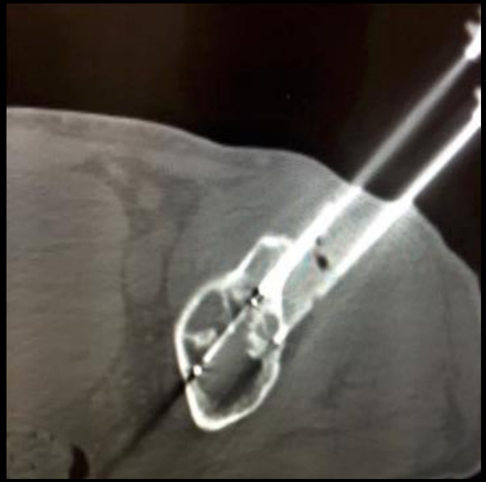
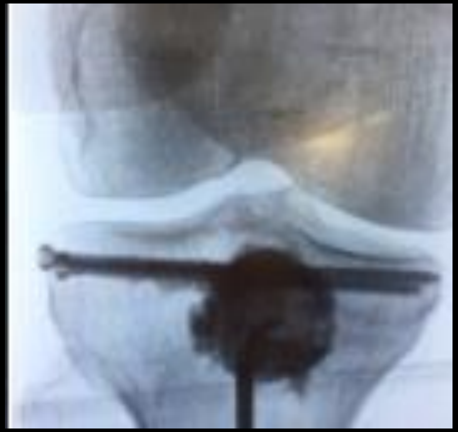
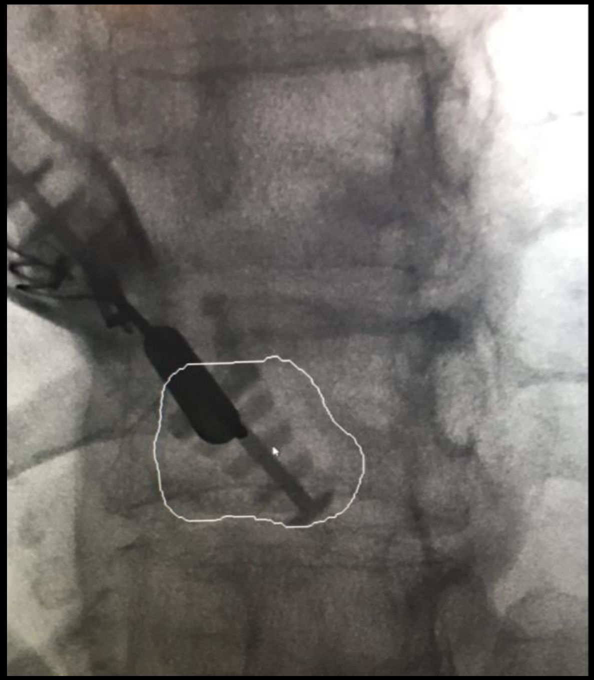


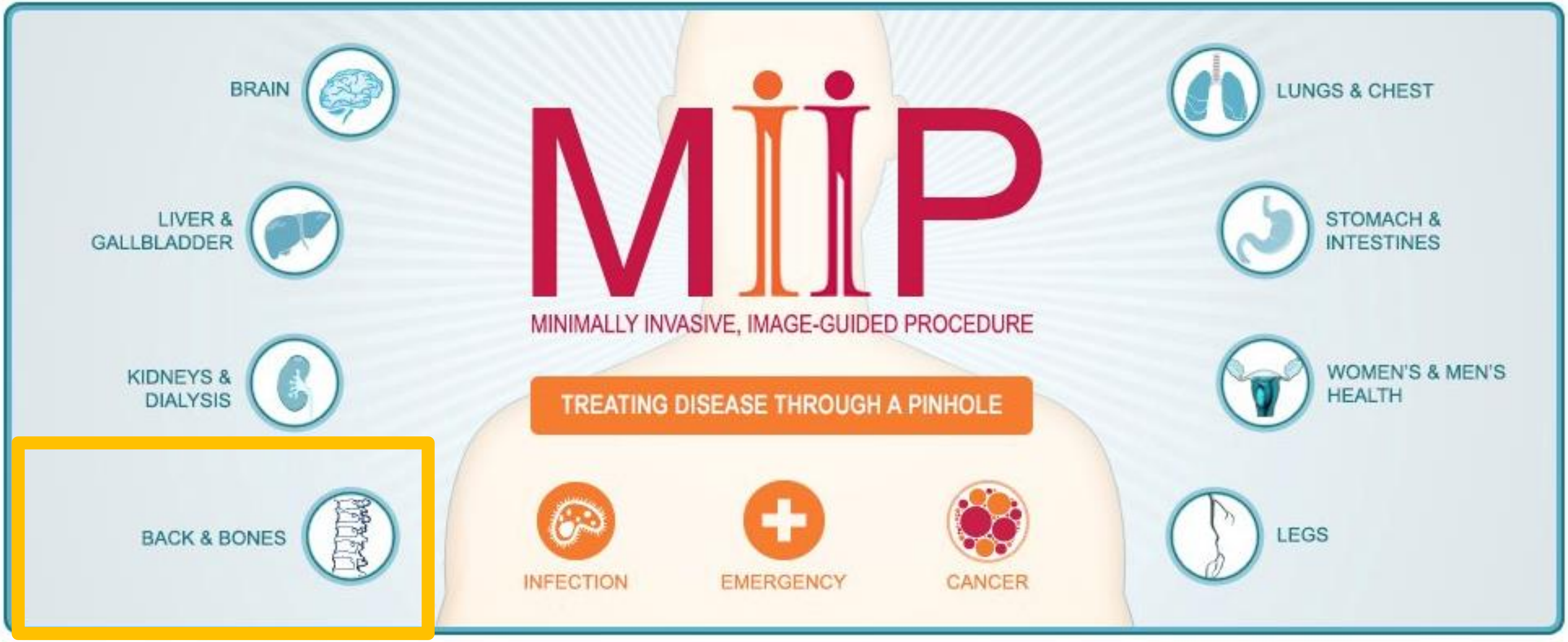


MSK Mets & MIIPs

Anthony Tadros

March 15, 2018

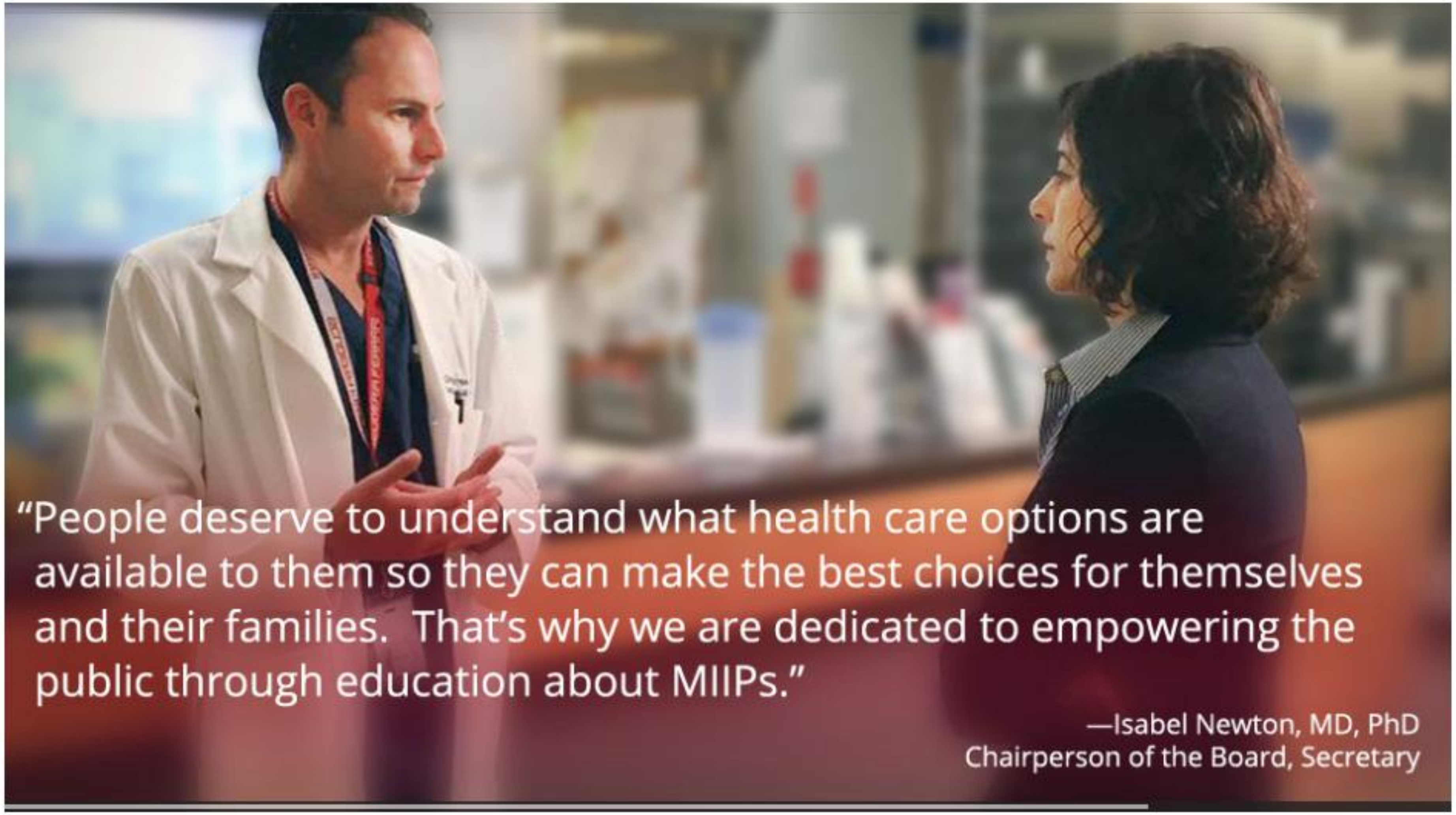



BRAIN
LIVER & GALLBLADDER
KIDNEYS & DIALYSIS
BACK & BONES
MIIP
MINIMALLY INVASIVE, IMAGE-GUIDED PROCEDURE
TREATING DISEASE THROUGH A PINHOLE
INFECTION
EMERGENCY
CANCER
LUNGS & CHEST
STOMACH & INTESTINES
WOMEN'S & MEN'S HEALTH
LEGS

the Interventional Initiative

Enter search string

HOME ABOUT THE II WHAT ARE MIIPs? THE DOCUMENTARY MEDIA ENGAGE DONATE



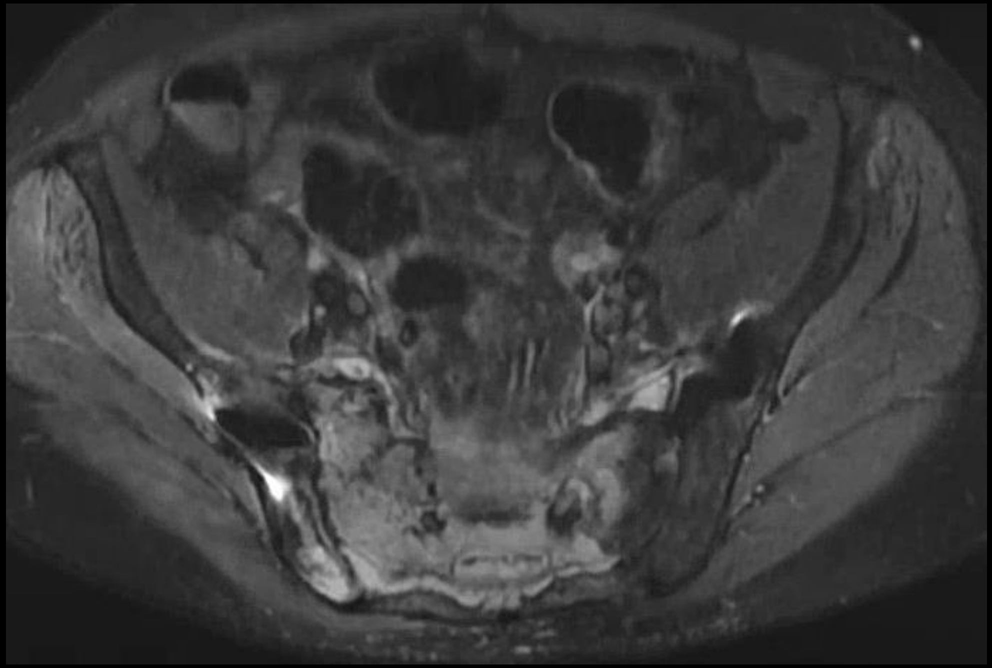

WITHOUT A
SCALPEL
EPISODE 2: THE CANCER SNIPERS

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



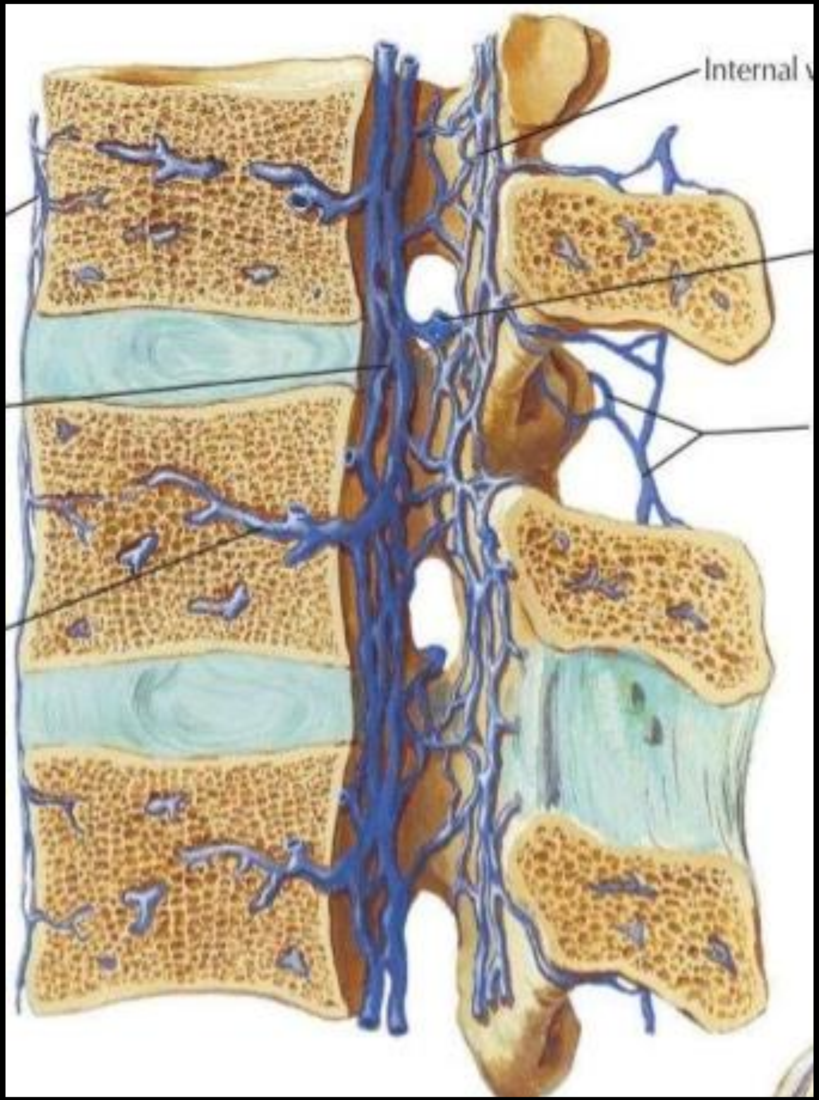
59 yo F with breast cancer and foot drop.

68 yo F with rhabdomyosarcoma of the thyroid. Case courtesy of Brady Huang, MD.

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

Routes of spread

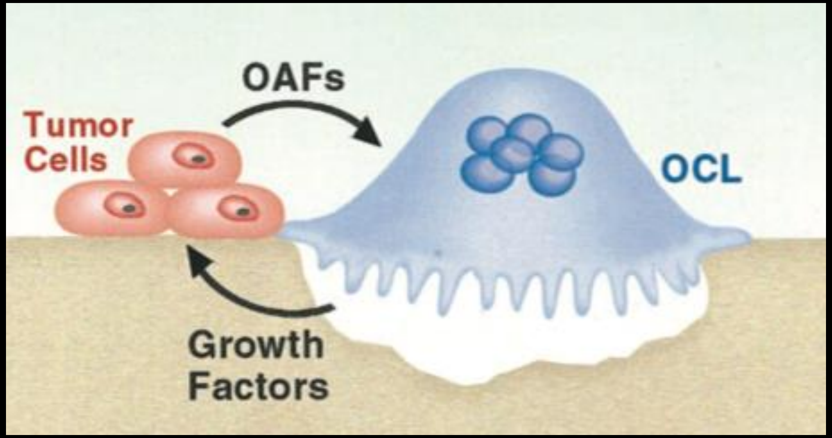
- Direct extension (e.g. Pancoast's tumor)
- Lymphatic
  - Draining lymph node involves adjacent bone (e.g. vertebral destruction in pelvic carcinoma)
- Hematogenous
  - Arterial – immunity to tumor penetration in absence of infection
  - Venous* – most common (Batson's plexus → direction connection to IVC/SVC with no valves)
- Intraspinal (e.g. CSF to spinal canal)

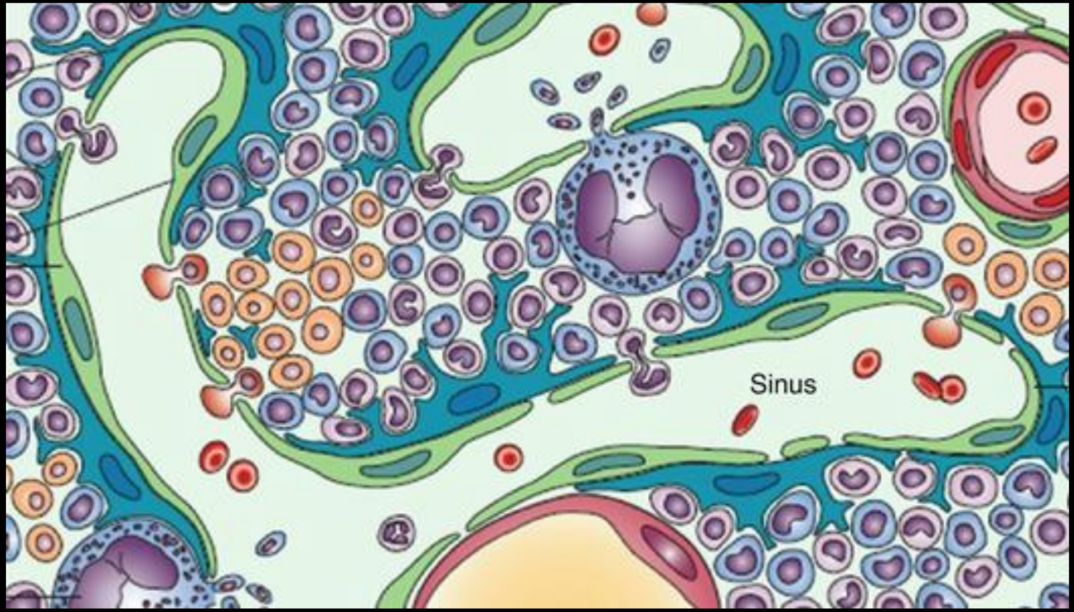


Resnick. Bone and Joint Imaging, 2004
Batson OV. Ann Surg. 1940;112:138.

Pathophysiology of bone metastases

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

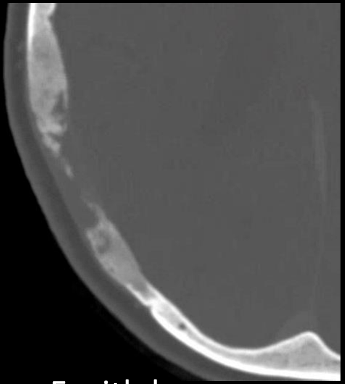




World J Radiol 2015 28; 7(8): 202-211
Valdez et al (2012) Hematopathology.
Journal of Clinical Oncology, 19, 15 2001

Pathophysiology of bone metastases

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

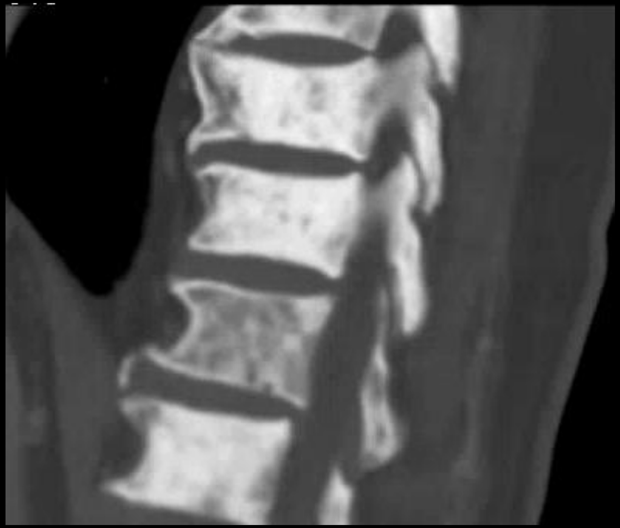


73 yo F with lung cancer.

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

70 yo F with breast cancer.

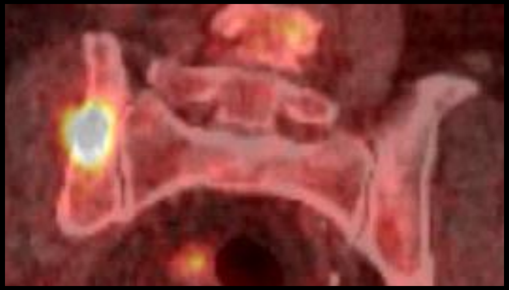
Osteoblastic
- Prostate
- Breast
- Carcinoid



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)


69 yo F with lung cancer

67 yo F with breast cancer.

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)

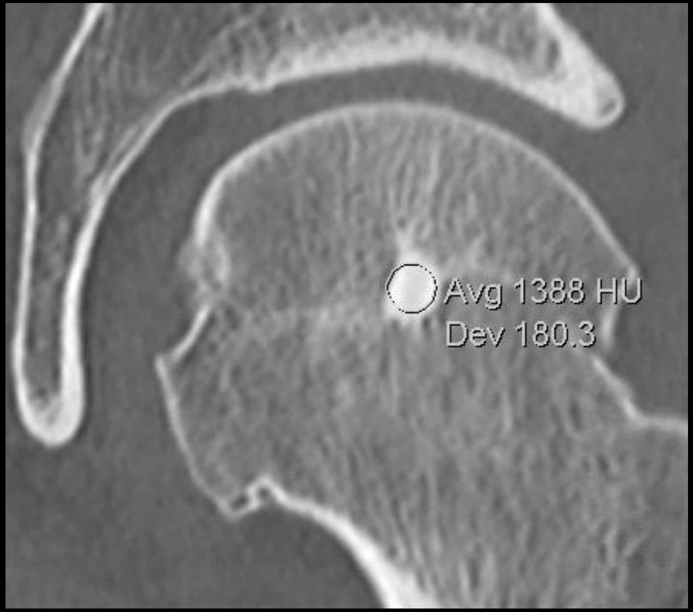
98 yo man with biopsy-proven metastasis to calcaneus. History prostate cancer.

