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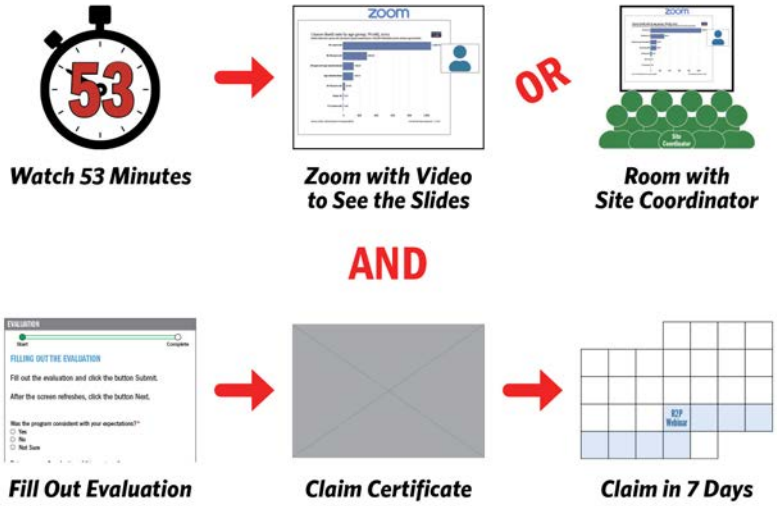

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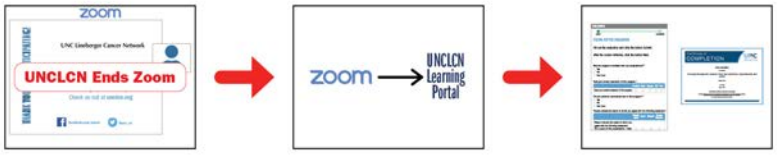

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7

Our Presenter

Michael Galgano,
MD, FAANS

Dr. Michael Galgano is a board-certified neurosurgeon specializing in complex spinal surgery.

While Dr. Galgano treats a variety of spinal conditions such as trauma, degenerative disease, and infections, his clinical and academic interest has focused on spinal oncology and deformity surgery.

Dr. Galgano first developed an interest in spinal conditions while working as a nurse attendant on the spinal cord and traumatic brain injury unit at Burke Rehabilitation Hospital in White Plains, NY. He then became a clinical research associate there, engaging in research projects focusing on both stroke and spinal cord injury rehabilitation with robotic applications.

After attending medical school at St. George's University, Dr. Galgano completed his neurosurgical residency at Upstate Medical University. During his final year of training, Dr. Galgano completed a complex and oncological spine surgery fellowship under the world-renowned spinal tumor surgeon, Dr. Ziya Gokaslan at Brown University.

8

Our Presenter

9

Our Presenter

5. Michael Galgano, MD, FAANS, was a nurse attendant for TBI/SCI patients prior to medical school.

4. He has a very robust surgical video library.

10

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12

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2. Dr. Galgano is a part time basketball coach for 7th/8th grade girls. He has been a basketball junkie his entire life.

13

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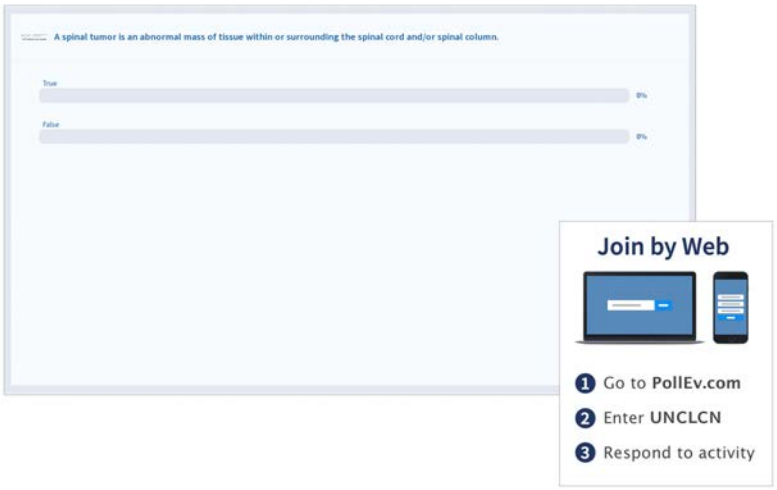
3. He enjoys going on tropical hikes & kayaking.
2. Dr. Galgano is a part time basketball coach for 7th/8th grade girls. He has been a basketball junkie his entire life.
1. His favorite part of the day is coming home to his beautiful wife Jessica & 4 kids (Caroline, Bella, Charlotte, and Mikey)!

14

Sample Poll Everywhere Question



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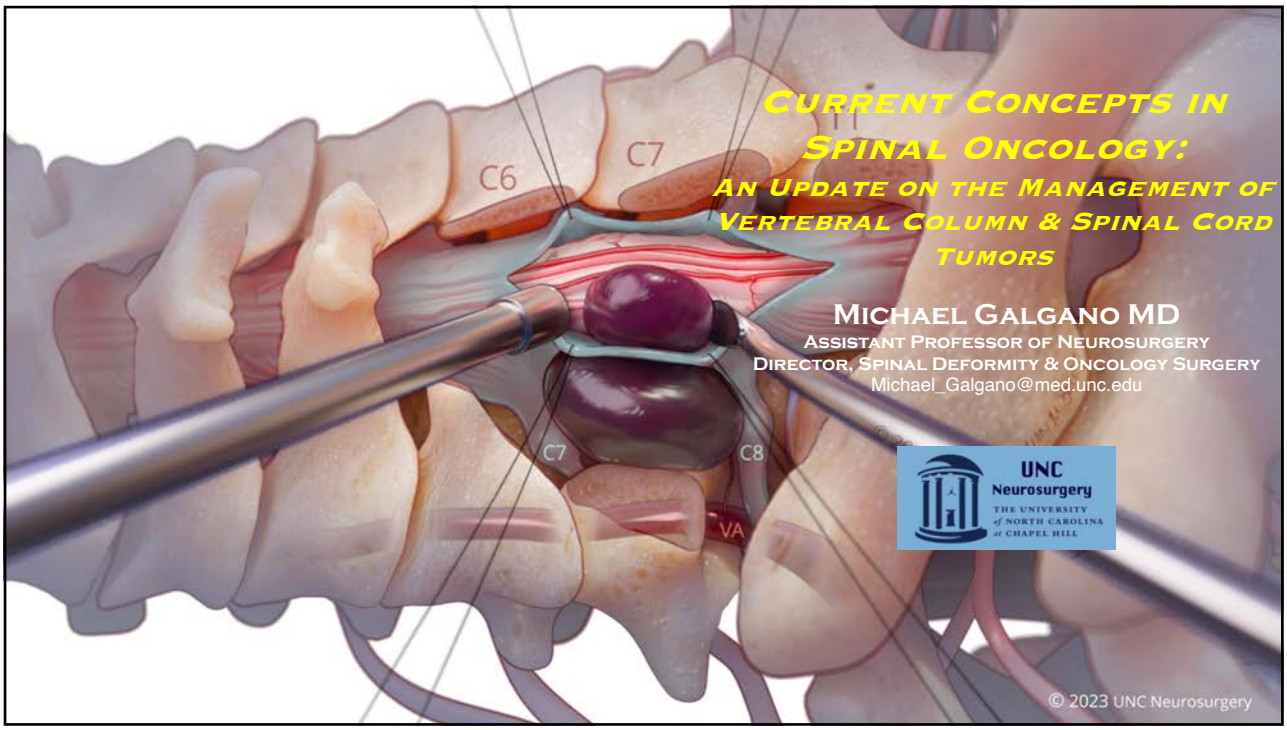

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- 2006 – 2010: St. George's University
  - MD
- 2010 – 2017: SUNY Upstate University
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- 2017-2018: Brown University
  - Complex & Oncological Spine Surgery Fellowship
- 2018 – 2022: SUNY Upstate University
  - Neurosurgery Faculty
- 2022 – Present: University of North Carolina
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Neurorehabilitation and Neural Repair

Intensive Sensorimotor Arm Training Mediated by Therapist or Robot Improves Hemiparesis in Patients With Chronic Stroke


A pilot study of activity-based therapy in the arm motor recovery post stroke: a randomized controlled trial

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Ziya Gokaslan MD

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UNC NEUROSURGERY

Spine Tumor Program

29

Objectives

- Understand the different management strategies for spinal cord & vertebral body tumors as they relate to location, neurological exam, histology, and overall prognosis
- Recognize the multi-faceted process of executing a patient-specific treatment plan
- Understand the contribution of co-morbidities and frailty to the management of patients with spinal tumors

30

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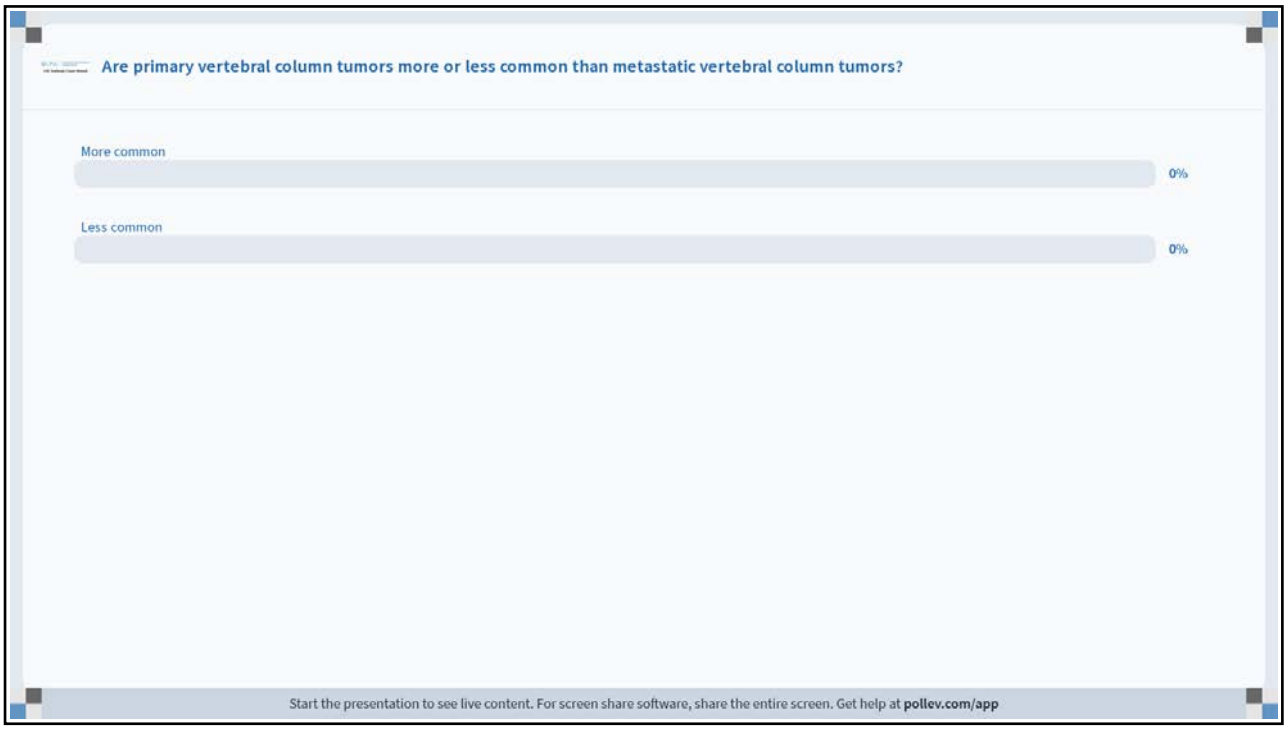
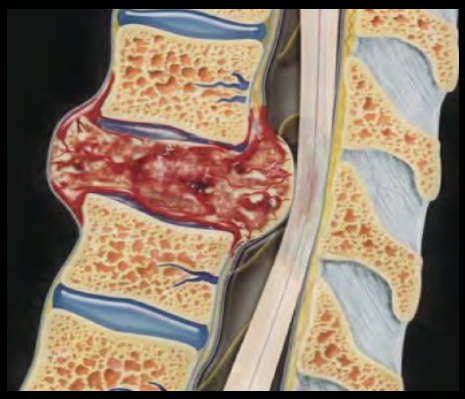


34

Metastatic Vertebral Column Tumors

Palliative

- Preserve neurological function
- Stabilize Spine
- Relieve Mechanical Pain
- Maintain / Regain Functionality



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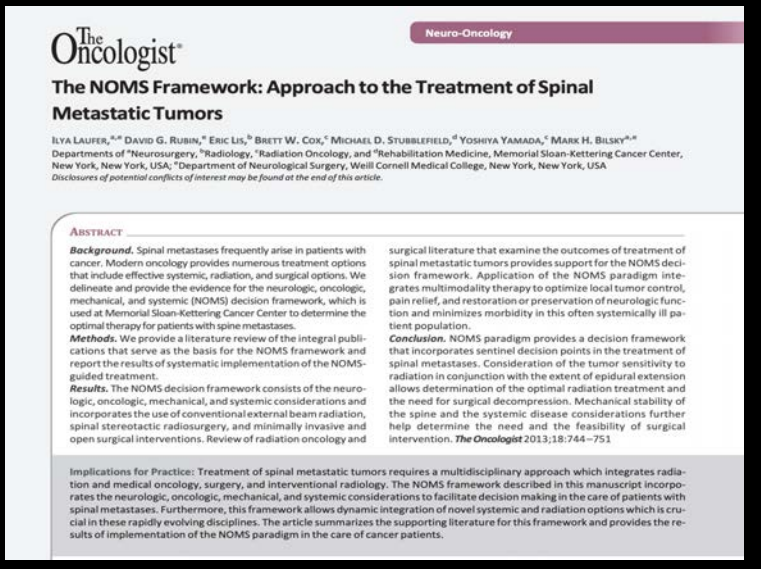
NOMS

- *N*eurologic
- *O*ncologic
- *M*echanical Stability
- *S*ystemic Disease



The Oncologist

Neuro-Oncology

The NOMS Framework: Approach to the Treatment of Spinal Metastatic Tumors

Ilya Laufer,[a,e] David G. Rubin,[a] Eric Lis,[b] Brett W. Cox,[c] Michael D. Stubblefield,[d] Yoshiya Yamada,[c] Mark H. Bilsky[a,e]
Departments of [a]Neurosurgery, [b]Radiology, [c]Radiation Oncology, and [d]Rehabilitation Medicine, Memorial Sloan-Kettering Cancer Center, New York, New York, USA, [e]Department of Neurological Surgery, Weill Cornell Medical College, New York, New York, USA

Disclosures of potential conflicts of interest may be found at the end of this article.

Abstract

Background. Spinal metastases frequently arise in patients with cancer. Modern oncology provides numerous treatment options that include effective systemic, radiation, and surgical options. We delineate and provide the evidence for the neurologic, oncologic, mechanical, and systemic (NOMS) decision framework, which is used at Memorial Sloan-Kettering Cancer Center to determine the optimal therapy for patients with spine metastases.

Methods. We provide a literature review of the integral publications that serve as the basis for the NOMS framework and report the results of systematic implementation of the NOMS-guided treatment.

Results. The NOMS decision framework consists of the neurologic, oncologic, mechanical, and systemic considerations and incorporates the use of conventional external beam radiation, spinal stereotactic radiosurgery, and minimally invasive and open surgical interventions. Review of radiation oncology and surgical literature that examine the outcomes of treatment of spinal metastatic tumors provides support for the NOMS decision framework. Application of the NOMS paradigm integrates multimodality therapy to optimize local tumor control, pain relief, and restoration or preservation of neurologic function and minimizes morbidity in this often systemically ill patient population.

Conclusion. NOMS paradigm provides a decision framework that incorporates sentinel decision points in the treatment of spinal metastases. Consideration of the tumor sensitivity to radiation in conjunction with the extent of epidural extension allows determination of the optimal radiation treatment and the need for surgical decompression. Mechanical stability of the spine and the systemic disease considerations further help determine the need and the feasibility of surgical intervention. ***The Oncologist*** 2013;18:744–751

Implications for Practice: Treatment of spinal metastatic tumors requires a multidisciplinary approach which integrates radiation and medical oncology, surgery, and interventional radiology. The NOMS framework described in this manuscript incorporates the neurologic, oncologic, mechanical, and systemic considerations to facilitate decision making in the care of patients with spinal metastases. Furthermore, this framework allows dynamic integration of novel systemic and radiation options which is crucial in these rapidly evolving disciplines. The article summarizes the supporting literature for this framework and provides the results of implementation of the NOMS paradigm in the care of cancer patients.

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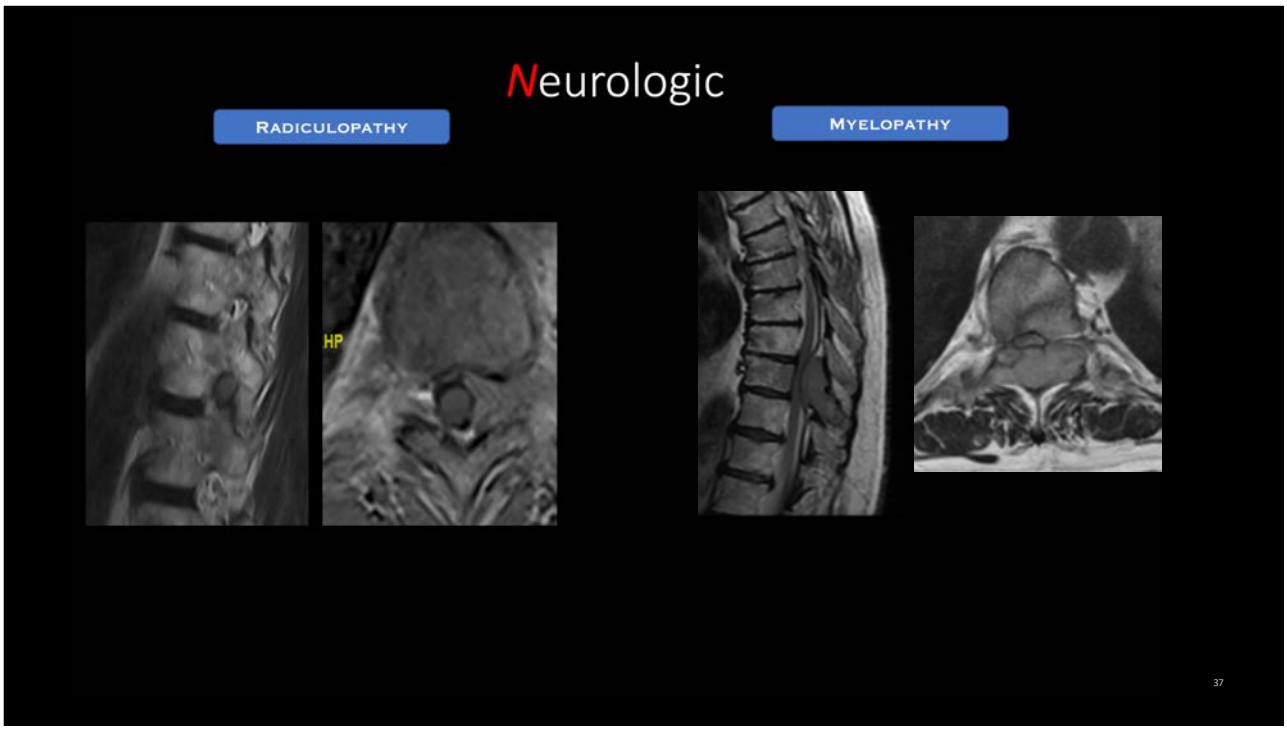
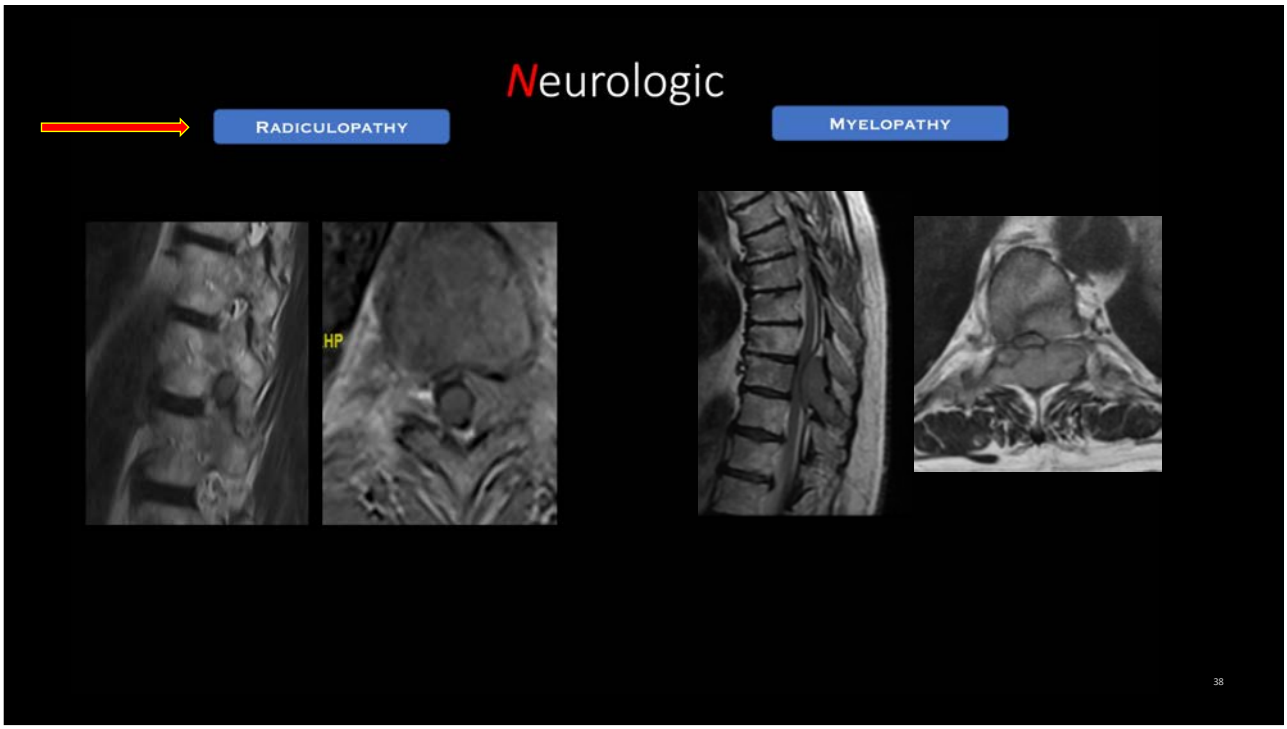

