MSK Mets & MIIPs

Anthony Tadros
March 15, 2018
MINIMALLY INVASIVE, IMAGE-GUIDED PROCEDURE

TREATING DISEASE THROUGH A PINHOLE

BACK & BONES
“People deserve to understand what health care options are available to them so they can make the best choices for themselves and their families. That’s why we are dedicated to empowering the public through education about MIIPs.”

—Isabel Newton, MD, PhD
Chairperson of the Board, Secretary
WITHOUT A SCALPEL

EPISODE 2: THE CANCER SNIPERS
Objectives

- Review imaging features of MSK metastatic disease
- Discuss clinical features and treatment algorithms for MSK metastatic disease
- Review minimally invasive techniques used in MSK palliation
MSK Metastases

• Most common site of metastatic disease

• Morbidity
  • Pain
  • Pathologic fracture
  • Neural compromise
  • Myelosuppresion

AJR 2017; 209:713–721
World J Radiol 2015 August 28; 7(8): 202-211
Routes of spread

• **Direct extension** (e.g. Pancoast’s tumor)

• **Lymphatic**
  • Draining lymph node involves adjacent bone (e.g. vertebral destruction in pelvic carcinoma)

• **Hematogenous**
  • Arterial – immunity to tumor penetration in absence of infection
  • Venous* – most common (Batson’s plexus → direction connection to IVC/SVC with no valves)

• **Intraspinal** (e.g. CSF to spinal canal)

Resnick. Bone and Joint Imaging, 2004
Pathophysiology of bone metastases

- Rich marrow sinusoidal system \(\rightarrow\) large endothelial gaps
- Tumor adhesion molecules bind to bone matrix
- Certain tumors upregulate:
  - Osteoclasts (e.g. TNF, PTHrP) \(\rightarrow\) lysis
  - Osteoblasts (e.g. EGF, IGF) \(\rightarrow\) sclerosis

Pathophysiology of bone metastases

**Osteolytic**
- Lung
- Kidney
- Thyroid
- Most SCCs
- Melanoma
- HCC
- Colon
- Bladder

**Mixed**
- Lung
- Breast
- Cervical
- Bladder
- Testicular
- Gastrointestinal

**Osteoblastic**
- Prostate
- Breast
- Carcinoid

73 yo F with lung cancer.
70 yo F with breast cancer.
79 yo M with prostate cancer.
Common sites of bone metastases

- Thoracolumbar spine + sacrum = vertebral body > posterior element
  - Lumbar (52%), Thoracic (36%), Cervical (12%)
- Pelvis
- Ribs
- Sternum
- Femoral and humeral shafts
- Skull (e.g. myeloma, breast lung)

Resnick. Bone and Joint Imaging, 2004
Infrequent sites of bone metastases

- Mandible (e.g. myeloma)
- Patella
- Appendicular
  - Hands and Feet → lung cancer
- Sites of disease (e.g. Paget’s) or surgery (e.g. implant)

98 yo man with biopsy-proven metastasis to calcaneus. History prostate cancer.

Resnick. Bone and Joint Imaging, 2004
World J Radiol 2015 August 28; 7(8): 202-211
Imaging Pearls: Sclerotic lesion

**Bone Island**
- Spiculated
- Growth < 50% in 1 year
- Normal surrounding marrow
- Can be warm or hot on bone scan

**Metastasis**
- Less homogenous
- Rim of edema – halo sign (99% specific)
- Mean attenuation < 885 HU

Planar Bone scan should not be used to exclude or mandate biopsy of a sclerotic lesion. Useful to find additional lesions.

AJR:208, May 2017
AJR 2016; 207:362–368
Imaging Pearls: Lytic lesion

• Asymptomatic + nonaggressive sclerotic margin + no treated malignancy = no additional imaging

• Indeterminate → MRI
  • Look for Fat (99.5% benign)
Imaging Pearls: Focal marrow abnormality

• Adult red marrow = Axial skeleton, proximal long bone metaphyses
  • T1 signal > muscle or disk
• Focal red marrow can appear masslike without macroscopic fat
• In and out of phase ➔ microscopic fat decrease in signal on OOP images when compared to muscle
• If no macro or micro fat ➔ 6% malignant
  • Breast, lung, lymphoma, myeloma
  • FDG PET/CT – 95% sensitive for mets/lymphoma

86 yo F with right chest wall sarcoma.
Soft-tissue metastases

• 1.3% of soft-tissue masses
• Large, painful, deep to fascia
• ~ 50% - first presentation of malignancy
  • Lung, skin, kidney

33 yo M with biopsy proven rectal cancer metastatic to gluteal musculature.