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

Imaging Pearls: Sclerotic lesion

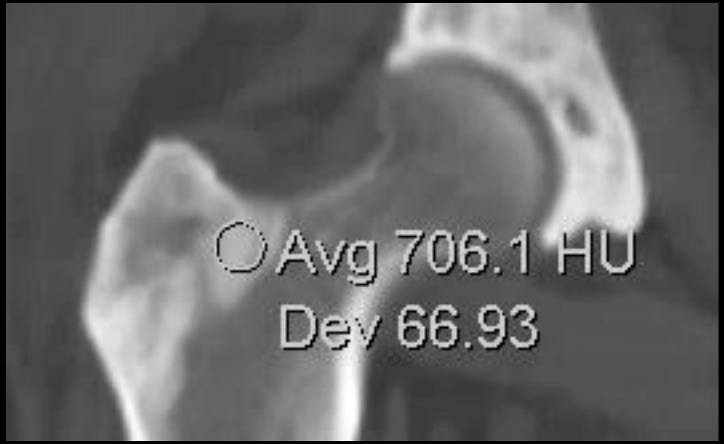
Bone Island

- 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



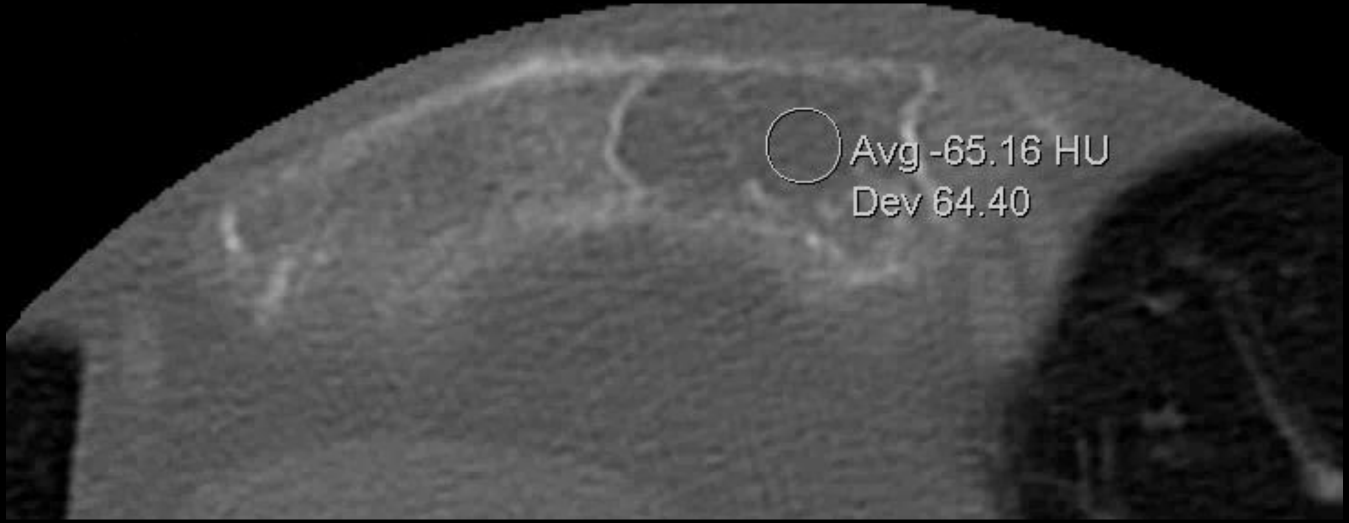
69 yo F with breast cancer.

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)

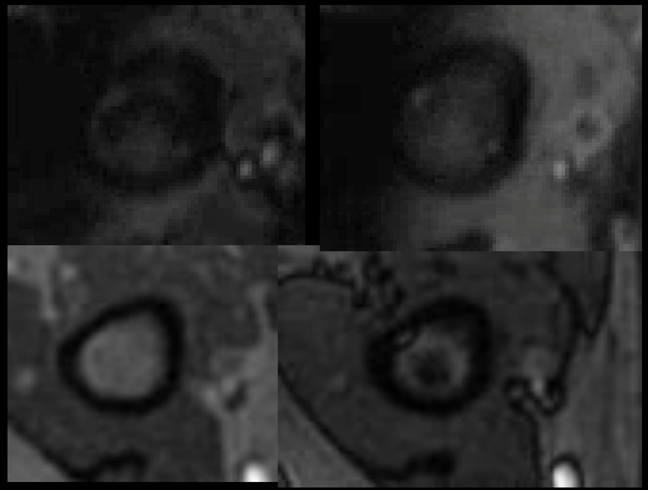


93 yo F with fall.

AJR:208, May 2017

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



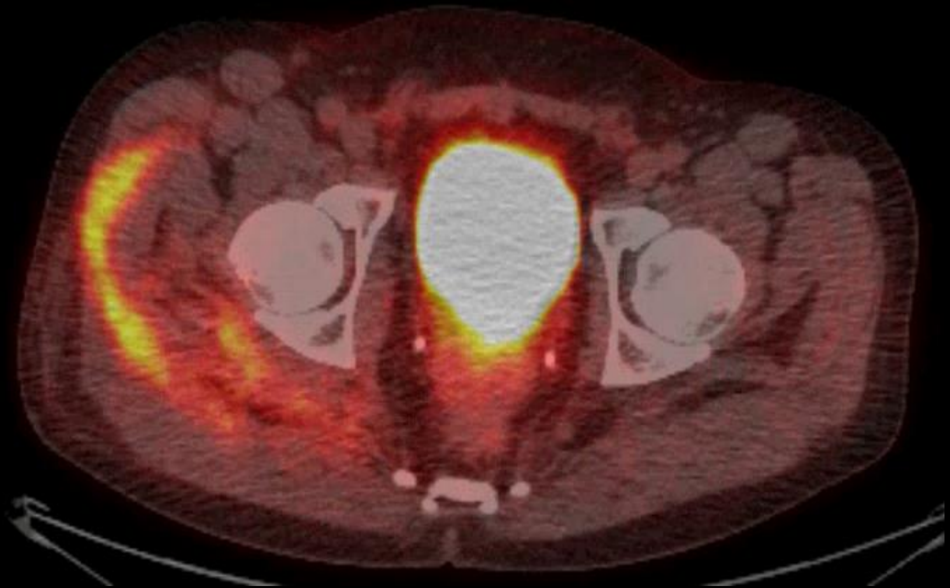
86 yo F with right chest wall sarcoma.

AJR:208, May 2017

Soft-tissue metastases

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

48 yo F with pulmonary artery sarcoma.



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

J Bone Joint Surg Br. 2009 Aug;91(8):1083-5.

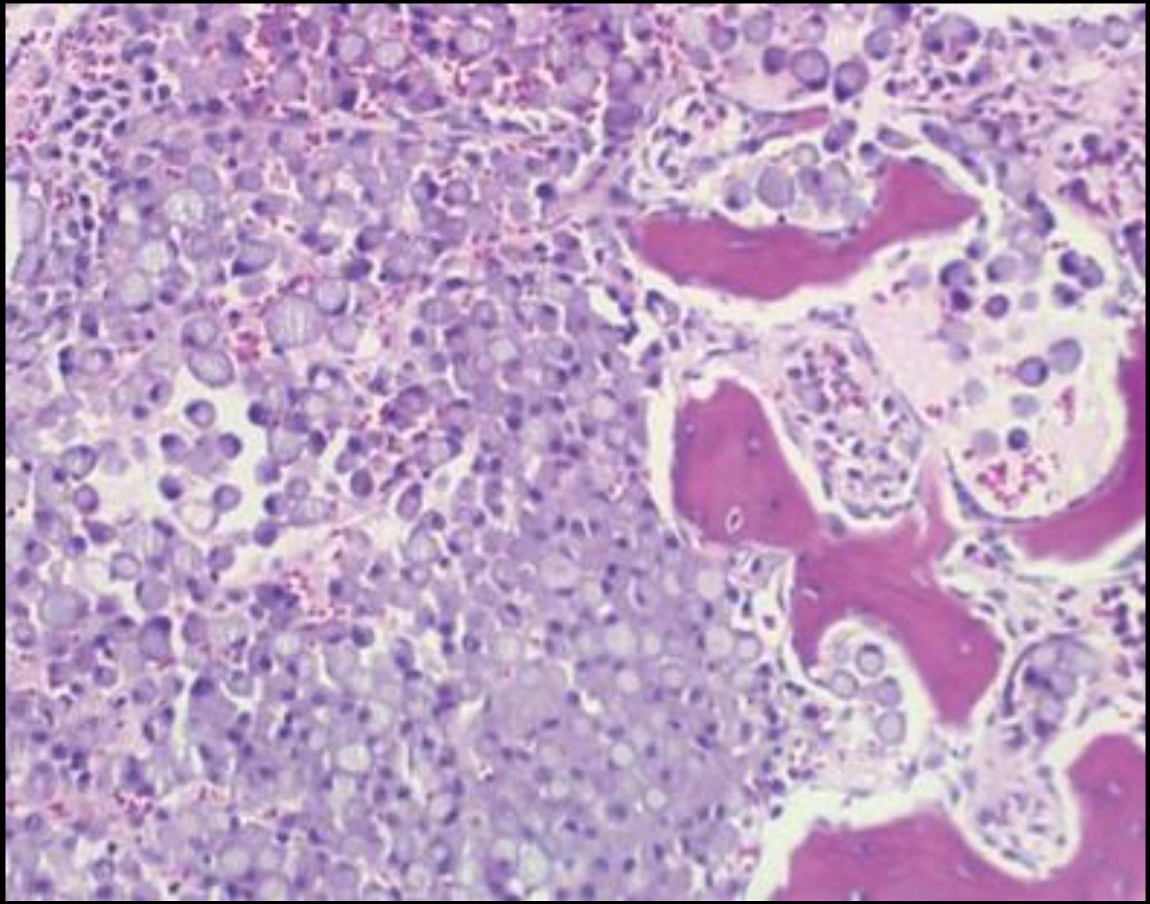
Clinical features of bone metastases

- Complication from bone met = skeletal-related event
- A patient with bone met → skeletal-related event every 3-6 mos
  - Cluster around periods of progression and reduced treatment options

Clin Cancer Res 2006;12(20 Suppl) 2006

Clinical features of bone metastases

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



Clin Cancer Res 2006;12(20 Suppl) 2006
Semin Intervent Radiol 2017;34:121–131.
J Gastrointest Oncol 2014;5(6):E113-E116.

Pain

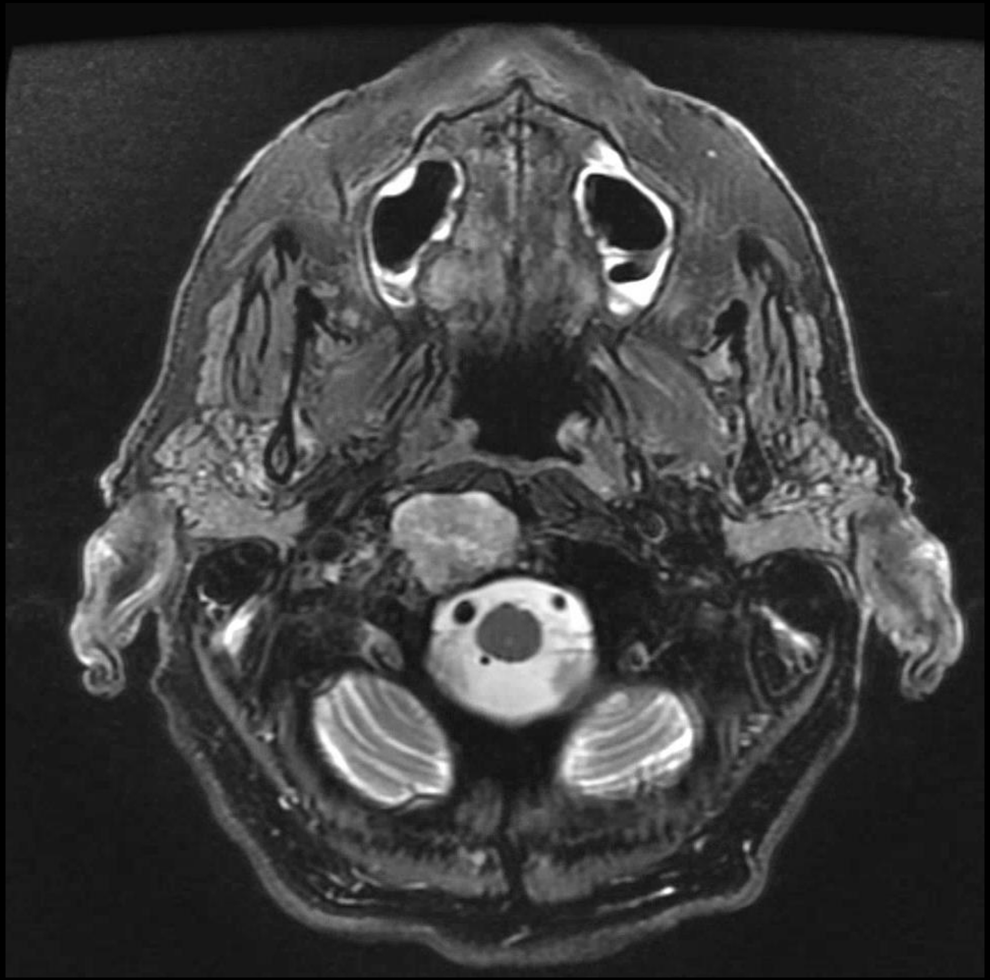
- Most common cause of of cancer-related pain
- Not adequately treated in 56-82% of patients
- Mechanisms
  - Tumor-induced osteolysis
  - Cytokine release
  - Infiltration of nerves
- Nociceptive type → damage to tissues
- Neuropathic type → damage to nerves

34 yo M with metastatic liposarcoma.

Clin Cancer Res 2006;12(20 Suppl) 2006
Diagnostic and Interventional Imaging (2017) 98 , 627—634
Semin Intervent Radiol 2017;34:328–336

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.

Clin Cancer Res 2006;12(20 Suppl) 2006

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

Clin Cancer Res 2006;12(20 Suppl) 2006

Pathologic fractures

- Reduced load bearing capability → microfracture (pain) → fracture
  - Most common = ribs and vertebrae
- Most disability = Long bone fracture or epidural extension

37 yo F with metastatic pheochromocytoma.

Clin Cancer Res 2006;12(20 Suppl) 2006

Spinal metastases

- Goals of treatment
  - Palliative pain control
  - Structural stabilization
  - Tumor control
- Patient evaluation
  - Structural integrity
  - Pain
  - Clinical factors

Semin Intervent Radiol 2017;34:121–131.

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

Semin Intervent Radiol 2017;34:121–131.

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

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

Element of SINS	Score
Location	
Junctional (occiput-C2, C7–T2, T11–L1, L5–S1)	3
Mobile spine (C3–C6, L2–L4)	2
Semi-rigid (T3–T10)	1
Rigid (S2–S5)	0
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

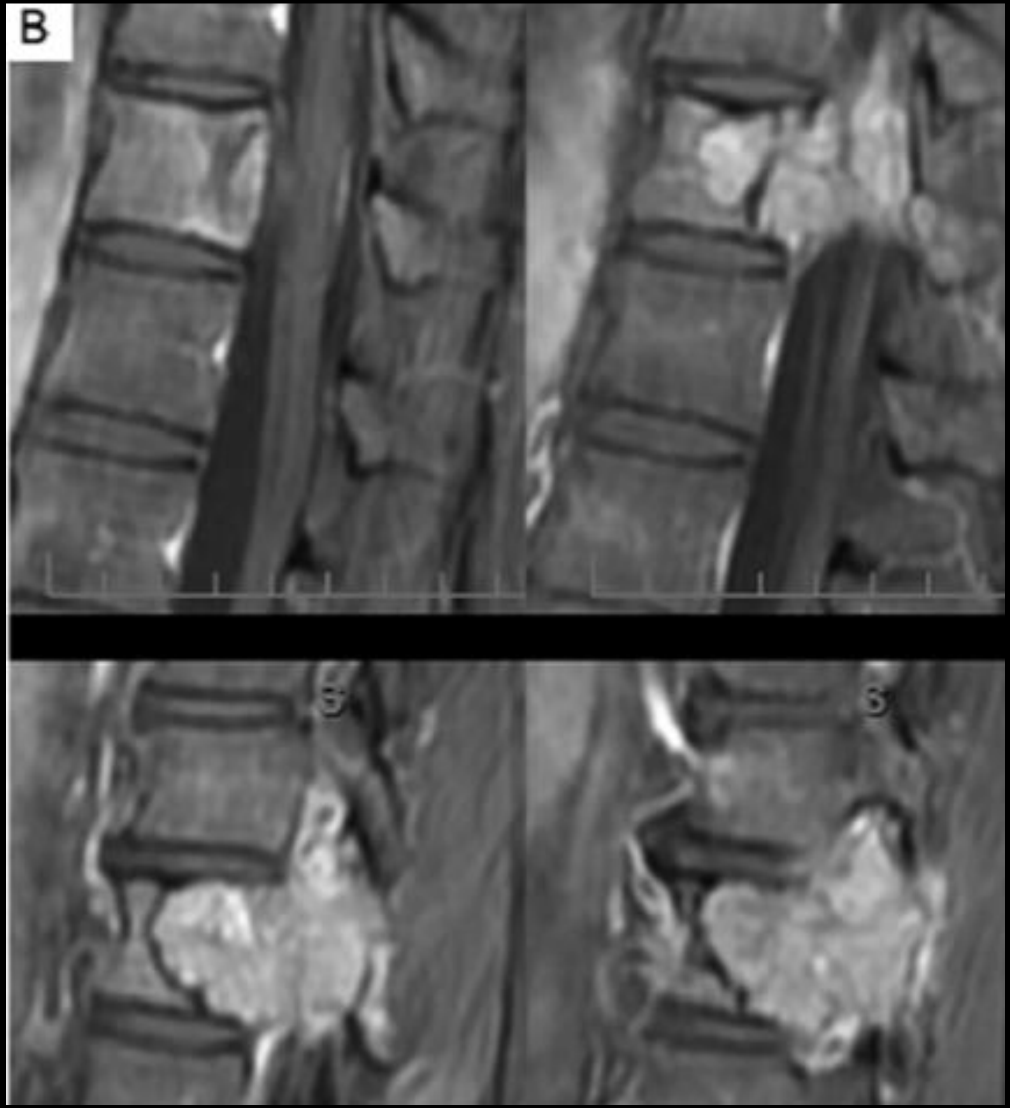
	Score (Total = 0-18)		
	1-6	7-12	13-18
Clinical categories	Stable	Potentially unstable	Unstable
Binary scale	Stable	Current or potentially unstable = possible surgical intervention	

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



SPINE Volume 35, Number 22, pp E1221–E1229

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

Semin Intervent Radiol 2017;34:121–131.

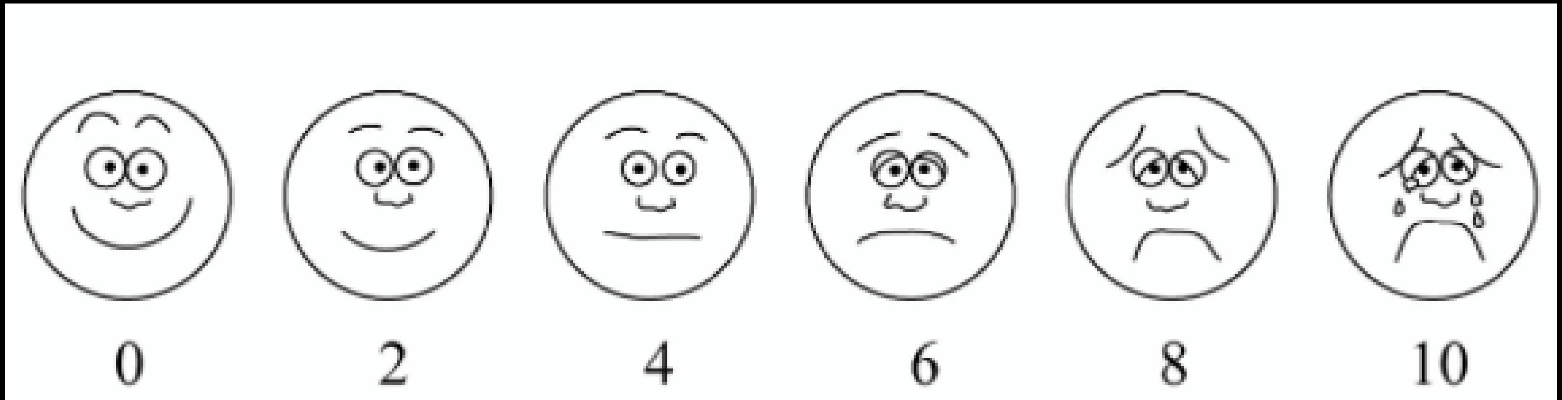
Radiation and fracture risk

- ? 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

Semin Intervent Radiol 2017;34:121–131.

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)



Semin Intervent Radiol 2017;34:121–131.

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

Semin Intervent Radiol 2017;34:121–131.

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

Semin Intervent Radiol 2017;34:121–131.

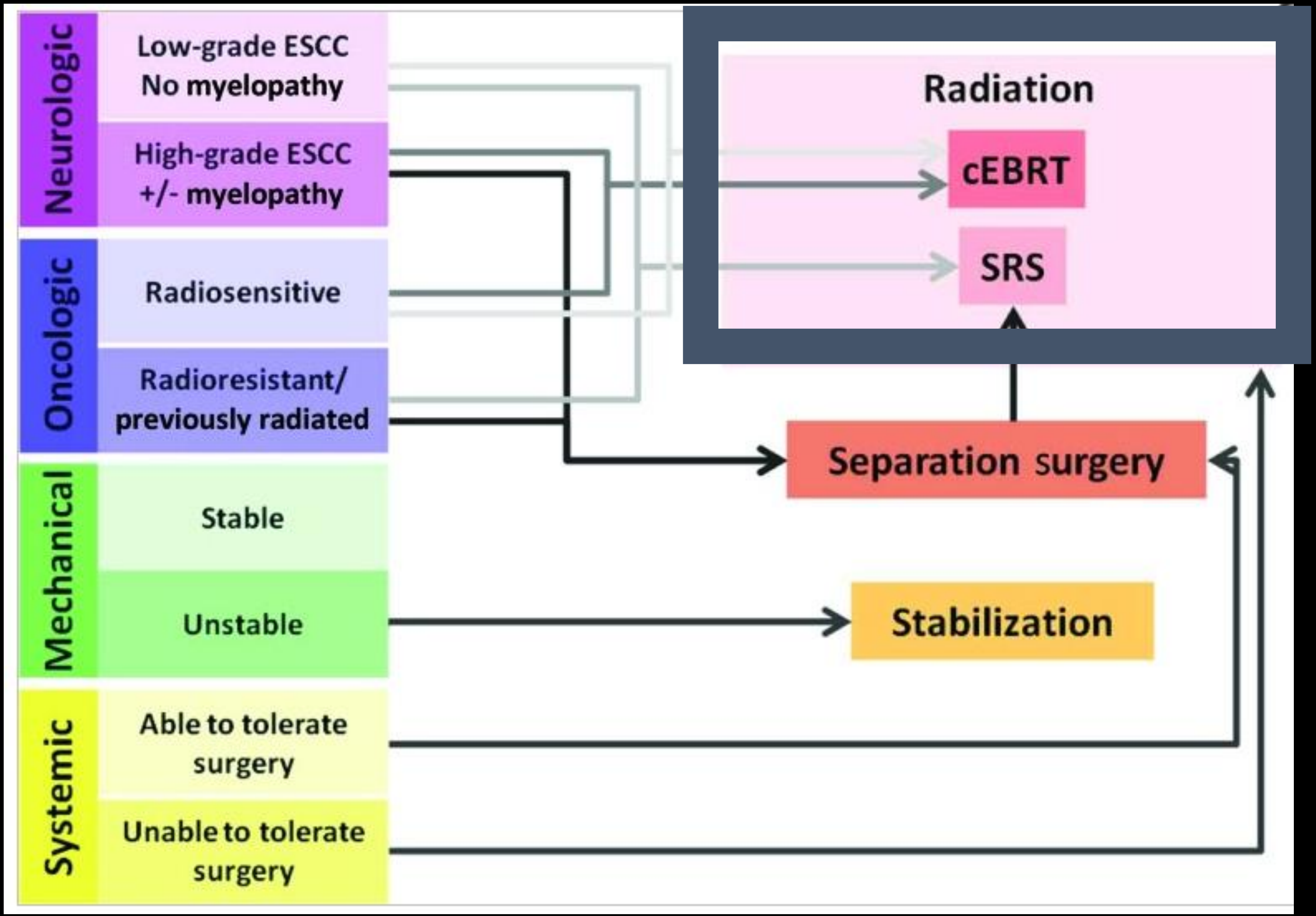
Developing a plan of care → NOMS decision framework

Neurologic	Oncologic	Mechanical	Systemic	Decision
Low-grade ESCC + no myelopathy	Radiosensitive	Stable		cEBRT
	Radiosensitive	Unstable		Stabilization followed by cEBRT
	Radioresistant	Stable		SRS
	Radioresistant	Unstable		Stabilization followed by SRS
High-grade ESCC ± myelopathy	Radiosensitive	Stable		cEBRT
	Radiosensitive	Unstable		Stabilization followed by cEBRT
	Radioresistant	Stable	Able to tolerate surgery	Decompression/stabilization followed by SRS
	Radioresistant	Stable	Unable to tolerate surgery	cEBRT
	Radioresistant	Unstable	Able to tolerate surgery	Decompression/stabilization followed by SRS
	Radioresistant	Unstable	Unable to tolerate surgery	Stabilization followed by cEBRT

Stabilization = percutaneous cement augmentation, percutaneous pedicle screw instrumentation, and open instrumentation

Oncologist. 2013 Jun; 18(6): 744–751.

