinical Utility of Biochemical Markers still Not Proven
FRAX

• Developed by WHO
  • Incorporates Risk Factors + BMD
    • Age, Sex, Ht, Wt, Family Hx, Previous Fx, Steroids, Smoking, EtOH,
      Secondary Causes, RA

• 10-yr Fracture Risk (%)
  • Hip
  • Other Major Fracture

• Online Tool

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Pathophysiology - Osteoporosis

• Imbalance in Removal/Replacement of Ca

• Not an Organic Matrix or Mineralization Defect

• Loss of Trabecular Plates, Cortical Thinning

• Structural Weakening

“Mechanical Problem”
Surgical Issues - Osteoporosis

- Difficult Fracture Fixation
  - Poor Screw Purchase
  - Excessive Bowing (Distal Nail Penetration)
- Immobilization or Minimal WB → Bone Loss
- Autogenous Bone Graft Not as Useful
Surgical Treatment Principles - Osteoporosis

• Fixation
  • Length
    • IM Nails, Long plates
  • Augmentation
    • Biologic Cements, Graft, Struts
  • Angular Stability
    • Locked screws with plates/nails
  • Arthroplasty
    • Shoulder, Elbow, Hip, Knee

• Allow WB if Possible
Recognition - Osteoporosis

• Ortho Often the First to See

• Assure All at Risk Patients Have F/U

• Develop a System in Your Hospital
  • Geriatric Program
  • AOA Own the Bone
Fractures Beget Fractures

- Risk of future fractures increases 1.5 - 9.5 fold following initial fracture

- History of fragility fracture is more predictive of future fracture than bone density
Treatment - Osteoporosis

Preventing osteoporosis in all women

- Stop smoking
- Calcium
- Vitamin D
- Medication
- Weight-bearing exercise
- Check your risk factors
- Reduce alcohol

Patients
Treatment - Osteoporosis

• Address Risk Factors
  • Avoid EtOH and Tob

• Ensure Nutrition
  • Ca (1200mg)
    • 600 mg po BID

• Vitamin D (>1500 IU)
  • Other Nutrients
    • Magnesium
    • Silicon
    • Vitamin K
    • Boron
Exercise and Rehab

• Improve Strength, Endurance, Posture
• Maintain Bone Density
• Prevent Falls
• 30 Minutes Moderate Intensity Daily
• Post Fracture Rehab May Reduce Future Fracture
Treatment - Osteoporosis

• Indication for Pharmacologic Intervention
  • T-score < -2.5 without other Risk Factors
  • T-score < -1.0 – 2.5 with other Risk Factors
    • Fragility Fx
    • FRAX Score Hip Fx 10-yr Risk >3%
    • FRAX Score Other Major Fx 10-yr Risk >20%
Pharmacological Therapy

- **Anti-Resorptive Drugs**
  - Hormonal Replacement Therapy: Estrogen/Progestin
  - **Bisphosphonates:**
    - Alendronate, Ibandronate, Risendronate, Zoledronic Acid
  - Selective Estrogen Receptor Modulators: Raloxifene
  - Calcitonin

- **Bone Forming Drugs**
  - Teriparatide
    - Recombinant Parathyroid Hormone
Bisphosphonates

- **Side-Effects**
  - GI
  - Jaw Osteonecrosis (Rare)

- **Atypical Fractures**
  - Risk with Long term use
  - Assess Both femurs
  - Difficult to heal

- **Must weigh risks of use against huge benefits of other Fx Prevention**
  - Hip, wrist, spine
Conclusions

- Osteoporosis: Prevalence – Recognition is Key
- Need Effective Tx to ↓ Fx Rate
  - Nutrition
  - Exercise
  - Fall Prevention
  - Medications
  - Assure Follow Up
- Surgical Improvements Help
Thank You!!!