Clinical features of bone metastases

• Complication from bone met = skeletal-related event
• A patient with bone met $\rightarrow$ skeletal-related event every 3-6 mos
  • Cluster around periods of progression and reduced treatment options
Clinical features of bone metastases

• Pain
• Pathologic fractures
• Neural compression
• Myelosuppresion
• Deconditioning
• Weakness
• Respiratory compromise
• Hypercalcemia
Pain

• Most common cause of cancer-related pain
• Not adequately treated in 56-82% of patients

Mechanisms
• Tumor-induced osteolysis
• Cytokine release
• Infiltration of nerves

• Nociceptive type → damage to tissues
• Neuropathic type → damage to nerves

34 yo M with metastatic liposarcoma.
Pain

- **Base of skull** – cranial nerve palsies, neuralgias, headaches
- **Vertebral** – neck and back pain with or without neurologic complication (epidural extension)
- **Pelvic and femoral** – pain in back and lower limbs, mechanical instability

60 yo M with RCC and lung cancer.
Pain in the spine

- **Periosteum → high density of sensory nerve endings**
  - Tumor invasion → local inflammatory environment
- **Medullary → little sensory innervation**
- **Extend directly into exiting nerve roots**
- **Compress dura or spinal cord**
- **Pathologic fracture**
  - Stabilize when possible
Pathologic fractures

• Reduced load bearing capability $\rightarrow$ microfracture (pain) $\rightarrow$ fracture
  • Most common = ribs and vertebrae

• Most disability = Long bone fracture or epidural extension

37 yo F with metastatic pheochromocytoma.
Spinal metastases

• **Goals of treatment**
  • Palliative pain control
  • Structural stabilization
  • Tumor control

• **Patient evaluation**
  • Structural integrity
  • Pain
  • Clinical factors
Spinal metastases – Structural assessment

• **Early surgical evaluation**
  • Aggressive multilevel or multicolumn disease
  • Significant deformity
  • Spinal canal encroachment
  • Bowel/bladder dysfunction
  • Lower extremity weakness or sensory deficits

• **Identify pathologic fractures and high risk lesions for future fracture**
  • MRI preferred
  • CT – Critical cortical boundaries, minimally displaced fractures
  • SPECT/CT – myeloma fractures
Spinal metastases – Predicting fracture risk

• Limited data-driven recommendations

• **Most validated scoring system** → **Spinal Instability Neoplastic Score (SINS)**
  - Published by Spine Oncology Study Group (2010)
  - Based on literature review and expert opinion – somewhat validated

• **Scores 6 variables**
  - Location
  - Mechanical pain
  - Type of bony lesion
  - Radiographic alignment
  - Vertebral body destruction
  - Involvement of posterolateral spinal elements
### Element of SINS

<table>
<thead>
<tr>
<th>Location</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junctional (occiput-C2, C7-T2, T11-L1, L5-S1)</td>
<td>3</td>
</tr>
<tr>
<td>Mobile spine (C3-C6, L2-L4)</td>
<td>2</td>
</tr>
<tr>
<td>Semi-rigid (T3-T10)</td>
<td>1</td>
</tr>
<tr>
<td>Rigid (S2-S5)</td>
<td>0</td>
</tr>
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</table>

Pain relief with recumbency and/or pain with movement/loading of the spine

- Yes: 3
- No (occasional pain but not mechanical): 1
- Pain free lesion: 0

Bone lesion

- Lytic: 2
- Mixed (lytic/blastic): 1
- Blastic: 0

Radiographic spinal alignment

- *Subluxation/translation present*: 4
- De novo deformity (kyphosis/scoliosis): 2
- Normal alignment: 0

Vertebral body collapse

- >50% collapse: 3
- <50% collapse: 2
- No collapse with >50% body involved: 1
- None of the above: 0

Posterolateral involvement of the spinal elements (facet, pedicle or CV joint fracture or replacement with tumor)

- Bilateral: 3
- Unilateral: 1
- None of the above: 0

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<table>
<thead>
<tr>
<th>Score (Total = 0-18)</th>
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<tr>
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<td>1-6</td>
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<tr>
<td>7-12</td>
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<tr>
<td>13-18</td>
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</tbody>
</table>