Neurologic
RADICULOPATHY
MYELOPATHY
HP
37

37


Neurologic
RADICULOPATHY
MYELOPATHY
HP
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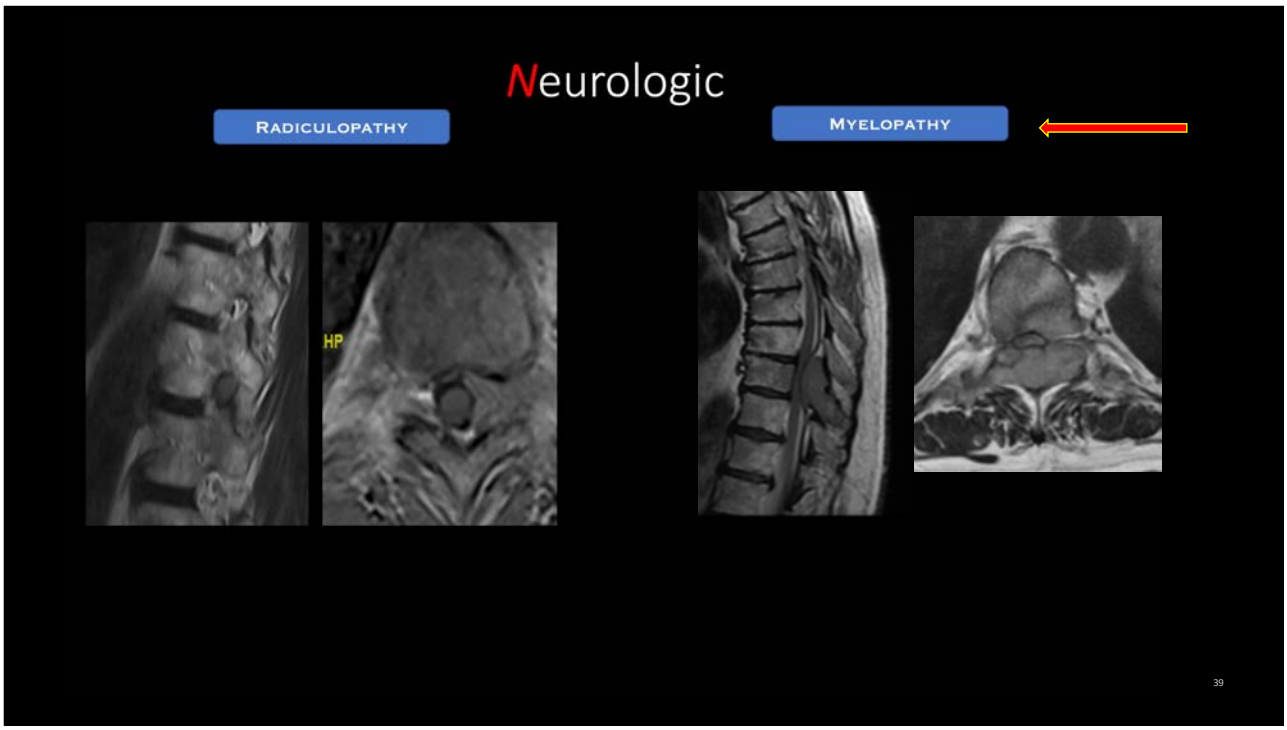
Neurologic
RADICULOPATHY
MYELOPATHY
HP
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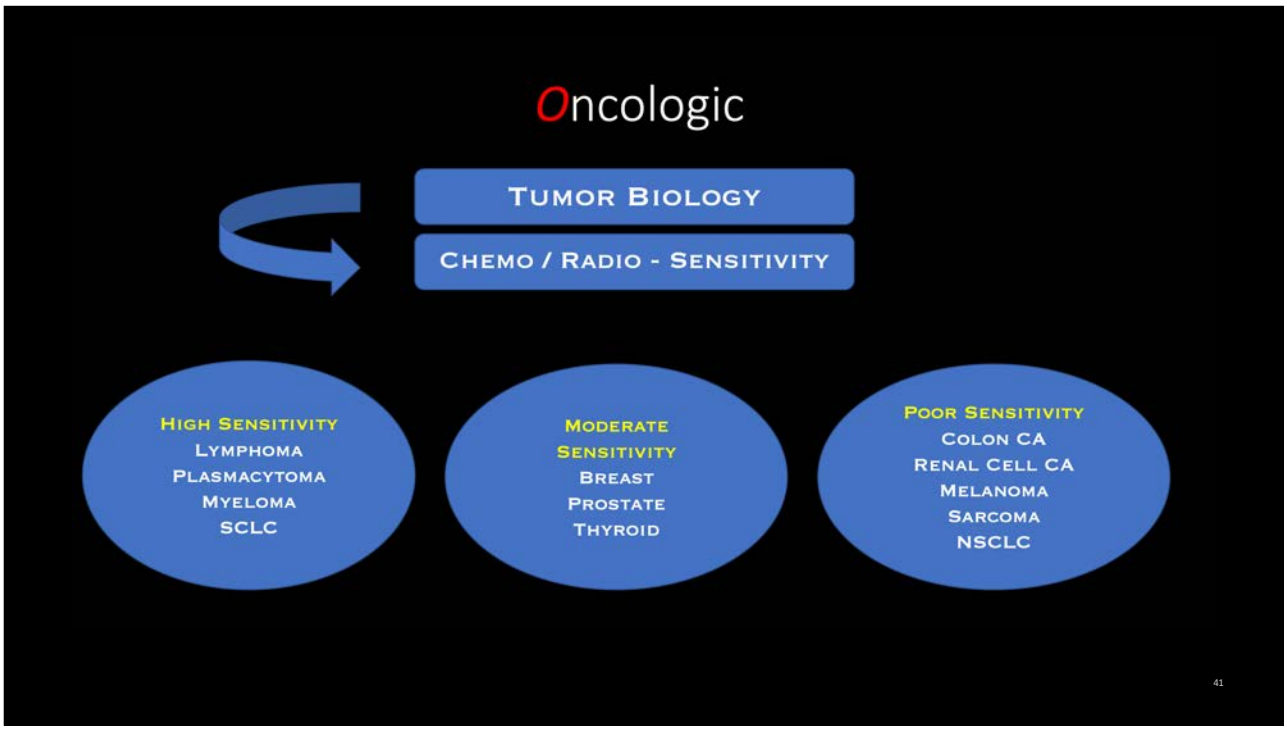
Neurologic
RADICULOPATHY
MYELOPATHY
HP
How long has the deficit been present?
40

40


Oncologic
TUMOR BIOLOGY
CHEMO / RADIO - SENSITIVITY
HIGH SENSITIVITY
LYMPHOMA
PLASMACYTOMA
MYELOMA
SCLC
MODERATE SENSITIVITY
BREAST
PROSTATE
THYROID
POOR SENSITIVITY
COLON CA
RENAL CELL CA
MELANOMA
SARCOMA
NSCLC
41

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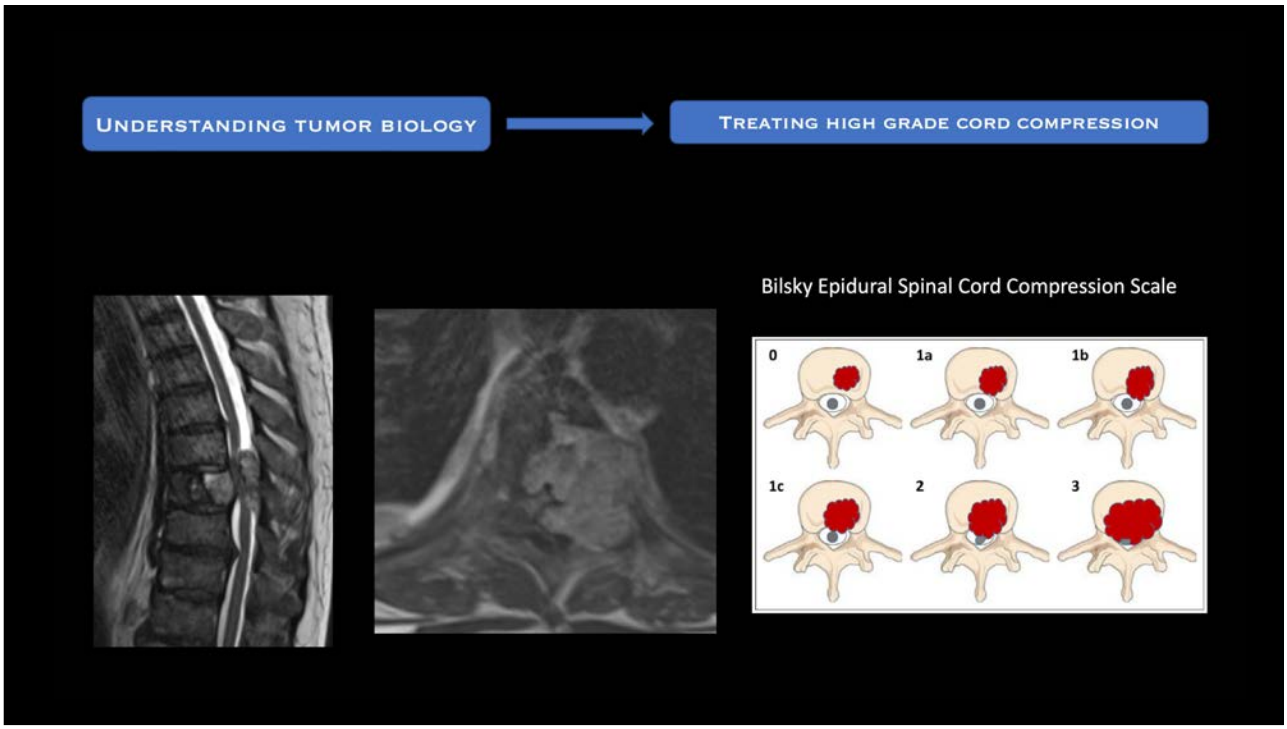
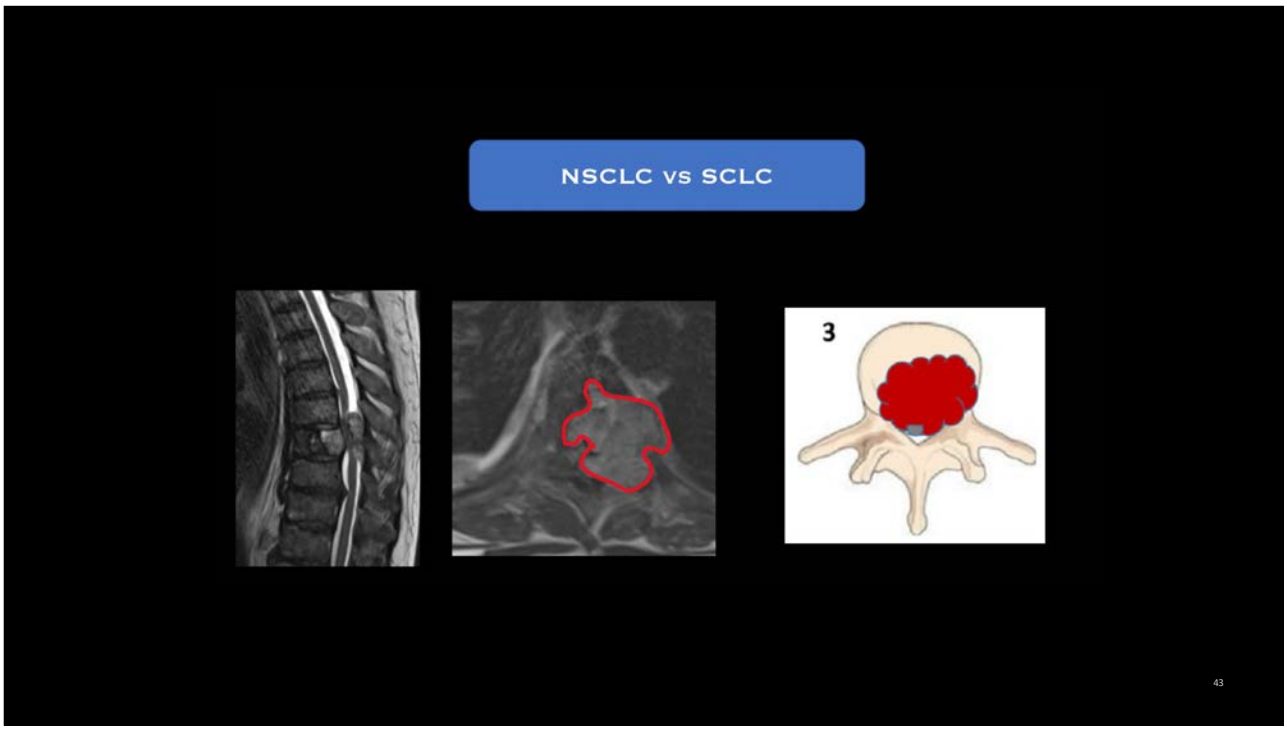

UNDERSTANDING TUMOR BIOLOGY
TREATING HIGH GRADE CORD COMPRESSION
Bilsky Epidural Spinal Cord Compression Scale
0
1a
1b
1c
2
3

42


NSCLC vs SCLC
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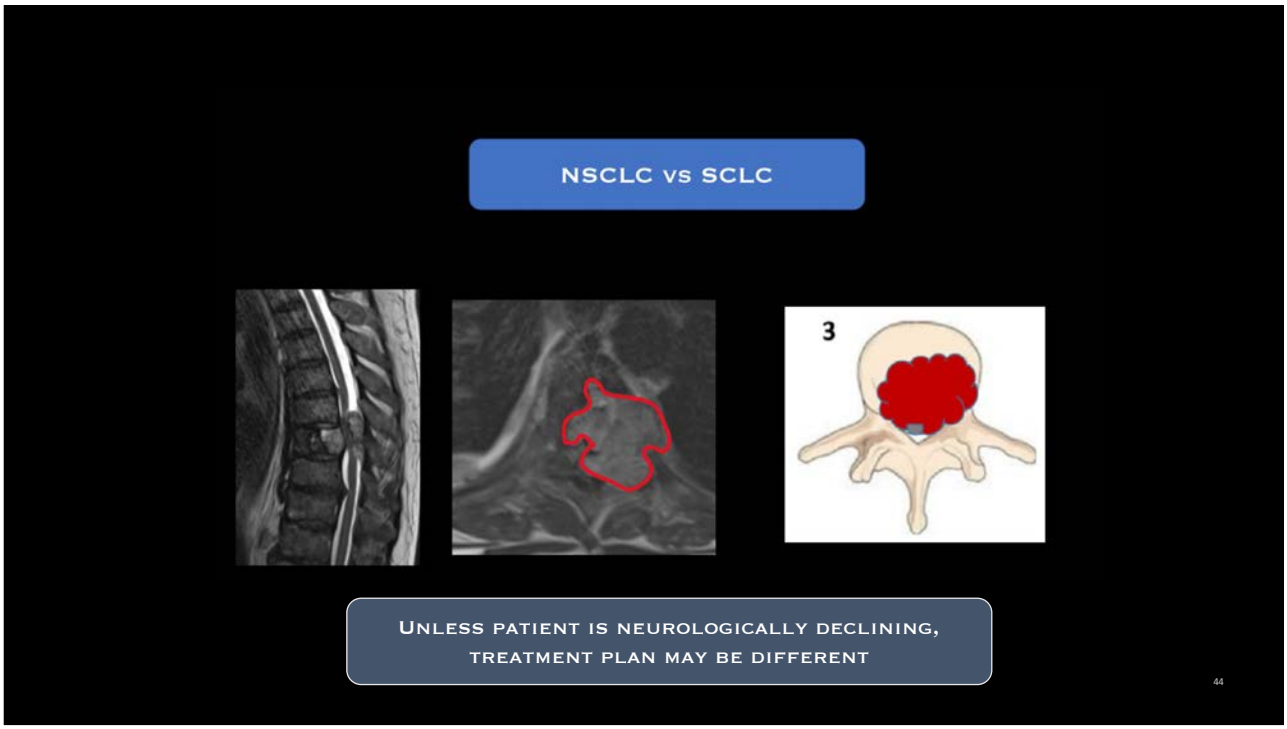
NSCLC vs SCLC
3
Unless patient is neurologically declining, treatment plan may be different
44

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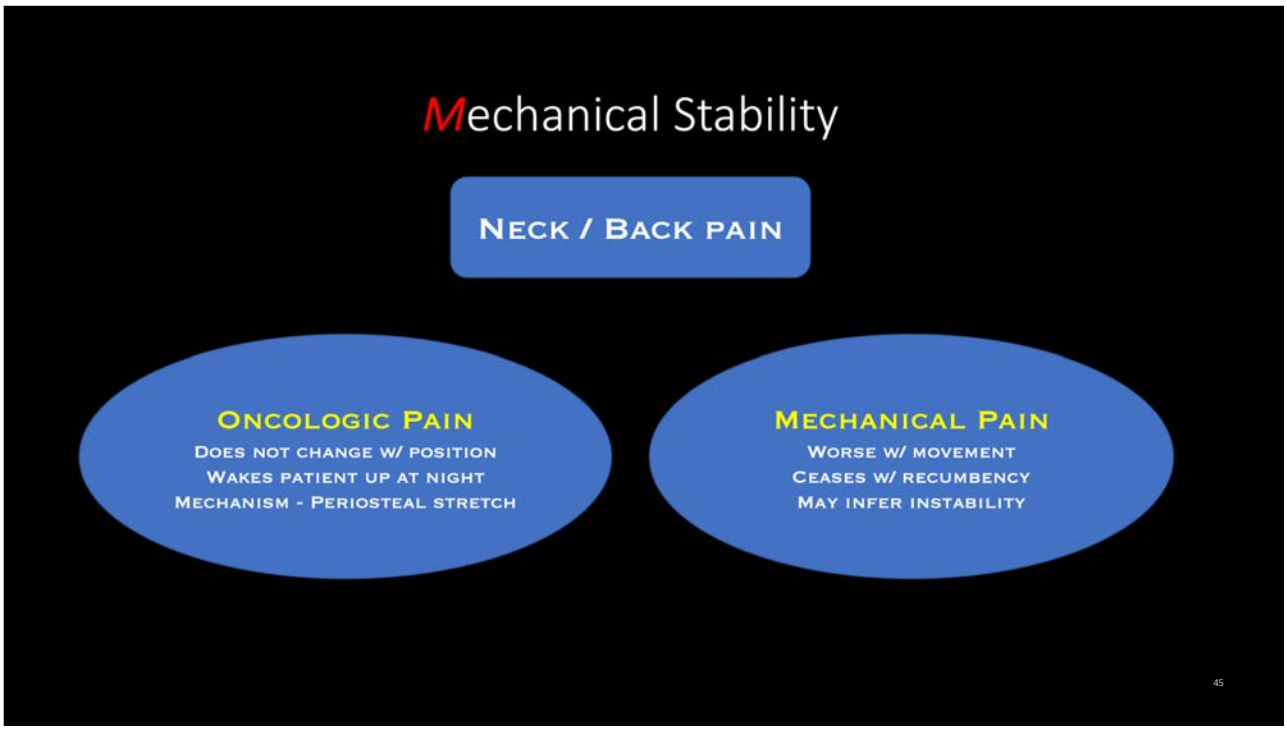
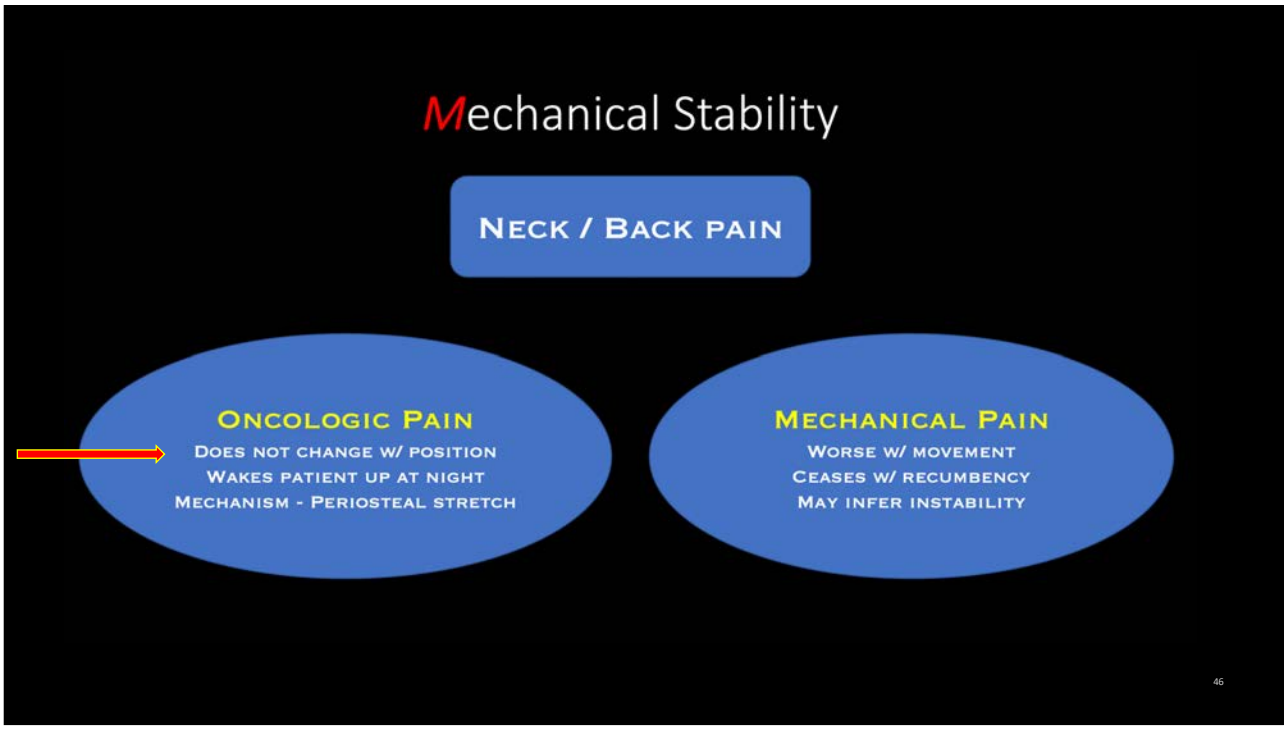

Mechanical Stability
Neck / Back pain
Oncologic Pain
Does not change w/ position
Wakes patient up at night
Mechanism - Periosteal stretch
Mechanical Pain
Worse w/ movement
Ceases w/ recumbency
May infer instability
45

45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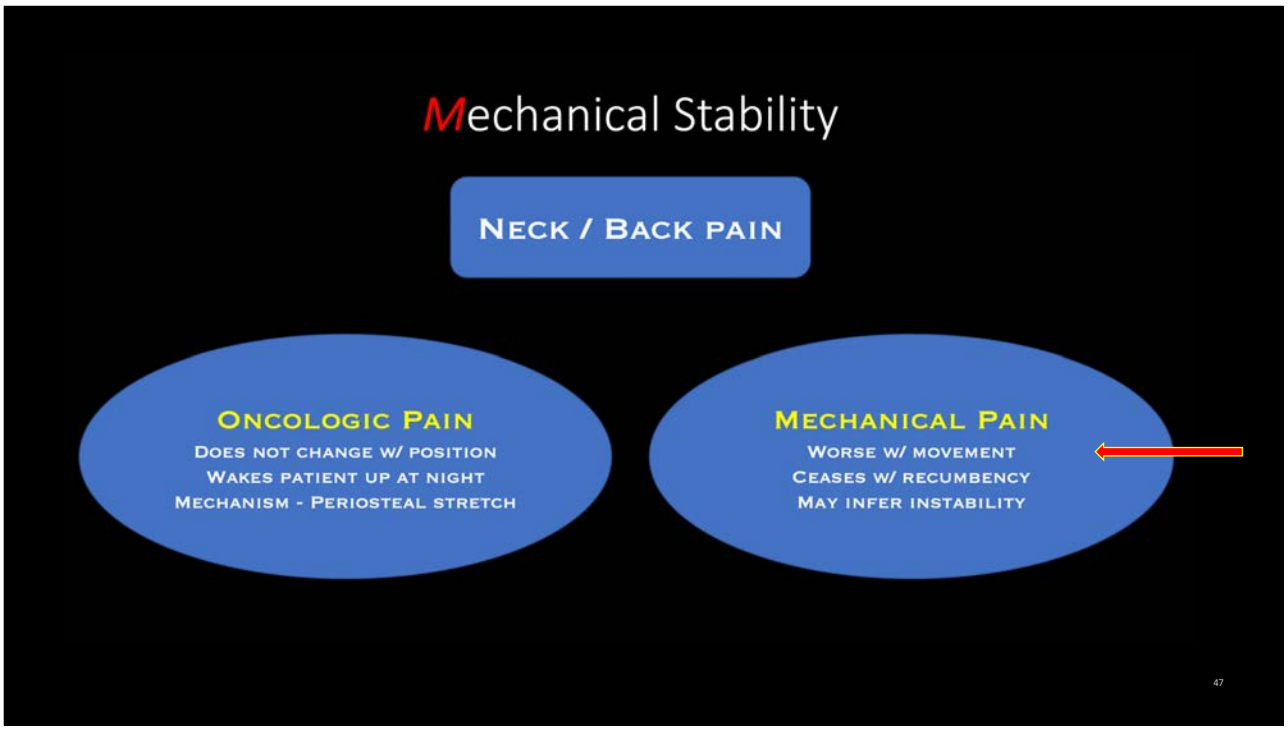

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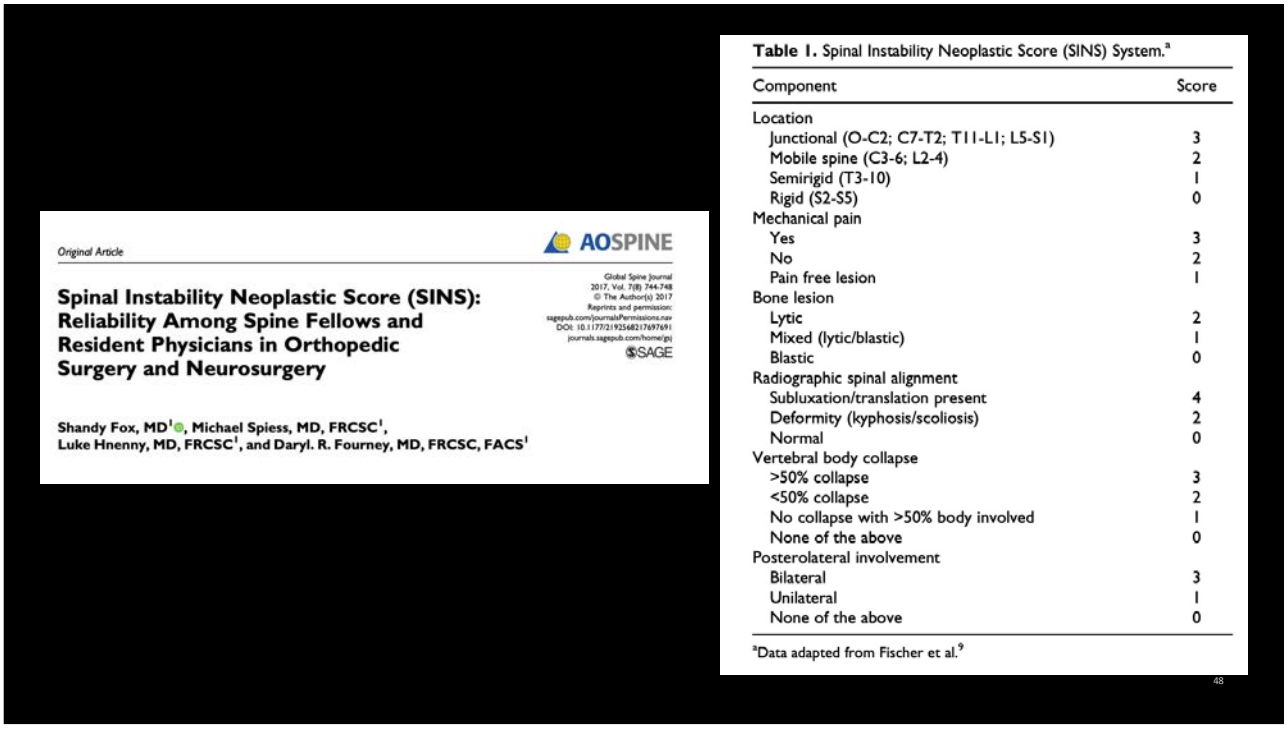