Developing a plan of care → NOMS decision framework



Oncologist. 2013
Jun; 18(6): 744–751.

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 → 57% of patients at median of 15 wks postradiation

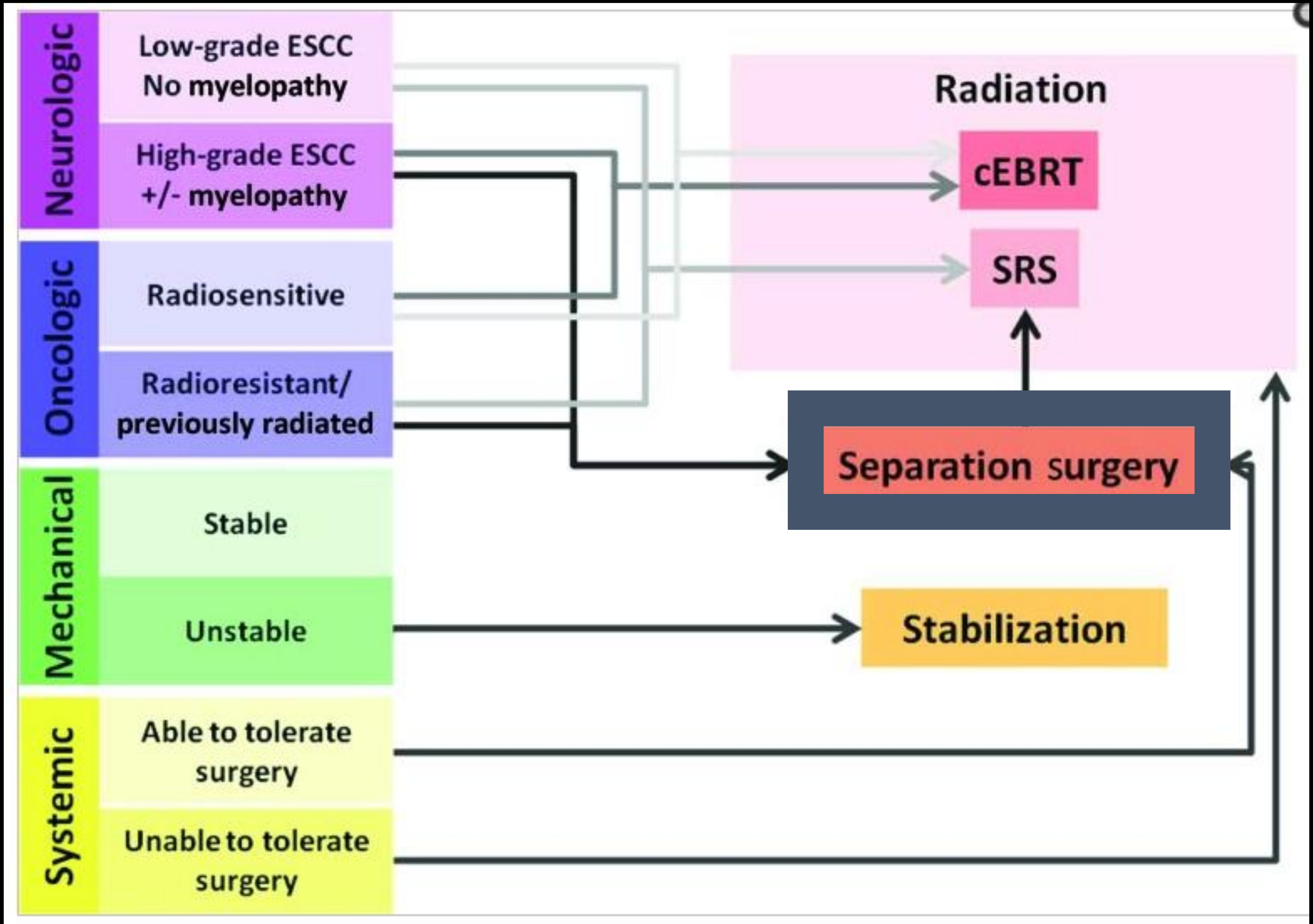
Semin Intervent Radiol 2017;34:121–131.

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

Semin Intervent Radiol 2017;34:121–131.

Developing a plan of care → NOMS decision framework



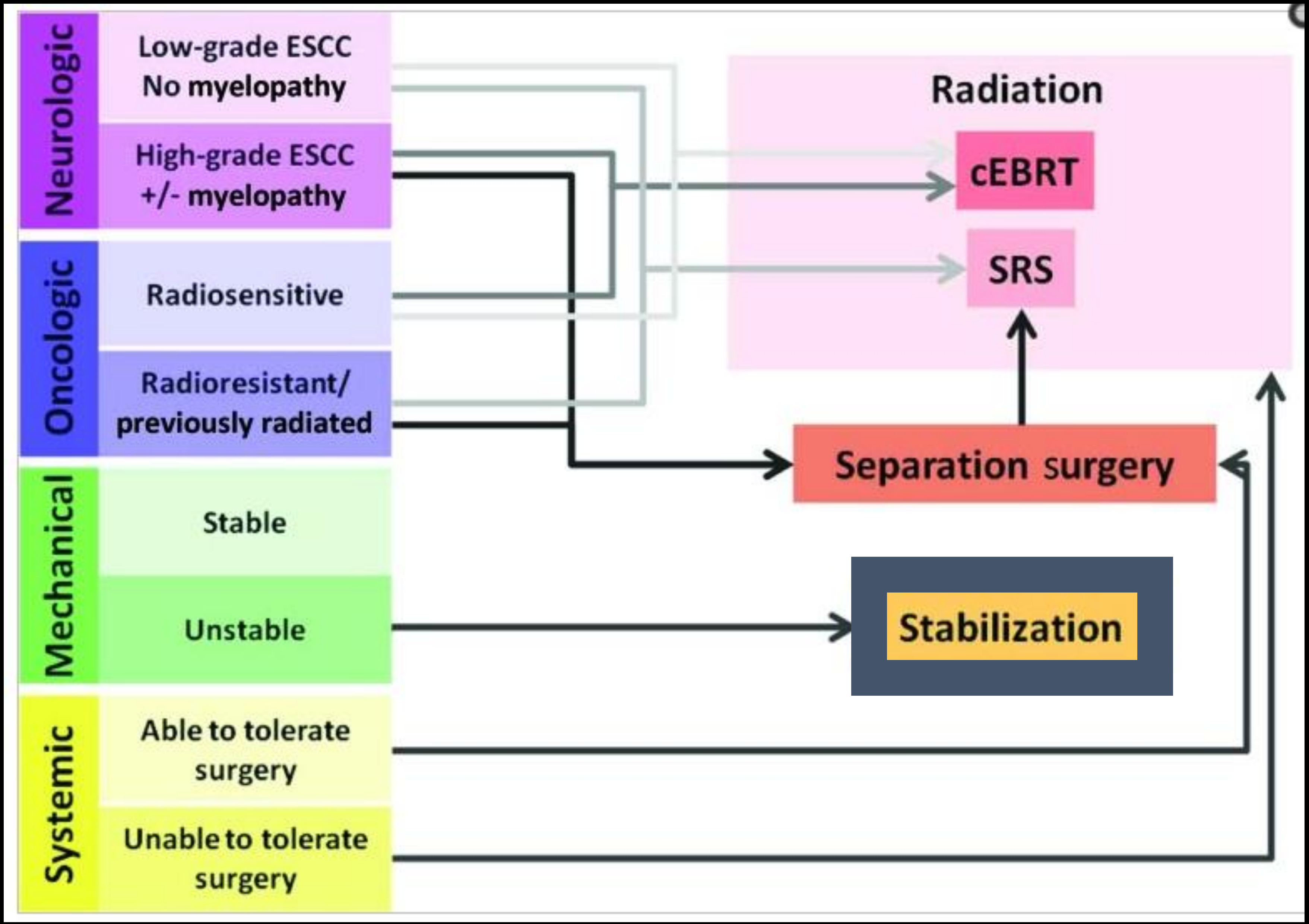
Oncologist. 2013
Jun; 18(6): 744–751.

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

Semin Intervent Radiol 2017;34:121–131.

Developing a plan of care → NOMS decision framework



Oncologist. 2013
Jun; 18(6): 744–751.

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)

Semin Intervent Radiol 2017;34:121–131.

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

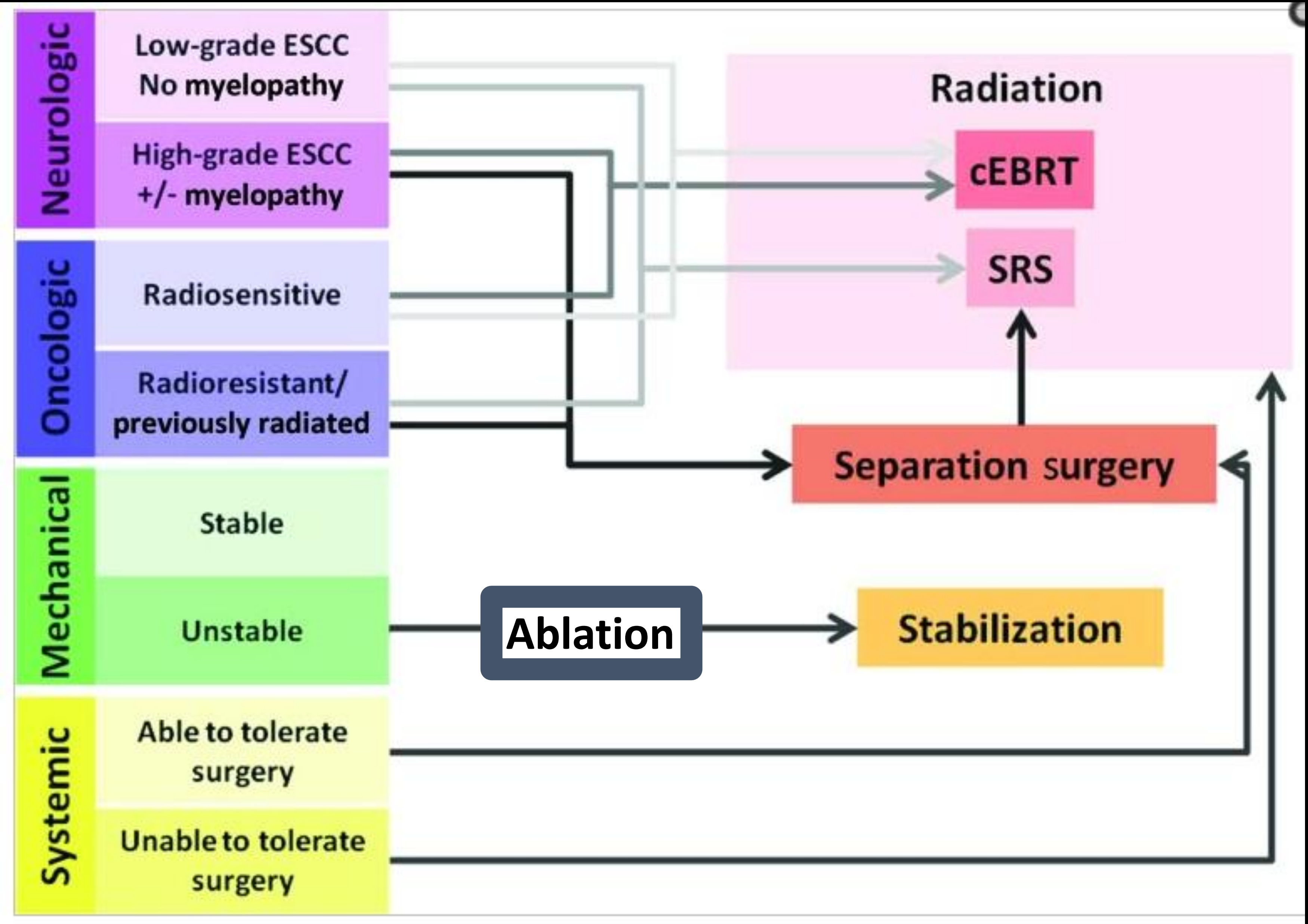
Semin Intervent Radiol 2017;34:121–131.

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

Semin Intervent Radiol 2017;34:121–131.

Developing a plan of care → NOMS decision framework



Oncologist. 2013
Jun; 18(6): 744–751.

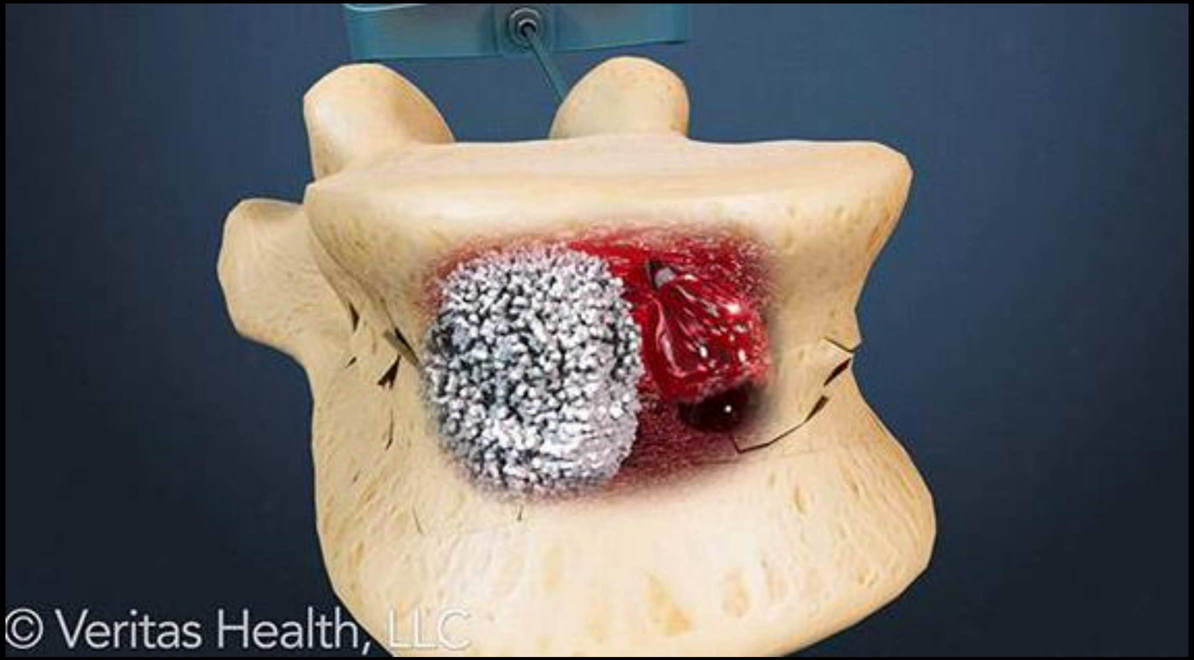
Spine Ablation

- 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

Semin Intervent Radiol 2017;34:121–131.

Spine Ablation

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



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Ablation options

- Chemical
  - Alcohol
- Thermal
  - RFA
  - Microwave
  - Cyroablation
  - MRgUS
  - Laser

AJR:207, September 2016

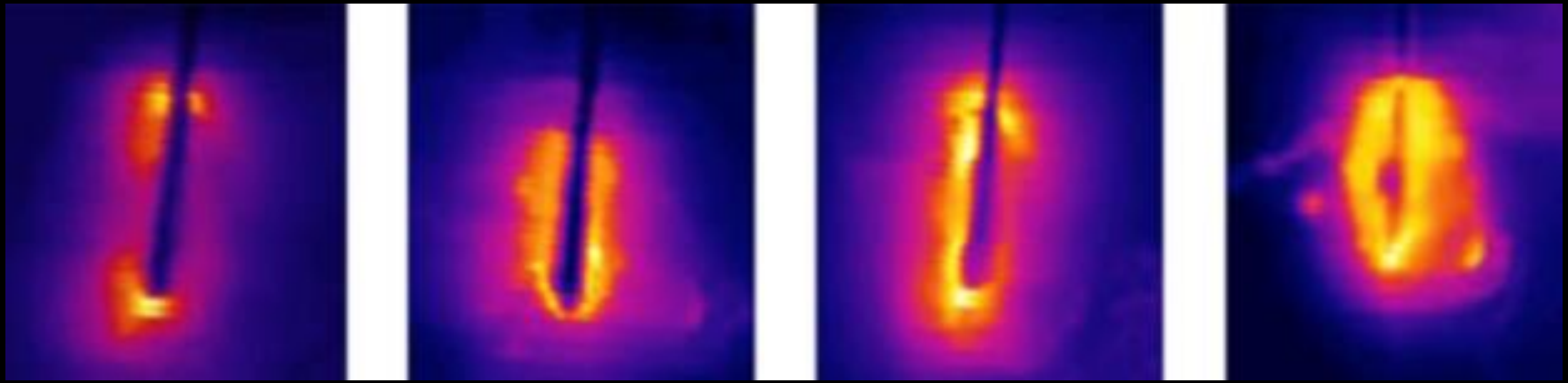
Chemical ablation → Alcohol

- 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

AJR:207, September 2016

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



J Vasc Interv Radiol 2010; 21:S179–S186
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, CO_2, warm saline/ice packs, heat/cold sink)

AJR:207, September 2016

Thermal ablation

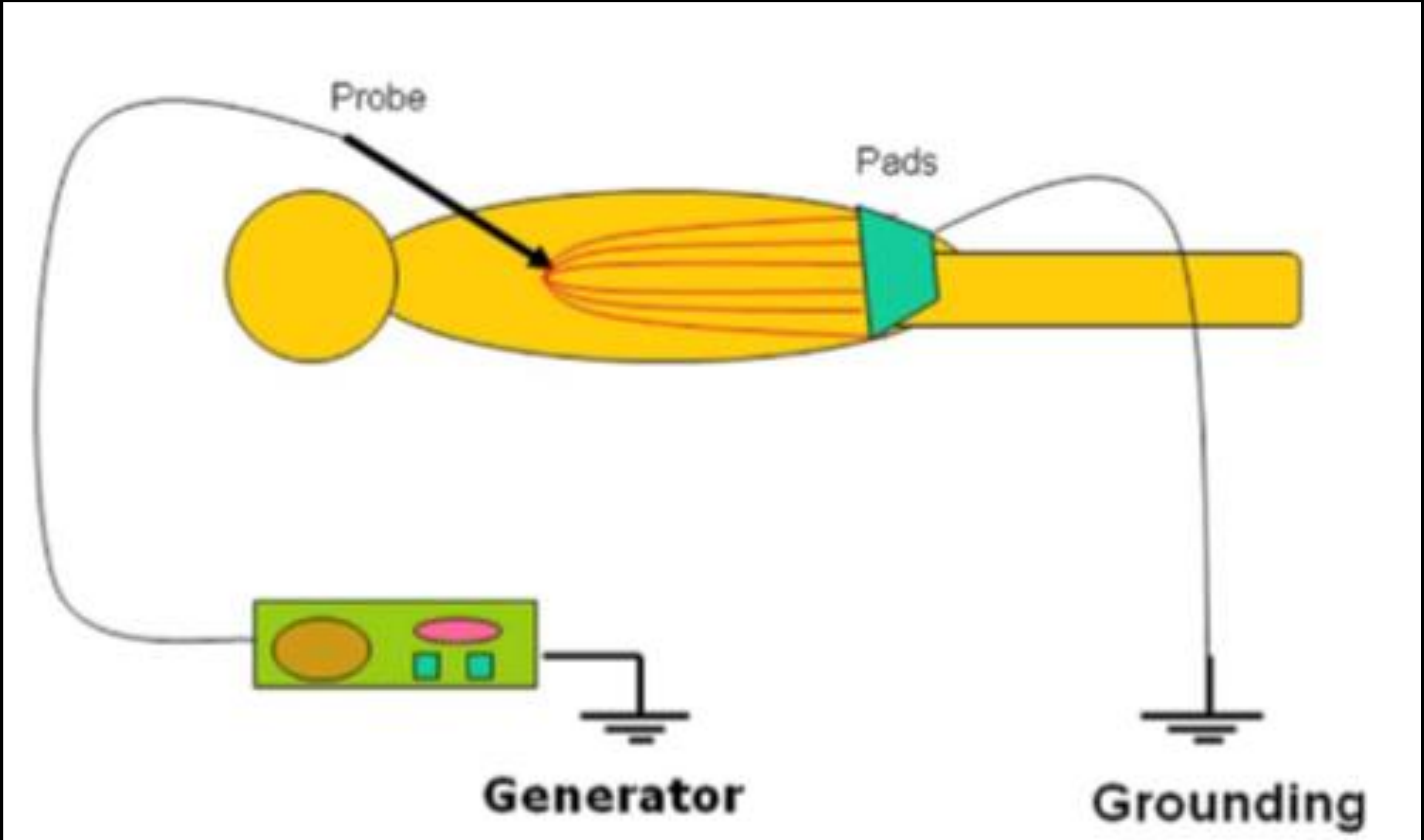
- General anesthesia or moderate to deep sedation with analgesic support
  - Needle into osteoid osteoma nidus → prostaglandin surge
- Antibiotic prophylaxis

AJR:207, September 2016

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

AJR:207, September 2016



J Vasc Interv Radiol 2010; 21:S179–S186

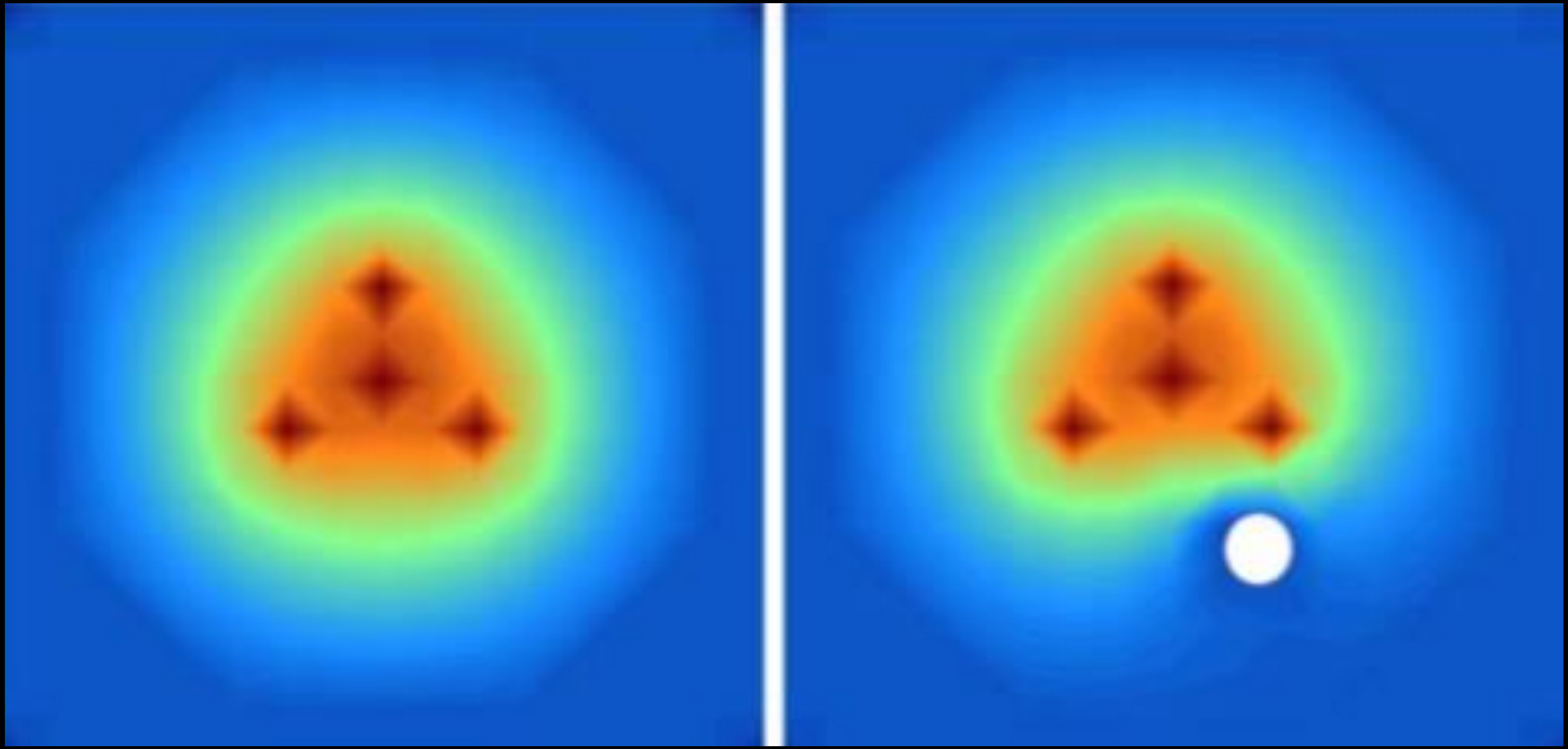
Radiofrequency ablation

- 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

Semin Intervent Radiol 2017;34:121–131.