**Clinical categories**

- Stable
- Potentially unstable
- Unstable

**Binary scale**

- Current or potentially unstable = possible surgical intervention

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SPINE Volume 35, Number 22, pp E1221–E1229
Global Spine Journal 2017, Vol. 7(8) 744-748
Spinal Instability Neoplastic Score (SINS)

69 yo M with RCC presenting with occasional back pain, not changed with posture, and right T10 radicular pain

Semirigid spine (T10) = 1
Lack of mechanical pain = 1
Lytic lesion = 2
Normal alignment = 0
No VB collapse, >50 % involved = 1
Unilateral spinal elements = 1
Radiation and fracture risk

• **Increased pathologic fractures postradiation**
  • Conformable external beam radiation therapy (cEBRT)
  • Stereotactic beam radiation therapy (SBRT) or stereotactic radiosurgery (SRS) → 15 to 40%

• **Occurs several weeks postradiation**
  • Highly lytic
  • Elevated SINS

Radiation and fracture risk

• ? Prophylactic stabilization prior to RT
  • No level 1 evidence
  • Some will perform vertebral augmentation of painful and nonpainful high-risk lesions prior to RT

• Other possible reasons for prophylactic augmentation
  • At levels for screw fixation prior to decompression = prevent screw pullout
  • Adjacent cranial levels to prevent proximal junction failure

Pain assessment

• Baseline pain
  • Visual Analog Scale (VAS), Numeric Rating Scale (NRS) or Brief Pain Inventory (BPI)

• Functional Assessment and mobility
  • Roland Morris Disability Questionnaire (RMDQ) or Oswestry Disability Index (ODI)

• Current pain medication regimen
  • Morphine equivalent daily dose (MEDD)
Developing a plan of care

- Patient often poorly tolerate prolonged conservative management (e.g. bed rest, bracing, oral analgesics)
  - Benefit from stabilization of fractures (acute/subacute and even > 1 yr unhealed)
- Important considerations
  - Patient age
  - Functional status
  - Tumor type
  - Long-term prognosis
  - Rate of disease progression

Developing a plan of care

- Ideally within multidisciplinary setting
- **NOMS decision framework - MSKCC**
  - Neurologic symptoms
  - Oncologic parameters
  - Mechanical instability
  - Systemic disease/medical comorbidities
- Based on literature review

### Developing a plan of care ➔ NOMS decision framework

<table>
<thead>
<tr>
<th>Neurologic</th>
<th>Oncologic</th>
<th>Mechanical</th>
<th>Systemic</th>
<th>Decision</th>
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<tr>
<td>Low-grade ESCC + no myelopathy</td>
<td>Radiosensitive</td>
<td>Stable</td>
<td></td>
<td>cEBRT</td>
</tr>
<tr>
<td>Radiosensitive</td>
<td>Stable</td>
<td></td>
<td></td>
<td>Stabilization followed by cEBRT</td>
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<tr>
<td>Radiosensitive</td>
<td>Unstable</td>
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<td>SRS</td>
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<td>High-grade ESCC ± myelopathy</td>
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<td>Unstable</td>
<td></td>
<td></td>
<td>Stabilization followed by cEBRT</td>
</tr>
<tr>
<td>Radiosensitive</td>
<td>Stable</td>
<td>Able to tolerate surgery</td>
<td></td>
<td>Decompression/stabilization followed by SRS</td>
</tr>
<tr>
<td>Radiosensitive</td>
<td>Unstable</td>
<td>Unable to tolerate surgery</td>
<td></td>
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Stabilization = percutaneous cement augmentation, percutaneous pedicle screw instrumentation, and open instrumentation

Developing a plan of care → NOMS decision framework
Radiation

• Mainstay treatment of spinal metastases
• Effective pain palliation in some patients
  • 70-80% some pain relief
  • 30% complete pain relief
• Takes several weeks for pain relief
• Pain often recurs \(\rightarrow\) 57% of patients at median of 15 wks postradiation

Radiation

• Historically = cEBRT for radiosensitive spinal metastases
  • Lymphoma, myeloma, prostate, breast
  • Median duration of improvement → 11 months
  • Radioresistant duration of improvement → 3 months

• SBRT/SRS → higher doses to tumors safely
  • Nearly all tumors are radiosensitive
  • High response rates
  • Minimal neurologic side effects

• Increased postradiation fractures with SBRT/SRS
  • Up to 40% vs. < 5% cEBRT
  • ? prophylactic vertebral body augmentation
Developing a plan of care ➔ NOMS decision framework
Surgical decompression