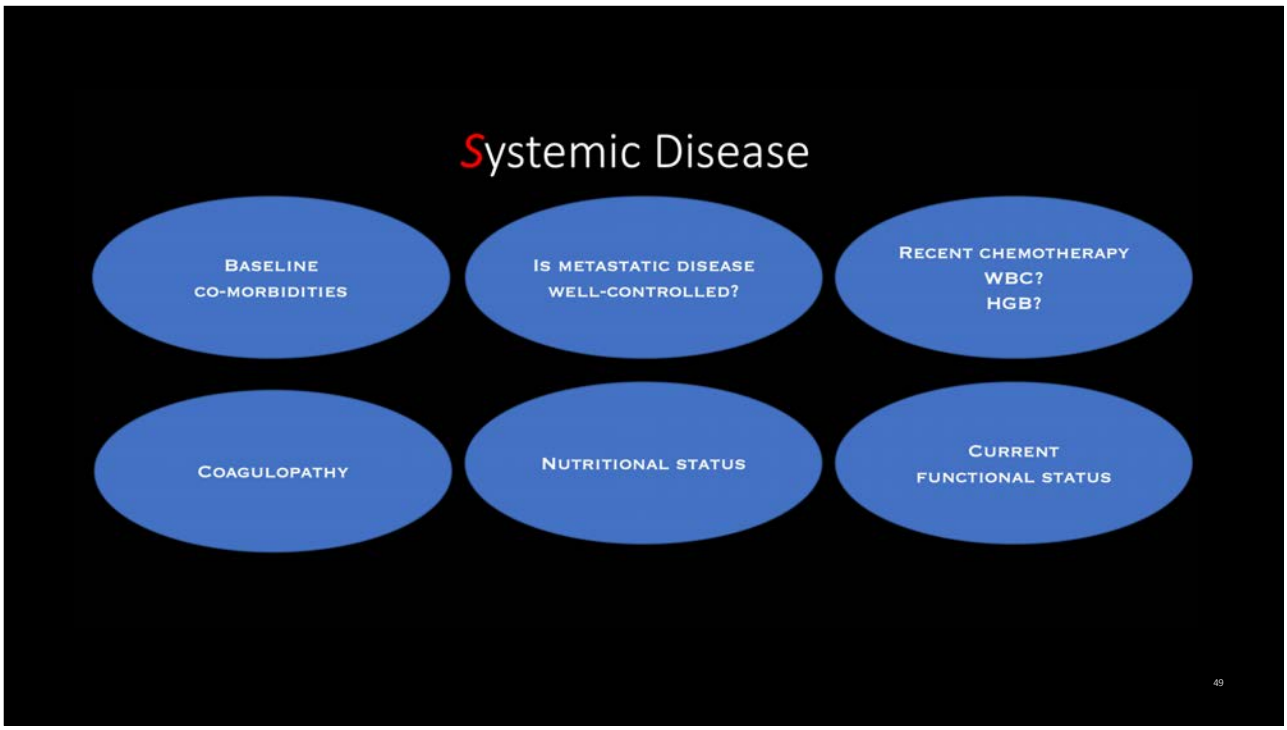
Table 1. Spinal Instability Neoplastic Score (SINS) System.[a]

Component	Score
Location	
Junctional (O-C2; C7-T2; T11-L1; L5-S1)	3
Mobile spine (C3-6; L2-4)	2
Semirigid (T3-10)	1
Rigid (S2-S5)	0
Mechanical pain	
Yes	3
No	2
Pain free lesion	1
Bone lesion	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
Radiographic spinal alignment	
Subluxation/translation present	4
Deformity (kyphosis/scoliosis)	2
Normal	0
Vertebral body collapse	
>50% collapse	3
<50% collapse	2
No collapse with >50% body involved	1
None of the above	0
Posterolateral involvement	
Bilateral	3
Unilateral	1
None of the above	0

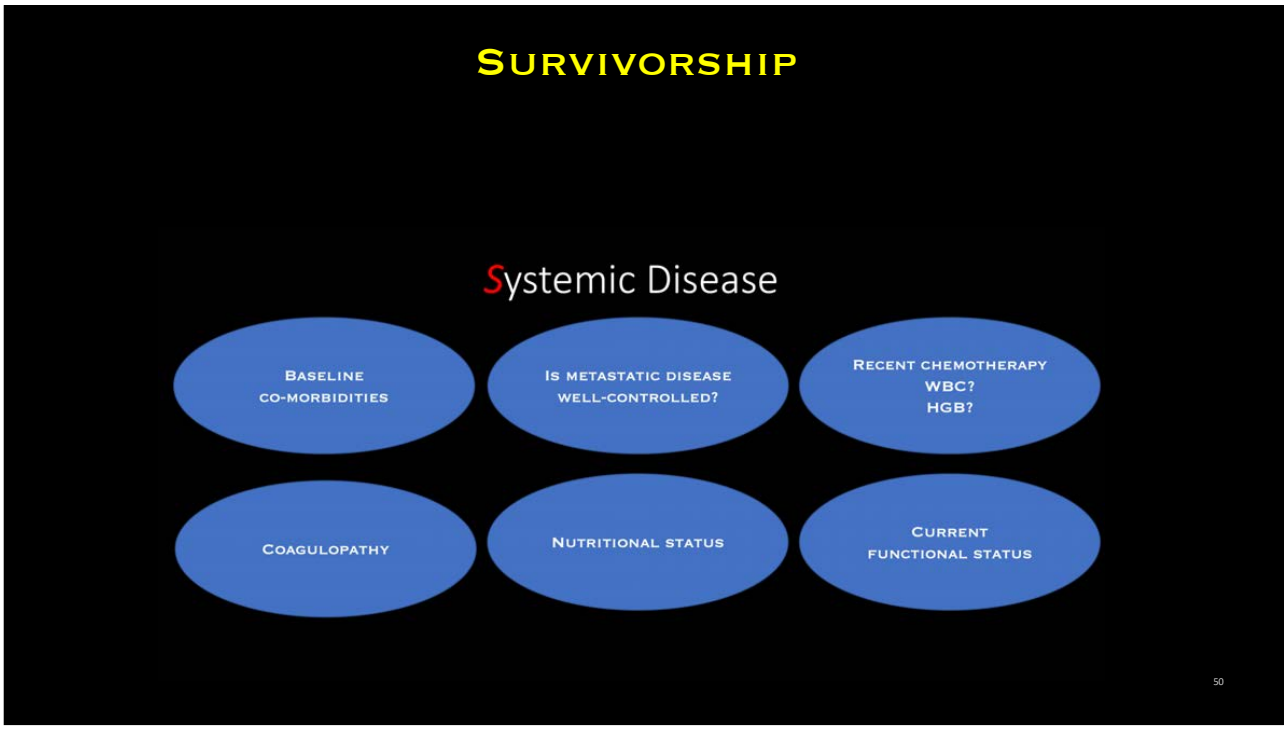
[a]Data adapted from Fischer et al.[9]

48

48


Systemic Disease
Baseline co-morbidities
Is metastatic disease well-controlled?
Recent chemotherapy WBC? HGB?
Coagulopathy
Nutritional status
Current functional status
49

49


Survivorship
Systemic Disease
Baseline co-morbidities
Is metastatic disease well-controlled?
Recent chemotherapy WBC? HGB?
Coagulopathy
Nutritional status
Current functional status
50

50

Why do we care about Accurate survivorship Prediction?

51

Why do we care about Accurate survivorship Prediction?

stratify treatment options from aggressive to palliation

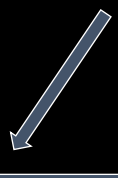
52

Why do we care about Accurate survivorship Prediction?

Stratify treatment options from aggressive to palliation

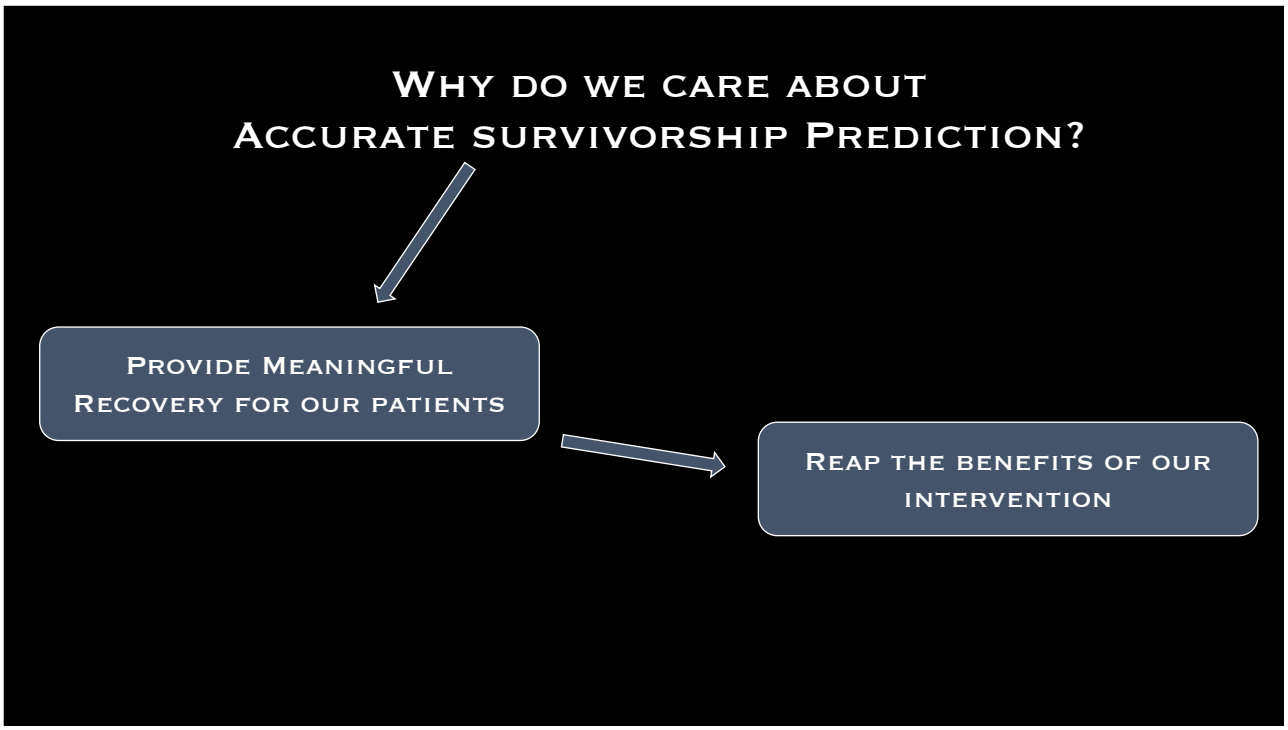
53

Why do we care about Accurate survivorship Prediction?

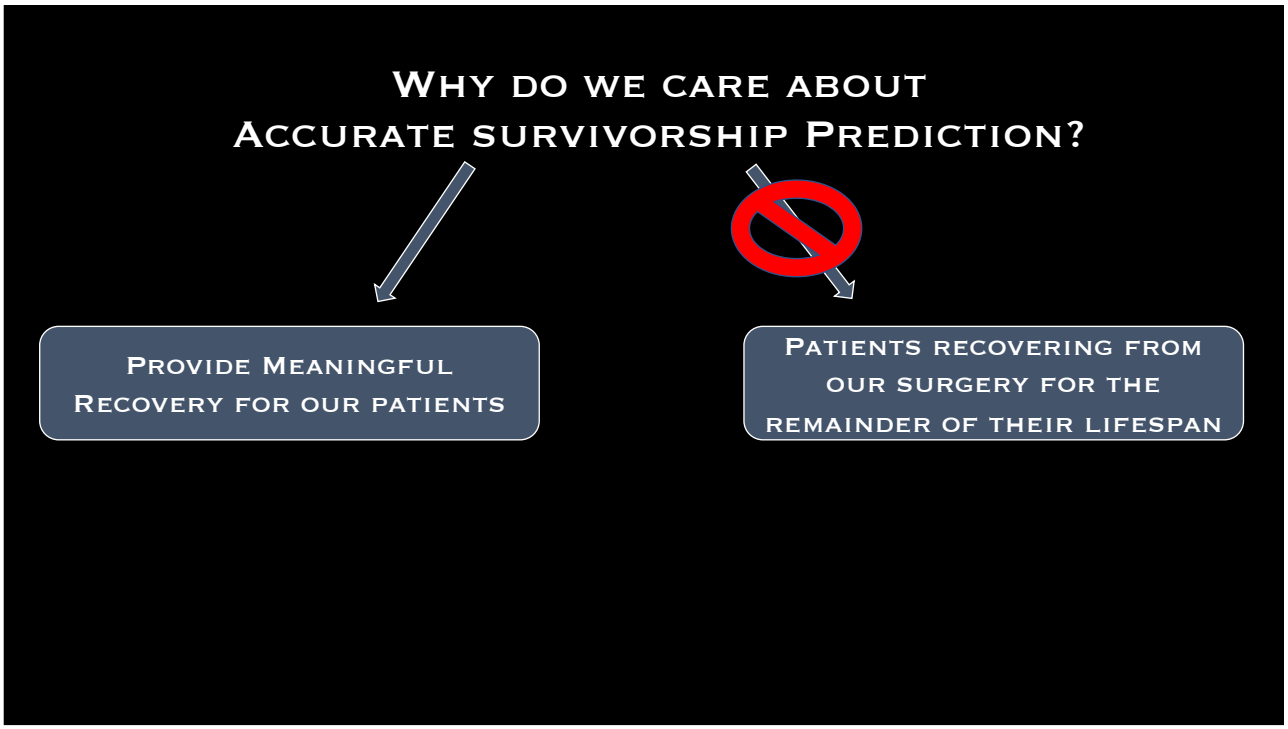


Provide Meaningful Recovery for our patients

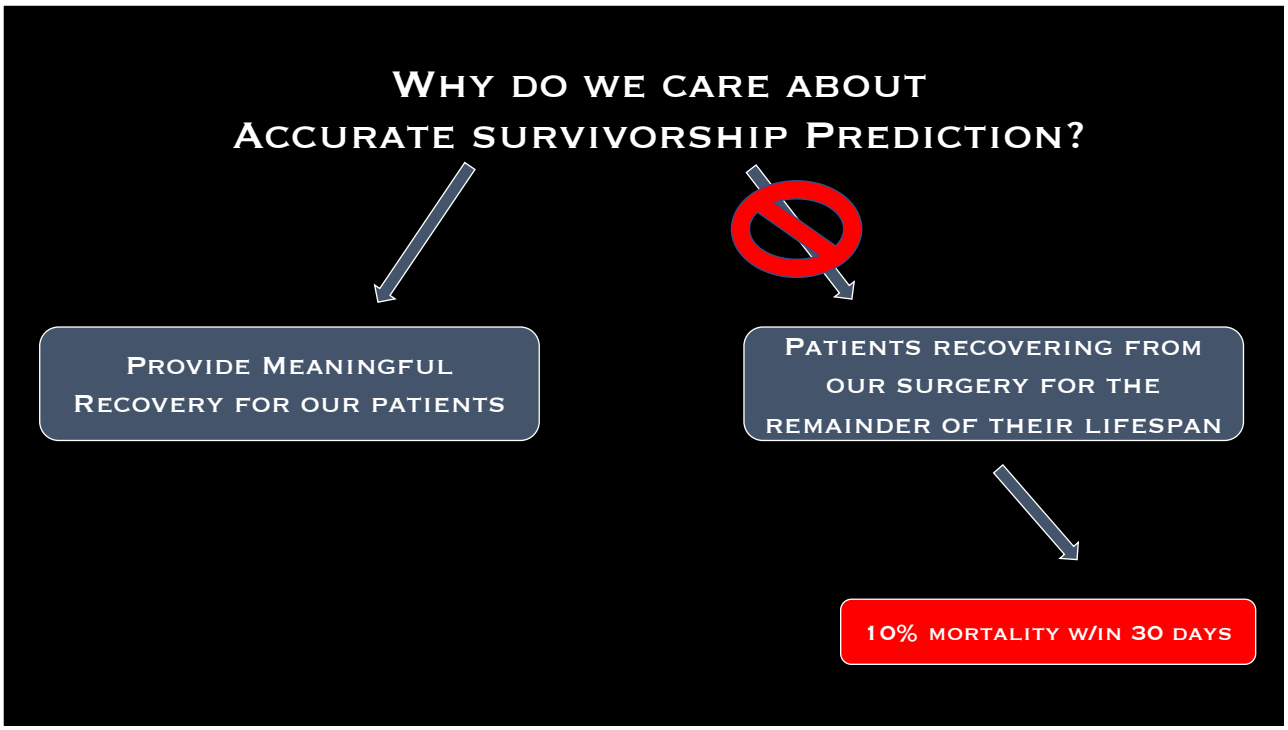
54


Why do we care about
Accurate survivorship Prediction?
Provide Meaningful Recovery for our patients
Reap the benefits of our intervention

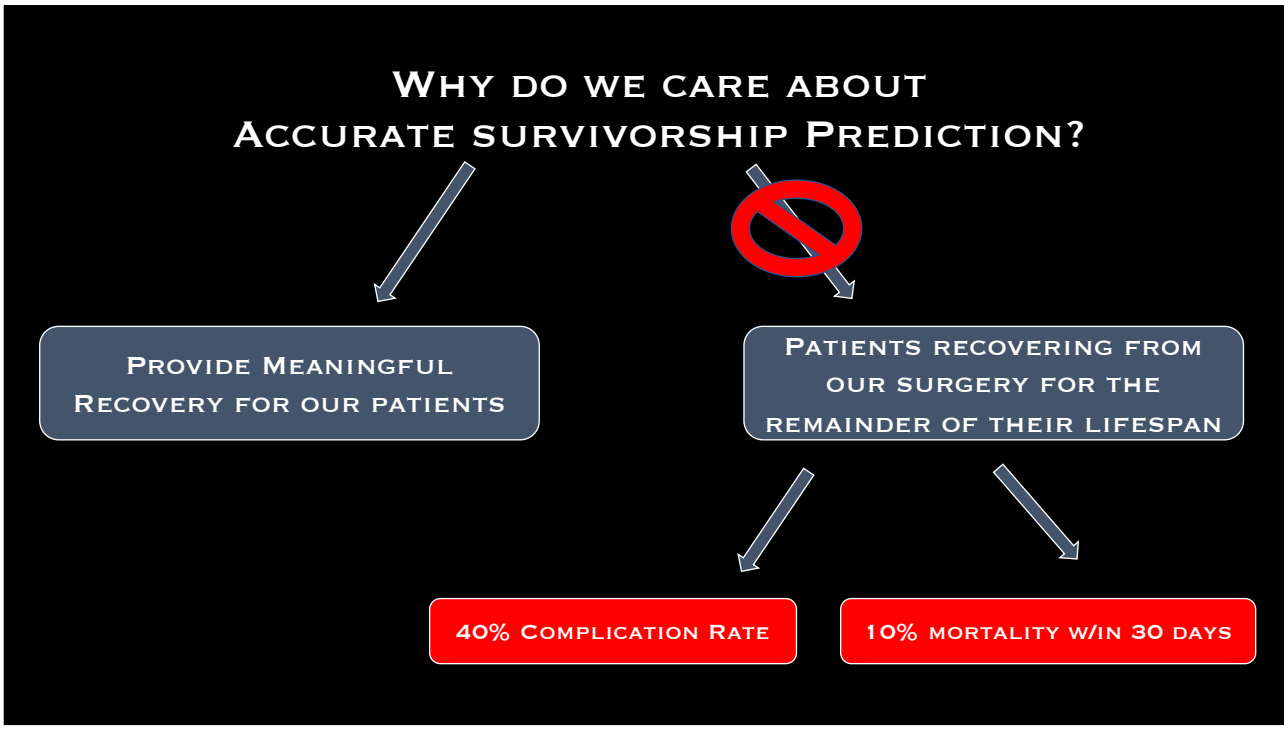
55


Why do we care about
Accurate survivorship Prediction?
Provide Meaningful Recovery for our patients
Patients recovering from our surgery for the remainder of their lifespan

56


Why do we care about
Accurate survivorship Prediction?
Provide Meaningful Recovery for our patients
Patients recovering from our surgery for the remainder of their lifespan
10% mortality w/in 30 days

57


Why do we care about
Accurate survivorship Prediction?
Provide Meaningful Recovery for our patients
Patients recovering from our surgery for the remainder of their lifespan
40% Complication Rate
10% mortality w/in 30 days

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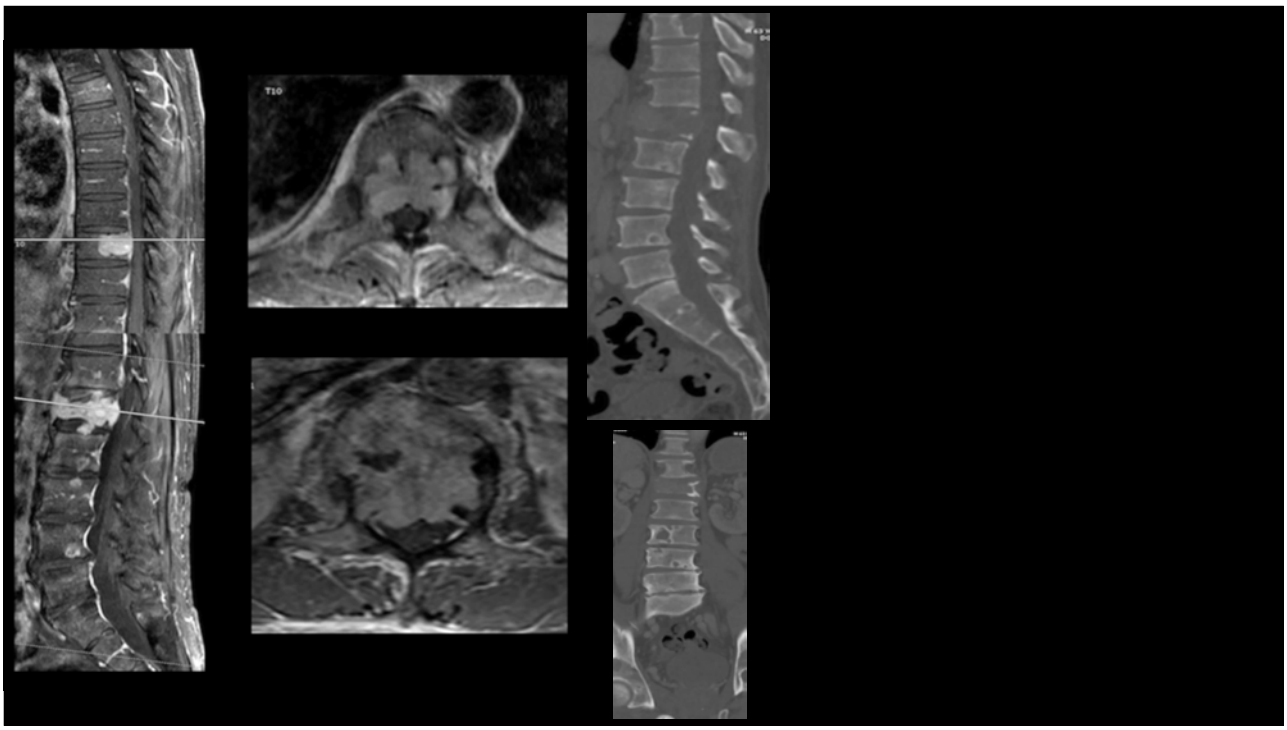

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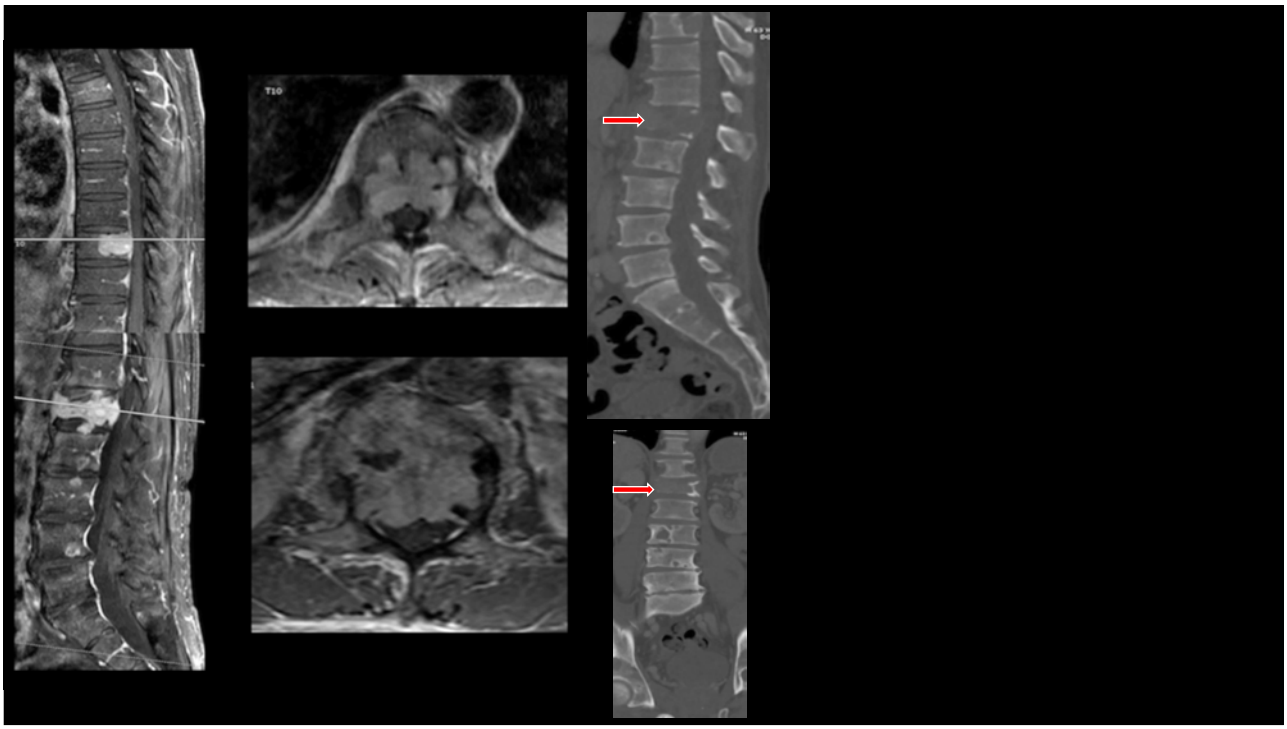