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

J Vasc Interv Radiol 2010; 21:S179–S186



J Vasc Interv Radiol 2010; 21:S179–S186

Radiofrequency ablation

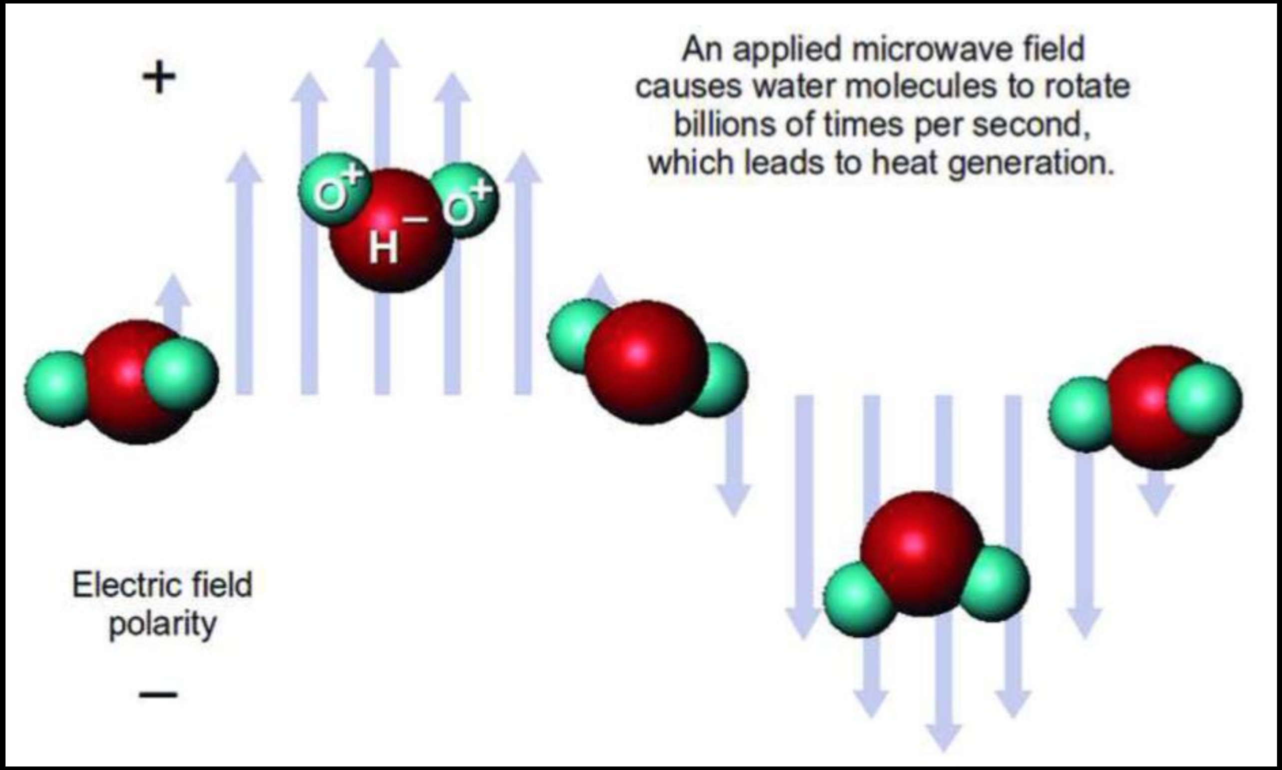
- Bone natural barrier for thermal energy
  - Heat does not dissipate through adjacent bone → protects adjacent structures
  - Reactive adjacent bone → added insulation
  - “Oven effect”
- Ideal for small soft-tissue lesion surrounded by bone (e.g. osteoid osteoma)
- Subchondral lesion → PMMA

Semin Intervent Radiol 2017;34:121–131.

AJR:207, September 2016

Microwave ablation

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

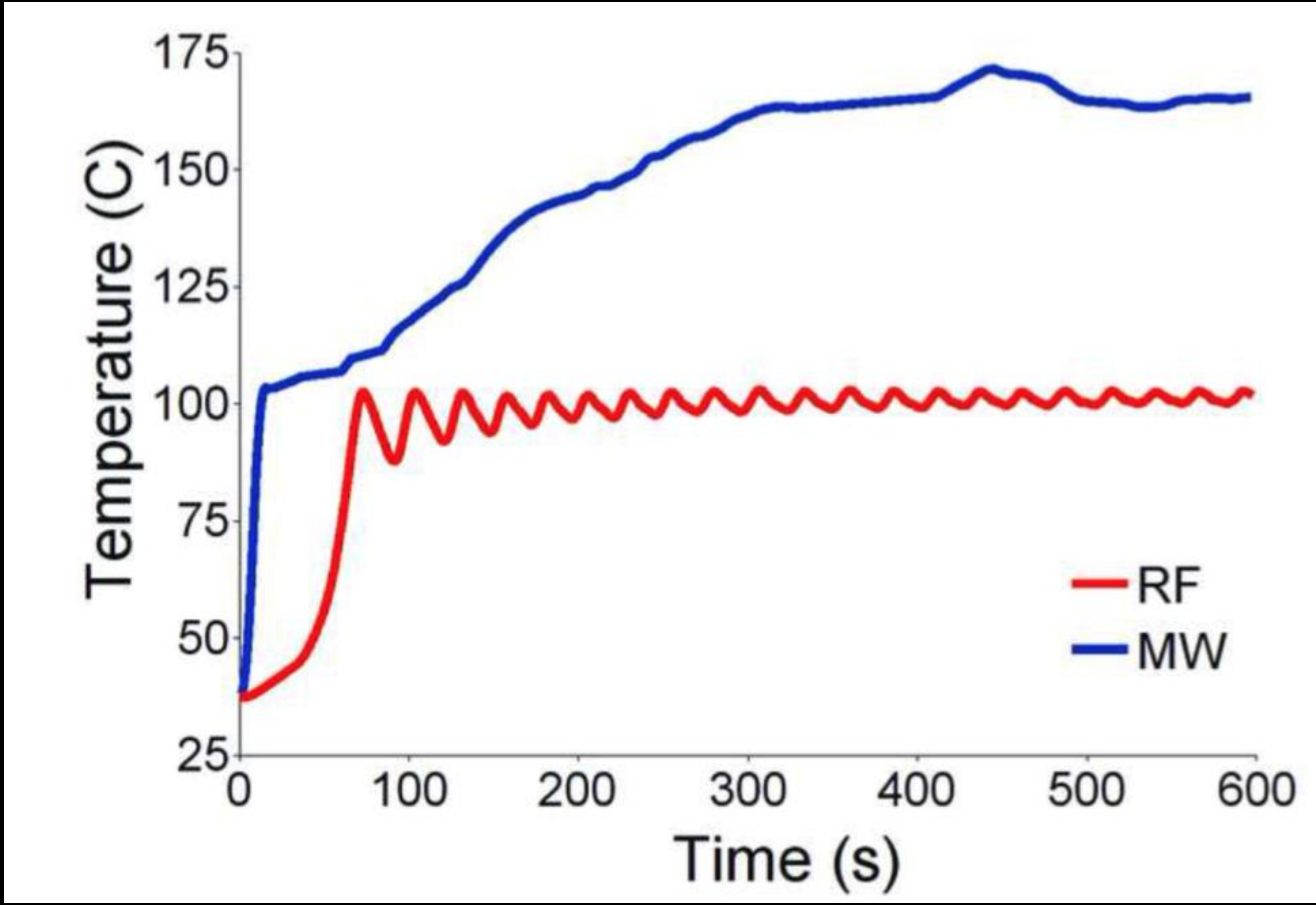


J Vasc Interv Radiol. 2010 August ; 21(8 Suppl): S192–S203.
AJR:207, September 2016

Microwave ablation

- Advantages
  - Faster
  - Multiple simultaneous probes = larger ablation zone
  - Less sensitivity to bone impedance → useful for sclerotic lesions
  - Less heat sink and charring
- Disdvantages
  - High learning curve → choice of antennas, frequencies, power output
  - Fragile probes → 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

Semin Intervent Radiol 2017;34:121–131.
AJR:207, September 2016



J Vasc Interv Radiol. 2010 August ; 21(8 Suppl): S192–S203.

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

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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

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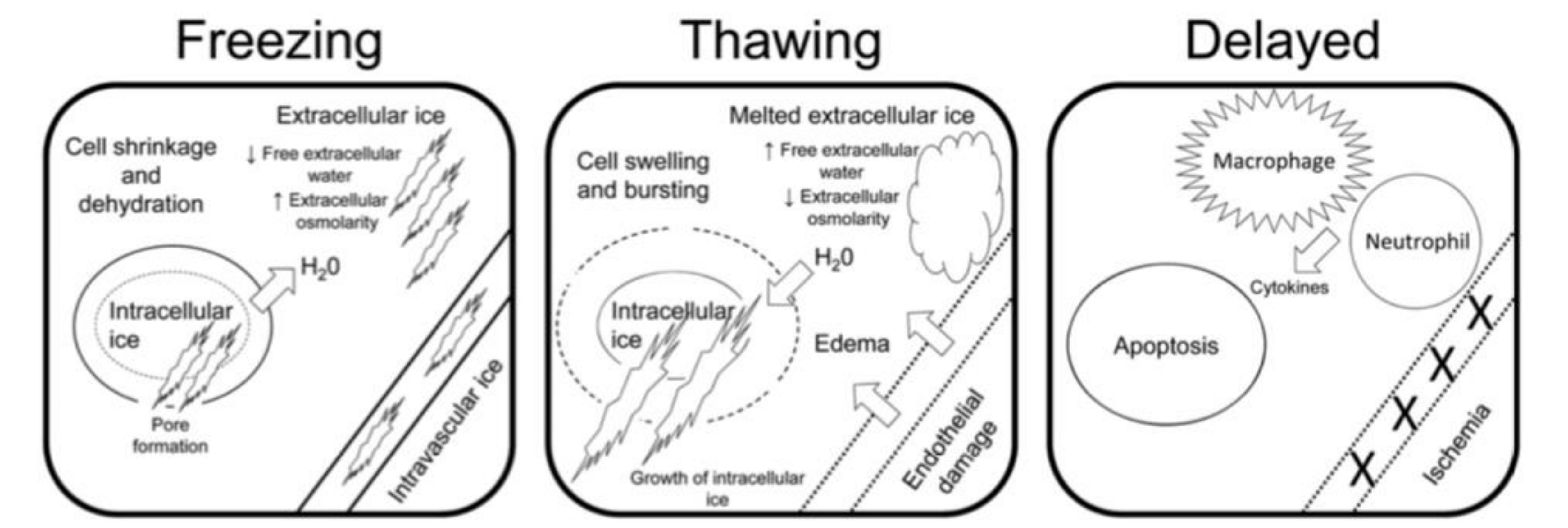

J Vasc Interv Radiol 2010; 21:S187–S191

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)

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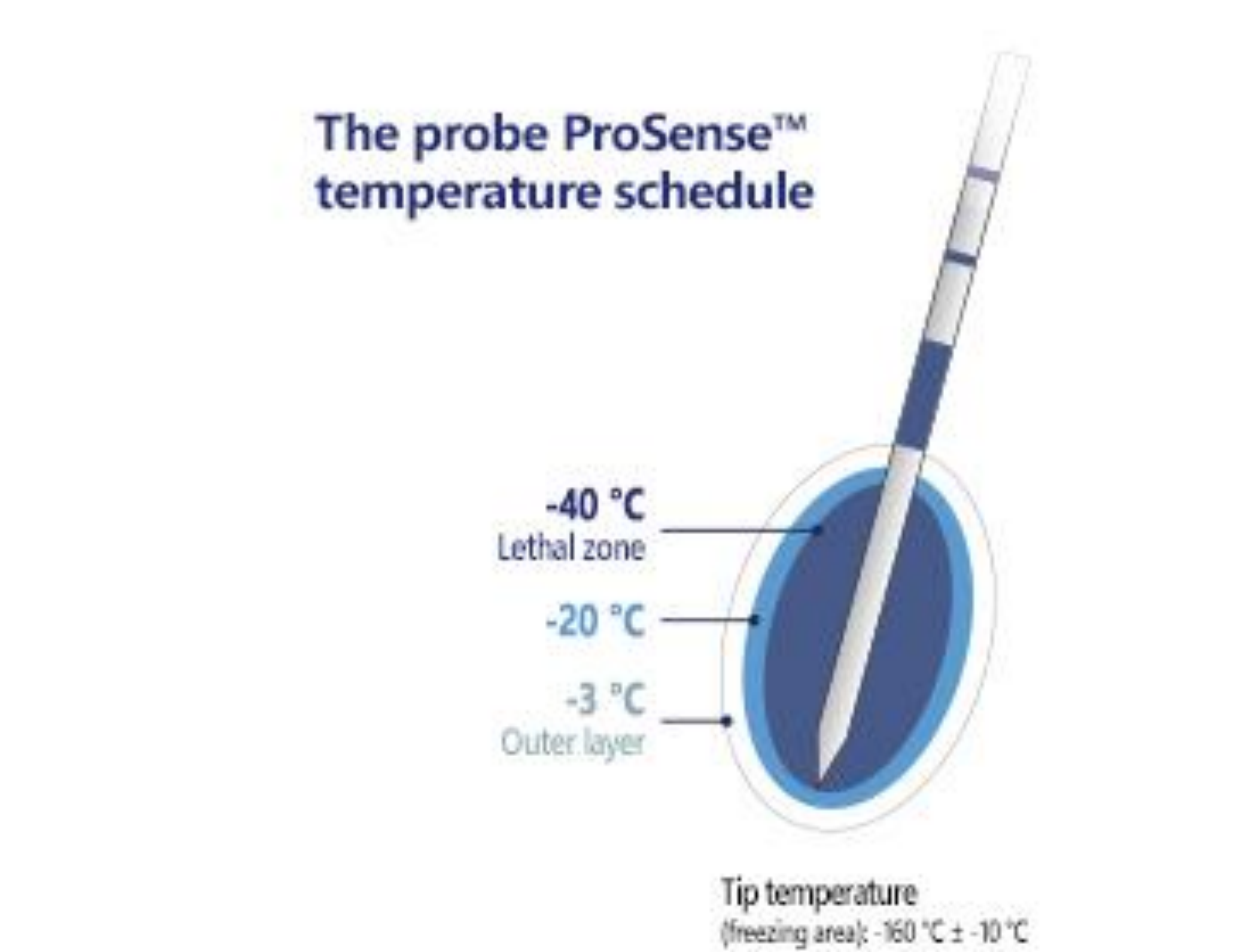

http://www.versandafne.it/en/core-business/cryoablation-prosense/breast-diseases.html

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

Semin Intervent Radiol 2017;34:121–131.

AJR:207, September 2016

Conf Proc IEEE Eng Med Biol Soc. 2012 Aug;2012:2327-30.

Laser ablation

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

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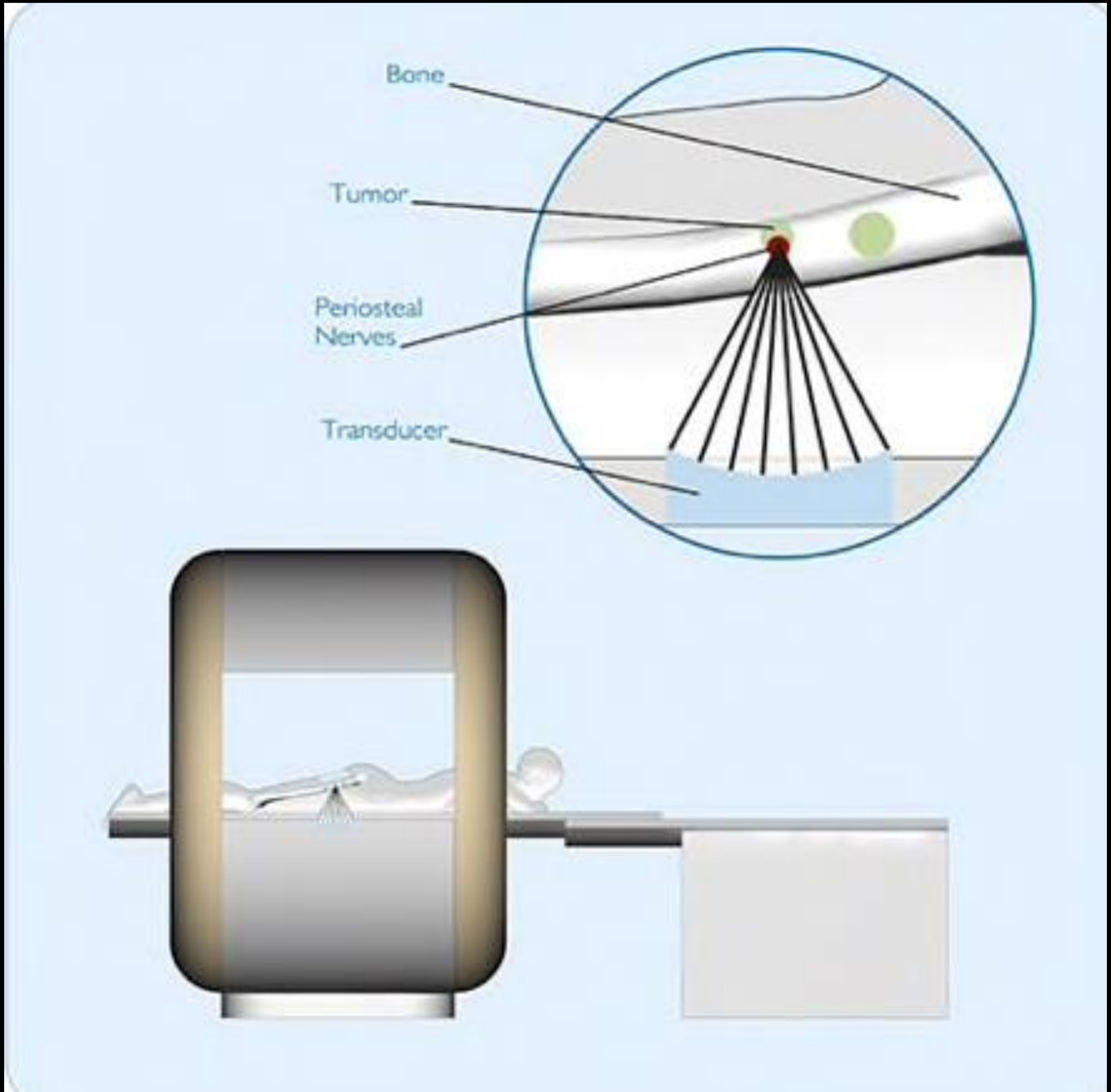
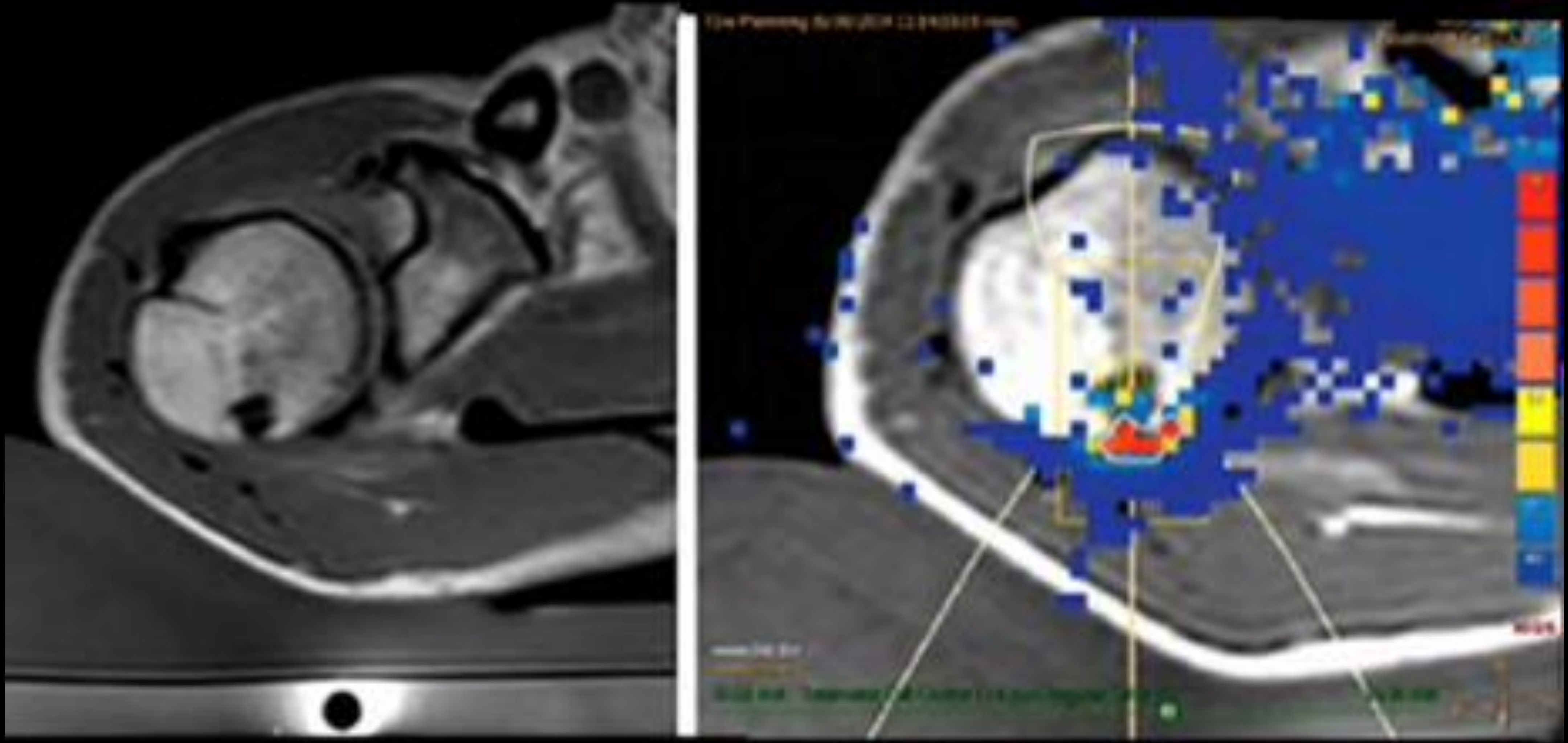
MR-guided focused ultrasound

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

Clinical Oncology 30 (2018) 233e242
Proceedings from the 14th International Symposium on Therapeutic Ultrasound
AIP Conf. Proc. 1821, 140001-1–140001-5;



https://www.philips.com.au/healthcare/education-resources/publications/hotspot/mr-hifu



https://www.philips.com.au/healthcare/education-resources/publications/hotspot/mr-hifu

Pre-ablation 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

Semin Intervent Radiol 2017;34:121–131.