- Long-term ambulatory benefit
- Recommended for young and/or highly function with reasonable long-term prognosis
- Multiple scoring systems to stratify survival after spine surgery for metastatic disease
Developing a plan of care ➔ NOMS decision framework

Vertebral Augmentation

• First described by Harrington in 1981 for pathologic spine fracture

• General features
  • Posterior approach through or adjacent to pedicles
  • +/- cavity creation
  • +/- placement of implant
  • Injection of polymethylmethacrylate (PMMA)
Vertebral Augmentation

• Vertebroplasty = PMMA injection into vertebral body
• Kyphoplasty = Balloon cavity creation + PMMA injection
• **Vertebral augmentation = all encompassing**
  • Cavity creation or device implantation
  • PMMA Injection

Vertebral Augmentation

• For patients not requiring or appropriate for surgical decompression and/or fixation

• Strong evidence ➔
  • Significant spinal stabilization
  • Functional improvement in osteoporotic and pathologic fractures
  • Pain relief

• Advantages ➔
  • Minimal disruption to chemotherapy and radiation
  • Avoidance of general anesthesia

Developing a plan of care → NOMS decision framework
Spine Ablation

• **Complete curative therapy**
  - 67% at 1 year → small lesions without significant cortical destruction or posterior element involvement
  - Difficult due to adjacent neurologic structures and predicting ablation zone

• **Noncurative cytoreduction**

• **Pain relief**
  - Target bone/tumor interfaces → maximal nerve ending irritation due to local tumor-induced inflammation

Spine Ablation

- Cavity for PMMA may minimize complications
- PMMA for all lytic or partially lytic lesions
Ablation options

• **Chemical**
  • Alcohol

• **Thermal**
  • RFA
  • Microwave
  • Cyroablation
  • MRgUS
  • Laser
Chemical ablation ➔ Alcohol

- Cell dehydration
- Tumor vessel thrombosis
- Unpredictable extent and volume of tumor ablation
- Preferred for vertebral hemangiomas
  - Subthreshold temperature due to cooling effect of flowing blood
- Test injection ➔ estimate tumor perfusion
Thermal ablation

• Induce cell death using extreme change in temperature
• Landmark paper → RFA of osteoid osteoma (Rosenthal et al, 1992)
• Choice of ablation method (RFA, MW, cryo, laser)
  • Operator experience
  • Equipment availability
  • Tumor size and location

AJR:207, September 2016
Radiology 1992; 183:29–33
Thermal ablation

- Ablation zone margins → need to encompass entire tumor
- Number and position probes → ablation zone
- Beware of adjacent critical structures (> 1 cm = safe distance)
  - Skin
  - Nerves (neurotoxic: > 45 °C or < 10°C)
- If unsafe distance → protective measures
  - Temperature monitoring = thermal couples
  - Nerve function monitoring = EEG, EMG
  - Thermal insulation (5% dextrose, CO₂, warm saline/ice packs, heat/cold sink)
Thermal ablation

- General anesthesia or moderate to deep sedation with analgesic support
  - Needle into osteoid osteoma nidus $\rightarrow$ prostaglandin surge
- Antibiotic prophylaxis
Radiofrequency ablation

- RFA = heat delivered by high-energy frequency electric current
- Current flows through patient to grounding pads
  - Grounding pads should be on large bulk soft tissue (e.g. thighs)
  - As far as possible from active electrode
- Bipolar RF probe
  - Active and return electrodes in same probe
Radiofrequency ablation

• Advantages
  • Long term experience
  • Mature product lines
    • One design includes articulating probe

• Disadvantages
  • Heat-sink effect and tissue charring → prevent adequate ablation
  • Highly vascular metastases may benefit from preablation embolization to reduce heat-sink
  • No real-time visualization of ablation zone

Multiple active curved tined

LeVeen (Boston Scientific)

Insulated main cannula

Starburst XL (Angiodynamics RITA)
Forward facing deployment, stepped deployment
Radiofrequency ablation

- **Bone natural barrier for thermal energy**
  - Heat does not dissipate through adjacent bone → protects adjacent structures
  - Reactive adjacent bone → added insulation
  - “Oven effect”

- Ideal for small soft-tissue lesion surrounded by bone (e.g. osteoid osteoma)

- Subchondral lesion → PMMA
Microwave ablation

- Electromagnetic waves in microwave energy spectrum to produce heat
  - Water oscillates trying to align with EM field = heat
Microwave ablation