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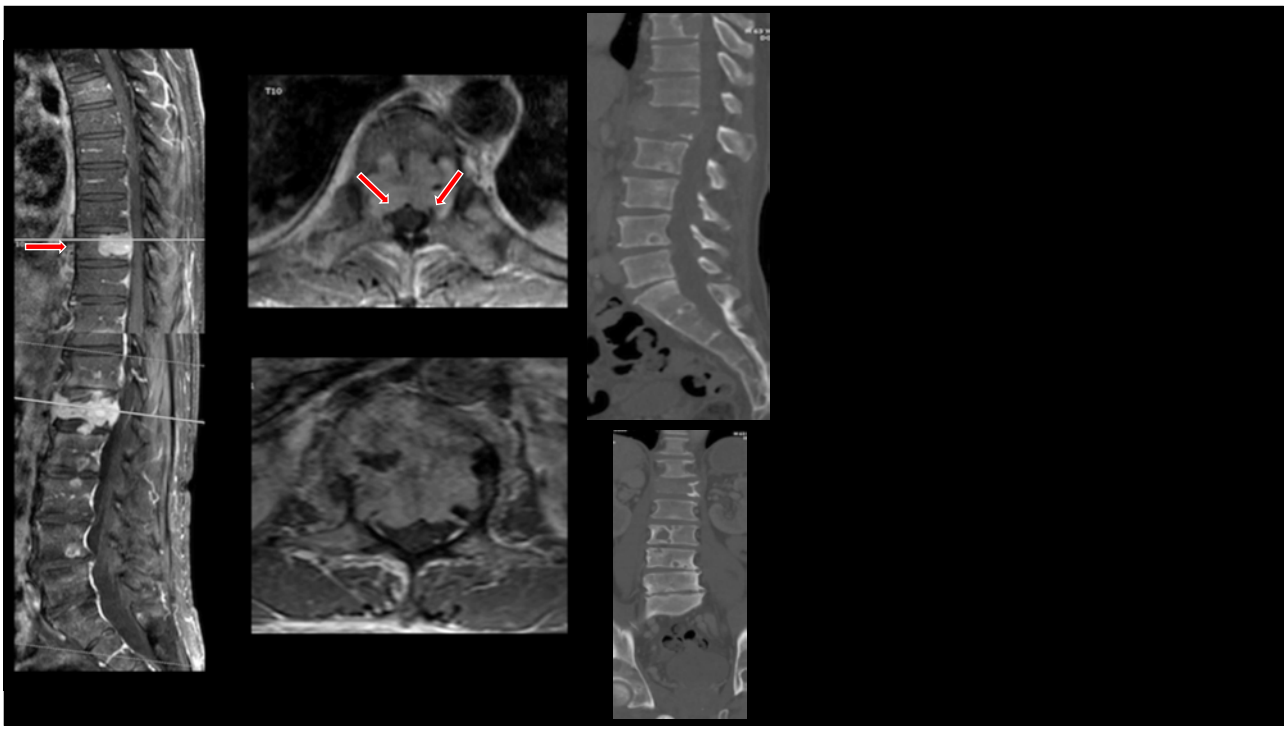

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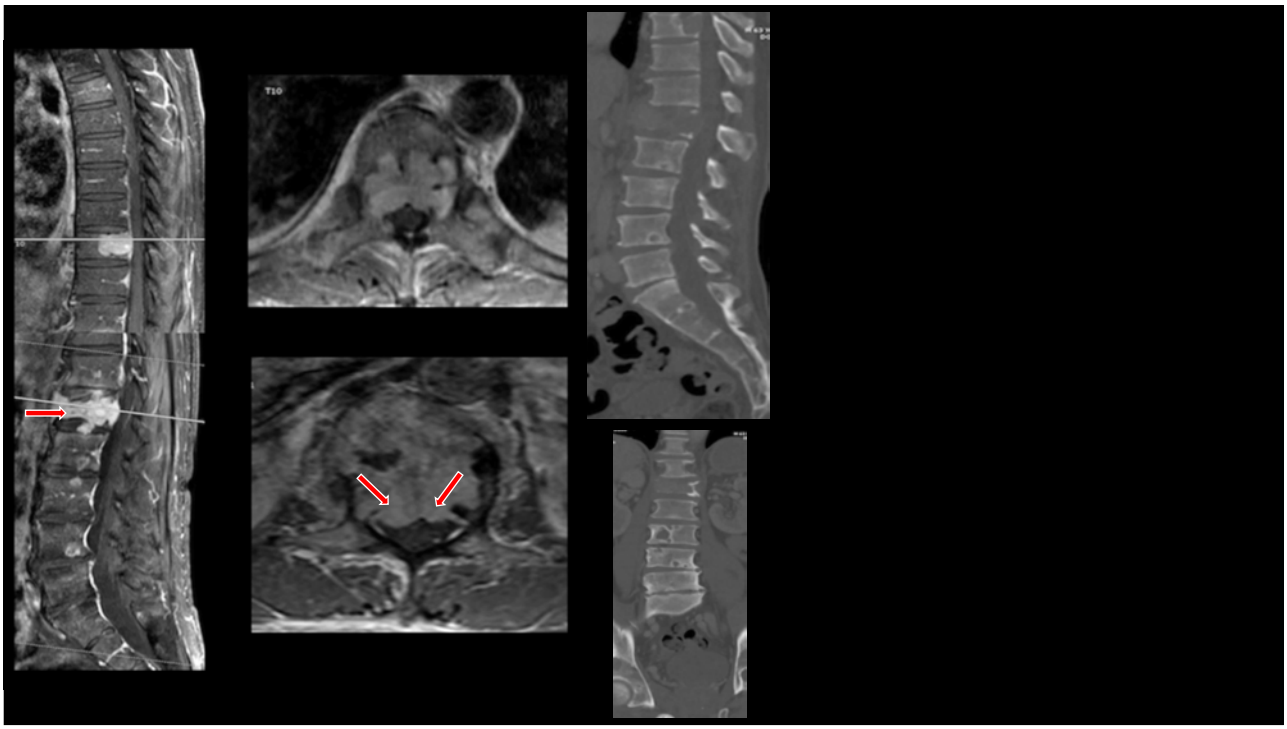

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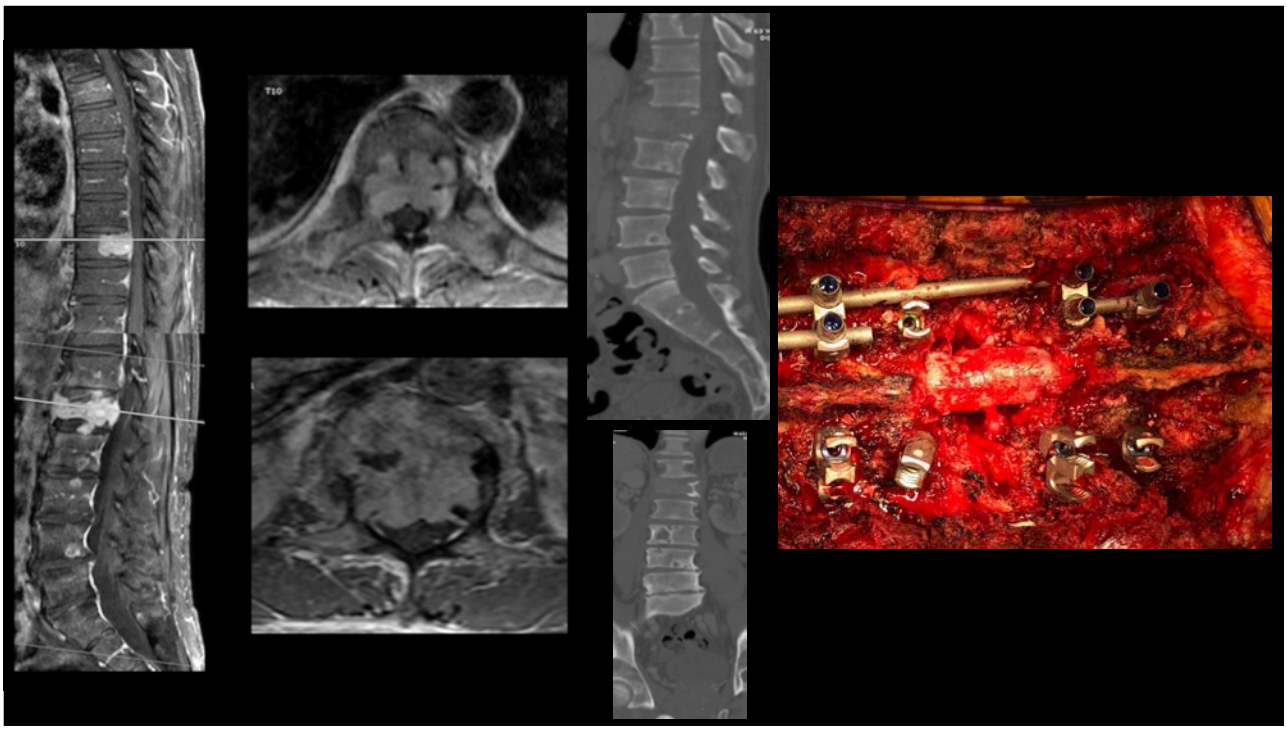

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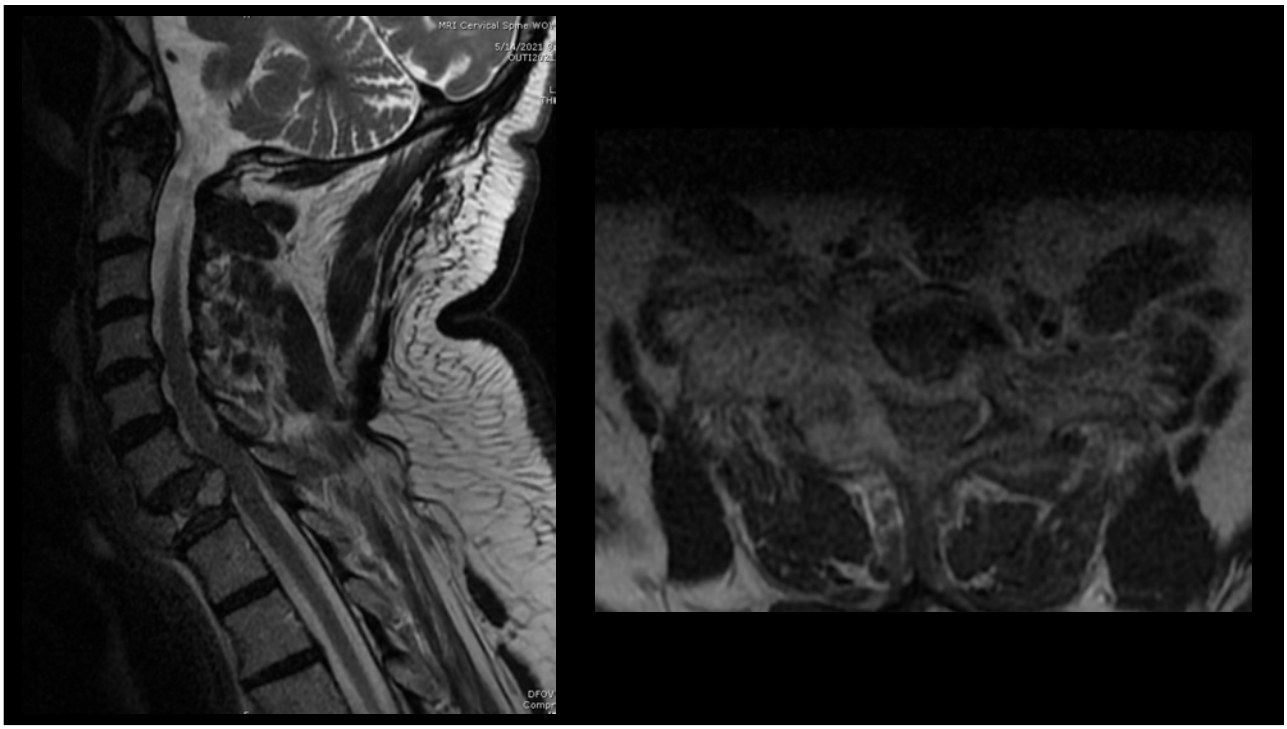

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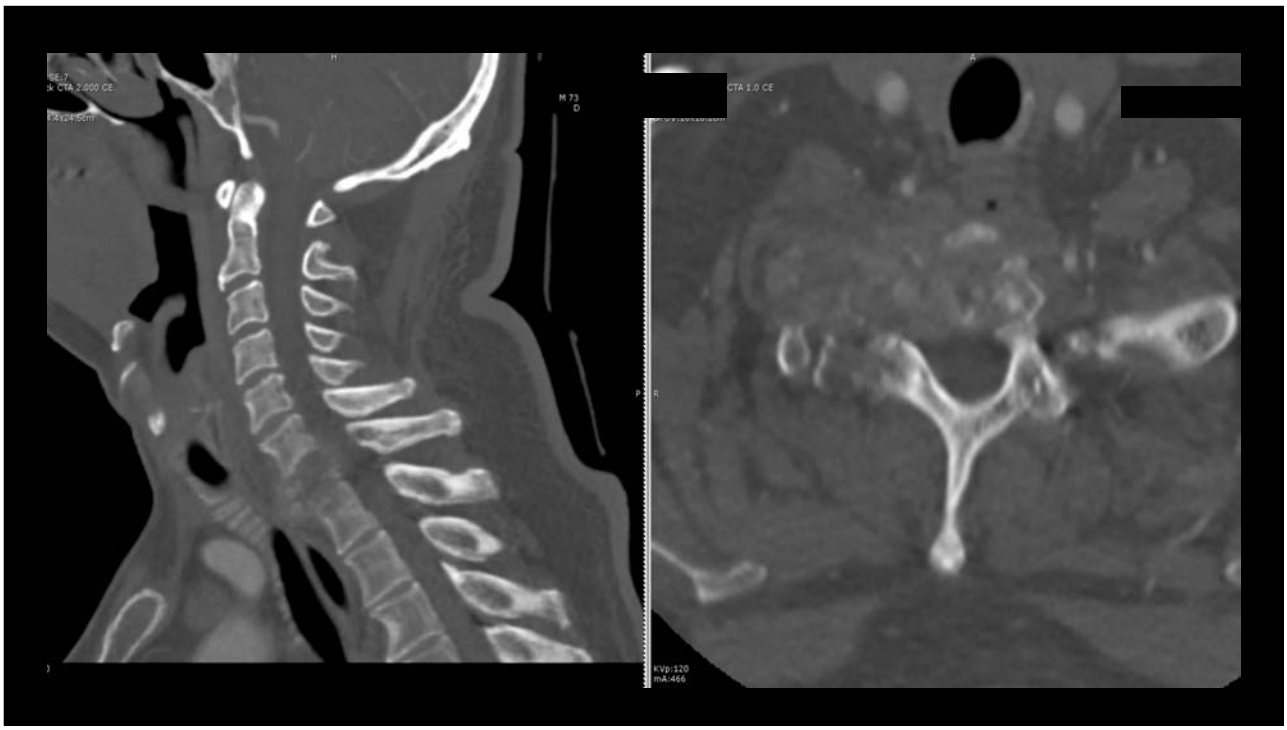

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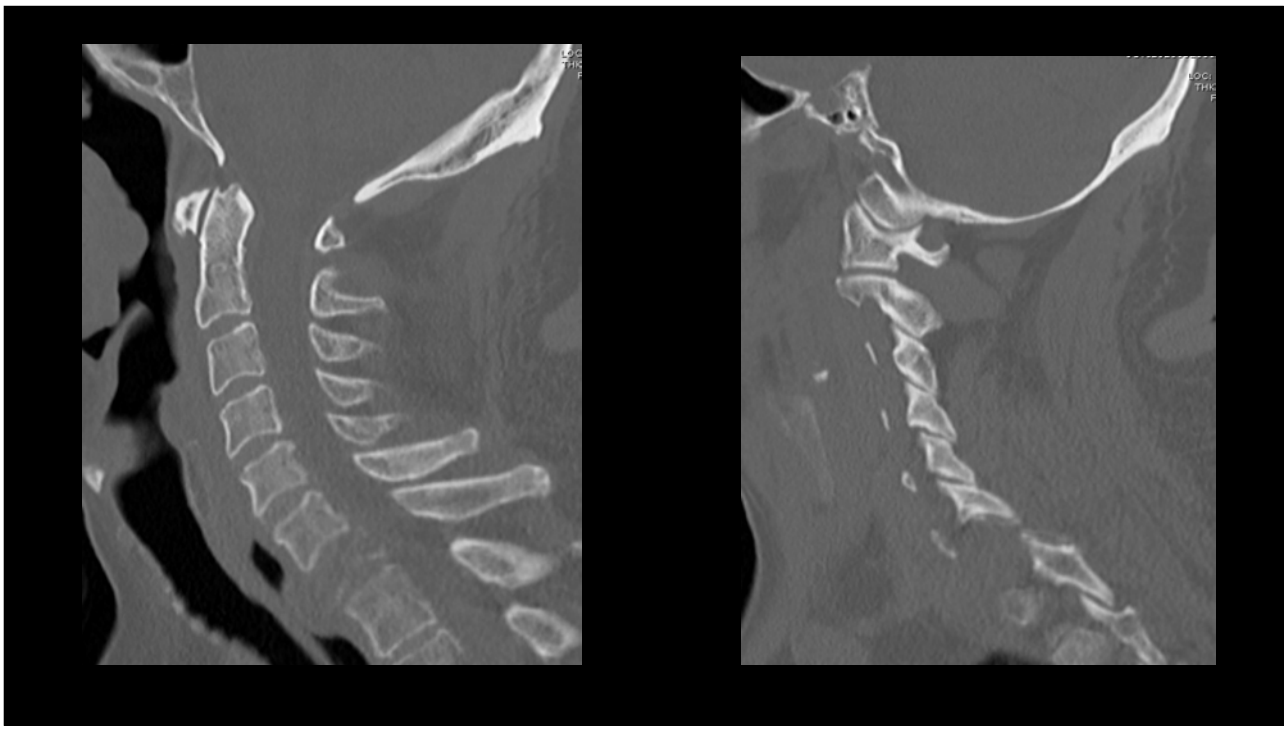

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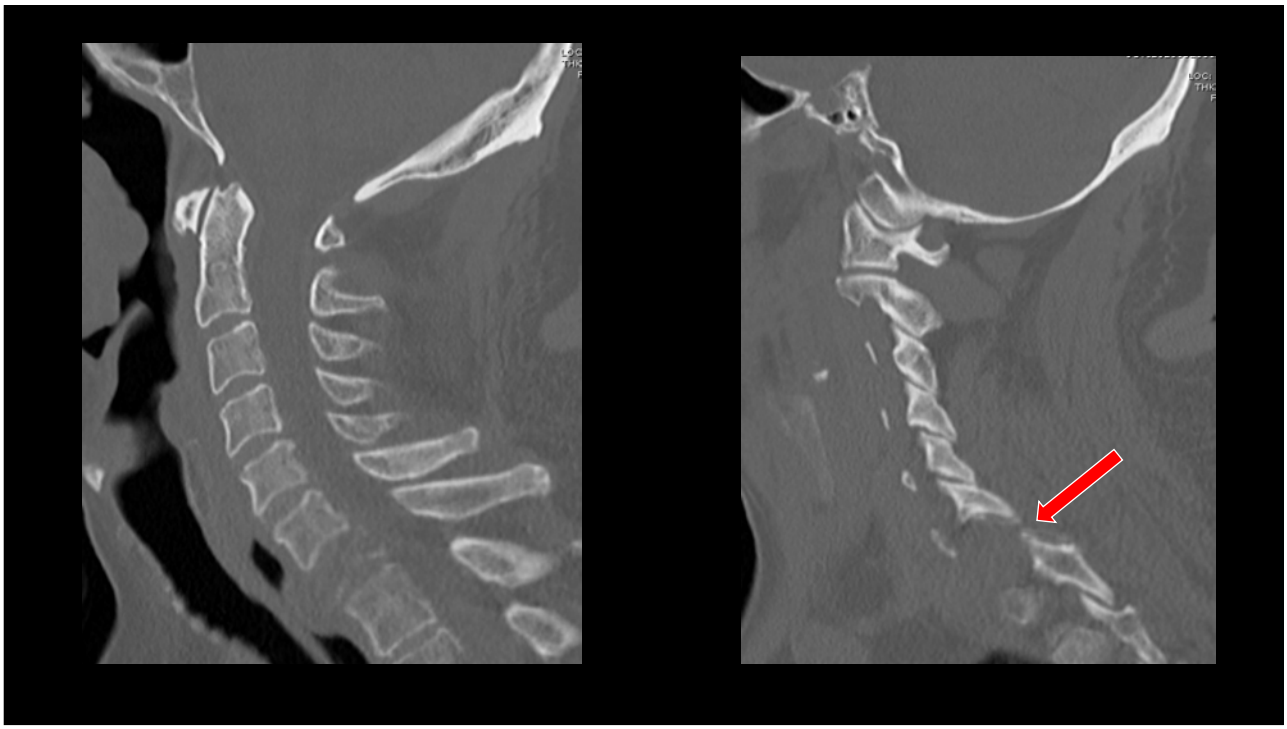
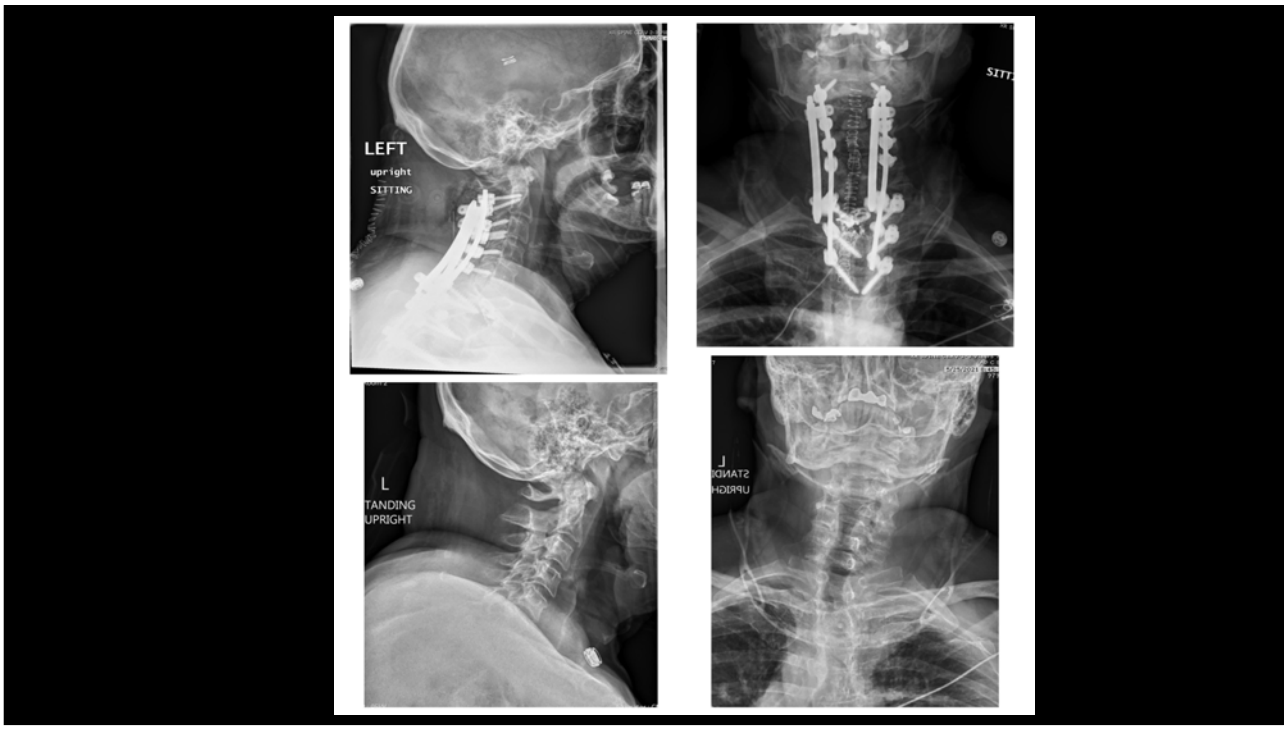