Pre-ablation planning

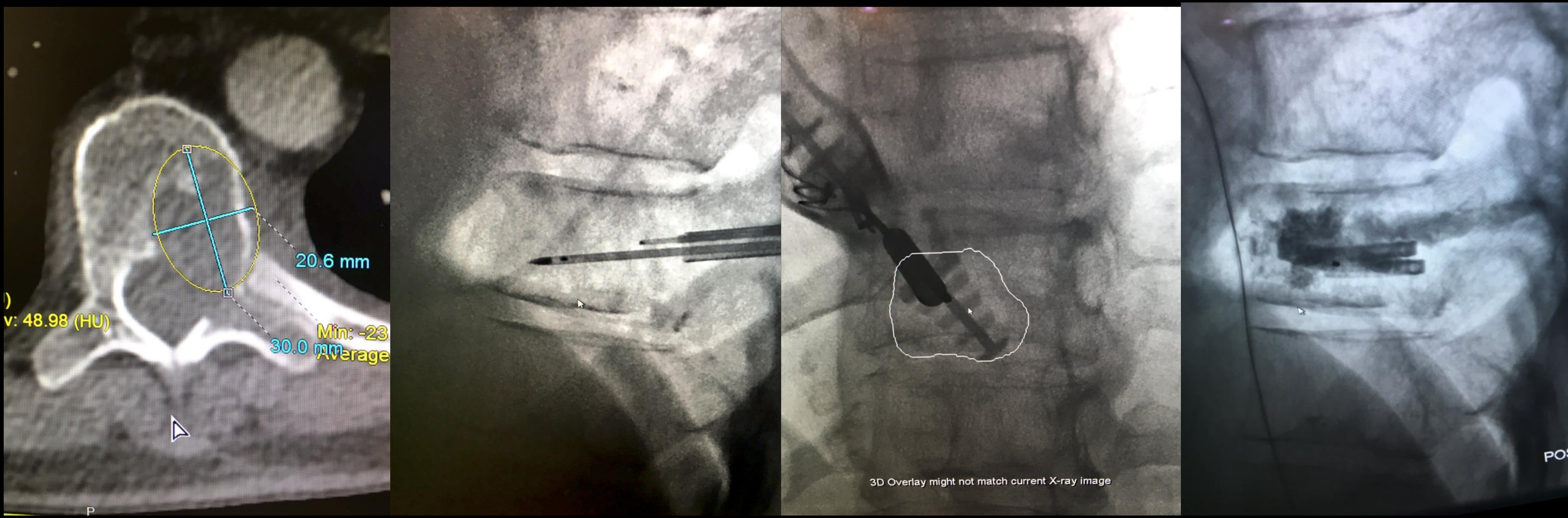
- Lytic lesions → most amenable to treatment
  - Easy access and PMMA injection
- Sclerotic and mixed lesions → more challenging
  - Drills for access
- Bipedicular access → complete targeting of lesion

Semin Intervent Radiol 2017;34:121–131.

A word about myeloma

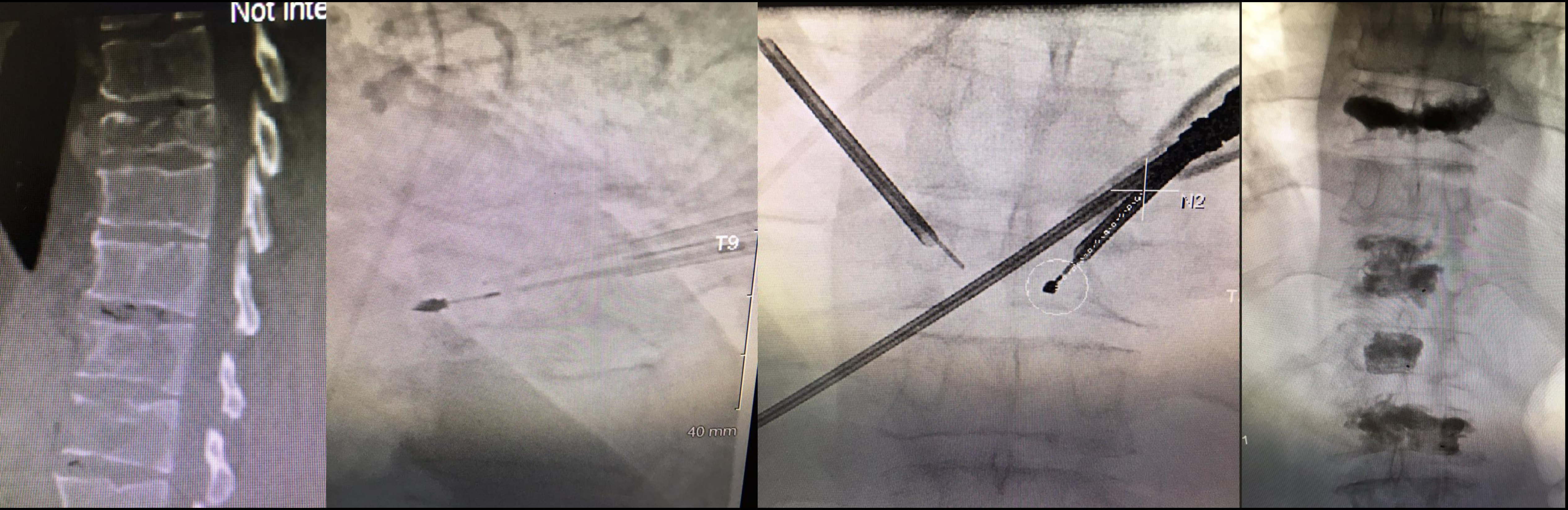
- Large lytic lesions → high incidence of pathologic fractures
  - Upregulation of osteoclasts and plasma cell invasion
- Highly radiosensitive
- Vertebroplasty is an effective treatment
  - PMMA polymerizes in vivo → transient temperature elevation
  - Soft tumor → some local tumor control
  - Pain control = structural stability and possibly PMMA exothermic process
- Posterior cortical destruction → vertebral augmentation implant
  - PEEK coil (e.g. KIVA) or metallic stent
- Ablation not usually necessary

Semin Intervent Radiol 2017;34:121–131.



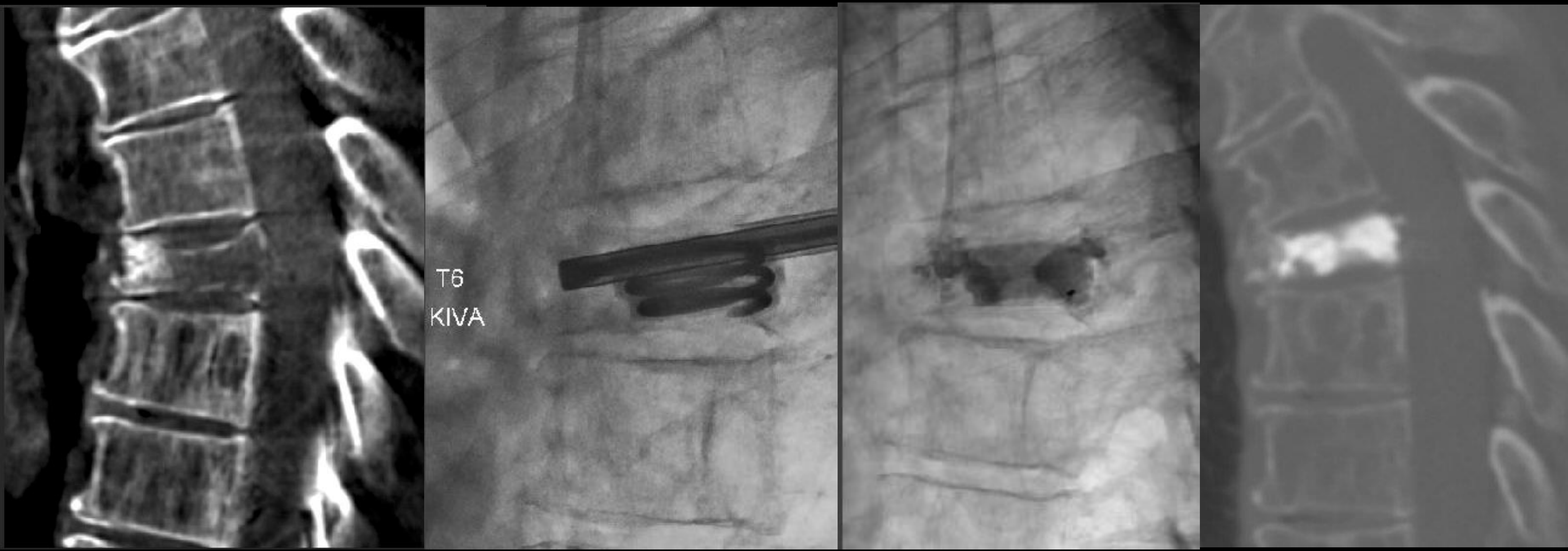
64 yo F with breast cancer. RFA with temperature monitoring, KIVA, and pedicle-plasty. Patient had no pain after procedure.

– Case courtesy of Sean Tutton, MD

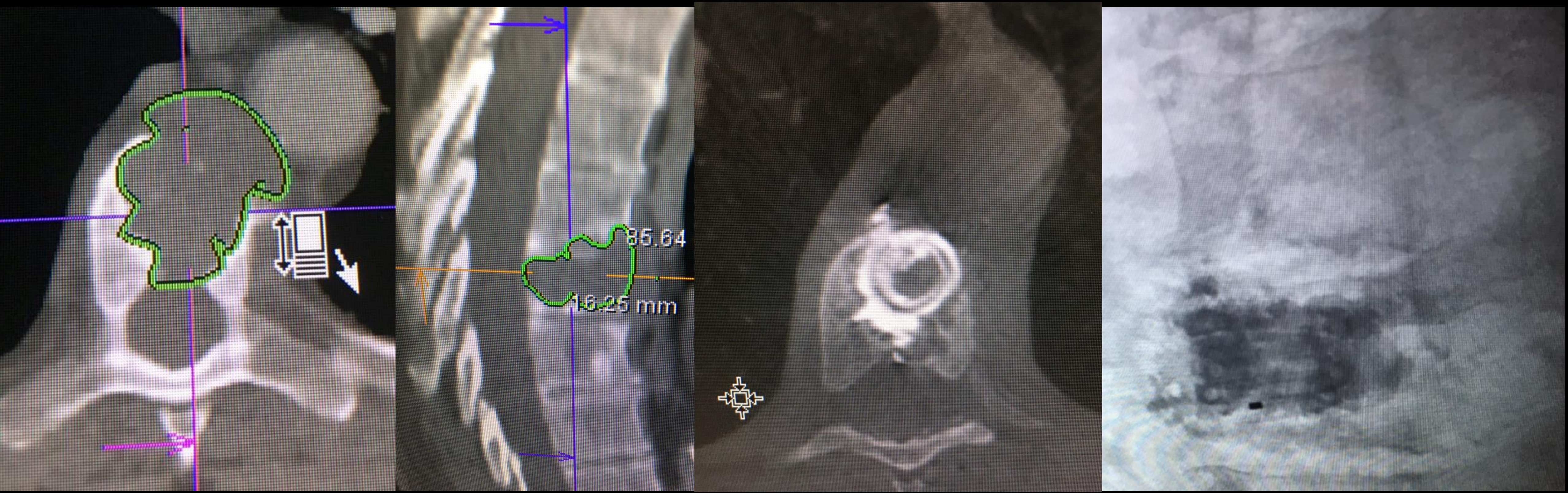


56 yo with RCC. MWA, temperature monitoring, and KIVA at T9, T11-L1.

– Case courtesy of Sean Tutton, MD

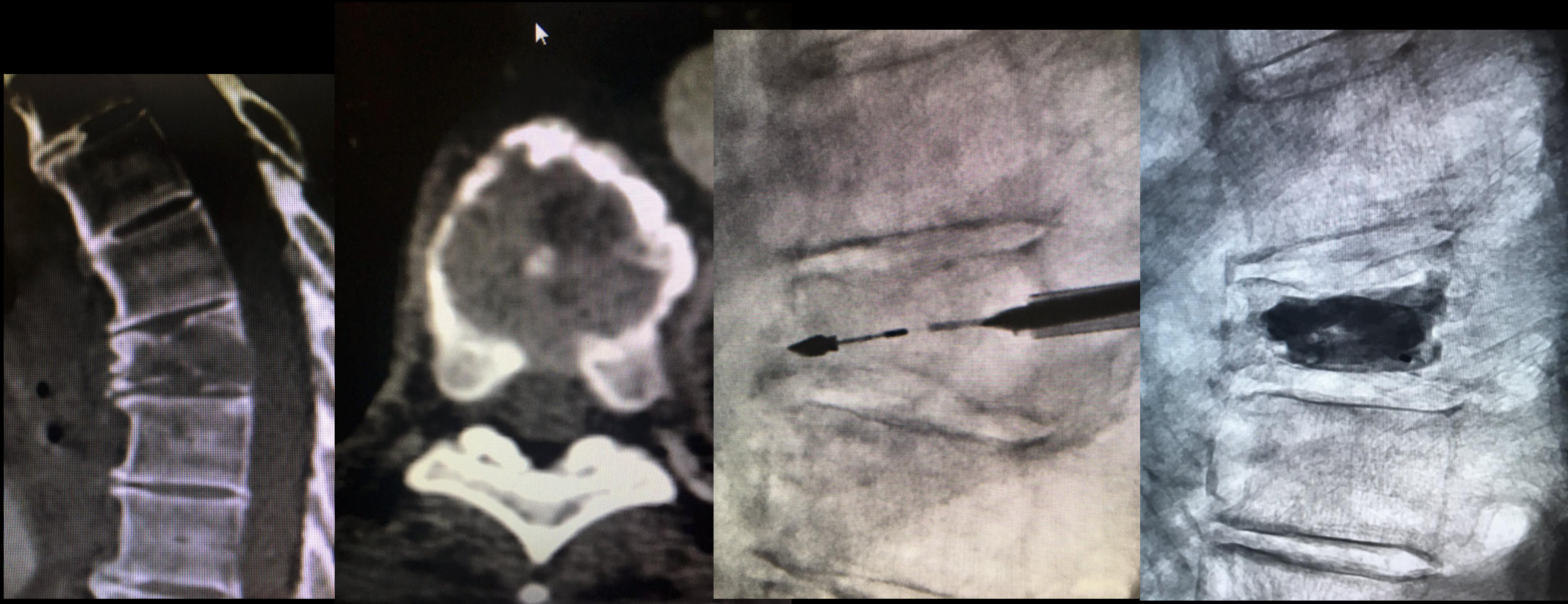


68 M with myeloma. KIVA with improved pain and mobility.
– Case courtesy of William Lea, MD

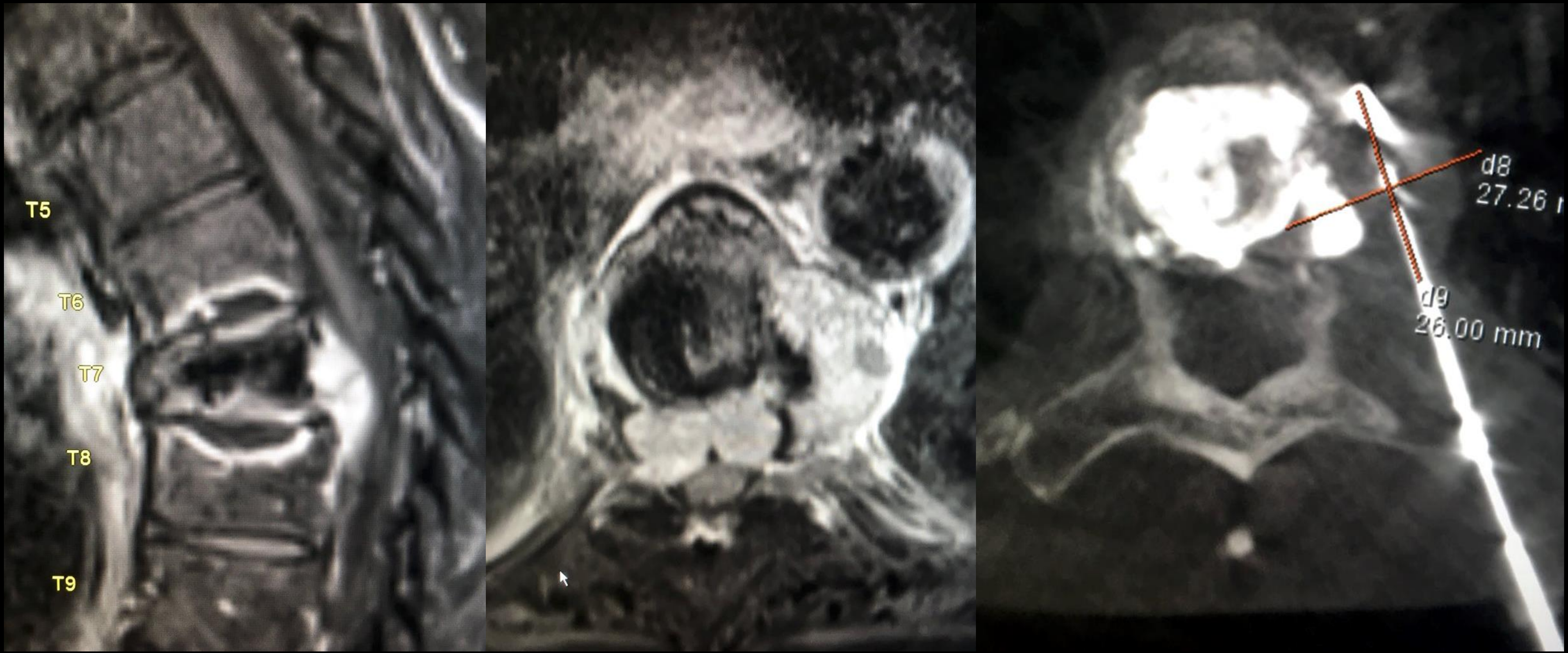


Metastatic prostate cancer. RFA with KIVA.

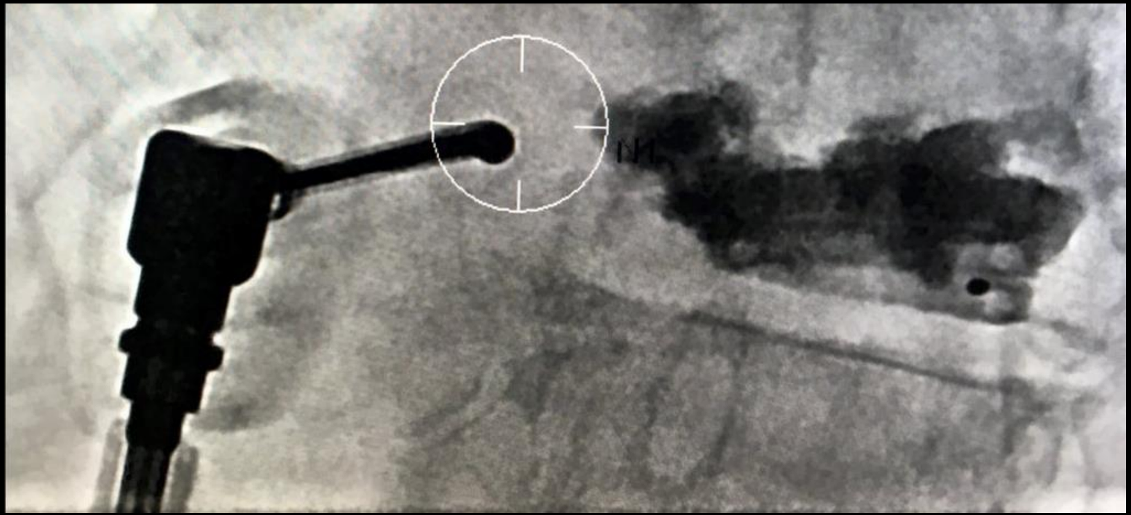
– Case courtesy of Blake Parsons, MD

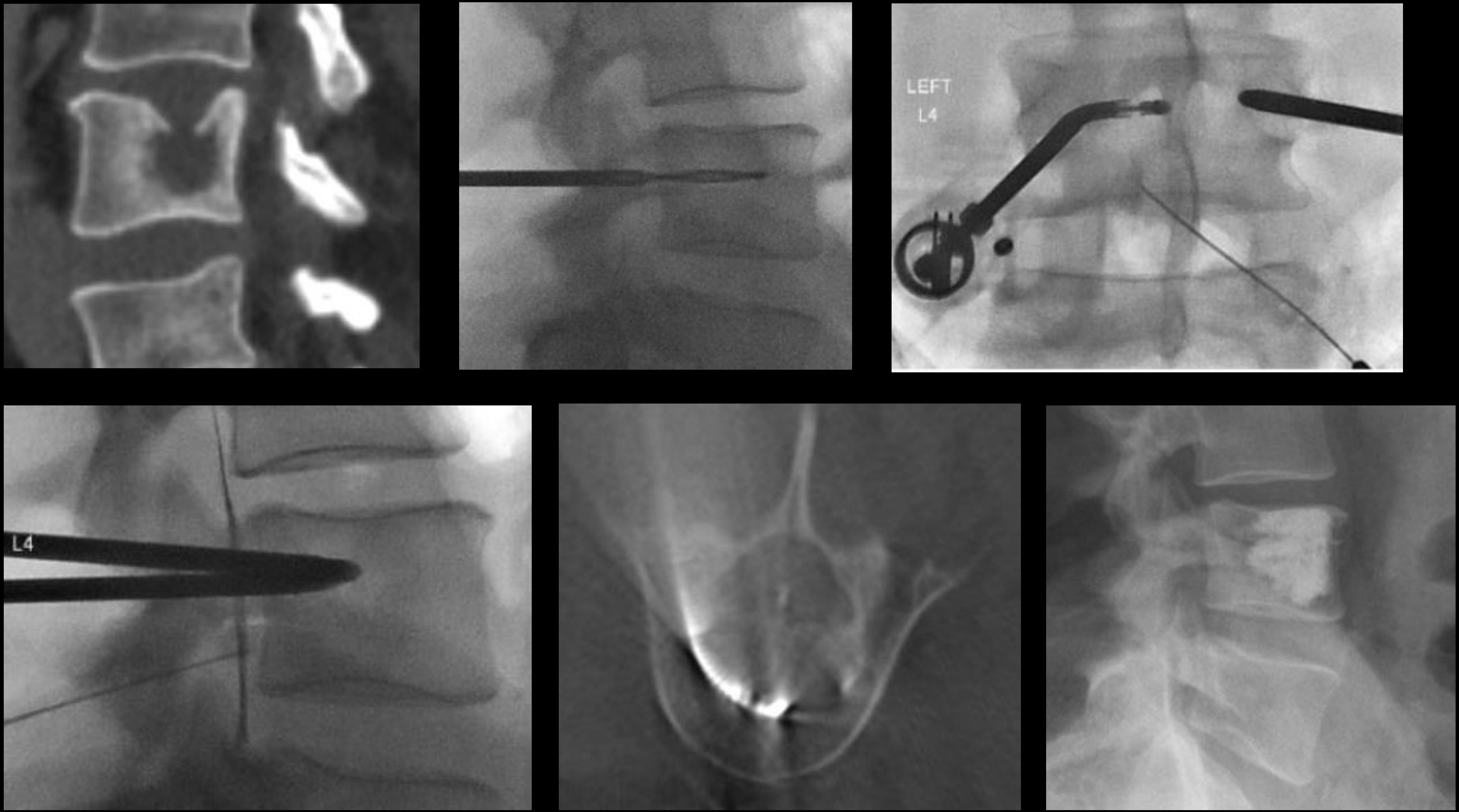


86 yo F with RCC. MWA and KIVA with RT to follow.
Patient went home same day without pain.
– Case courtesy of William Lea, MD



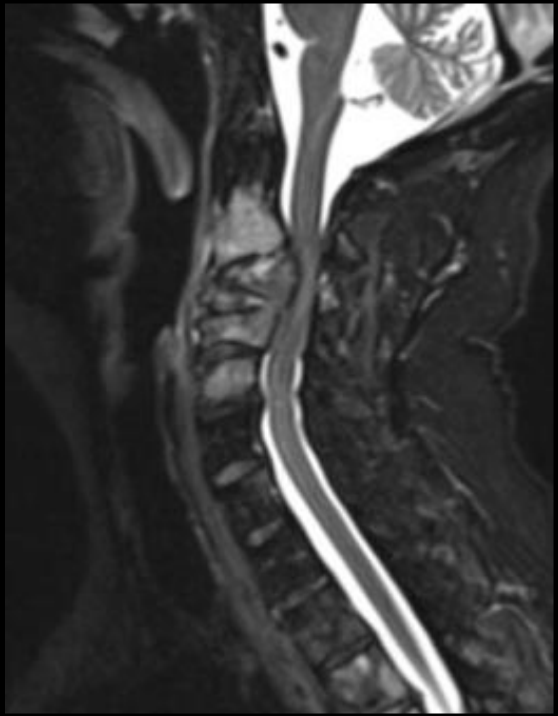
6 month follow-up with progressive disease and new myelopathy despite RT. Repeat MWA prior to surgery.
– Case courtesy of William Lea, MD

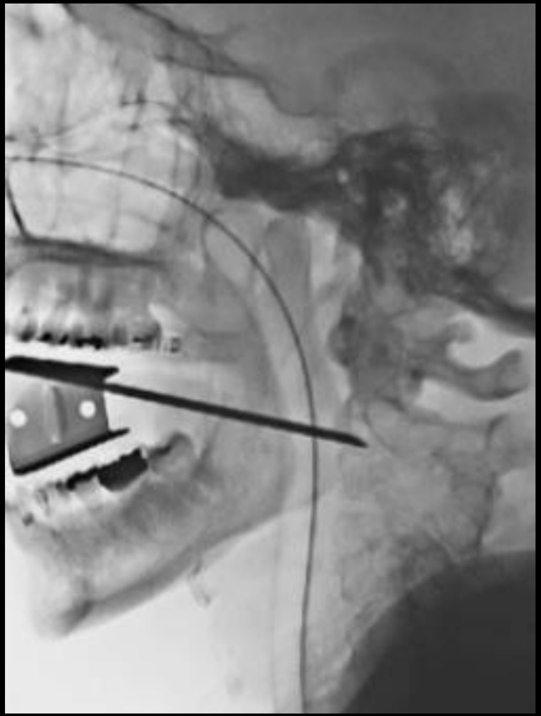




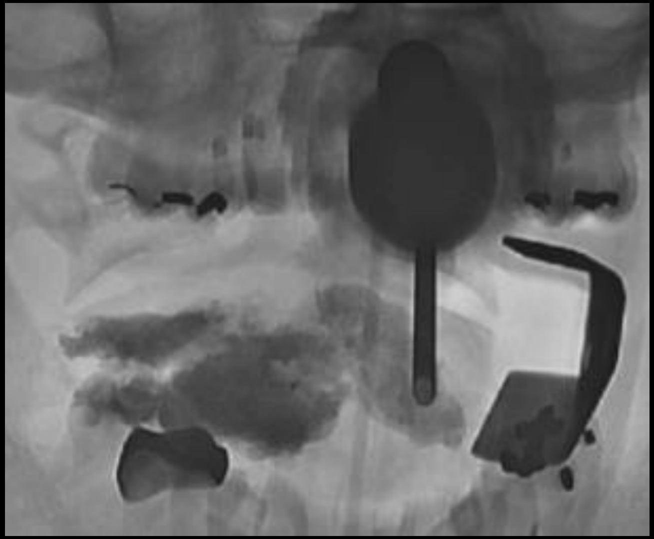
46 yo M with lung cancer and pathologic L4 fracture. Articulating RFA with epidural hydrodissection.