- **Advantages**
  - Faster
  - Multiple simultaneous probes = larger ablation zone
  - Less sensitivity to bone impedance $\rightarrow$ useful for sclerotic lesions
  - Less heat sink and charring

- **Disadvantages**
  - High learning curve $\rightarrow$ choice of antennas, frequencies, power output
  - Fragile probes $\rightarrow$ probe fracture or malfunction
    - Sclerotic lesion needs advanced drill access
  - Less predictable ablation zone
    - Heat transmission less efficient in cancellous bone and more reflected at cortex
Microwave ablation

• **Useful for sclerotic bone lesions (more effective heating)**
  • Ceramic tip design may fracture → advanced drill access

• **Avoiding overheating**
  • Temperature monitoring
  • Short ablation cycles
Cryoablation

• Extremely cold temperature → cell death
  • Conversion of intra and extracellular water to ice
  • Central necrosis and peripheral apoptosis

• Unlike heat based ablation
  • No charring → extracellular matrix maintained
  • Not limited by cortical bone
Cryoablation

• Probes use compressed argon (cool) and helium (thaw) gas
  • Joule-Thompson effect
  • 2.4 mm probe → 3 cm lethal ablation zone

• Important to get very low temperature at a fast rate
  • Double freeze technique – 10 min with intervening 5 minute passive thaw
  • Active thaw at end of procedure – extract from ice ball

• Lethal and nonlethal temperatures
  • Nonlethal at outer margins
  • Ablation zone planning based on lethal temperatures (-20 °C to -40 °C)
The probe ProSense™
temperature schedule

-40 °C
Lethal zone

-20 °C

-3 °C
Outer layer

Tip temperature
(freezing area): -160 °C ± 10 °C
Cryoablation

• Widely used in many organ systems
• Large bulky tumor → ablation size and sculpting
• Advantages
  • Depict ablation margins on CT = low density ball
  • Direct analgesic effect
  • Neurologic monitoring = no electrical interference
• Disadvantages
  • Longer ablation time
  • Partial melting needed prior to PMMA
  • Expensive equipment

AJR:207, September 2016
Laser ablation

- Infrared light energy through optical fiber → heat
  - Nd:YAG diode laser fibers
- Small ablation zones up to 1.6 cm
- Predictable size of necrosis
- Ideal for osteoid osteoma when RFA contraindicated (e.g., pacemaker)
- MRI-compatible

AJR:207, September 2016
MR-guided focused ultrasound

- Focused ultrasound delivered within lesion
- Real-time thermal monitoring by MR guidance
- Non-invasive
- Improved physical functioning and symptomatic quality of life measures
Pre-ablating planning

• Degree of tumor lysis
• Posterior cortical destruction
• Retropulsion
• Pedicle involvement/fracture → parapedicular access
• Dural invasion
• Neural compression
• Tumor vascularity
• Paraspinous soft-tissue component
• Bone quality

Pre-ablation planning

• **Lytic lesions** → most amenable to treatment
  - Easy access and PMMA injection

• **Sclerotic and mixed lesions** → more challenging
  - Drills for access

• **Bipedicular access** → complete targeting of lesion

A word about myeloma

• Large lytic lesions $\rightarrow$ high incidence of pathologic fractures
  • Upregulation of osteoclasts and plasma cell invasion

• Highly radiosensitive

• Vertebroplasty is an effective treatment
  • PMMA polymerizes in vivo $\rightarrow$ transient temperature elevation
  • Soft tumor $\rightarrow$ some local tumor control
  • Pain control = structural stability and possibly PMMA exothermic process

• Posterior cortical destruction $\rightarrow$ vertebral augmentation implant
  • PEEK coil (e.g. KIVA) or metallic stent

• Ablation not usually necessary

64 yo F with breast cancer. RFA with temperature monitoring, KIVA, and pedicle-plasty. Patient had no pain after procedure.
– Case courtesy of Sean Tutton, MD
56 yo with RCC. MWA, temperature monitoring, and KIVA at T9, T11-L1.

– Case courtesy of Sean Tutton, MD
68 M with myeloma. KIVA with improved pain and mobility.

– Case courtesy of William Lea, MD
Metastatic prostate cancer. RFA with KIVA.

– Case courtesy of Blake Parsons, MD
86 yo F with RCC. MWA and KIVA with RT to follow. Patient went home same day without pain. – Case courtesy of William Lea, MD
6 month follow-up with progressive disease and new myelopathy despite RT. Repeat MWA prior to surgery.

