Biomechanics of Percutaneous tumor Therapy

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Epidemiology

- Metastasis are the most common spinal tumors
- Vertebral body is the most common site
- 40% of cancer patients develops vertebral metastasis
  - Breast 75%
  - Lung 35%
  - Renal 25%
Conventional Treatment

- **Medical**
  - Steroids (*Decadron 10mg IV – stat, then 4 mg IV/PO Q6hr*)
  - Pain Management
  - Chemotherapy

- **Radiation Therapy**
  - Radio-resistant tumors
  - Instability
  - Spinal cord compression
  - Acute or progressive neurologic deterioration
  - Previous radiation exposure to spinal cord
  - Life expectancy of at least 3-6 month

- **Surgical (palliative)** (*Fourney DL 2004*)
  - Palliative surgical procedures for symptomatic relief and stabilization.
Radiation Therapy

- Most common treatment schedule is 3000cGy in 10 fractions
- Side effects limited to normal structures in treatment field
- A long proven record in pain relief, decrease use of analgesics, local control of the disease as well as minimal side effects.
- Up to 70% neurologic improvement

Maranzano E. Int J Radiat Oncol Biol Phys 1995
Treatment Results

- More than 3 months to restabilize vertebra and may not be effective in the impending collapse

- Pain relief may be delayed for up to 2 weeks

- Most cases in which patients meets clinical criteria for surgery, the role of radiation therapy is that of adjuvant therapy and must be performed after surgery to reduce the risk of post operative complications

Biomechanics of Pathologic Spine Fractures

• Center of gravity (CG) moves forward
• Large bending moment created
• Posterior muscles and ligaments must counterbalance increased bending
• Anterior spine must resist larger compressive stresses

White III and Panjabi 1990
Stability and Pain in malignant lesions

- Pain in malignant lesions is due to
  - Local involvement
  - Spinal Instability
- Stability is needed for both
  - Prevent future collapse
  - Pain relief
- Up to 41% of patients who undergo radiation experience bone fractures

Stability and Pain in malignant lesions

Tumor → Instability collapse → Pain
78 years old man with Multiple Myeloma

2 years later
Metastatic Breast Cancer, 45 years-old
Columns of Denis
**Location** of tumor and hence, bone destruction
May play a role in the patient's risk of fracture
Destruction of equal amount of tissue

Anterior and Middle column of Denis are disrupted

1/3 Anterior and Middle column of Denis are disrupted
Anterior approach

Anterior and Posterior approach
76 year old man with Hepatoma
45 years old women with Breast Cancer
82 y male, L5 Metastatic Sq. Cell Lung
Spinal Instability in patients with tumors

Kostuik et al

Unstable if:

3 or more segments are involved
Angulations more than 20 degrees
Weinstein 1989

Anterior Corpectomy and reconstruction
Why this is important

• It is not just injecting cement …Smart augmentation

• Anterior placement of cement is beneficial
  – Away from thecal sac
    • Compromised posterior wall
    • Epidural extension
  – Helps stabilization
Cadaver studies

- Combined anterior and posterior reconstruction using a cement provides equal to or more stability than the intact spine.
- Posterior stabilization alone is an inferior method of reconstruction following total spondylectomy.
- PMMA has the advantage over traditional anterior reconstruction techniques in that it can be inserted using a posterior approach.
- Interestingly enough this had been suggested by Harrington KD [had described the use of PMMA for vertebral body anterior stabilization for metastatic lesions in 1981.

Why this is important

• Can we alter surgical management safely!!
  – Stabilization of the anterior column
  – Controlled anterior cement injection with posterior laminectomy in stead of anterior corpectomy!

JJ Verlaan, WJ Dhert, AJ Verbout, FC Oner
balloon VP in combination with pedicle screws in treatment of burst fractures Spine; (30) E73-E79, 2005

Biomechanical Analysis of Anterior Poly-Methyl-Methacrylate Reconstruction Following Total Spondylectomy for Metastatic Disease

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Daniele Ottaviano, BSc,† Andrew Castro, MD,‡ John H. Hooley, MD,* and
Patrick J. Boland, MD*
Combined anterior and posterior reconstruction using a cement construct provides equal to or more stability than the intact spine in all testing modes.
Summary
Radiation therapy and Cement Augmentation

- Radiation therapy is the gold standard but
  - Does not provide stabilization
  - Delayed pain relief
  - May weaken the bones initially
- Cement Augmentation
  - Provide stability
  - Immediate pain relief
  - Potential to alter surgical management
  - Allows concurrent diagnosis
  - Does not interfere with Radiation
Pitfalls

- Vertebrae post-vertebroplasty may show greater spinal canal narrowing under load
  - Cement moderately compresses tumor and fills cancellous regions around lesion.
  - Exacerbated when cement anterior and lateral to lesion and if disruption of posterior cortex/better with posterior cement filling

- Vertebroplasty (?Kypho) produces higher intravertebral pressures in vertebrae containing simulated lytic metastasis than in intact vertebrae.
  - Pressures generated in tumor specimens are sufficiently elevated to cause embolic phenomenon.
Why consider Ablation?

• Restoration of intact vertebral stability is possible in metastatic vertebrae after 30% tumor ablation and 1-2 ml bone cement augmentation.

• Ablation therapy adds the benefit of immediate cell death, controlled lesion size (cavity creation without pressure), thrombosis of intra-vertebral venous plexus using image guidance.
  – Schaefer O et al. AJR 2003; 180: 1075-77
Cadaver studies and mathematical models

• Creation of a cavity in the vertebra;
  – Allow for preferential cement deposition in the region affected by lytic disease.
  – Facilitate restoration of stability to the involved vertebrae.

• A protocol was developed on the basis of the findings of this study suggesting recommended cement volume for injection as a function of remaining tumor volume after ablation.

• Tschirhart CE, Finkelstein JA, MD, Whyne CM. Optimization of Tumor Volume Reduction and Cement Augmentation in Percutaneous Vertebroplasty for Prophylactic Treatment of Spinal tumors. Spinal Disord Tech 2006;19(8) 584-590
Transverse cross-section of metastatic tumor reduction and PMMA augmentation scenarios.

11.5% initial tumor

23% initial tumor
The recommended volume is based on restoration of intact VB.

1-No cement is suggested with tumor volume below 7.5% vertebral body volume
2-PMMA volume should be equivalent to at least the volume of ablated tumor to ensure sufficient infiltration of voids previously occupied by metastatic tissue.
Ablation/ creation of void in Metastatic Lesions
Benefits of Anterior ablation

- 1-Controlled cement delivery
- 2-Add stabilization of anterior column
- 3-Potential to alter surgical treatment
- 4-Restoration of intact vertebral stability
- 5-Decrease intra-vertebral pressure
- 6-Avoid embolic phenomena
- 7-Away from thecal sac
  - Epidural extension
  - Compromised posterior cortex
How to ablate

• Radiofrequency
  – Heat generation, general anesthesia, potential for complete irradication

• Coblation (Plasma Mediated RF)
  – No heat
  – Tissue debulking or removal

• Cryo-ablation
  – Very well controlled, CT guidance

• Microwave, laser …..
Kyphoplasty

1. Create cavity with tissue displacement
2. This is different from tissue ablation or removal
3. Balloon follows the pass of least resistance
4. Does not work in sclerotic bones
5. Tumor embolization
Thank you