Southeastern Multidisciplinary Approaches to Cancer Symposium

Supportive Care in Oncology: Physiology of Bone Metastases and Interventional Pain Techniques

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Disclosures

- Consultant for Medtronic & Stryker.

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This presentation and/or comments will provide a balanced, non-promotional, and evidence-based approach to all diagnostic, therapeutic and/or research related content.

This presentation has been peer-reviewed and no conflicts were noted.

Cultural Linguistic Competency (CLC) & Implicit Bias (IB)

STATE LAW:
The California legislature has passed Assembly Bill (AB) 1195, which states that as of July 1, 2006, all Category 1 CME activities that relate to patient care must include a cultural diversity/linguistics component. It has also passed AB 241, which states that as of January 1, 2022, all continuing education courses for a physician and surgeon **must** contain curriculum that includes specified instruction in the understanding of implicit bias in medical treatment.

The cultural and linguistic competency (CLC) and implicit bias (IB) definitions reiterate how patients' diverse backgrounds may impact their access to care.

EXEMPTION:
Business and Professions Code 2190.1 exempts activities which are dedicated solely to research or other issues that do not contain a direct patient care component.

This presentation is dedicated solely to research or other issues that do not contain a direct patient care component.

Objectives

1. **Expand definition of spinal bone pain**
2. **Follow mechanism based approach to spinal bone pain**
3. **Understand limitations and benefits of spine metastasis treatment options**

Etiology of Bone Pain and Tumor Source of Pain

Physician grand rounds | metastatic spine disease, pain generators, and procedural implications

Clinical focus

- Why metastatic bone hurts
- How tumor biology shapes pain phenotype
- Where kyphoplasty and ablation fit in the pathway

Core themes

- Epidemiology of spine and skeletal metastasis
- Osteolytic vs osteoblastic remodeling failure
- Mechanical, inflammatory, neural, and treatment-related pain

Van den Brande 2022; Jiang 2020; Coleman 2006; Maccauro 2011

Why this matters clinically

Metastatic disease—not the primary tumor—is often the driver of morbidity and mortality

Key epidemiology

15.67%
clinical spinal metastasis rate

30–70%
autopsy prevalence in cancer patients

30–75%
back pain with spinal metastatic tumors

- Metastatic involvement of bone is common, under-detected, and frequently symptomatic
- Spinal disease matters because pain, instability, deformity, and neurologic compromise converge in one site
- Symptom burden may precede overt neurologic deficit; pain is often the earliest actionable signal

Perrin & Laxton 2004; Van den Brande 2022; Jiang 2020; Coleman 2006

Primary tumors with high skeletal metastatic burden

Autopsy data highlight which oncologies most commonly seed bone

Primary	Skeletal metastasis	Range
Breast	**73%**	47–85%
Prostate	**68%**	33–85%
Thyroid	**42%**	28–60%
Lung	**36%**	30–55%
Kidney	**35%**	33–40%
Rectal	**11%**	8–13%
Esophageal	**6%**	5–7%
GI tract	**5%**	3–11%

Clinical implication: breast, prostate, thyroid, lung, and renal malignancies warrant high vigilance for vertebral involvement when new axial pain emerges.

Coleman 2006

Pathobiology of tumor-related bone pain

Pain begins with remodeling failure at the bone–tumor interface

Cancer cell arrival in bone → **Osteoclast / osteoblast dysregulation** → **Microstructural failure + inflammatory signaling** → **Pain**

- Tumor-derived factors amplify osteoclast-mediated resorption or osteoblast-mediated disorganized deposition
- Trabecular weakening creates microfracture, endplate failure, and instability before gross collapse appears
- Inflammation and local neural irritation convert structural injury into persistent nociceptive pain

Weilbaecher 2011; Yin 2005; Lipton 2004; Maccauro 2011

Osteolytic lesions

The dominant morphology in spinal metastasis

78.3%

reported osteolytic fraction of spinal metastases

Clinical signature

- Trabecular destruction
- Void creation
- Compression susceptibility
- Often highly mechanical pain