– Case courtesy of William Lea, MD
46 yo M with lung cancer and pathologic L4 fracture. Articulating RFA with epidural hydrodissection.
52 yo F with lung cancer. Surgical decompression and fusion optimal but complicated by poor bone quality.

- C2 PMMA using transoral approach.
- C5 and C7 PMMA using anterolateral US guided approach.

Pelvis metastases ➔ MIIPS

• Similar work-up as spine lesions ➔ assess for instability
• High risk for pathologic fracture (acetabulum, sacroiliac region)
  • Focal or permeative lytic lesion
  • Large size
  • Pain with stress
  • Location
• Minimally displaced fractures
• Cementoplasty, +/- ablation, +/- screw fixation
• Minimal interruption to chemo/RT
Enneking classification

Zone 2 = articular part of major long bones (humerus, femur, & tibia)

Zones 1 and 3 = non-weight-bearing bones of the extremity and trunk (clavicle, sternum, & fibula)

Greatest risk for mechanical failure

Do not compromise mechanical stability of the pelvis

Metastatic acetabular classification

A

Type 1

Dome

Type 2

Medial wall

Type 3

Posterior column

Type 4

Anterior column

Posterior column

Anterior column

Acetabular metastases

• **Nonoperative** (disphosphonates, RT)
  • Does not compromise posterior column, dome, or medial wall

• **Surgical reconstruction**
  • Large acetabular lesion that compromises stability
  • Pathologic fracture
  • Radioresistant tumor
  • Debilitating pain despite nonoperative/interventional management

• **Preoperative embolization**
  • Reduce intraoperative blood loss
  • RCC, thyroid, HCC
  • Large extraosseous soft tissue mass

Acetabular metastases → MIIPs

• Alternative to surgical reconstruction → extensive surgery, potentially significant blood loss, large fluid shifts, SIRS

• Percutaneous cementoplasty
  • Complete pain relief in 15 of 20 patients, x 7.3 months (Scaramuzzo et al)
  • Usually combined with ablation
  • Avoid lateral femoral cutaneous nerve, sciatic nerve, & superior gluteal artery
  • Contraindications = impending/completion fractures, medial wall insufficiency

• Ablation
  • Marked decrease in pain scores, analgesic use in 30 patients treated with RFA (Thanos et al)
53 yo M with RCC presenting with hip pain. Ablation and fixation.
– Case courtesy of William Lea, MD
69 yo M with RCC. Embolization, RFA, and PMMA with neuromonitoring
– Case courtesy of Kris Schramm, MD
53 yo with myeloma. Fixation with cementoplasty.
– Case courtesy of William Lea, MD
67 yo with RCC. Embolization, ablation, and fixation with cementoplasty. Walked out of hospital next day.
– Case courtesy of Kris Schramm, MD
61 yo F with thyroid cancer and painful fracture s/p I-131 and RT.
Walking same day.
– Case courtesy of William Lea, MD
Proximal femur metastases

• Most reliable predictor of impending fracture → mechanical pain
  • Cannot withstand physical stress = risk for fracture
• Mirel scoring system → prophylactic fixation score 9+
  • High mortality and morbidity in cancer patients
• Cementoplasty +/- screw fixation
  • Cementoplasty alone – high risk of fracture with cortical involvement > 30 mm or prior lesser trochanter fracture

R.J. Pignolo et al. (eds.), Fractures in the Elderly, Aging Medicine
J Vasc Interv Radiol 2012; 23:1311–1316
Mirels’ scoring system for predicting risk of pathological fracture. Prophylactic fixation is recommended with a score of 9 or above\textsuperscript{10}

<table>
<thead>
<tr>
<th>Score</th>
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<th>2</th>
<th>3</th>
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<tr>
<td>Site</td>
<td>Upper limb</td>
<td>Lower limb</td>
<td>Pertrochanteric</td>
</tr>
<tr>
<td>Pain</td>
<td>Mild</td>
<td>Moderate</td>
<td>Functional</td>
</tr>
<tr>
<td>Lesion</td>
<td>Blastic</td>
<td>Mixed</td>
<td>Lytic</td>
</tr>
<tr>
<td>Size\textsuperscript{a}</td>
<td>&lt;1/3</td>
<td>1/3</td>
<td>&gt;2/3</td>
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</table>

\textsuperscript{a} As seen on plain radiograph, maximum destruction of cortex in any view.
<table>
<thead>
<tr>
<th>Score</th>
<th>Fracture risk</th>
<th>Recommendation</th>
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<tbody>
<tr>
<td>≥9</td>
<td>33%–100%</td>
<td>Prophylactic fixation is recommended</td>
</tr>
<tr>
<td>8</td>
<td>15%</td>
<td>Clinical judgment should be used</td>
</tr>
<tr>
<td>≤7</td>
<td>&lt;4%</td>
<td>Observation and radiation therapy can be used</td>
</tr>
</tbody>
</table>
61 yo M with metastatic RCC. MWA, screw fixation cementoplasty. Home same day.