68


XR SPINE-ENTIRE THORACIC AND LUMBAR
L
STANDING
UPRIGHT
Room 2
L
STANDING
UPRIGHT

69

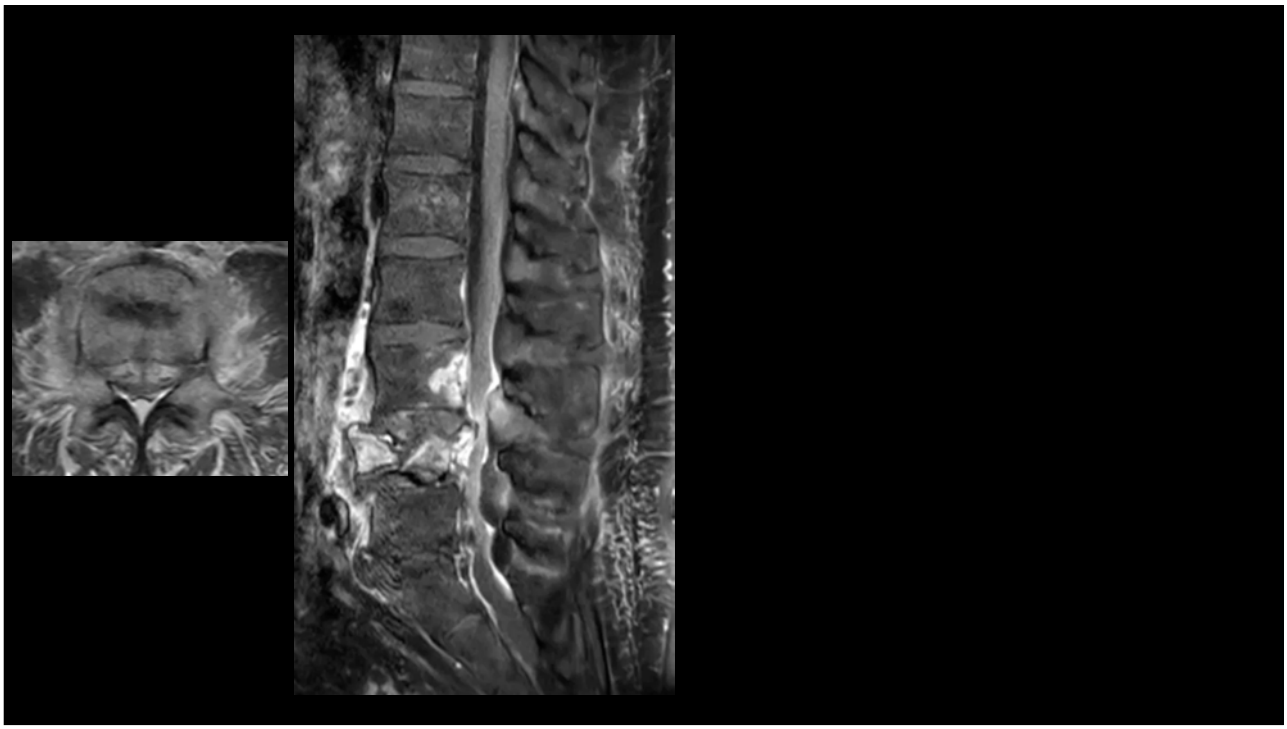

LEFT
upright
SITTING
L
STANDING
UPRIGHT

70

71

72

73



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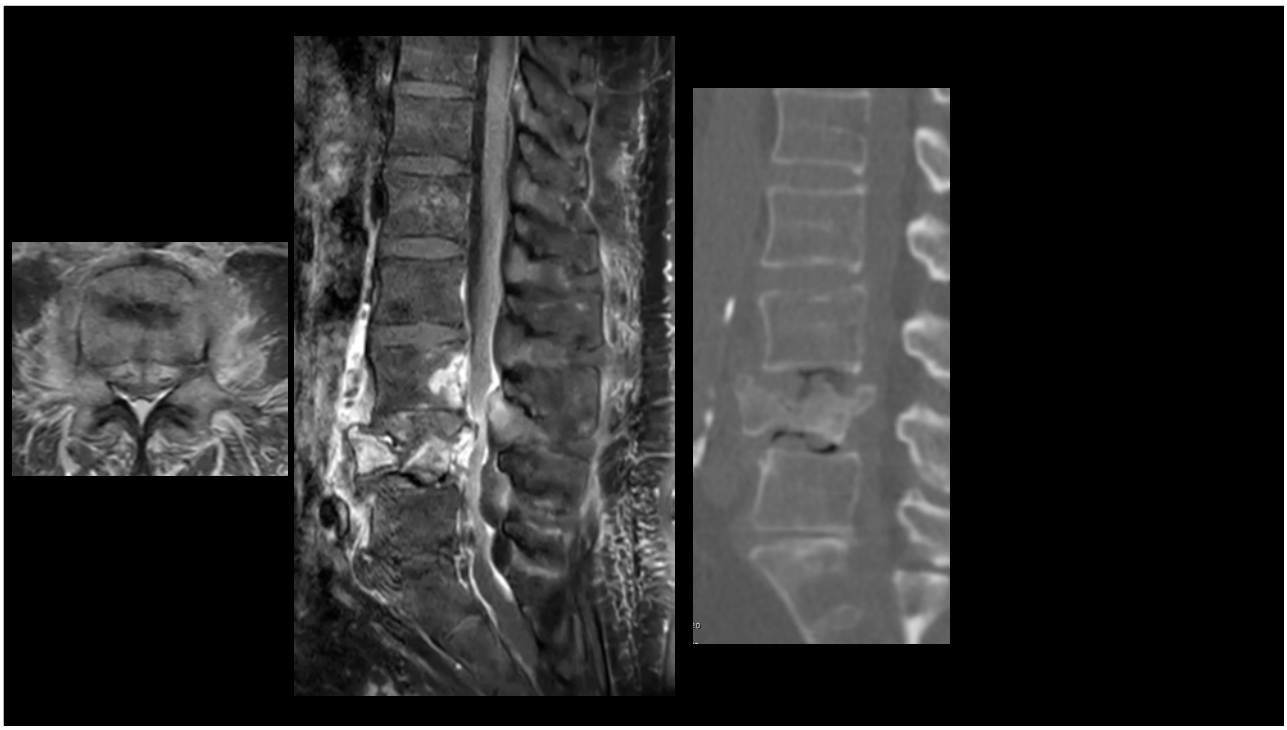

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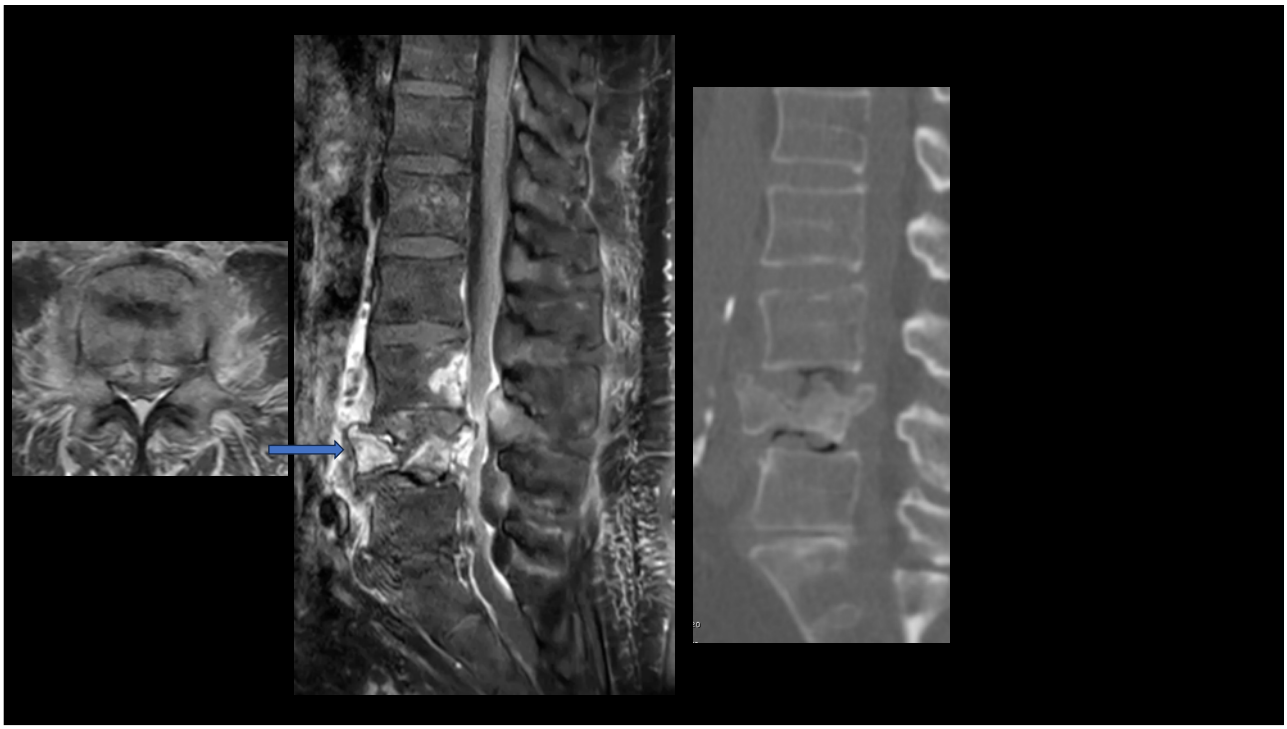

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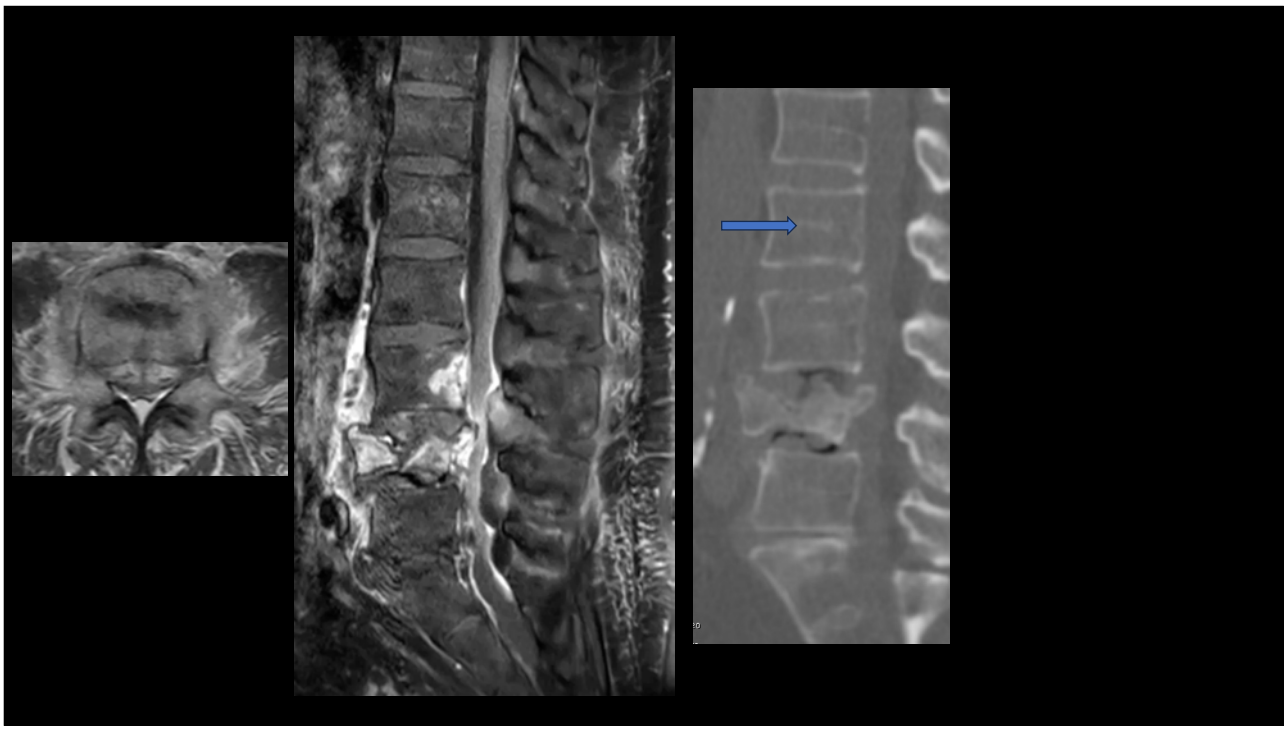

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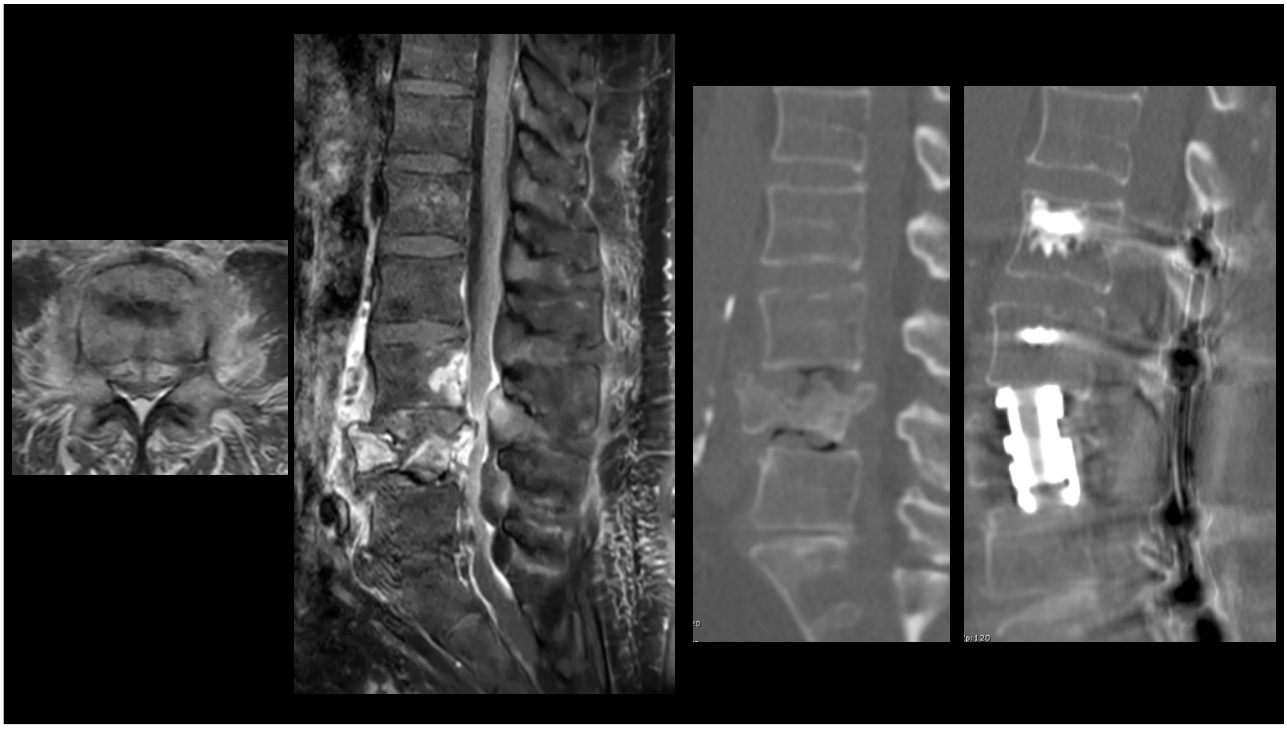

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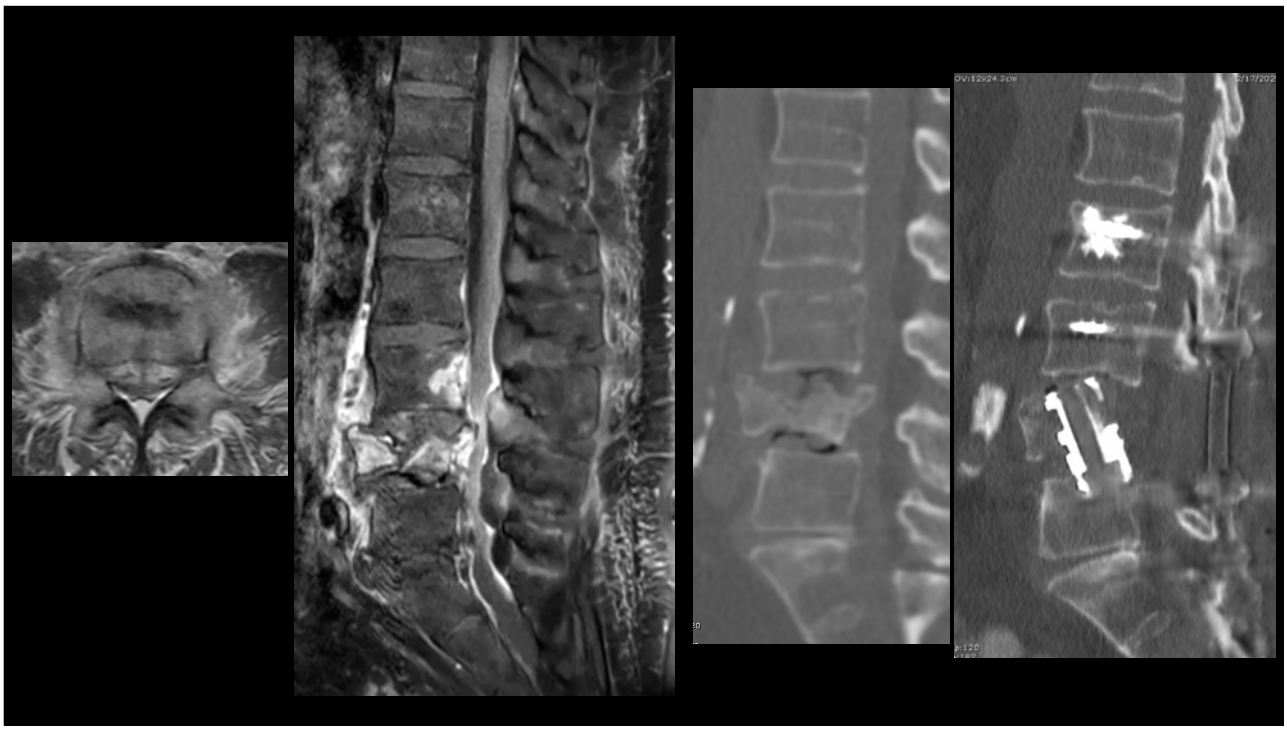

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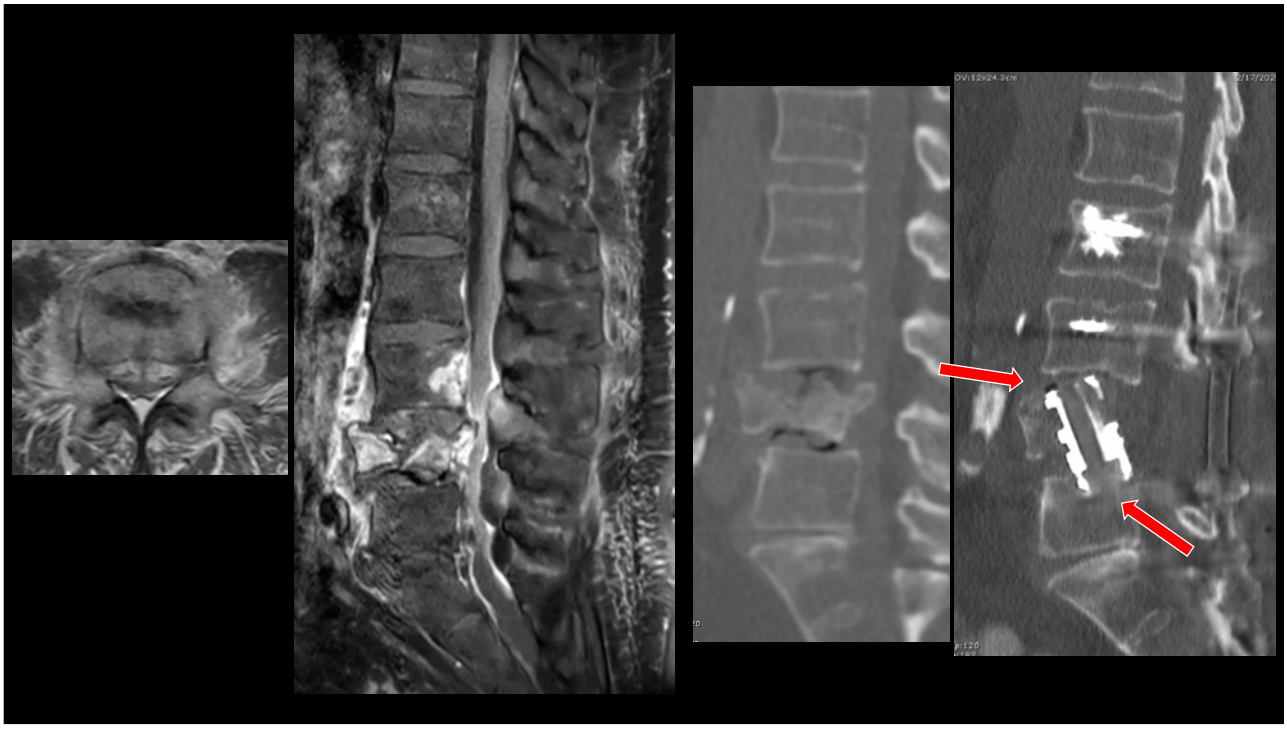

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How do we predict patient mortality?