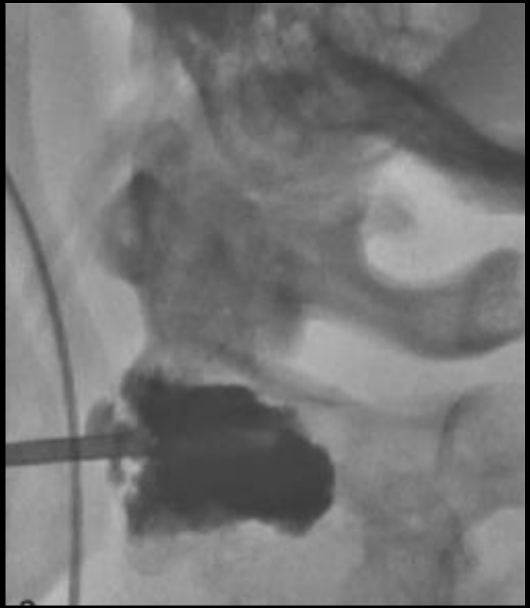
Semin Intervent Radiol 2017;34:121–131.





52 yo F with lung cancer. Surgical decompression and fusion optimal but complicated by poor bone quality.





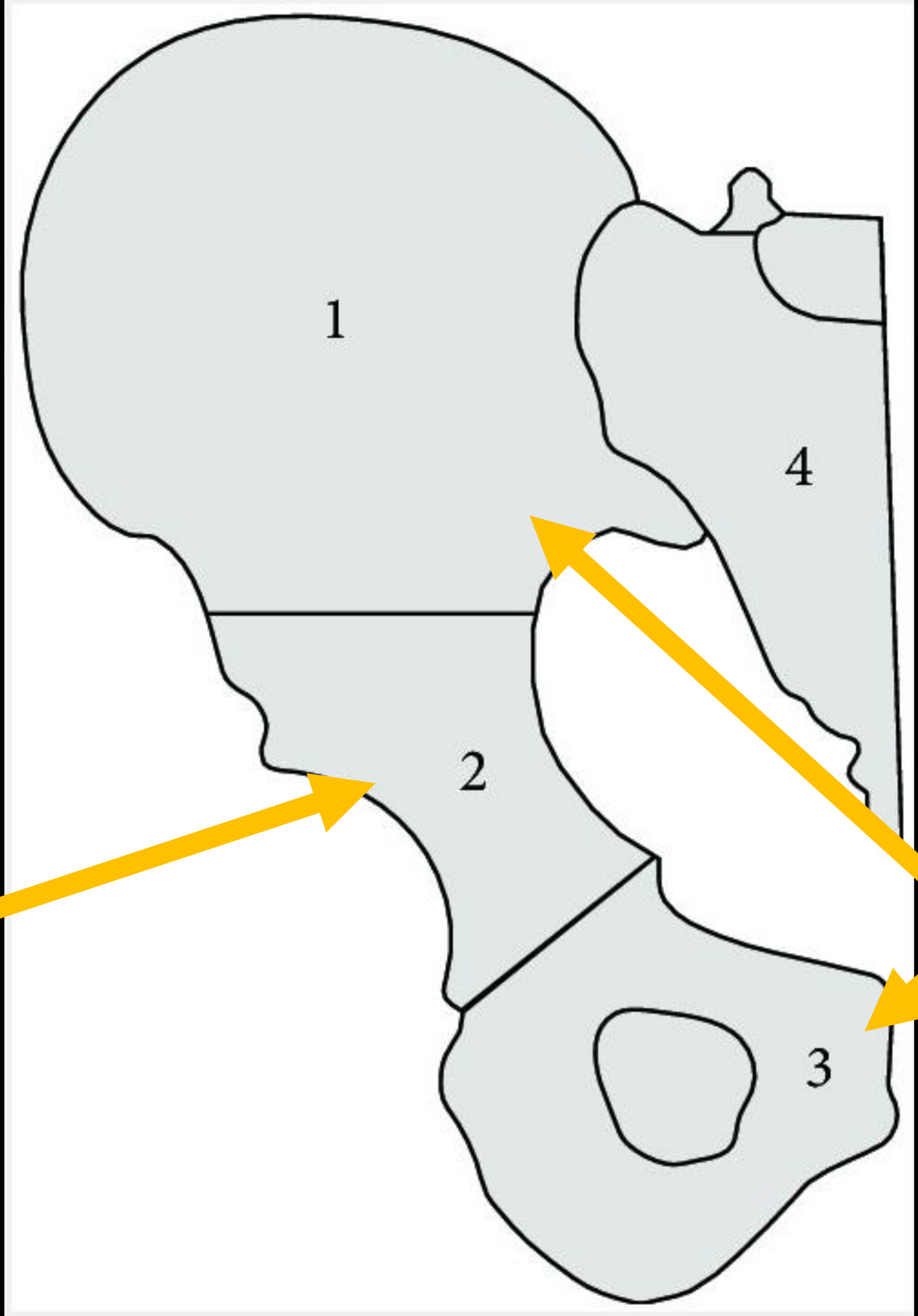
- C2 PMMA using transoral approach.
- C5 and C7 PMMA using anterolateral US guided approach.

Semin Intervent Radiol 2017;34:121–131.

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)

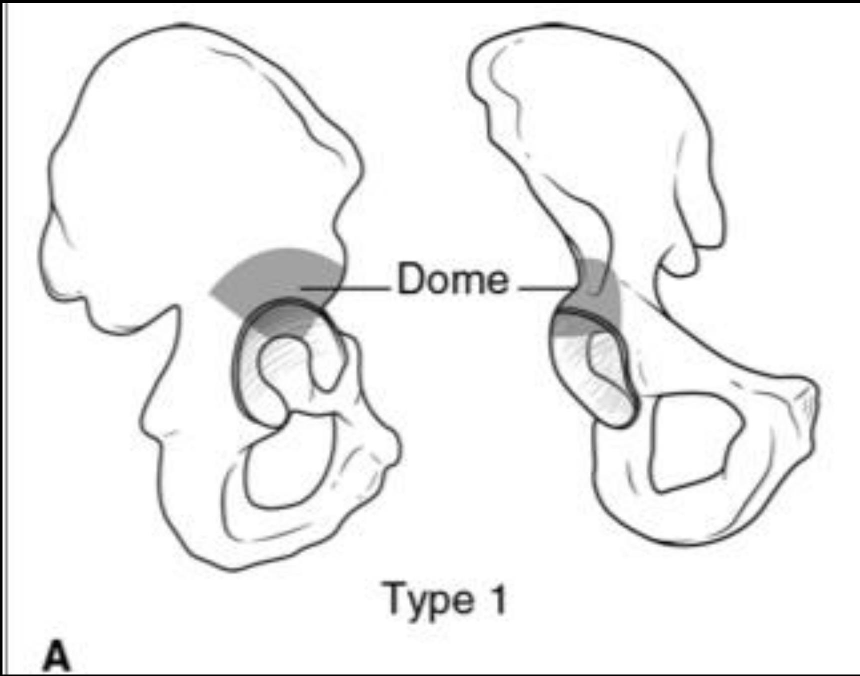
Zones 1 and 3 =
non-weight-bearing bones of the extremity and trunk (clavicle, sternum, & fibula)

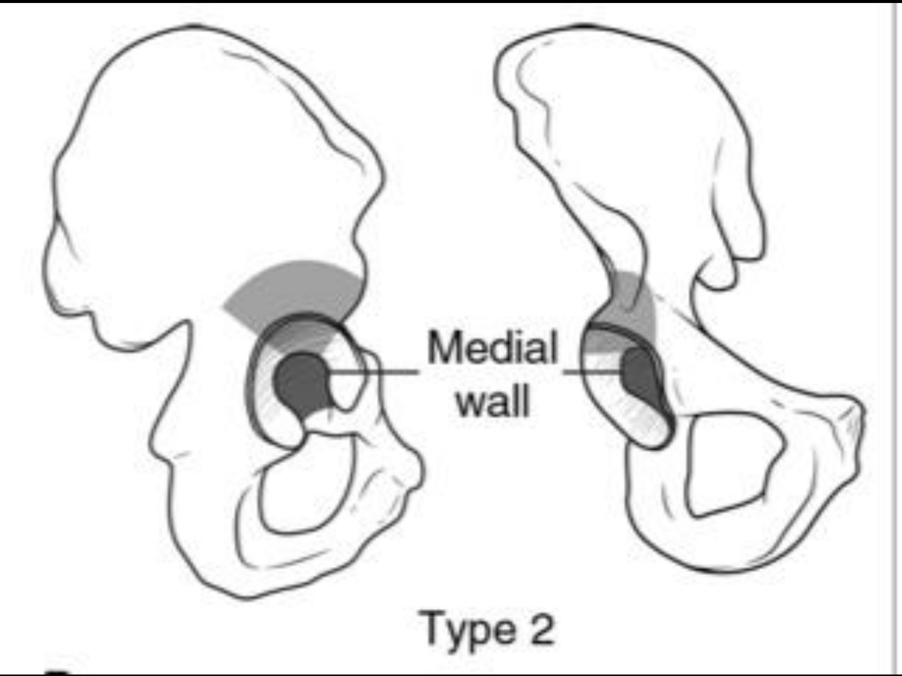
Greatest risk for mechanical failure

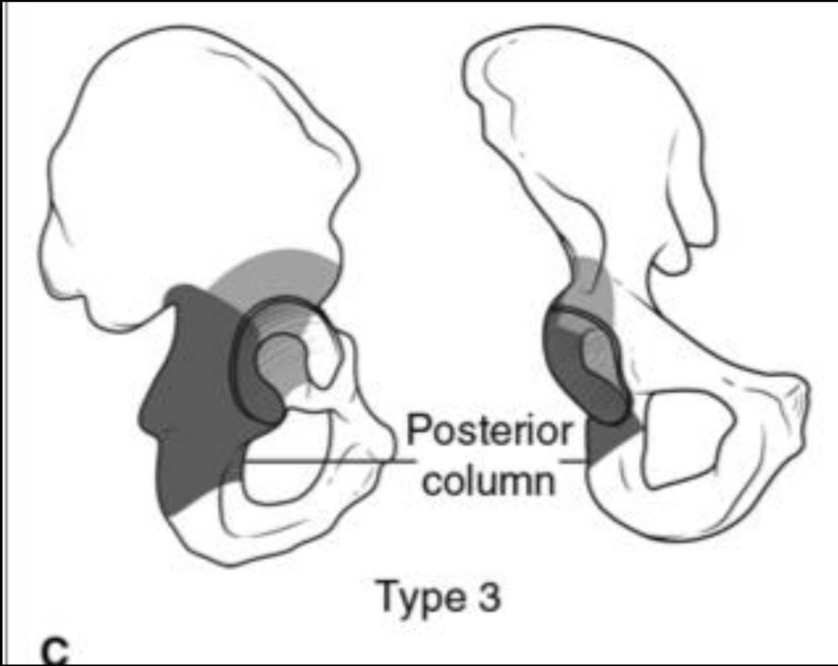
Do not compromise mechanical stability of the pelvis

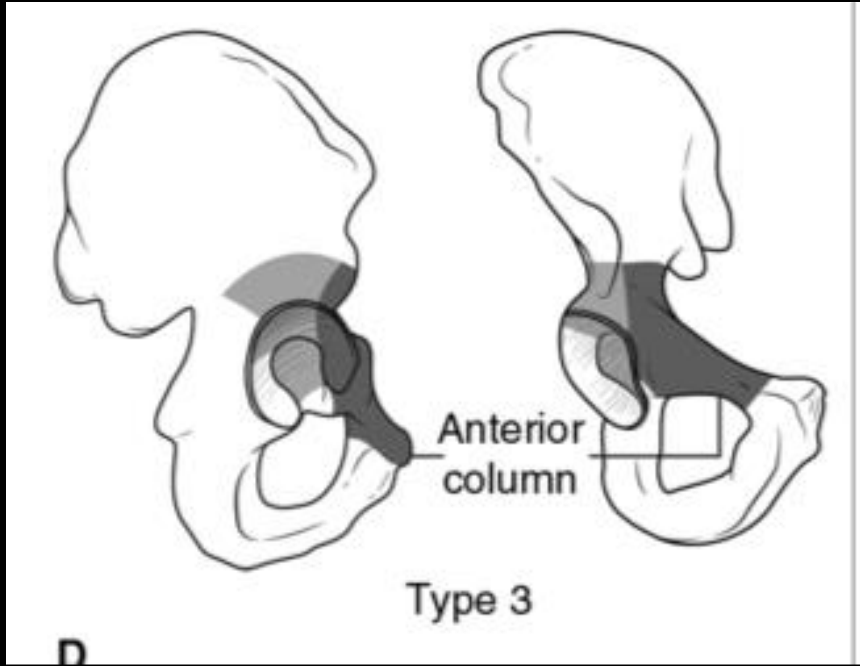
Adv Orthop. 2015;2015:525363.

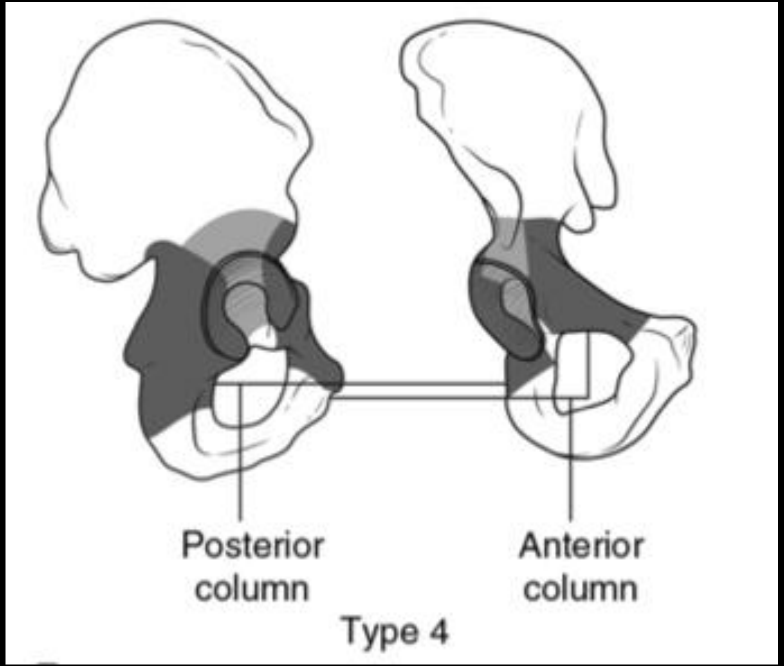
Metastatic acetabular classification











J Am Acad Orthop Surg 2013;21: 685-695

Acetabular metastases

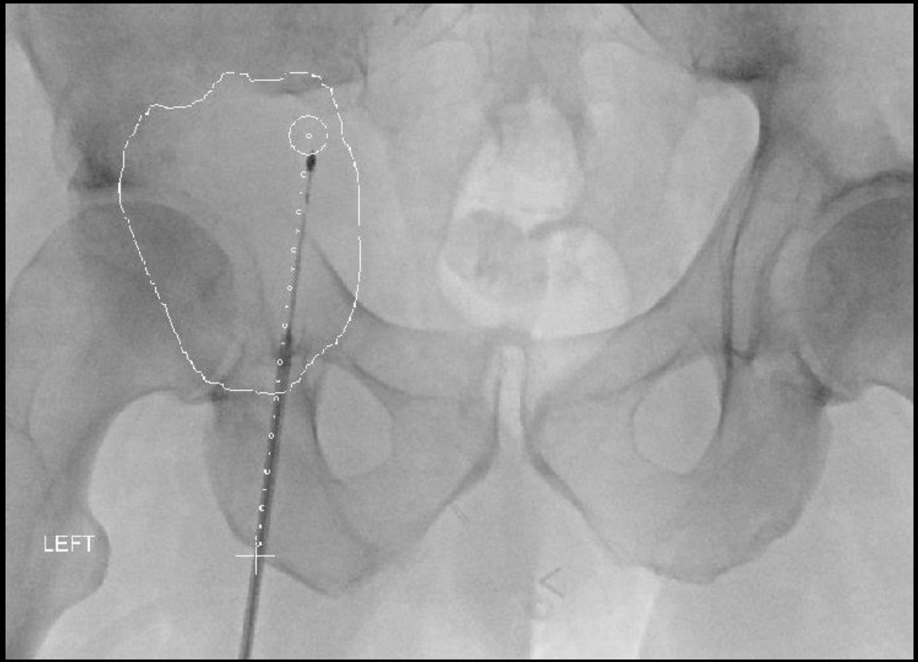
- Nonoperative (disphosphonates, RT)
  - Does not compromise posterior column, dome, or medial wall
- Surgical reconstruction
  - Large acetabular lesion that compromises stability
  - Pathologic fracture
  - Radioresistant tumor
  - Debilitating pain despite nonoperative/interventional management
- Preoperative embolization
  - Reduce intraoperative blood loss
  - RCC, thyroid, HCC
  - Large extraosseous soft tissue mass

J Am Acad Orthop Surg 2013;21: 685-695

Acetabular metastases → MIIPs

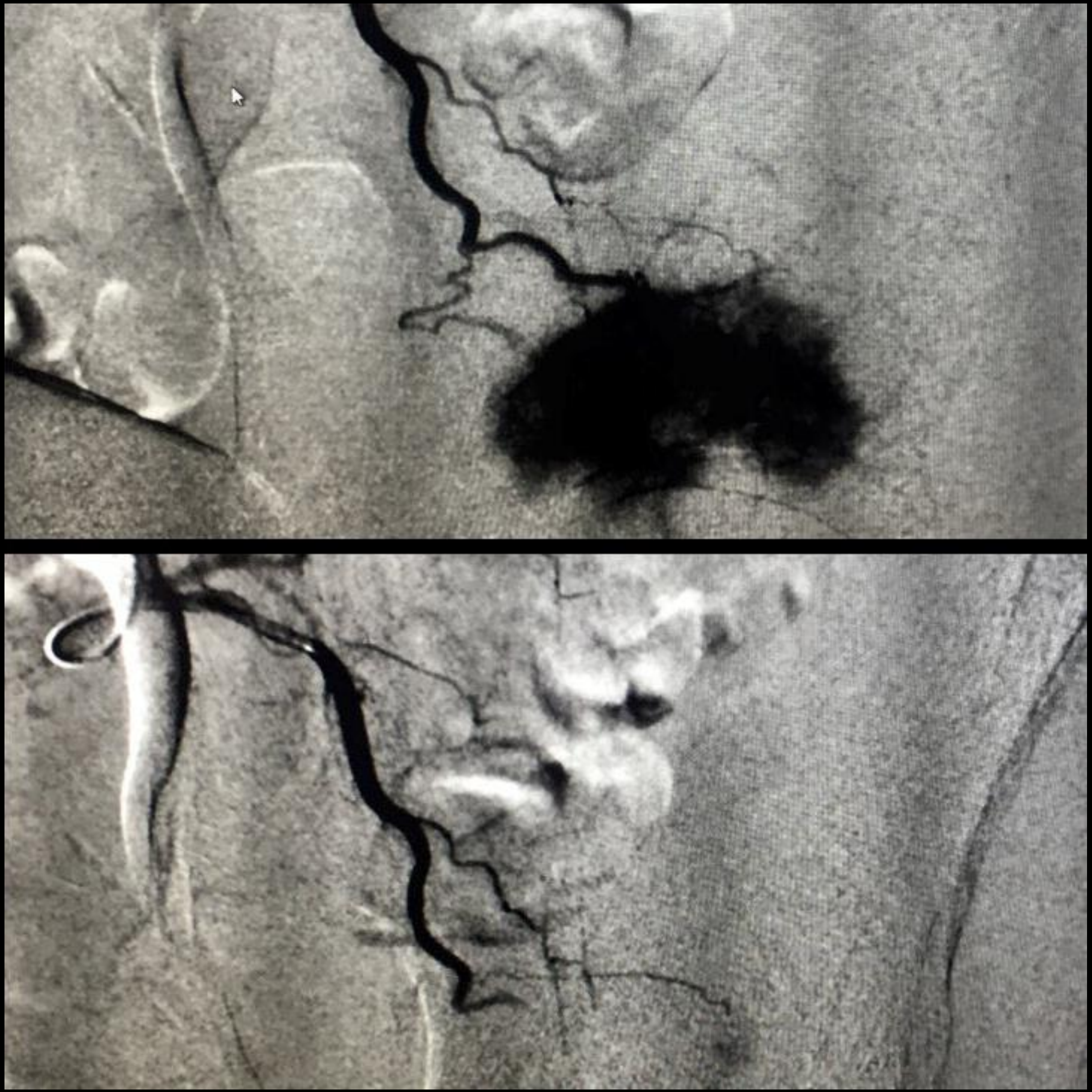
- Alternative to surgical reconstruction → extensive surgery, potentially significant blood loss, large fluid shifts, SIRS
- Percutaneous cementoplasty
  - Complete pain relief in 15 of 20 patients, x 7.3 months (Scaramuzzo et al)
  - Usually combined with ablation
  - Avoid lateral femoral cutaneous nerve, sciatic nerve, & superior gluteal artery
  - Contraindications = impending/complete fractures, medial wall insufficiency
- Ablation
  - Marked decrease in pain scores, analgesic use in 30 patients treated with RFA (Thanos et al)

J Am Acad Orthop Surg 2013;21: 685-695

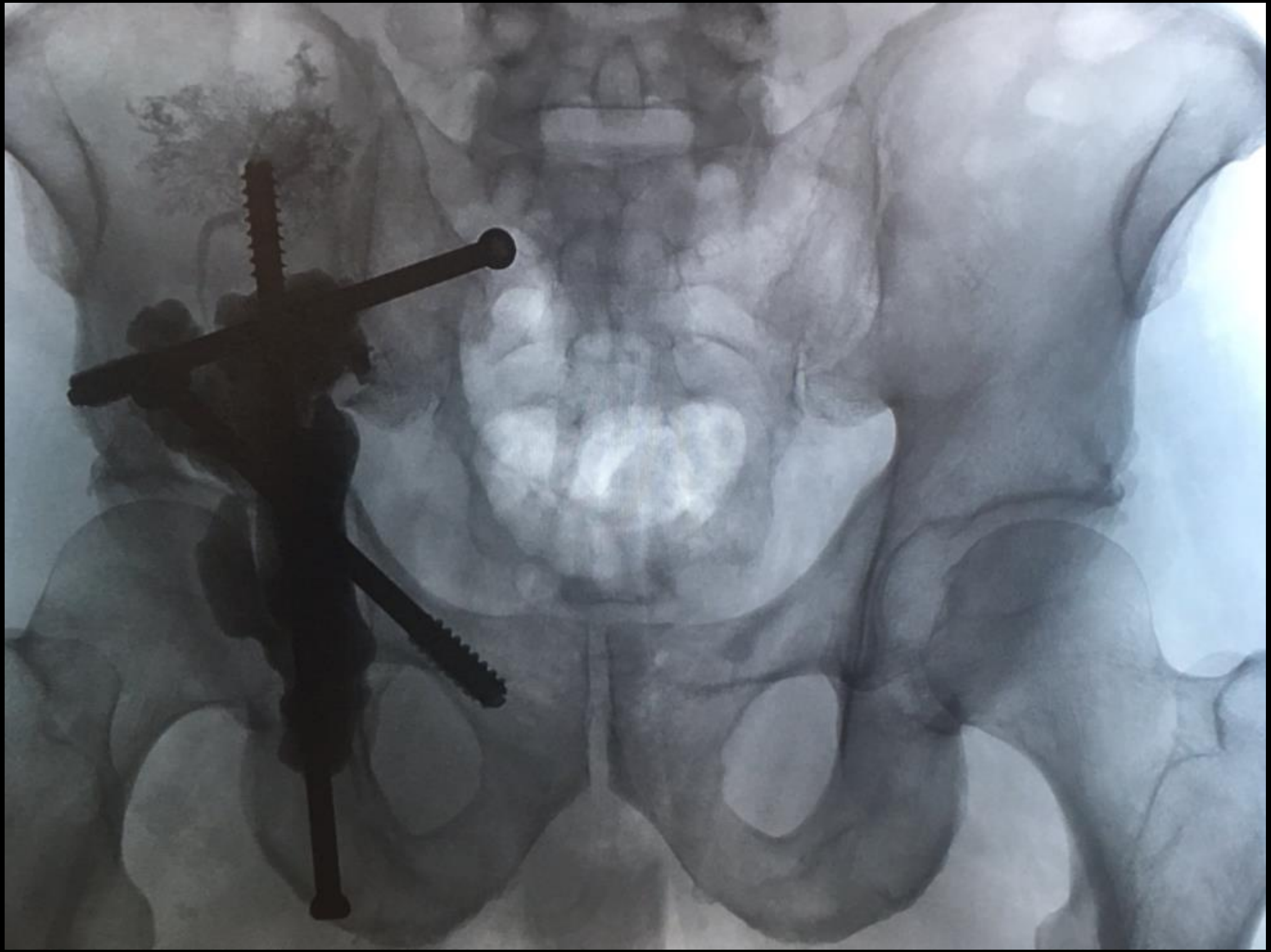


53 yo M with RCC presenting with hip pain. Ablation and fixation.