- Osteoclast-predominant resorption produces structural hollowness and local collapse risk
- Pain derives from microfracture, periosteal stress, endplate violation, and instability-driven motion
- These lesions are often procedurally favorable for ablation + cement augmentation because there is biologic target plus mechanical void

Yin 2005; Lipton 2004; Chen 2013

Osteoblastic and mixed lesions

Pain still occurs—even when the vertebra looks “full” rather than lytic

Biology

- Disordered osteoblastic deposition around tumor cells
- Sclerotic architecture does not equal biomechanical normality
- Mixed lesions often combine brittle sclerosis with focal lysis

Procedural implications

- Less available void for cement
- Higher intravertebral pressure during injection
- Need for slow fill, pressure awareness, and careful leakage surveillance

Lipton 2004; Chen 2013; Murphy 2007; Alpantaki 2021

Source of pain

The vertebra hurts because it is failing as a load-bearing organ

- Tumor invasion
- Endplate collapse
- Nerve compression
- Edma and swelling
- Facet loading change

Burton 2005; Schallmo 2024; Lee & Park 2019

Mechanical source of pain

The vertebra hurts because it is failing as a load-bearing organ

Microfracture → **Collapse / endplate failure** → **Pain with motion**

- Trabecular disruption starts before dramatic radiographic collapse
- Periosteal stretch and endplate injury increase nociceptive load
- Schmorl-like endplate violations may represent clinically relevant fracture behavior in metastatic bone

Burton 2005; Schallmo 2024; Lee & Park 2019

Tumor interface, inflammation, and neural pain

Not all vertebral pain is purely fracture-driven

Tumor interface

- Bone–tumor border is metabolically active
- Local cytokines sensitize nociceptors
- Ongoing resorption/deposition sustains pain even at rest

Neural contribution

- Basivertebral nerve irritation
- Epidural or foraminal extension → radicular symptoms
- Inflammatory edema can amplify pain before frank compression

Chiu & Mehta 2020; Burton 2005; Heymann 2021

Radiation as both treatment and pain modifier

Radiotherapy helps many patients—but it can also alter the bone pain landscape

Benefits

- Established palliative option for painful bone metastasis
- Can reduce tumor burden and nociceptive signaling
- Often integrated with systemic therapy and/or procedures

Limitations / iatrogenic effects

- Local tissue injury
- Vertebral compression fracture risk after SBRT
- Rare but important myelopathy risk in retreatment settings

McVeigh 2024; Sahgal 2013; Dibs 2024; Gales 2023; Schaub 2019

Which tumors are less radiosensitive?

Histology matters when pain persists despite standard radiation pathways

Often discussed as less favorable for conventional Radiotherapy response

- NSCLC
- Renal cell carcinoma
- Melanoma
- Sarcoma

- Radioresistance is not absolute; modern stereotactic approaches still have a major role
- However, persistent focal pain, progressive lytic destruction, or need for immediate mechanical stabilization may favor adjunctive ablation/augmentation
- Thermal ablation is comparatively histology-agnostic at the level of direct local cytotoxicity

Fertil 1981; Malaise 1986; Gerszten 2009; Di Staso 2011

When does kyphoplasty enter the pain pathway?

Best aligned with vertebral mechanical failure and painful pathologic compression

- Painful pathologic vertebral compression fracture
- Mechanical axial pain with collapse or threatened collapse
- Need for rapid stabilization and improved mobilization
- Adjunct to ablation when tumor pain and fracture pain coexist

What it treats best

- Micromotion
- Load-related pain
- Vertebral body instability
- Kyphotic progression tendency

Evidence base: improved pain and function in cancer-related VCFs; lower leakage profile often cited for kyphoplasty vs vertebroplasty.