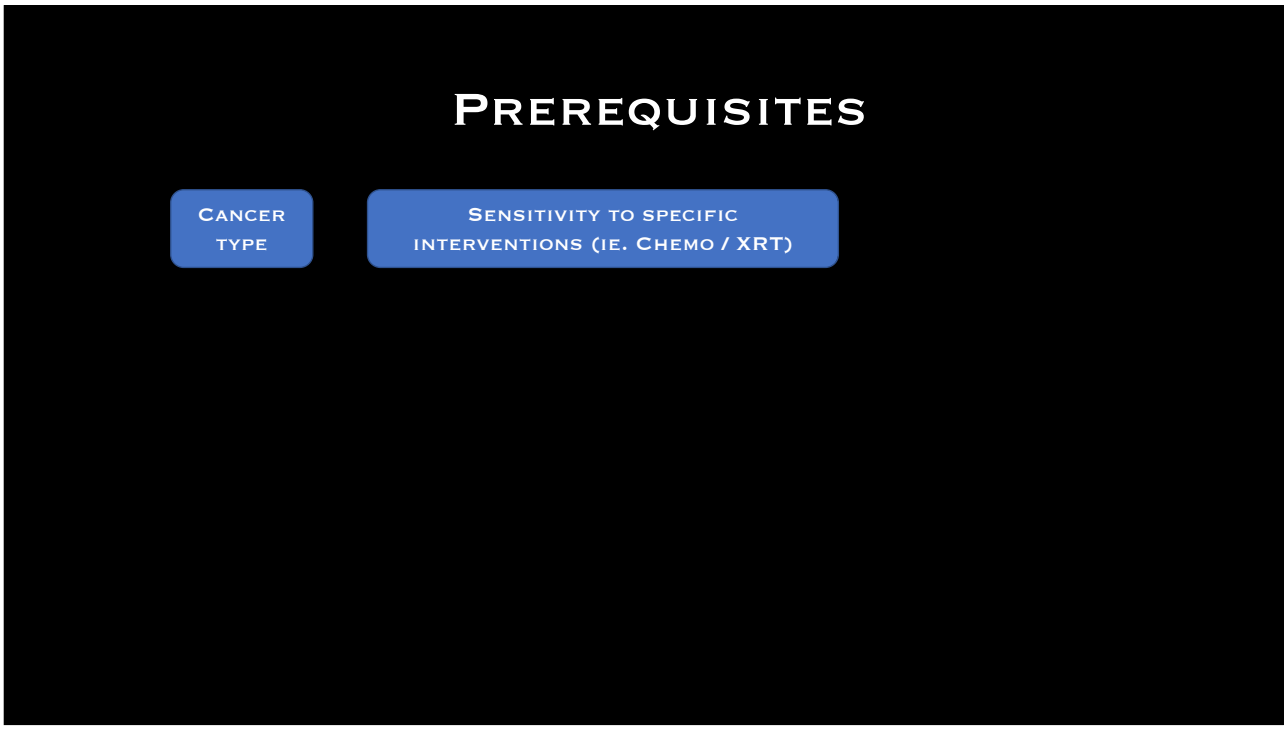
81

Prerequisites

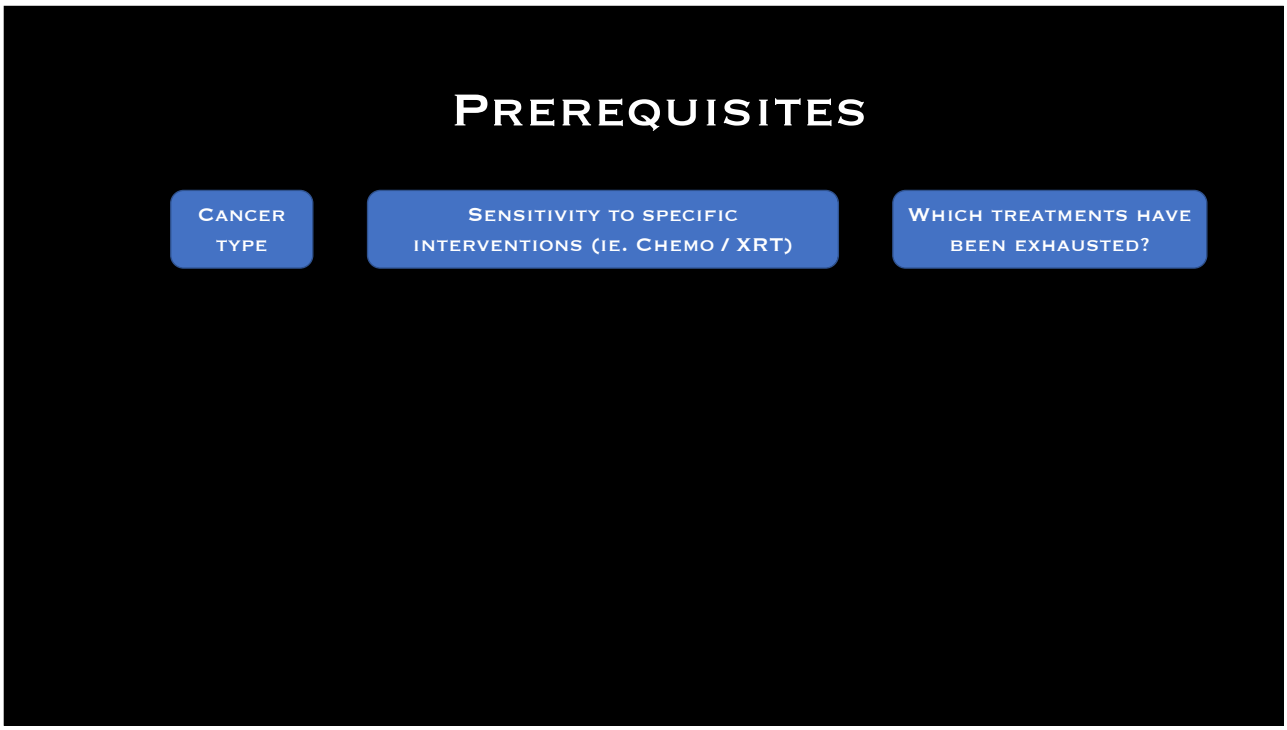
82


Prerequisites
Cancer type

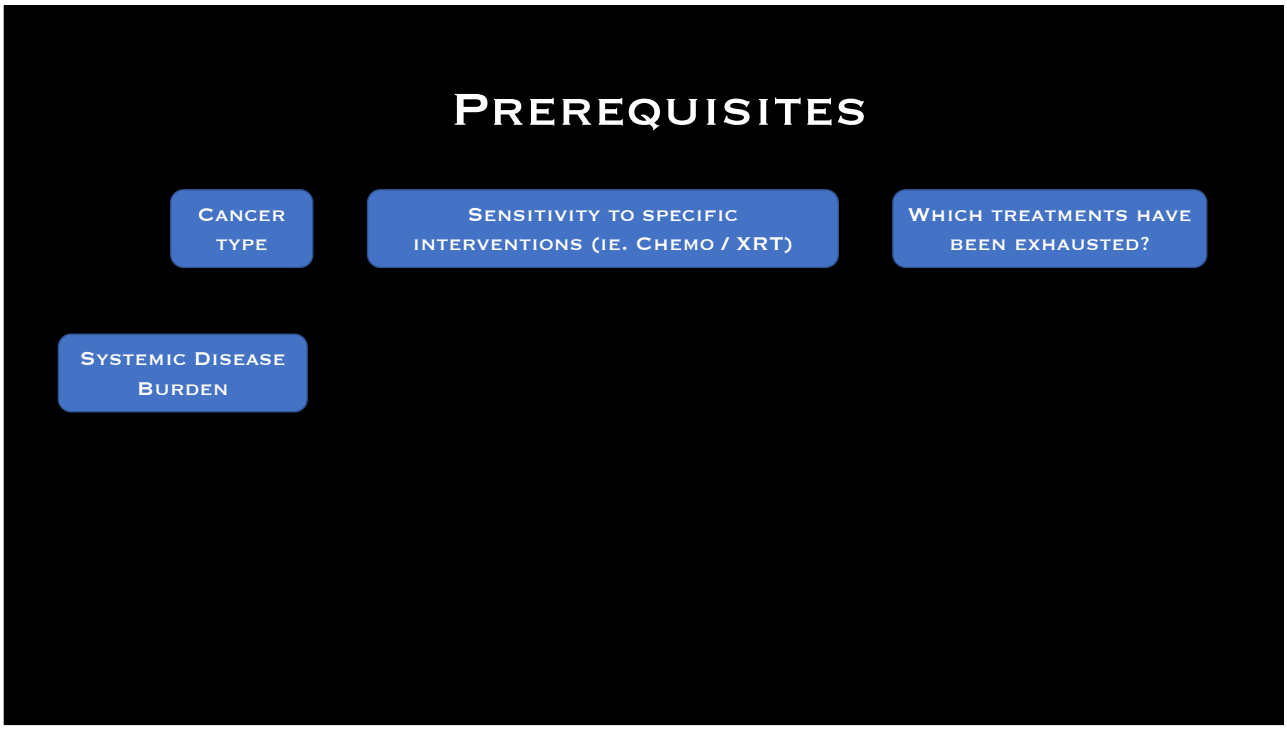
83


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)

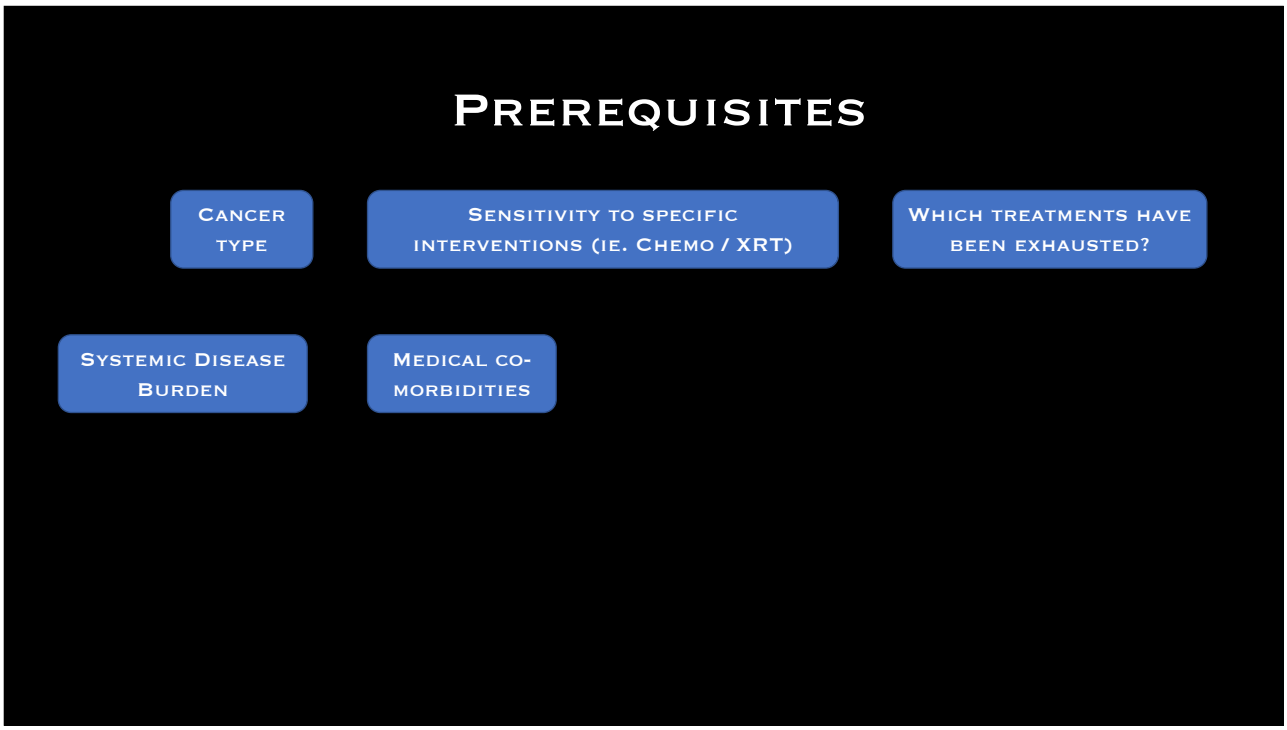
84


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?

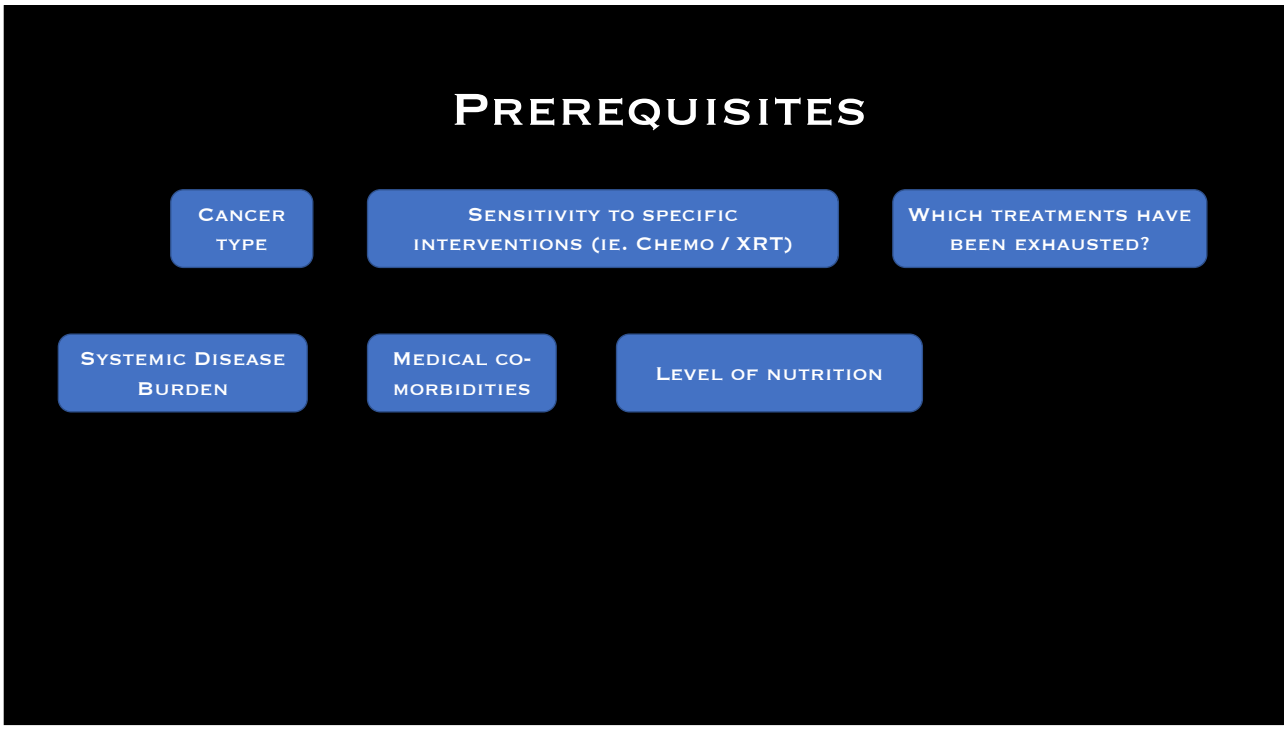
85


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden

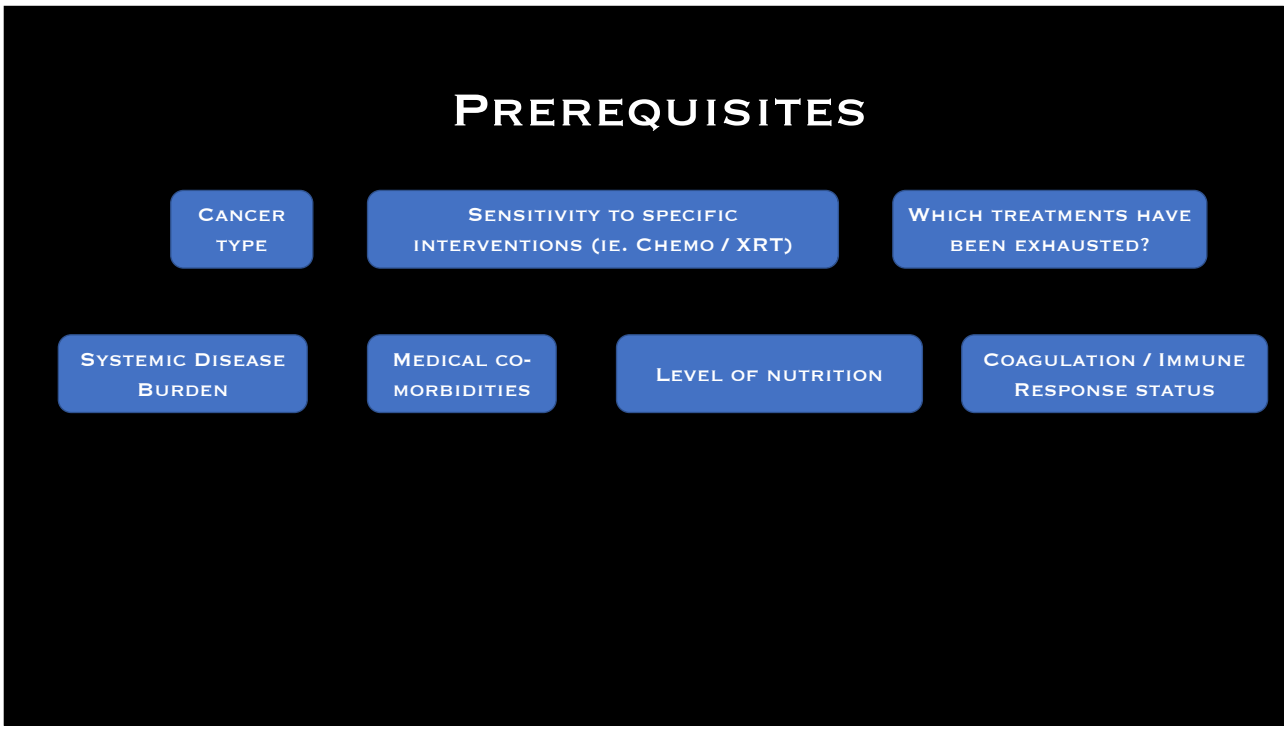
86


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities

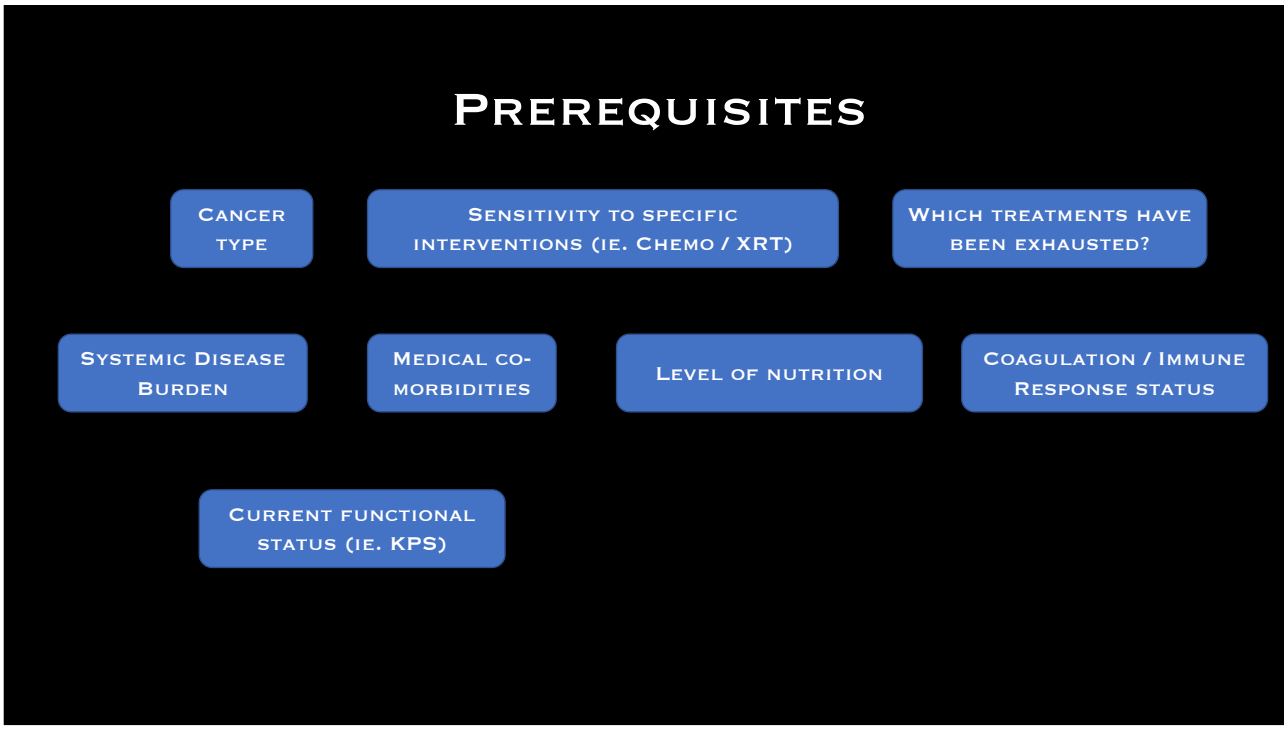
87


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities
Level of nutrition

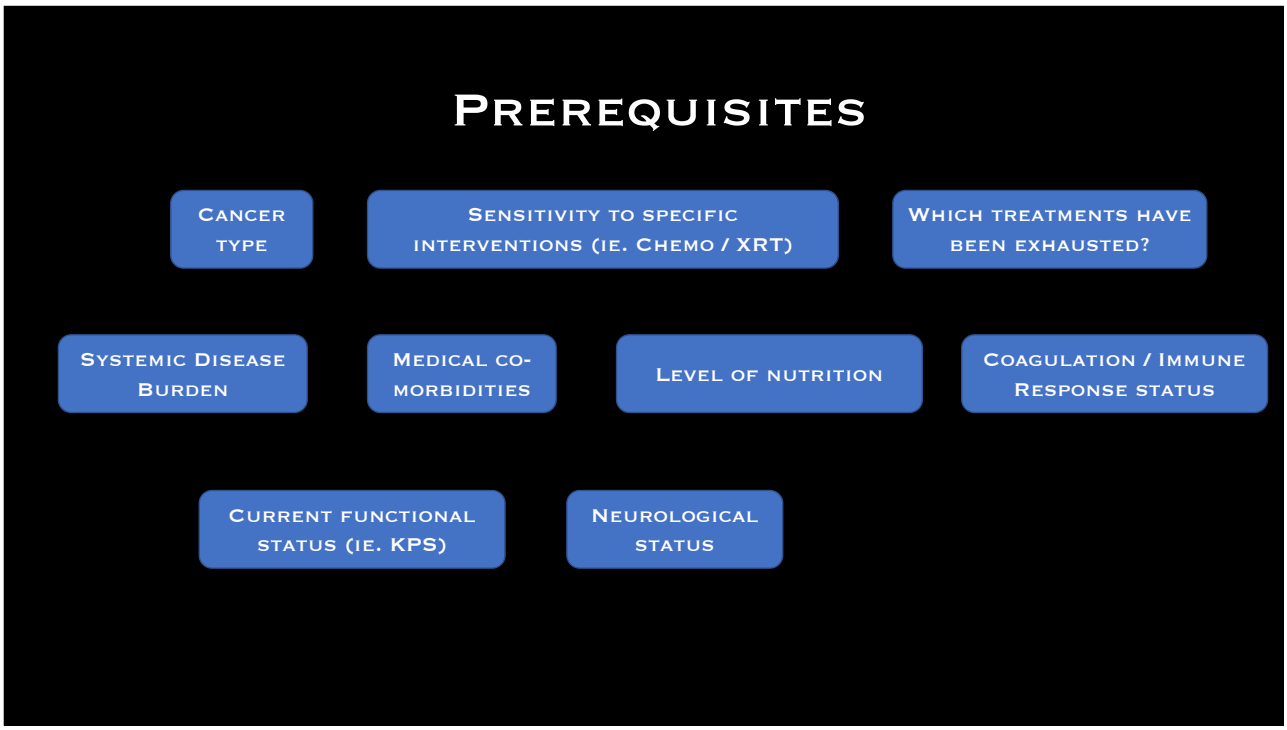
88


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities
Level of nutrition
Coagulation / Immune Response status

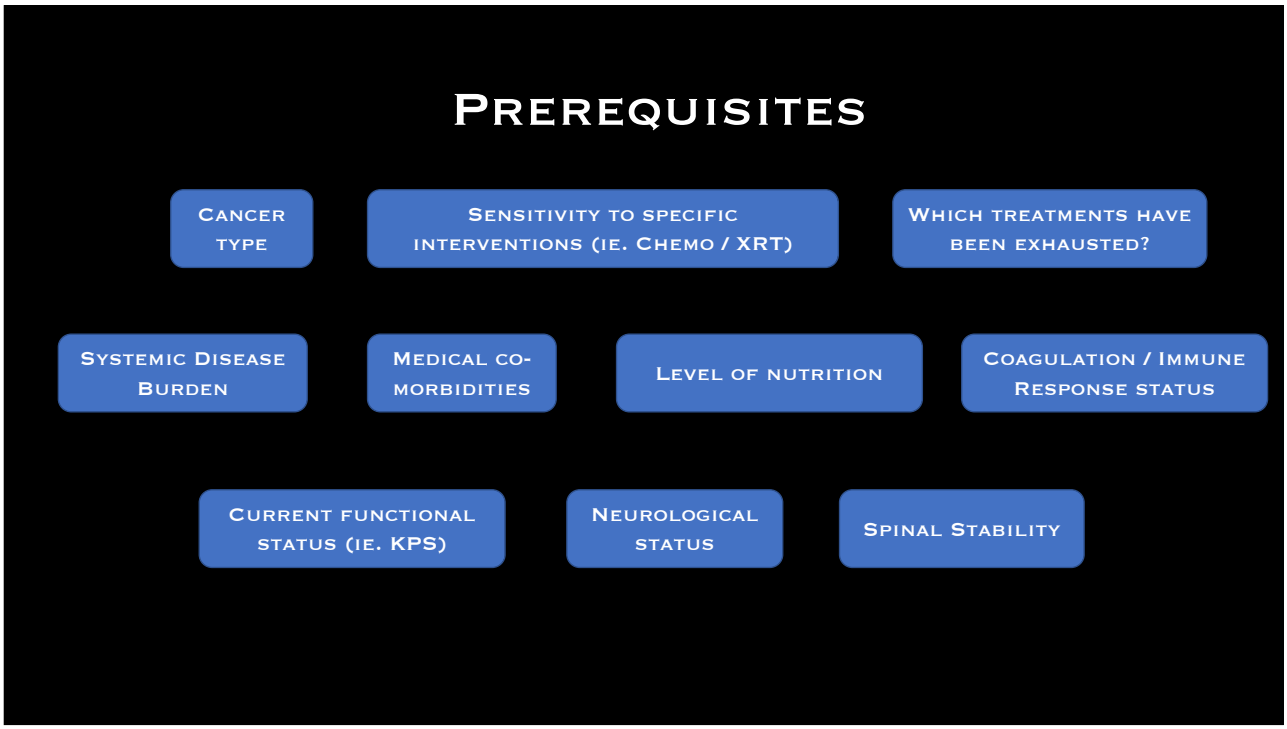
89


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities
Level of nutrition
Coagulation / Immune Response status
Current functional status (ie. KPS)

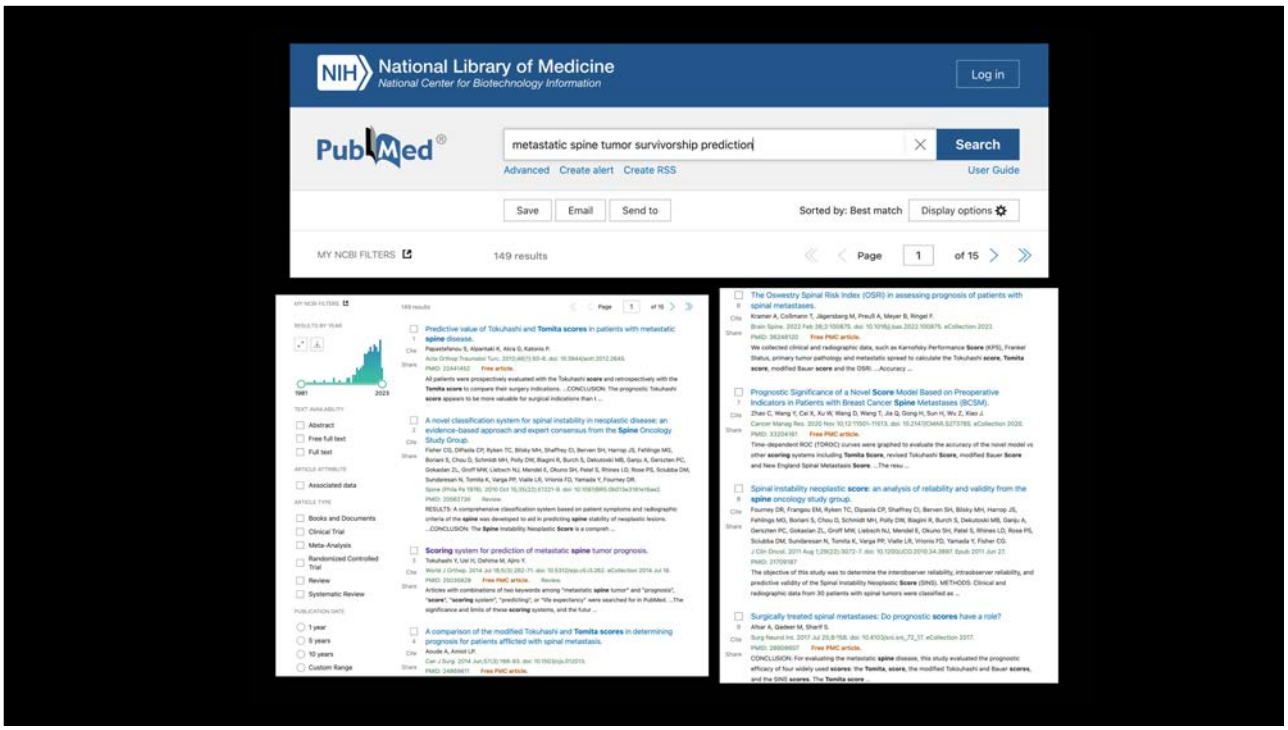
90


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities
Level of nutrition
Coagulation / Immune Response status
Current functional status (ie. KPS)
Neurological status