– Case courtesy of William Lea, MD

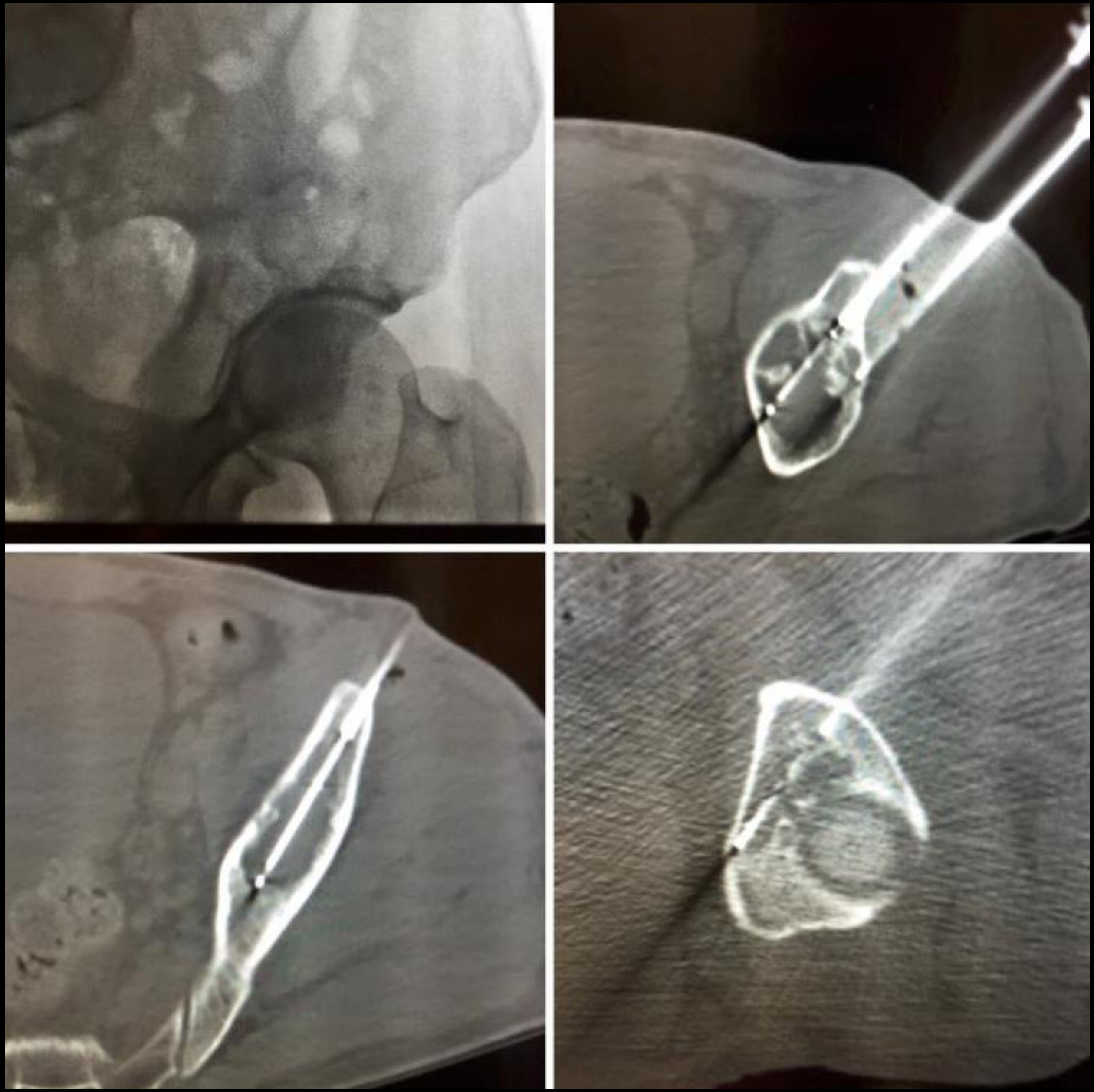


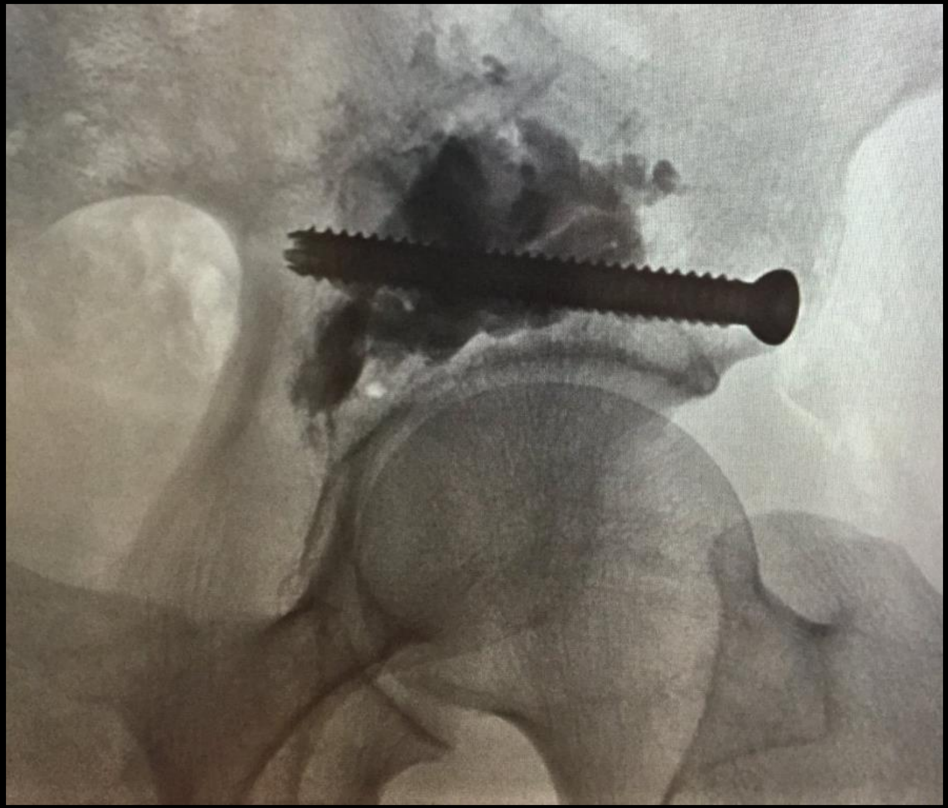
69 yo M with RCC. Embolization, RFA, and PMMA with neuromonitoring
– Case courtesy of Kris Schramm, MD



53 yo with myeloma. Fixation with cementoplasty.

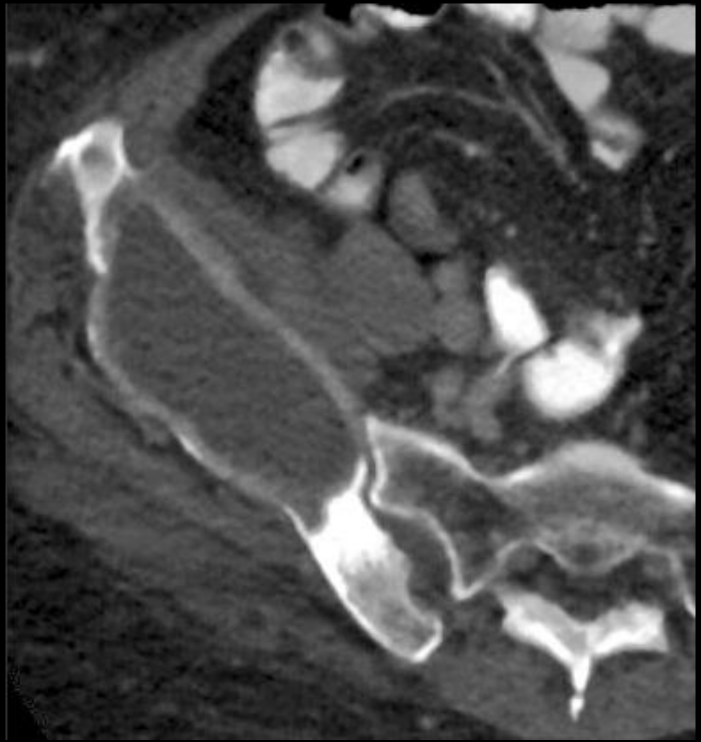
– Case courtesy of William Lea, MD

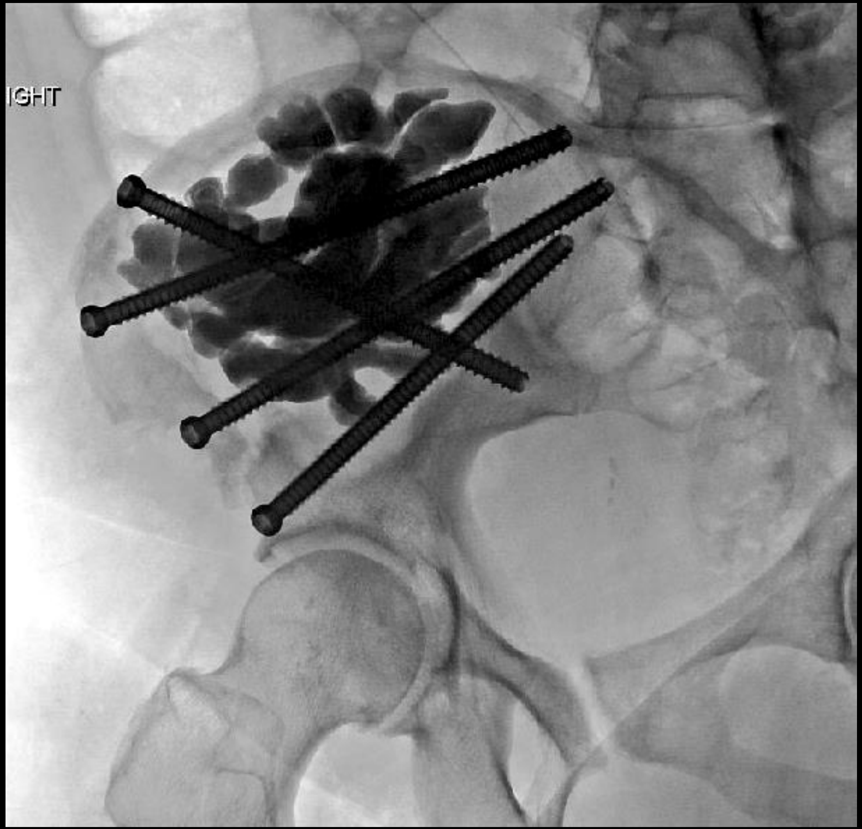




67 yo with RCC. Embolization, ablation, and fixation with cementoplasty. Walked out of hospital next day.

– 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

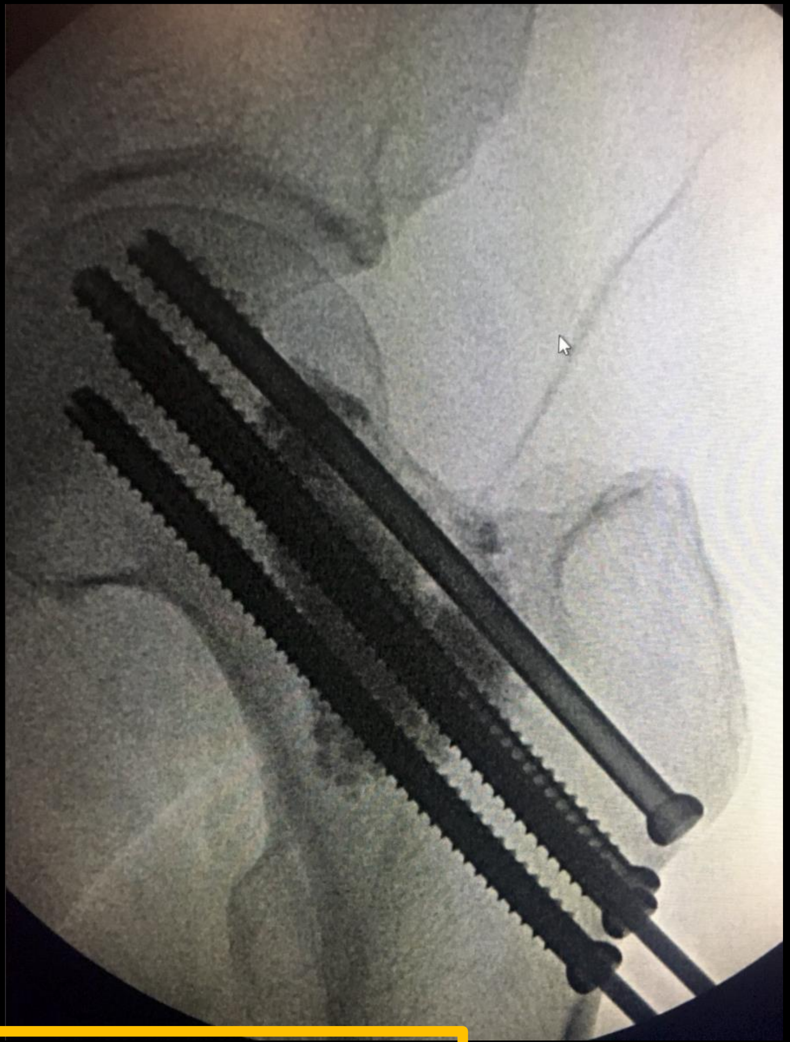
Mirels' scoring system for predicting risk of pathological fracture. Prophylactic fixation is recommended with a score of 9 or above[10]

Score	1	2	3
Site	Upper limb	Lower limb	Pertrochanteric
Pain	Mild	Moderate	Functional
Lesion	Blastic	Mixed	Lytic
Size[a]	<1/3	1/3	>2/3

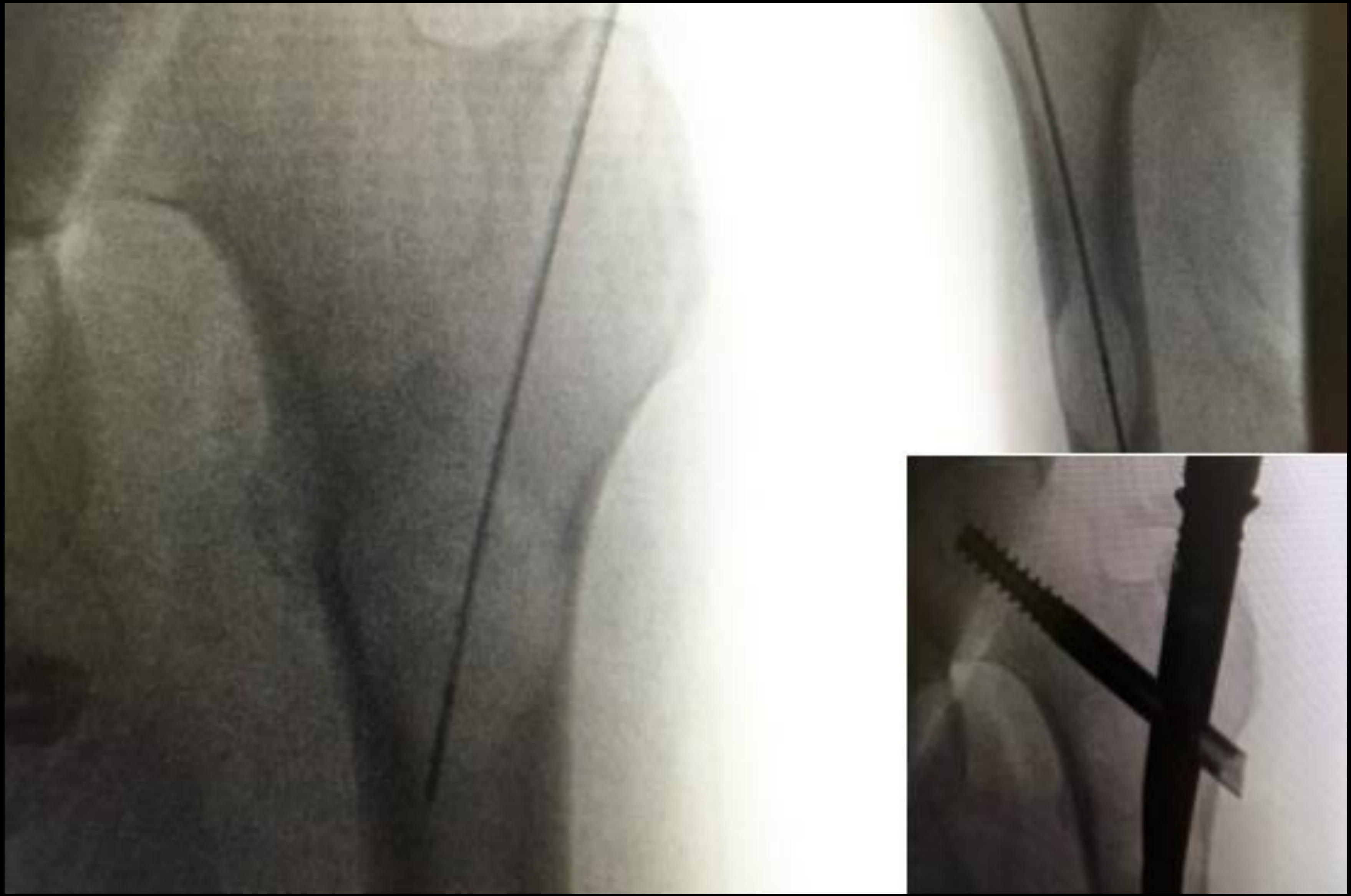
[a] As seen on plain radiograph, maximum destruction of cortex in any view.