Berenson 2011; Sørensen 2019; Phillips 2002

How ablation relieves pain

Biologic debulking plus local denervation effect

Tumor-directed effects

- Thermal cytotoxicity reduces viable tumor burden
- Decreases local inflammatory signaling
- Can create additional cavity for subsequent cement fill

Pain-directed effects

- Interrupts pain-conducting fibers within lesion field
- Targets painful bone–tumor interface
- Useful when pain is not purely fracture-mediated

Tomasian 2016; Tomasian 2018; Aman 2021

Ablation platforms in practice

Technology differs; principle remains local cytotoxic control

RFA

Most established
Most published
Often paired with cement

Microwave

Fast heating
Potentially larger zones
Some series: more complications

Cryoablation

Ice-ball visualization
Useful near critical structures
Strong pain data

Other

HIFU
Brachytherapy
ECT / electroporation

Goetz 2004; Anchala 2014; Evans 2024; Yao 2023; Khanmohammadi 2023; Cazzato 2022

Why combine ablation with cement augmentation?

Most patients have both biologic pain and mechanical pain

Ablation + **Kyphoplasty / cementoplasty** = **Biologic + structural pain control**

- Ablation treats tumor burden and painful interface biology
- Cement augmentation treats fracture biology and instability
- Combined strategy often fits lytic vertebral lesions with pain, collapse, or threatened collapse

Tomasian & Jennings 2020; Levy 2020; Zheng 2014

Outcome signal: rapid pain relief is plausible

Prospective and multicenter data support meaningful short-term palliation

OPuS One

Pain improvement by day 3
Reduced opioid use
Durability beyond 1 year

- Registry data suggest clinically meaningful and often rapid palliation after RFA-based vertebral tumor ablation + cementoplasty
- Signal appears durable and may be independent of prior or subsequent radiation in selected patients
- Interpretation remains limited by heterogeneity in lesion type, histology, devices, and combined-treatment sequencing

Levy 2020; Levy 2023; Lindquester 2025

Contraindications and procedural risk flags

Patient selection remains the main safety intervention

Risk conditions

- Extensive posterior wall disruption
- Marked epidural disease with cord compromise
- Uncontrolled coagulopathy
- Active infection

Technical risk amplifiers

- Blastic fill / high intravertebral pressure
- Posterior cortical breach
- Large vascular channels
- Heat risk to neural structures without planning margins

Newman 2020; Tomasian & Jennings 2020; Aman 2021

Extra-axial lesions: same principles, different biomechanics

Pelvis and long bone metastases require anatomy-specific safety planning

Pelvis / sacrum / acetabulum

- Load transfer and cortical breach are major issues
- Leakage can violate joints, foramina, or soft tissues
- Fixation may need to accompany ablation/cementoplasty

Long bones

- Weight-bearing failure risk may dominate pain pathway
- Need to consider impending fracture thresholds
- Ablation often paired with osteosynthesis rather than stand-alone cement

Lee 2023; Garnon 2019; Wallace 2016; Zheng 2024; Pusceddu 2021

NCCN / multidisciplinary positioning

The question is not radiation versus procedure—it is which mechanism needs treatment now

- Use multidisciplinary frameworks to separate oncologic control, mechanical instability, neurologic urgency, and systemic reserve
- Radiation oncology is essential for field control and histology-specific planning
- Interventional procedures matter when pain is mechanical, focal, rapid-relief dependent, or relatively radiorefractory
- Shared triage improves sequencing, referrals, and patient-centered palliation

Useful frameworks: NOMS, multidisciplinary metastatic spine algorithms, NCCN adult cancer pain guidance.

Newman 2020; Wallace 2019; Swarm 2019; NCCN 2026 site

Take-home points

Bone metastasis pain is biologic, mechanical, neural, and treatment-modified—often all at once

- Osteolytic destruction is the dominant vertebral pain substrate; fracture is often the treatable mechanism
- Tumor interface biology and inflammatory/neural signaling explain pain beyond simple collapse
- Kyphoplasty addresses structural pain; ablation addresses tumor biology and nerve component; combination therapy addresses both
- Best practice is multidisciplinary and mechanism-driven—not modality-driven

Van den Brande 2022; Coleman 2006; Tomasian 2020; Swarm 2019

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