– Case courtesy of Sean Tutton, MD
History of metastatic cholangiocarcinoma to bilateral femurs. Intraoperative MWA to reduce hemorrhage prior to IMNs.

– Case courtesy of William Lea, MD
HCC metastasis with pain. MWA and cementoplasty.
– Case courtesy of Sean Tutton, MD
49 yo M with myeloma with pain s/p RT. 
Scapular screw fixation. 
– Case courtesy of William Lea, MD
History of RCC in lunate. RFA and cementoplasty. Great pain relief – now able to use screw driver again.
– Case courtesy of William Lea, MD
78 yo M with pancreatic cancer and chronic opioid use for 8/10 constant chest wall pain from T2/3 rib metastases.

RFA of T2-4 intercostal nerves. 0/10 pain postop.

– Case courtesy of Kris Schramm, MD
MSK MIIP Complications

• Overall, infrequent
• Hemorrhage and infection are most common
• Iatrogenic fracture
• Burns (e.g. grounding pad site)
• **Non-target ablation**
  • Neurovascular structures = central and peripheral nerves
  • Cartilage damage = juxtaepiphyseal location
53 yo F with metastatic sarcoma to right sacral ala treated with cementoplasty.

Extravasation of cement into S1 neuroforamen.
62 yo F with lymphoma and right paraspinal mass. T9 intercostal artery pseudoaneurysm post biopsy.
Outcomes

• Pain palliation (multiple prospective multicenter clinical trials)
  • 4-6 point decrease in mean pain score in 3-6 mos follow-up
  • Reduction in analgesic dose
  • No head to head RCT between ablation and RT
  • One matched cohort study → RT + RFA > RT alone

• Local control of oligometastatic disease
  • Five or fewer metastases
  • Studies in patients with limited renal, breast, and prostate cancer
  • Highly variable local tumor control rates = 36 – 97%
  • Can postpone or avoid initiation of systemic therapy
## Outcomes

### TABLE I: Outcomes of Percutaneous Ablation of Skeletal Metastases for Pain Palliation

<table>
<thead>
<tr>
<th>Study</th>
<th>Ablation Device</th>
<th>No. of Patients (No. of Tumors)</th>
<th>Mean Tumor Size (cm)</th>
<th>Mean Pain Score Changea</th>
<th>No. (%) of Patients With Reduced Pain</th>
<th>Follow-Up (mo)</th>
<th>No. (%) of Major Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goetz et al. [48]</td>
<td>RFA</td>
<td>43 (43)</td>
<td>6.3</td>
<td>7.9–1.4 (6.5/10)</td>
<td>41 (95)</td>
<td>6</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Dupuy et al. [49]</td>
<td>RFA</td>
<td>55 (55)</td>
<td>5.2</td>
<td>NR (14.2/100)</td>
<td>NR</td>
<td>3</td>
<td>3 (5)</td>
</tr>
<tr>
<td>Wallace et al. [50]b</td>
<td>RFA</td>
<td>72 (110)</td>
<td>NR</td>
<td>8.0–2.9 (5.1/10)</td>
<td>45 (78)</td>
<td>1</td>
<td>4 (6)</td>
</tr>
<tr>
<td>Callstrom et al. [51]</td>
<td>CA</td>
<td>61 (69)</td>
<td>4.8</td>
<td>7.1–1.4 (5.7/10)</td>
<td>42 (69)</td>
<td>6</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Prologo et al. [52]</td>
<td>CA</td>
<td>50 (54)</td>
<td>NR</td>
<td>8–3 (5/10)</td>
<td>47 (94)</td>
<td>3</td>
<td>4 (8)</td>
</tr>
<tr>
<td>Tomasian et al. [53]b</td>
<td>CA</td>
<td>14 (31)</td>
<td>NR</td>
<td>8–3 (5/10)</td>
<td>14 (100)</td>
<td>10</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Pusceddu et al. [11]</td>
<td>MWA</td>
<td>18 (21)</td>
<td>5.3</td>
<td>5.6–0.5 (5.1/10)</td>
<td>17 (94)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Kastler et al. [10]</td>
<td>MWA</td>
<td>15 (25)</td>
<td>4.7</td>
<td>7.2–1.8 (5.4/10)</td>
<td>14 (93)</td>
<td>6</td>
<td>1 (7)</td>
</tr>
</tbody>
</table>
### Outcomes