Fracture risk and recommendation from Mirels' scoring system[10]

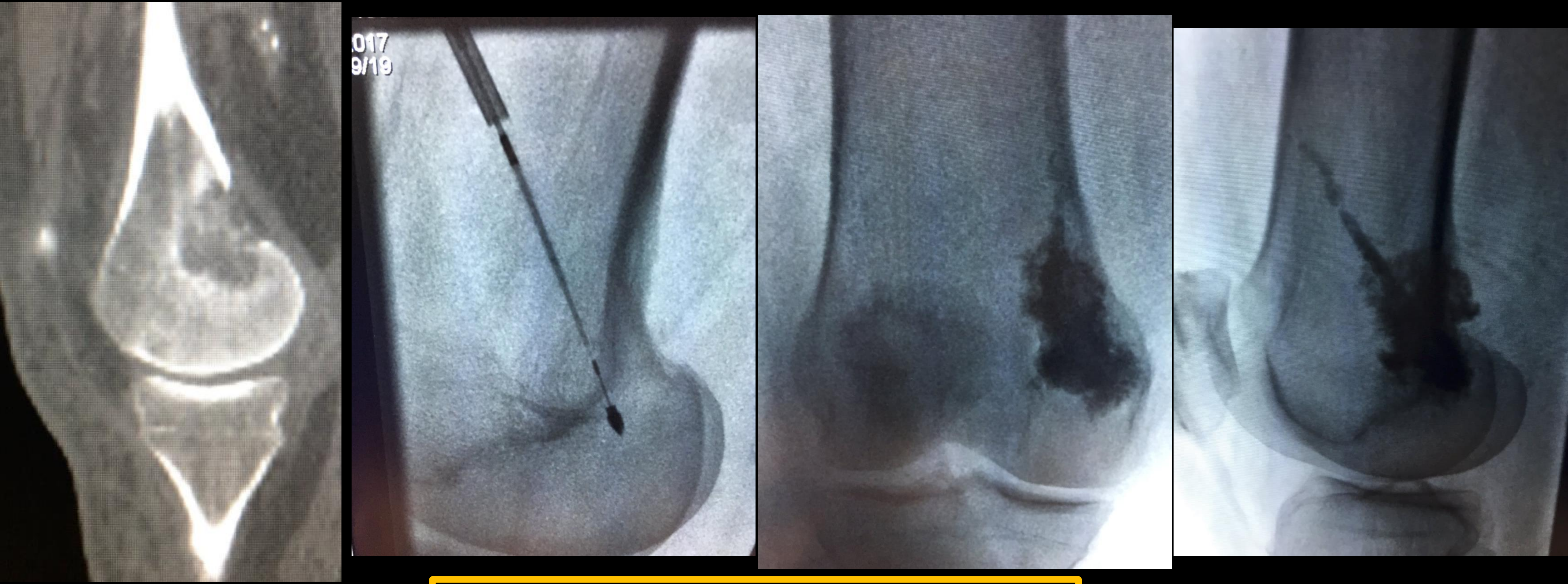
Score	Fracture risk	Recommendation
≥9	33%–100%	Prophylactic fixation is recommended
8	15%	Clinical judgment should be used
≤7	<4%	Observation and radiation therapy can be used



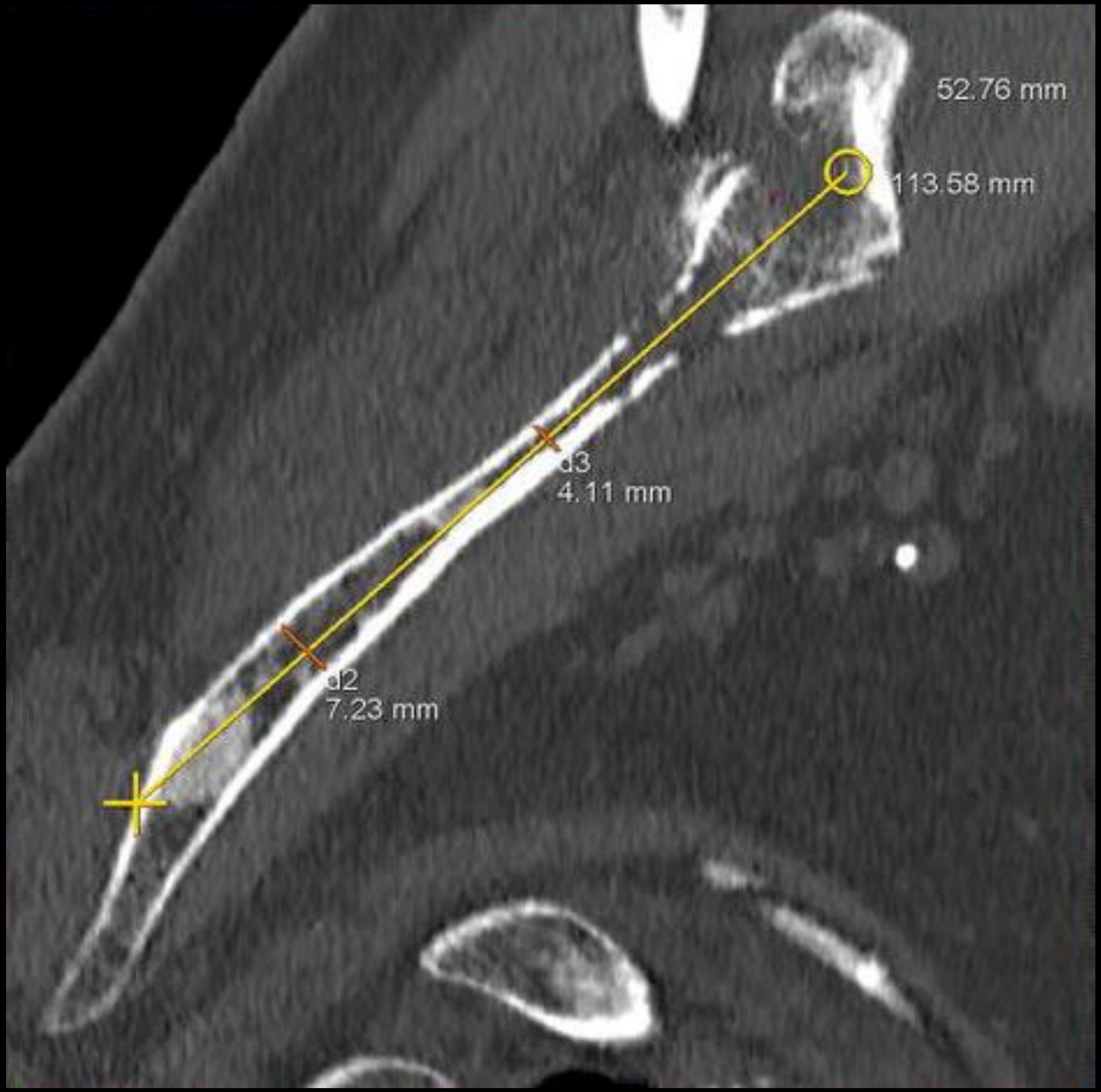
61 yo M with metastatic RCC. MWA, screw fixation cementoplasty.
Home same day.
– Case courtesy of Sean Tutton, MD



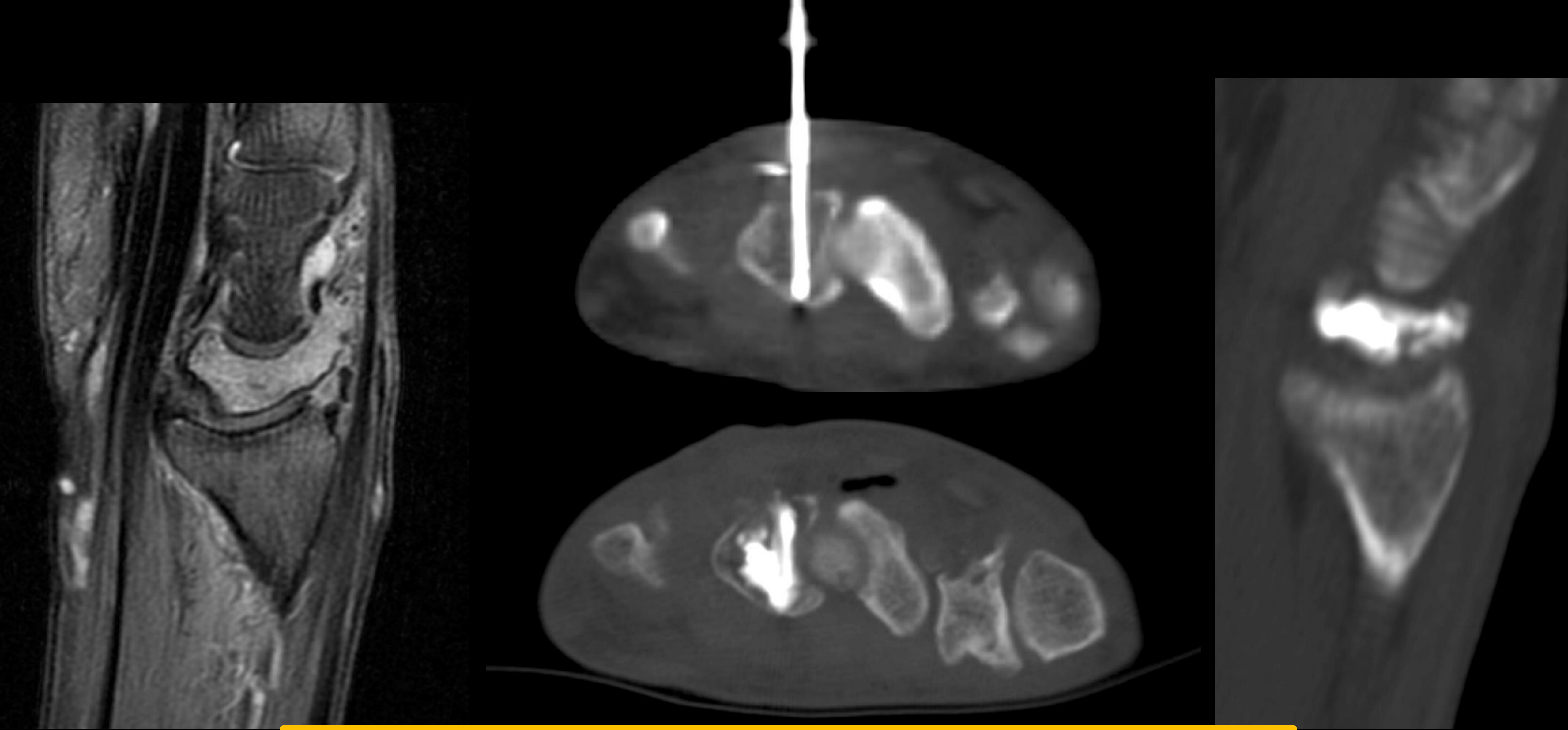
History of metastatic cholangiocarcinoma to bilateral femurs. Intraoperative MWA to reduce hemorrhage prior to IMNs.
– Case courtesy of William Lea, MD



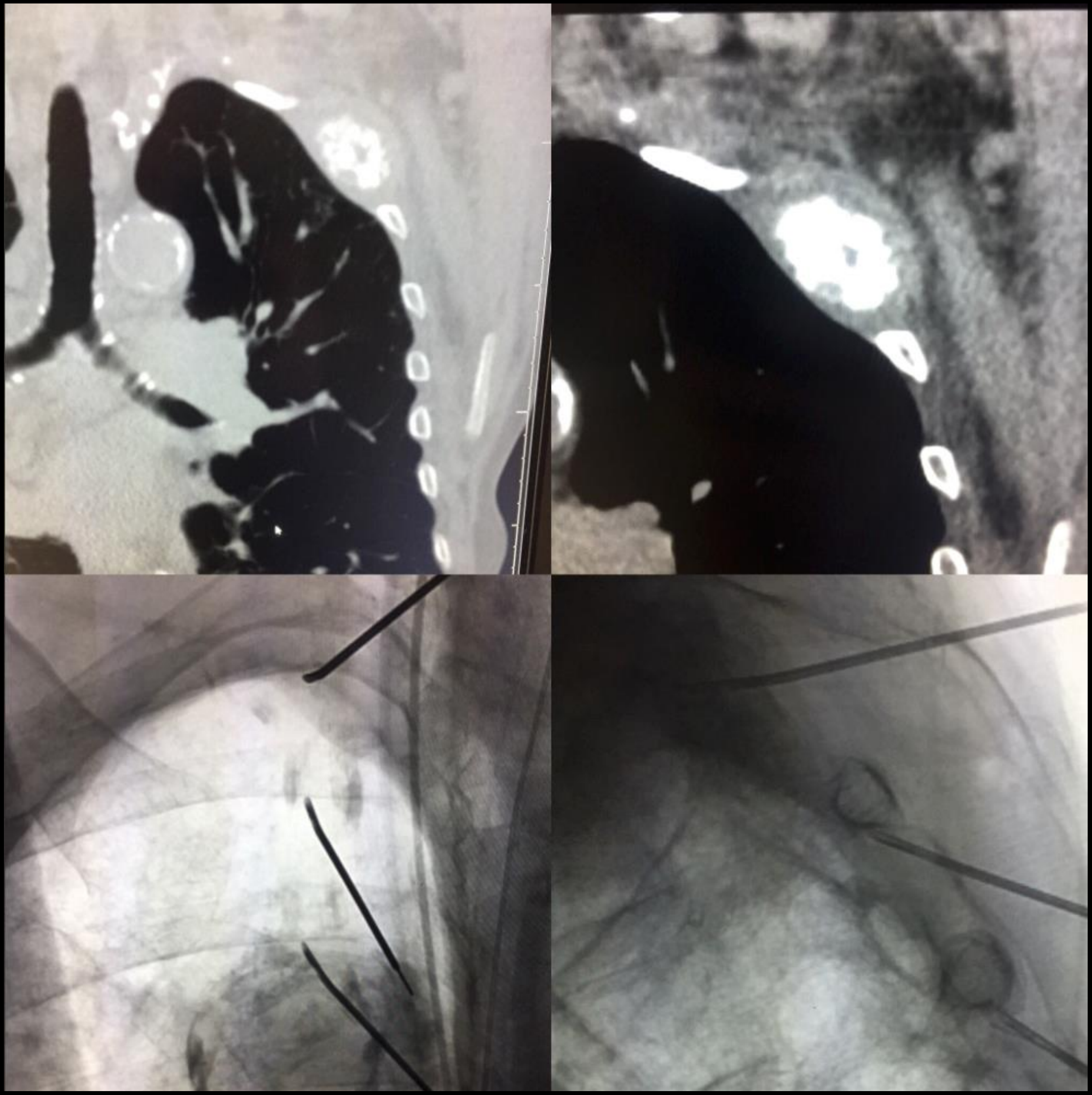
HCC metastasis with pain. MWA and cementoplasty.
– Case courtesy of Sean Tutton, MD



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.

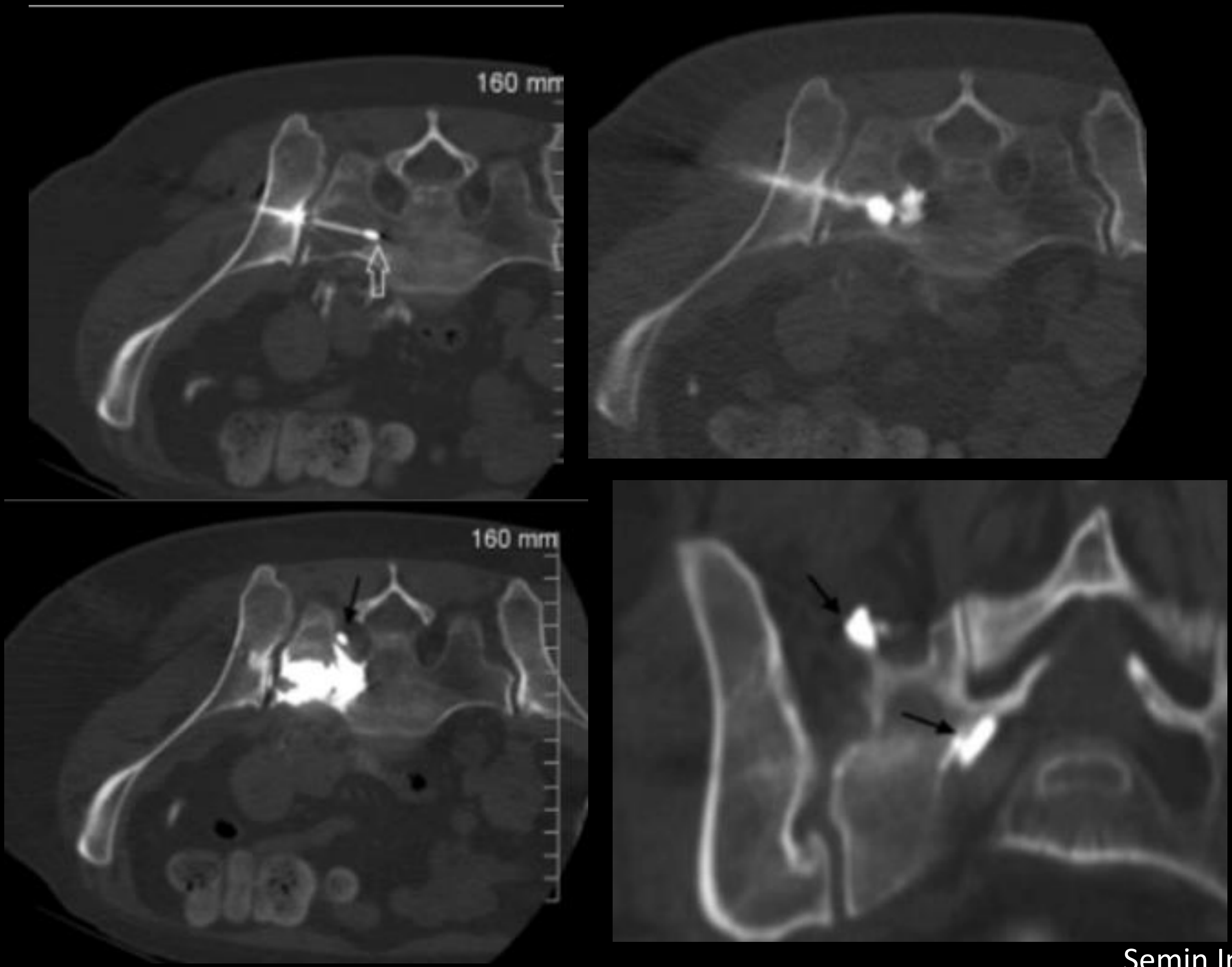
RFA of T2-4 intercostal nerves. 0/10 pain postop.

– 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

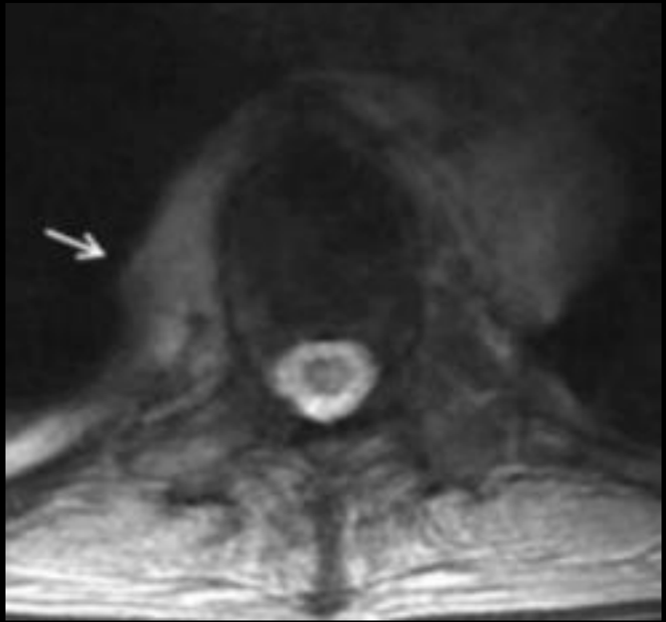
Semin Intervent Radiol 2015;32:163–173

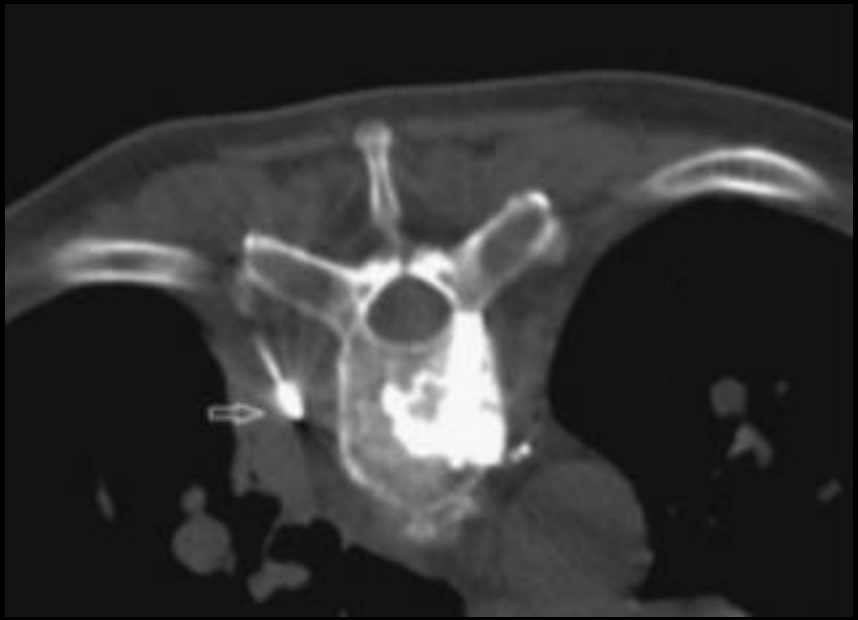


53 yo F with metastatic sarcoma to right sacral ala treated with cementoplasty.

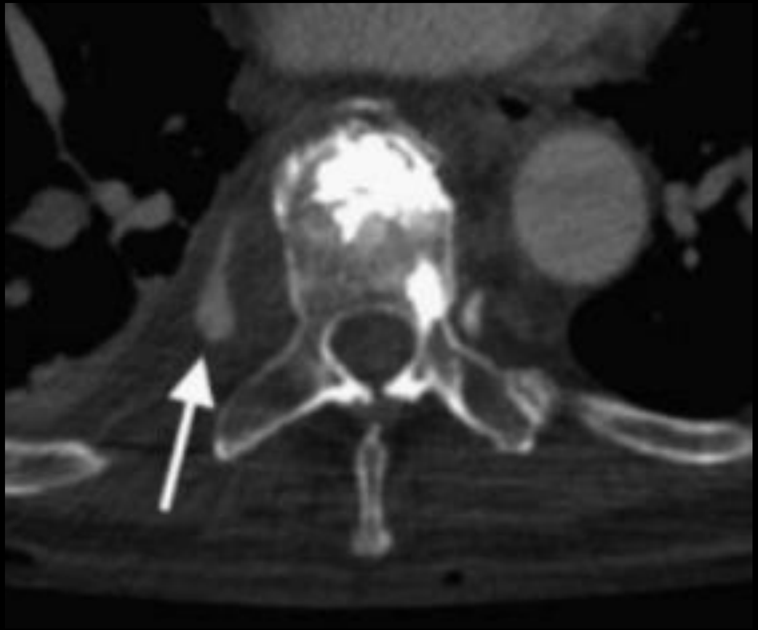
Extravasation of cement into S1 neuroforamen.

Semin Intervent Radiol 2015;32:163–173





62 yo F with lymphoma and right paraspinal mass. T9 intercostal artery pseudoaneurysm post biopsy.



Semin Intervent Radiol 2015;32:163–173

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

AJR:209, October 2017

Outcomes

TABLE 1: Outcomes of Percutaneous Ablation of Skeletal Metastases for Pain Palliation

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

AJR:209, October 2017

Outcomes

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

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

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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

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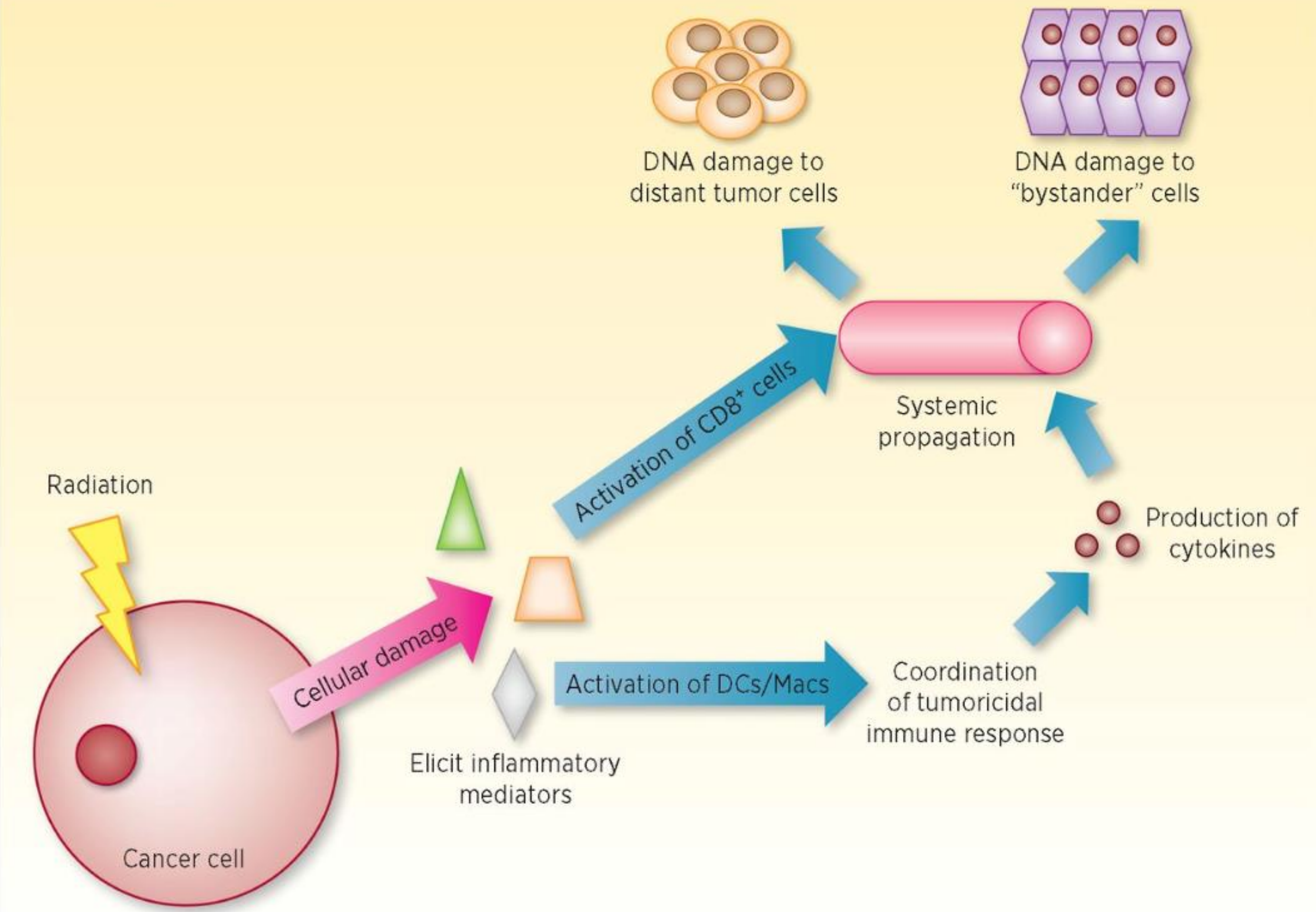

DNA damage to distant tumor cells
DNA damage to "bystander" cells
Activation of CD8+ cells
Systemic propagation
Radiation
Production of cytokines
Cellular damage
Activation of DCs/Macs
Coordination of tumoricidal immune response
Elicit inflammatory mediators
Cancer cell

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!