91


Prerequisites
Cancer type
Sensitivity to specific interventions (ie. Chemo / XRT)
Which treatments have been exhausted?
Systemic Disease Burden
Medical co-morbidities
Level of nutrition
Coagulation / Immune Response status
Current functional status (ie. KPS)
Neurological status
Spinal Stability

92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User Guide
Save Email Send to
Sorted by: Best match
Display options
MY NCBI FILTERS
149 results
Page 1 of 15

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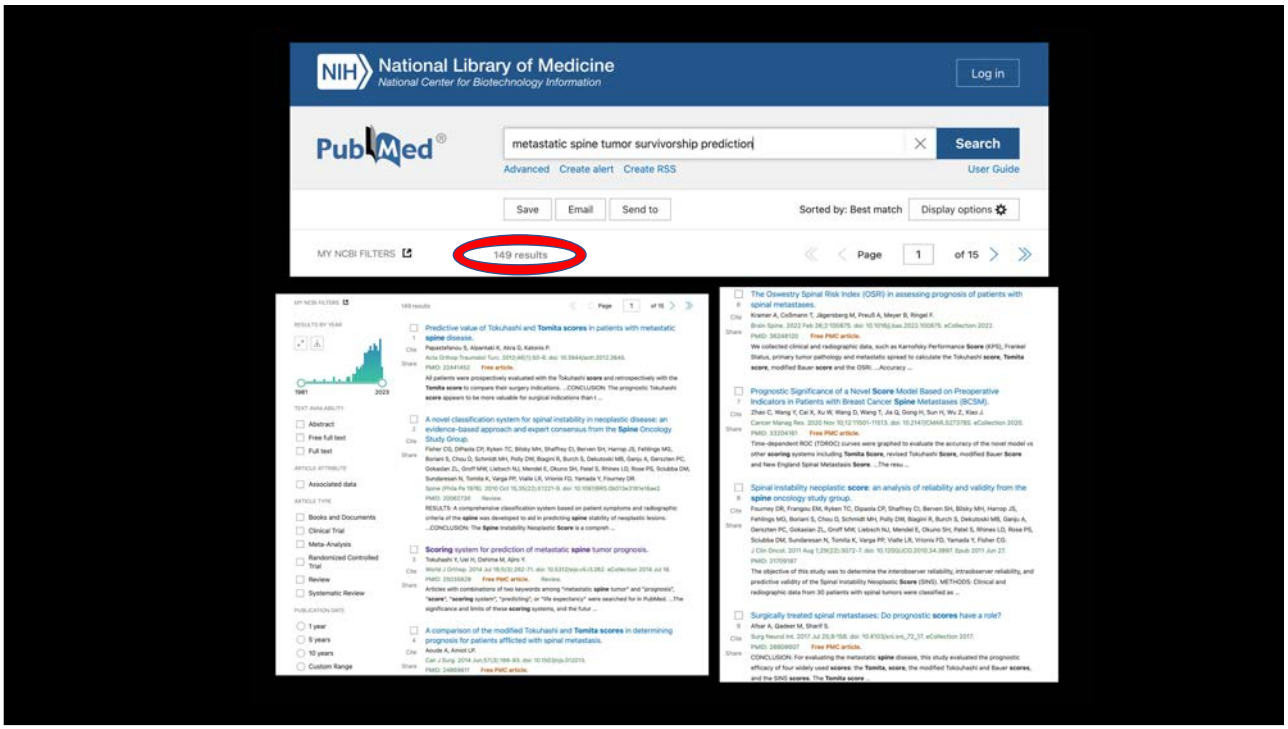
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User Guide
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Sorted by: Best match
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149 results
Page 1 of 15

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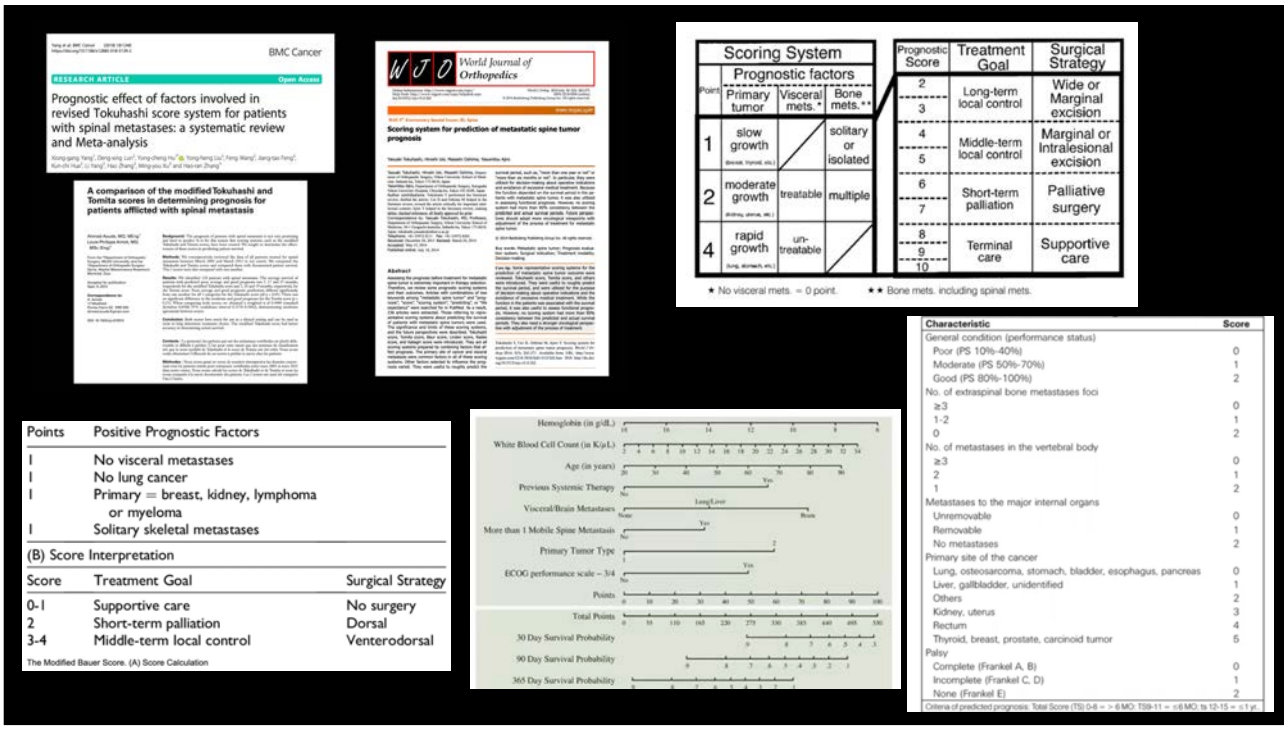
BMC Cancer
RESEARCH ARTICLE
Open Access
Prognostic effect of factors involved in revised Tokuhashi score system for patients with spinal metastases: a systematic review and Meta-analysis
A comparison of the modified Tokuhashi and Tomita scores in determining prognosis for patients afflicted with spinal metastasis
World Journal of Orthopedics
Scoring system for prediction of metastatic spine tumor prognosis

95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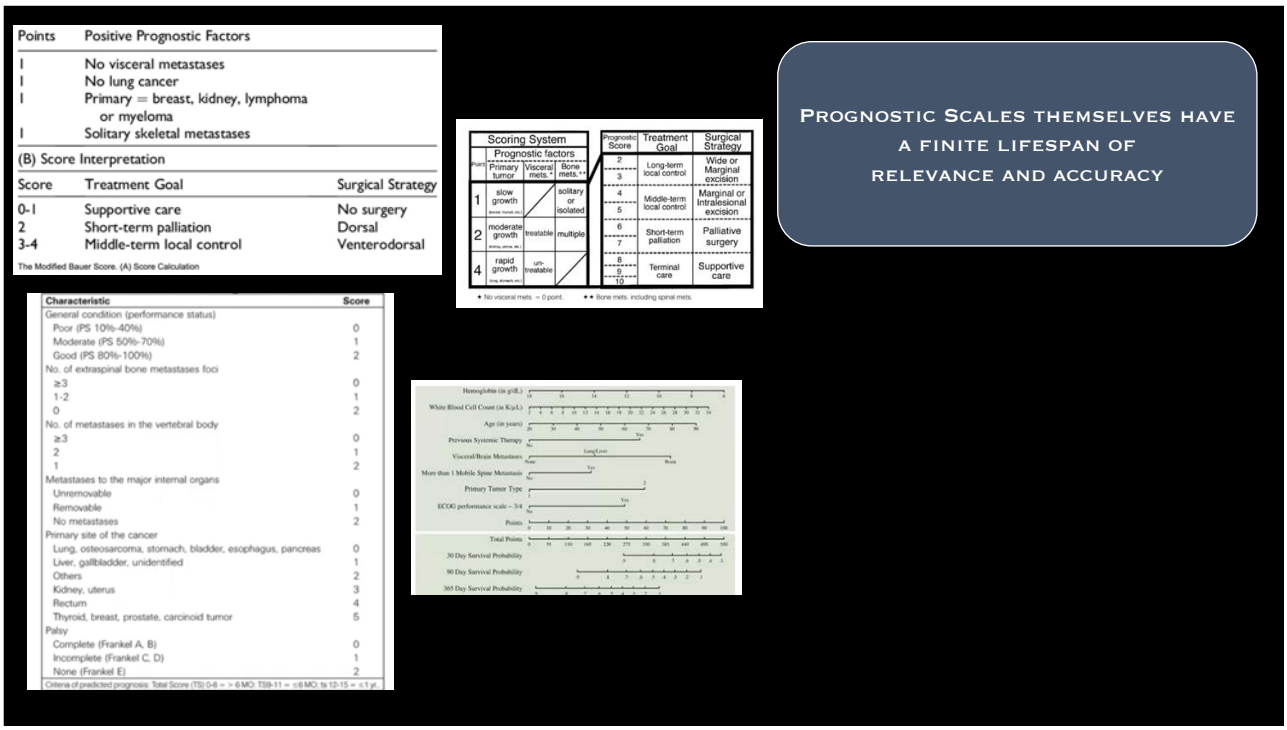
World Journal of Orthopedics
Scoring system for prediction of metastatic spine tumor prognosis
Scoring System
Prognostic factors
Point
Primary tumor
Visceral mets.*
Bone mets.**
1 slow growth solitary or isolated
2 moderate growth treatable multiple
4 rapid growth untreatable
Prognostic Score
Treatment Goal
Surgical Strategy
2 3 Long-term local control Wide or Marginal excision
4 5 Middle-term local control Marginal or Intralesional excision
6 7 Short-term palliation Palliative surgery
8 9 10 Terminal care Supportive care
★ No visceral mets. = 0 point. ★★ Bone mets. including spinal mets.
Points Positive Prognostic Factors
1 No visceral metastases
1 No lung cancer
1 Primary = breast, kidney, lymphoma or myeloma
1 Solitary skeletal metastases
(B) Score Interpretation
Score Treatment Goal Surgical Strategy
0-1 Supportive care No surgery
2 Short-term palliation Dorsal
3-4 Middle-term local control Venterodorsal
The Modified Bauer Score. (A) Score Calculation
Hemoglobin (in g/dL)
White Blood Cell Count (in K/μL)
Age (in years)
Previous Systemic Therapy
Visceral/Brain Metastases
More than 1 Mobile Spine Metastasis
Primary Tumor Type
ECOG performance scale – 3/4
Points
Total Points
30 Day Survival Probability
90 Day Survival Probability
365 Day Survival Probability
Characteristic Score
General condition (performance status)
Poor (PS 10%-40%) 0
Moderate (PS 50%-70%) 1
Good (PS 80%-100%) 2
No. of extraspinal bone metastases foci
≥3 0
1-2 1
0 2
No. of metastases in the vertebral body
≥3 0
2 1
1 2
Metastases to the major internal organs
Unremovable 0
Removable 1
No metastases 2
Primary site of the cancer
Lung, osteosarcoma, stomach, bladder, esophagus, pancreas 0
Liver, gallbladder, unidentified 1
Others 2
Kidney, uterus 3
Rectum 4
Thyroid, breast, prostate, carcinoid tumor 5
Palsy
Complete (Frankel A, B) 0
Incomplete (Frankel C, D) 1
None (Frankel E) 2
Criteria of predicted prognosis: Total Score (TS) 0-8 = > 6 MO; TS9-11 = ≤ 6 MO; ts 12-15 = ≤ 1 yr.

96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Score Treatment Goal Surgical Strategy
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The Modified Bauer Score. (A) Score Calculation
Scoring System
Prognostic factors
Primary tumor
Visceral mets.*
Bone mets.**
slow growth
moderate growth
rapid growth
solitary or isolated
multiple
Prognostic Score
Treatment Goal
Surgical Strategy
Long-term local control
Wide or Marginal excision
Middle-term local control
Marginal or Intralesional excision
Short-term palliation
Palliative surgery
Terminal care
Supportive care
Characteristic Score
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Kidney, uterus 3
Rectum 4
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Palsy
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Incomplete (Frankel C, D) 1
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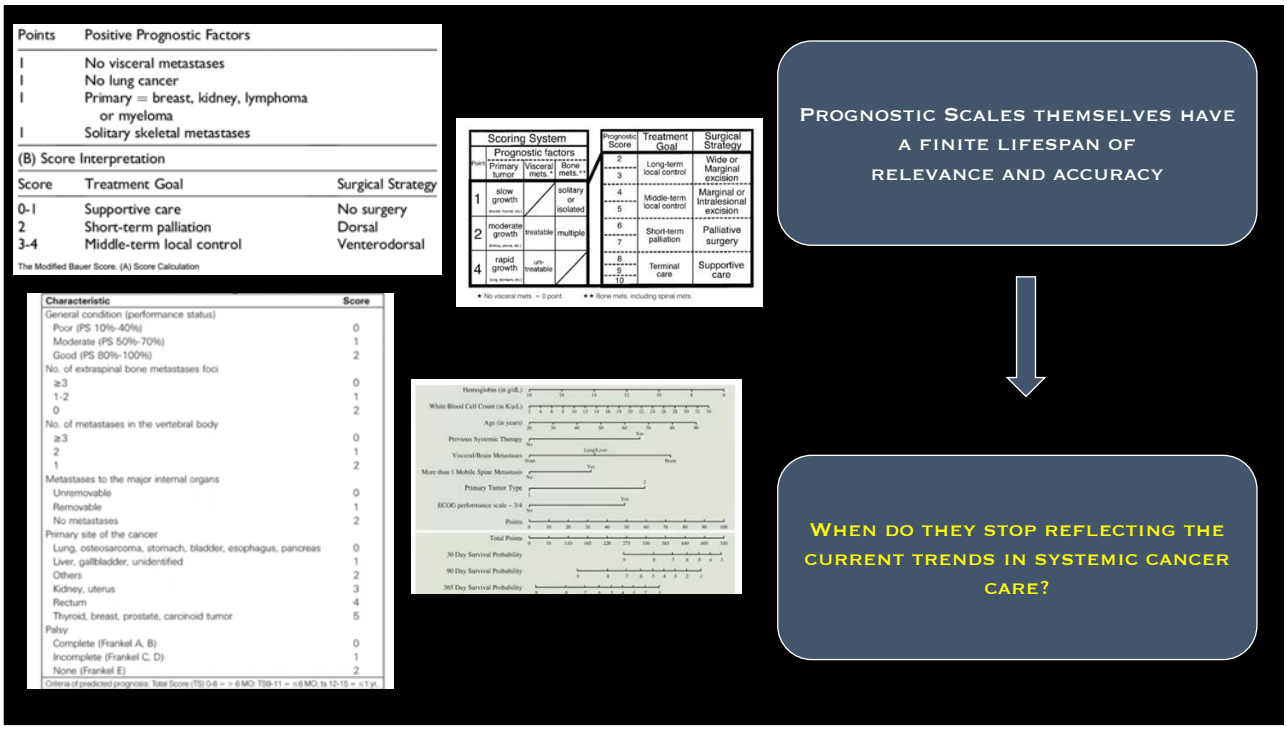
Prognostics Scales themselves have a finite lifespan of relevance and accuracy

97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Thyroid, breast, prostate, carcinoid tumor 5
Palsy
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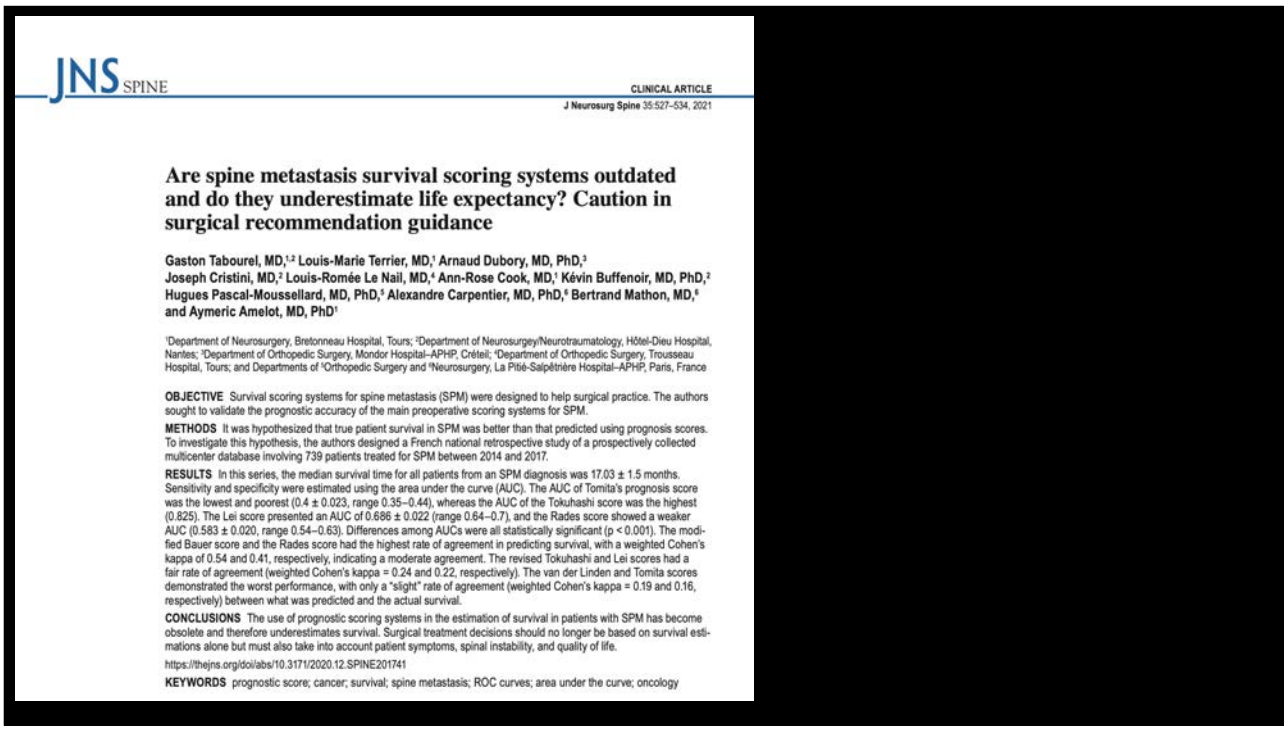
Incomplete (Frankel C, D) 1
None (Frankel E) 2
Prognostics Scales themselves have a finite lifespan of relevance and accuracy
When do they stop reflecting the current trends in systemic cancer care?

98



JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 35:527–534, 2021

Are spine metastasis survival scoring systems outdated and do they underestimate life expectancy? Caution in surgical recommendation guidance

Gaston Tabourel, MD,[1,2] Louis-Marie Terrier, MD,[1] Arnaud Dubory, MD, PhD,[3] Joseph Cristini, MD,[2] Louis-Romée Le Nail, MD,[4] Ann-Rose Cook, MD,[1] Kévin Buffenoir, MD, PhD,[2] Hugues Pascal-Moussellard, MD, PhD,[5] Alexandre Carpentier, MD, PhD,[6] Bertrand Mathon, MD,[6] and Aymeric Amelot, MD, PhD[1]

[1]Department of Neurosurgery, Bretonneau Hospital, Tours; [2]Department of Neurosurgey/Neurotraumatology, Hôtel-Dieu Hospital, Nantes; [3]Department of Orthopedic Surgery, Mondor Hospital–APHP, Créteil; [4]Department of Orthopedic Surgery, Trousseau Hospital, Tours; and Departments of [5]Orthopedic Surgery and [6]Neurosurgery, La Pitié-Salpêtrière Hospital–APHP, Paris, France

OBJECTIVE Survival scoring systems for spine metastasis (SPM) were designed to help surgical practice. The authors sought to validate the prognostic accuracy of the main preoperative scoring systems for SPM.

METHODS It was hypothesized that true patient survival in SPM was better than that predicted using prognosis scores. To investigate this hypothesis, the authors designed a French national retrospective study of a prospectively collected multicenter database involving 739 patients treated for SPM between 2014 and 2017.

RESULTS In this series, the median survival time for all patients from an SPM diagnosis was 17.03 ± 1.5 months. Sensitivity and specificity were estimated using the area under the curve (AUC). The AUC of Tomita's prognosis score was the lowest and poorest (0.4 ± 0.023, range 0.35–0.44), whereas the AUC of the Tokuhashi score was the highest (0.825). The Lei score presented an AUC of 0.686 ± 0.022 (range 0.64–0.7), and the Rades score showed a weaker AUC (0.583 ± 0.020, range 0.54–0.63). Differences among AUCs were all statistically significant ($p < 0.001$). The modified Bauer score and the Rades score had the highest rate of agreement in predicting survival, with a weighted Cohen's kappa of 0.54 and 0.41, respectively, indicating a moderate agreement. The revised Tokuhashi and Lei scores had a fair rate of agreement (weighted Cohen's kappa = 0.24 and 0.22, respectively). The van der Linden and Tomita scores demonstrated the worst performance, with only a "slight" rate of agreement (weighted Cohen's kappa = 0.19 and 0.16, respectively) between what was predicted and the actual survival.

CONCLUSIONS The use of prognostic scoring systems in the estimation of survival in patients with SPM has become obsolete and therefore underestimates survival. Surgical treatment decisions should no longer be based on survival estimations alone but must also take into account patient symptoms, spinal instability, and quality of life.

https://thejns.org/doi/abs/10.3171/2020.12.SPINE201741

KEYWORDS prognostic score; cancer; survival; spine metastasis; ROC curves; area under the curve; oncology

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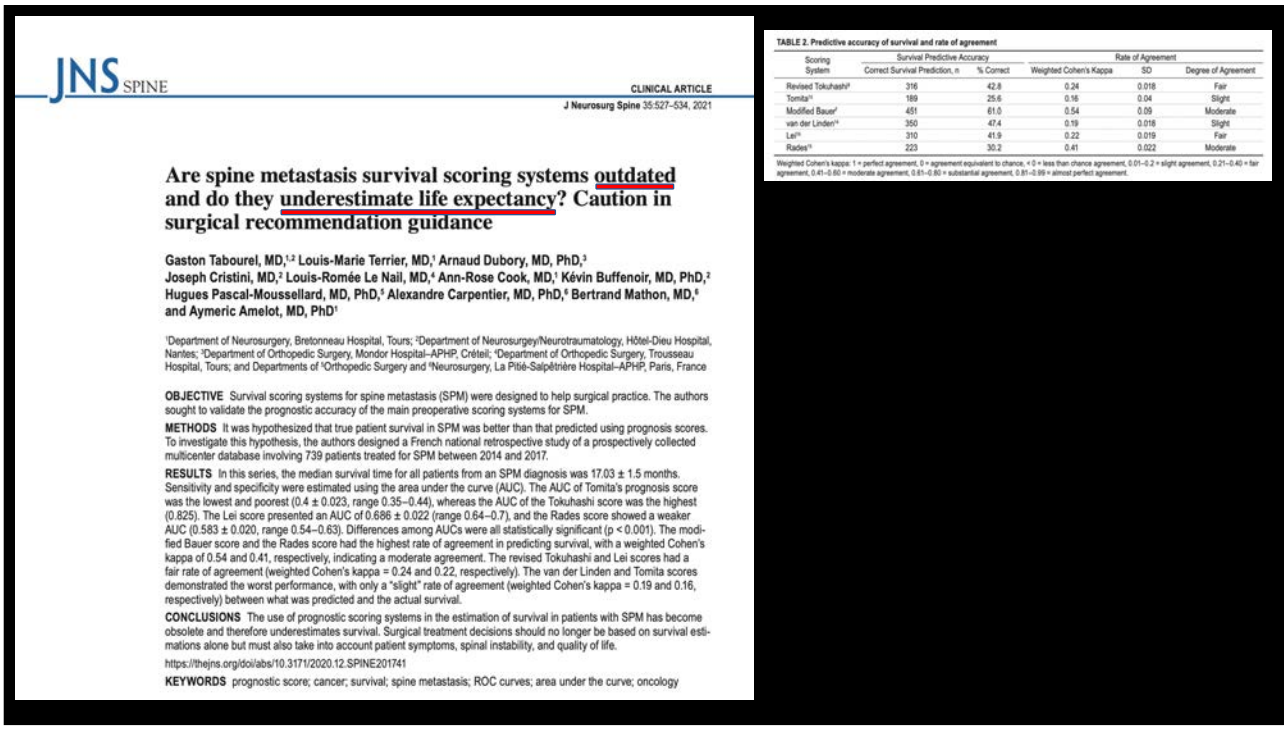

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OBJECTIVE Survival scoring systems for spine metastasis (SPM) were designed to help surgical practice. The authors sought to validate the prognostic accuracy of the main preoperative scoring systems for SPM.