**TABLE 2: Outcomes of Percutaneous Ablation for Local Tumor Control of Bone and Soft-Tissue Metastases**

<table>
<thead>
<tr>
<th>Study</th>
<th>Tumor Histology</th>
<th>Site</th>
<th>Ablation Modality</th>
<th>Mean Size (cm)</th>
<th>No. of Patients (No. of Tumors)</th>
<th>Local Control No. (%)</th>
<th>Survival Rate</th>
<th>Follow-Up (mo)</th>
<th>No. (%) of Major Complicationsa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bang et al. [35]</td>
<td>NSCLC</td>
<td>Otherb</td>
<td>CA</td>
<td>3.1</td>
<td>8 (18)</td>
<td>17 (94)</td>
<td>NR</td>
<td>11</td>
<td>2 (11)</td>
</tr>
<tr>
<td>Bang et al. [36]</td>
<td>Renal</td>
<td>Otherb</td>
<td>CA</td>
<td>3.7</td>
<td>27 (48)</td>
<td>47 (97)</td>
<td>NR</td>
<td>16</td>
<td>1 (2)</td>
</tr>
<tr>
<td>McMenomy et al. [54]</td>
<td>Mixed</td>
<td>MSK</td>
<td>CA</td>
<td>2.0</td>
<td>40 (52)</td>
<td>45 (87)</td>
<td>91% 1 year, 84% 2 years</td>
<td>21</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Litrup et al. [55]</td>
<td>Mixed</td>
<td>ST</td>
<td>CA</td>
<td>3.3</td>
<td>126 (251)</td>
<td>225 (90)</td>
<td>NR</td>
<td>11</td>
<td>5 (2)</td>
</tr>
<tr>
<td>Deschamps et al. [56]</td>
<td>Mixed</td>
<td>Bone</td>
<td>RFA, CA</td>
<td>NR</td>
<td>89 (122)</td>
<td>67% 1 year</td>
<td>NR</td>
<td>22.8</td>
<td>11 (9)</td>
</tr>
<tr>
<td>Welch et al. [57]</td>
<td>Renal</td>
<td>Otherb</td>
<td>RFA, CA</td>
<td>NR</td>
<td>NR (46)</td>
<td>43 (93)</td>
<td>NR</td>
<td>22.5</td>
<td>0</td>
</tr>
<tr>
<td>Aubry et al. [58]</td>
<td>Mixed</td>
<td>MSK</td>
<td>MWA</td>
<td>5.5</td>
<td>13 (16)</td>
<td>4 (36)</td>
<td>NR</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Wallace et al. [59]</td>
<td>Mixed</td>
<td>Spine</td>
<td>RFA</td>
<td>NR</td>
<td>NR (55)</td>
<td>70% 1 year</td>
<td>NR</td>
<td>7.9</td>
<td>0</td>
</tr>
<tr>
<td>Tomasian et al. [53]</td>
<td>Mixed</td>
<td>Spine</td>
<td>CA</td>
<td>NR</td>
<td>14 (31)</td>
<td>30 (97)</td>
<td>NR</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Erie et al. [37]</td>
<td>Prostate</td>
<td>MSK</td>
<td>RFA, CA</td>
<td>1.6</td>
<td>16 (18)</td>
<td>15 (83)</td>
<td>100% 2 years</td>
<td>27</td>
<td>0</td>
</tr>
</tbody>
</table>
Abscopal effect

• Ablation and transarterial therapies stimulate local and systemic immune responses

• Responses are mediated by immune checkpoint proteins

• Early studies show synergy between ablation and immune checkpoint inhibition
  • Tumor response remote from treated tumor
Conclusion

• Musculoskeletal metastatic disease is common and a significant source of pain and disability
• Multidisciplinary care is key in the treatment of these patients
• Several minimally invasive options are available and play an increasingly important role in the palliation and treatment of these patients
Thank you!