METHODS It was hypothesized that true patient survival in SPM was better than that predicted using prognosis scores. To investigate this hypothesis, the authors designed a French national retrospective study of a prospectively collected multicenter database involving 739 patients treated for SPM between 2014 and 2017.

RESULTS In this series, the median survival time for all patients from an SPM diagnosis was 17.03 ± 1.5 months. Sensitivity and specificity were estimated using the area under the curve (AUC). The AUC of Tomita's prognosis score was the lowest and poorest (0.4 ± 0.023, range 0.35–0.44), whereas the AUC of the Tokuhashi score was the highest (0.825). The Lei score presented an AUC of 0.686 ± 0.022 (range 0.64–0.7), and the Rades score showed a weaker AUC (0.583 ± 0.020, range 0.54–0.63). Differences among AUCs were all statistically significant ($p < 0.001$). The modified Bauer score and the Rades score had the highest rate of agreement in predicting survival, with a weighted Cohen's kappa of 0.54 and 0.41, respectively, indicating a moderate agreement. The revised Tokuhashi and Lei scores had a fair rate of agreement (weighted Cohen's kappa = 0.24 and 0.22, respectively). The van der Linden and Tomita scores demonstrated the worst performance, with only a "slight" rate of agreement (weighted Cohen's kappa = 0.19 and 0.16, respectively) between what was predicted and the actual survival.

CONCLUSIONS The use of prognostic scoring systems in the estimation of survival in patients with SPM has become obsolete and therefore underestimates survival. Surgical treatment decisions should no longer be based on survival estimations alone but must also take into account patient symptoms, spinal instability, and quality of life.

https://thejns.org/doi/abs/10.3171/2020.12.SPINE201741

KEYWORDS prognostic score; cancer; survival; spine metastasis; ROC curves; area under the curve; oncology

TABLE 2. Predictive accuracy of survival and rate of agreement

Scoring System	Survival Predictive Accuracy		Rate of Agreement		
	Correct Survival Prediction, n	% Correct	Weighted Cohen's Kappa	SD	Degree of Agreement
Revised Tokuhashi[9]	316	42.8	0.24	0.018	Fair
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Modified Bauer[7]	451	61.0	0.54	0.09	Moderate
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Weighted Cohen's kappa: 1 = perfect agreement, 0 = agreement equivalent to chance, < 0 = less than chance agreement, 0.01–0.2 = slight agreement, 0.21–0.40 = fair agreement, 0.41–0.60 = moderate agreement, 0.61–0.80 = substantial agreement, 0.81–0.99 = almost perfect agreement.

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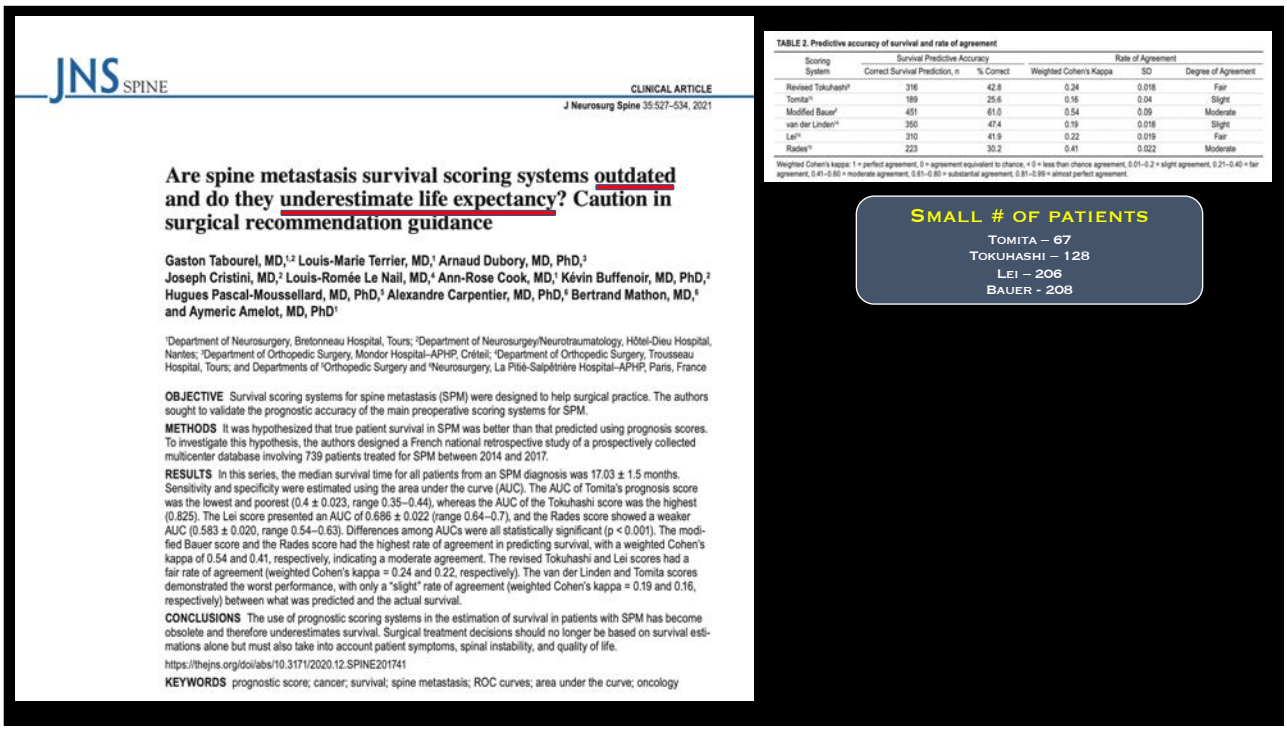
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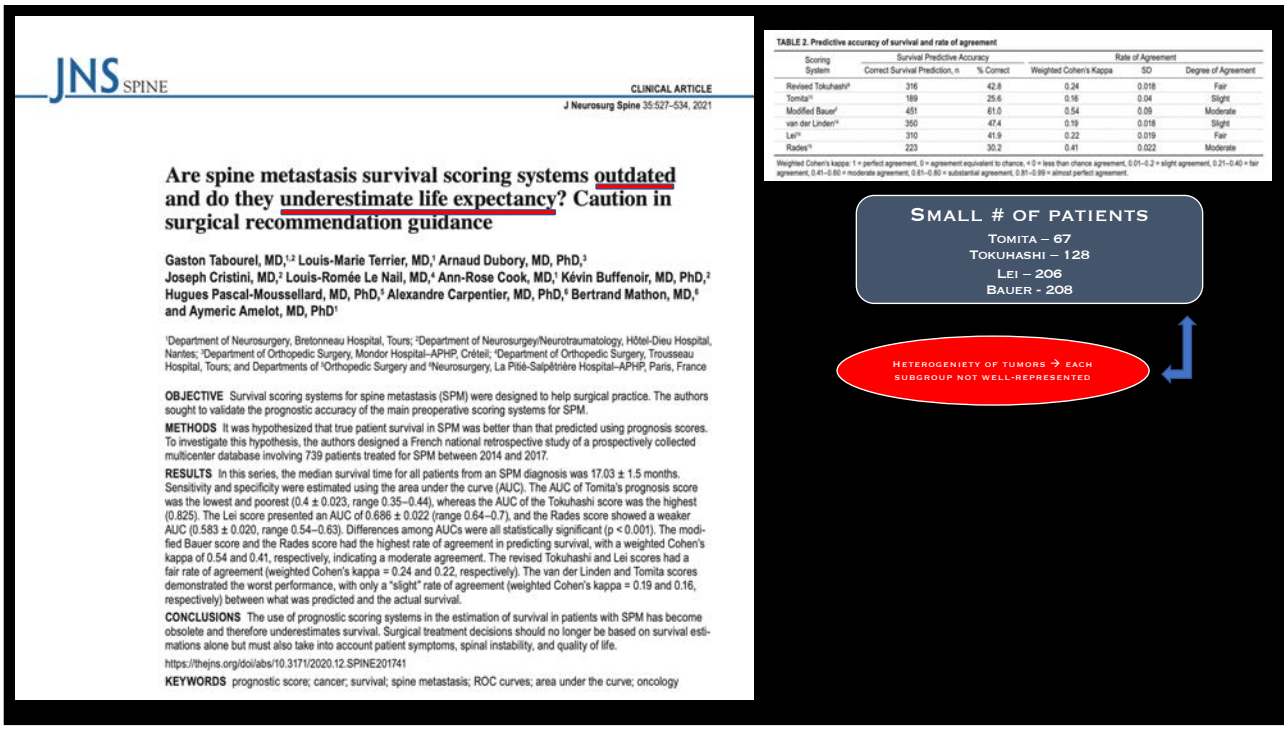
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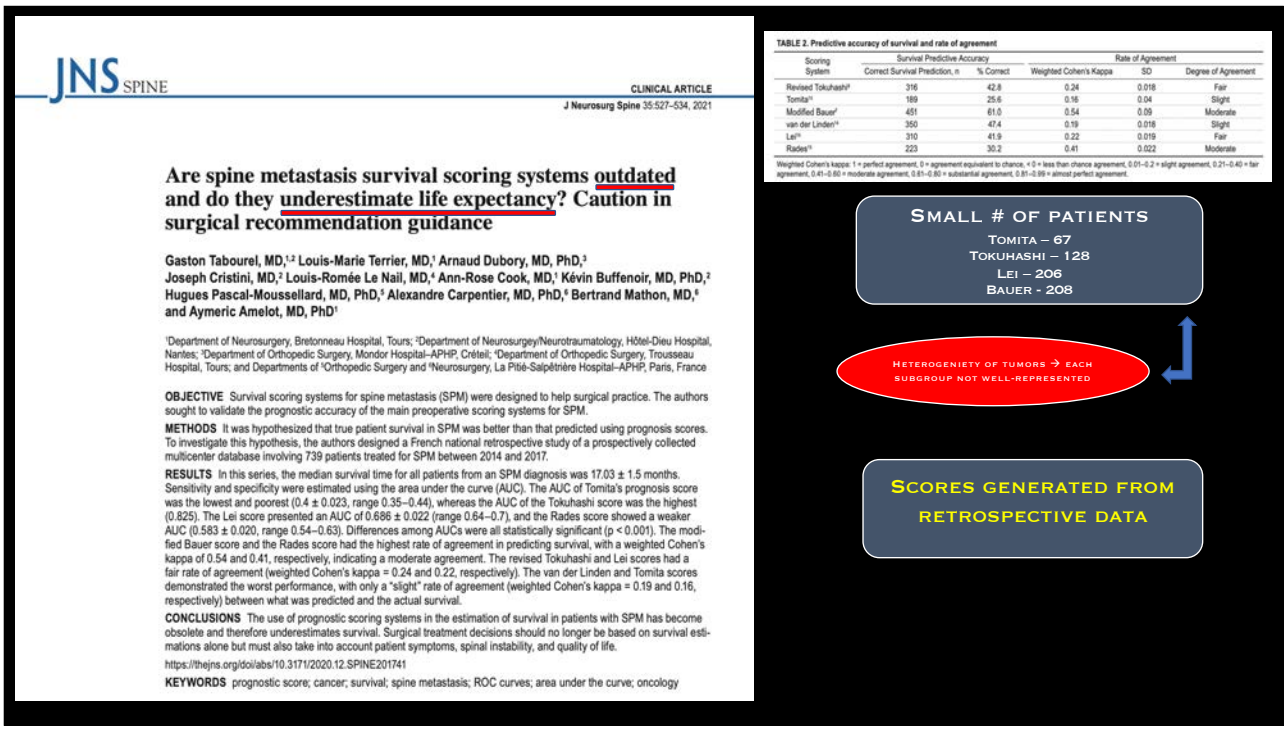
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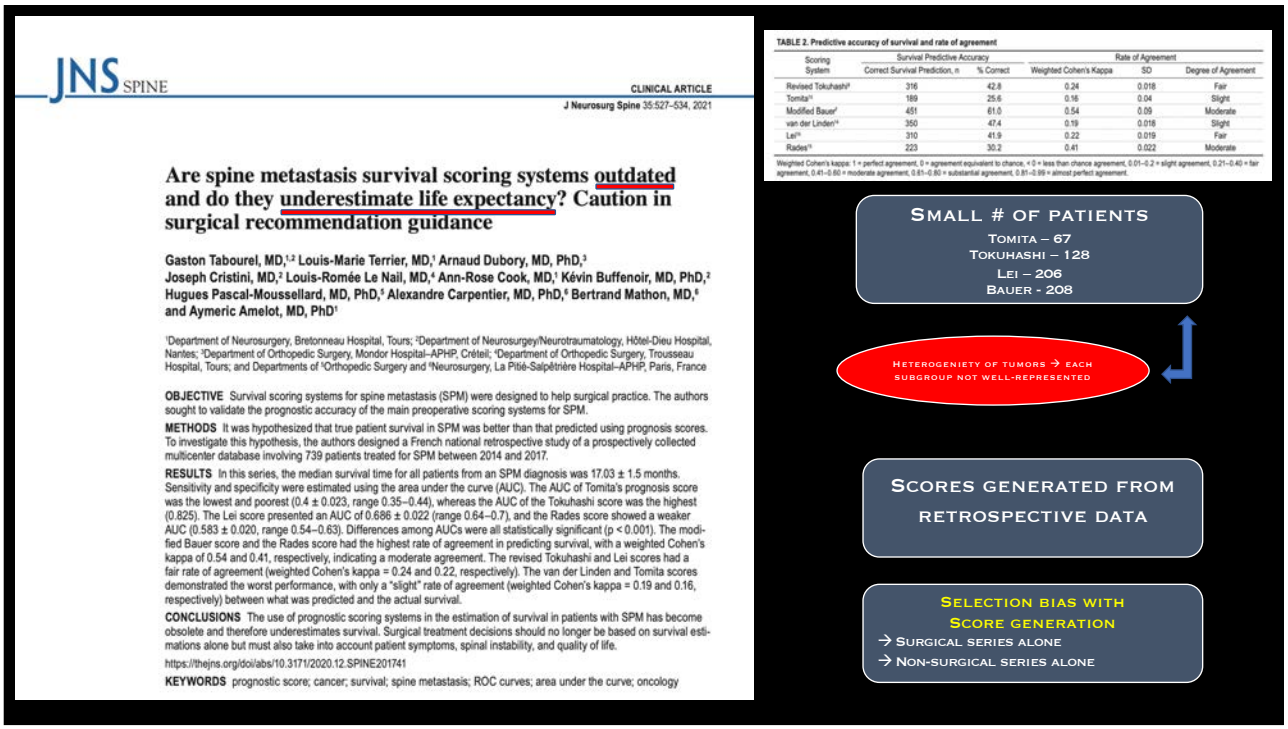
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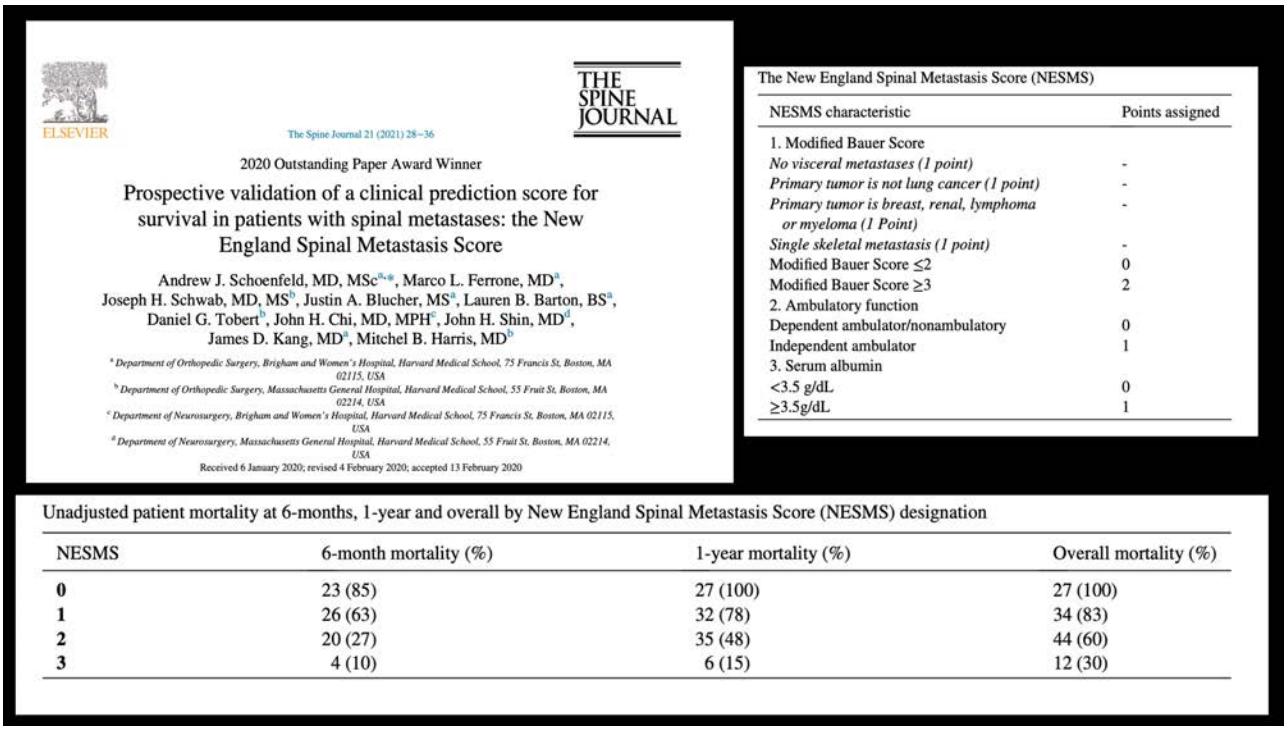

ELSEVIER
The Spine Journal 21 (2021) 28–36
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2020 Outstanding Paper Award Winner

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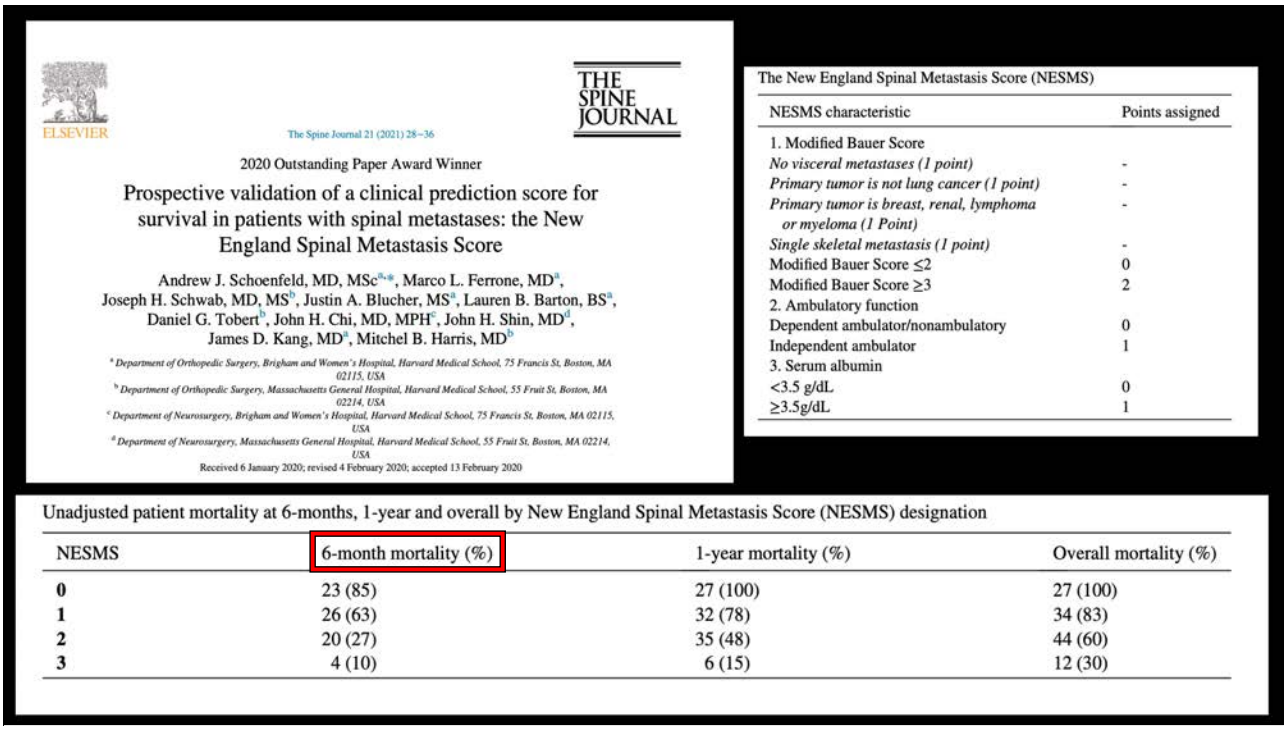
The New England Spinal Metastasis Score (NESMS)

NESMS characteristic	Points assigned
1. Modified Bauer Score	
No visceral metastases (1 point)	-
Primary tumor is not lung cancer (1 point)	-
Primary tumor is breast, renal, lymphoma or myeloma (1 Point)	-
Single skeletal metastasis (1 point)	-
Modified Bauer Score ≤2	0
Modified Bauer Score ≥3	2
2. Ambulatory function	
Dependent ambulator/nonambulatory	0
Independent ambulator	1
3. Serum albumin	
<3.5 g/dL	0
≥3.5g/dL	1

Unadjusted patient mortality at 6-months, 1-year and overall by New England Spinal Metastasis Score (NESMS) designation

NESMS	6-month mortality (%)	1-year mortality (%)	Overall mortality (%)
0	23 (85)	27 (100)	27 (100)
1	26 (63)	32 (78)	34 (83)
2	20 (27)	35 (48)	44 (60)
3	4 (10)	6 (15)	12 (30)

105



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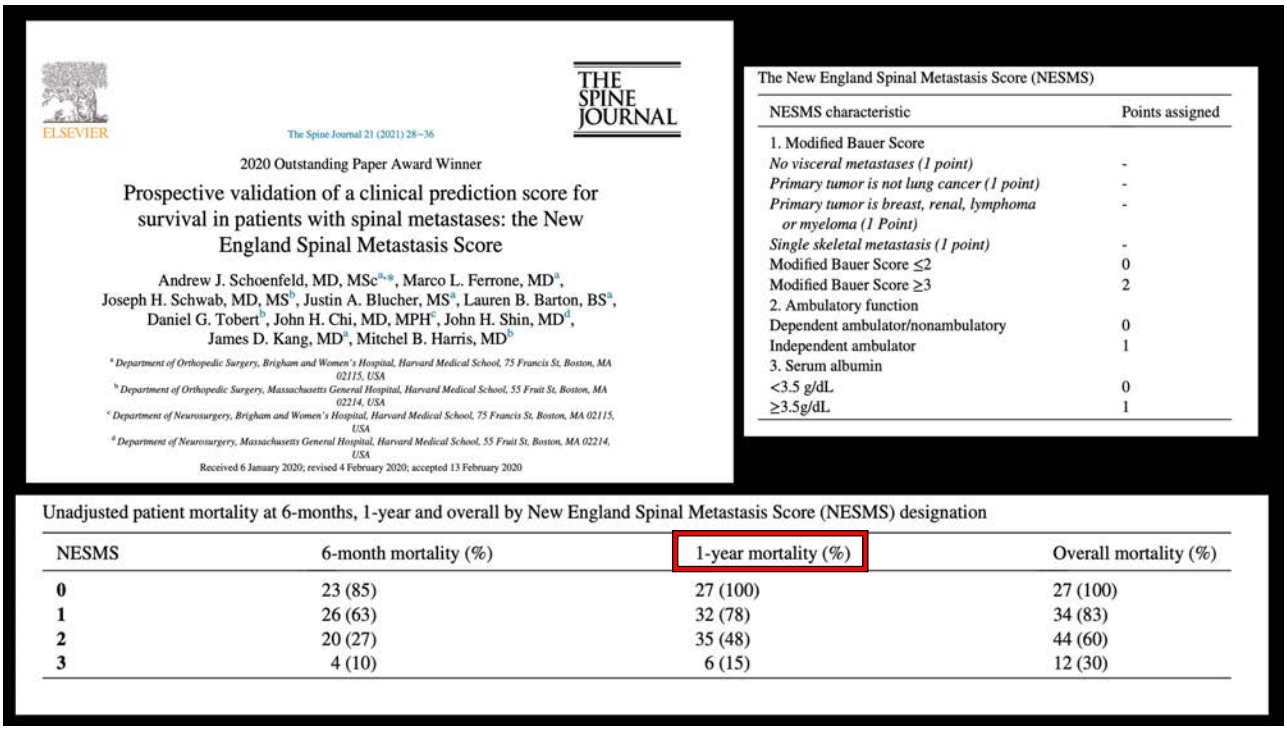

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Modified Bauer Score ≤2	0
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2. Ambulatory function	
Dependent ambulator/nonambulatory	0
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Unadjusted patient mortality at 6-months, 1-year and overall by New England Spinal Metastasis Score (NESMS) designation

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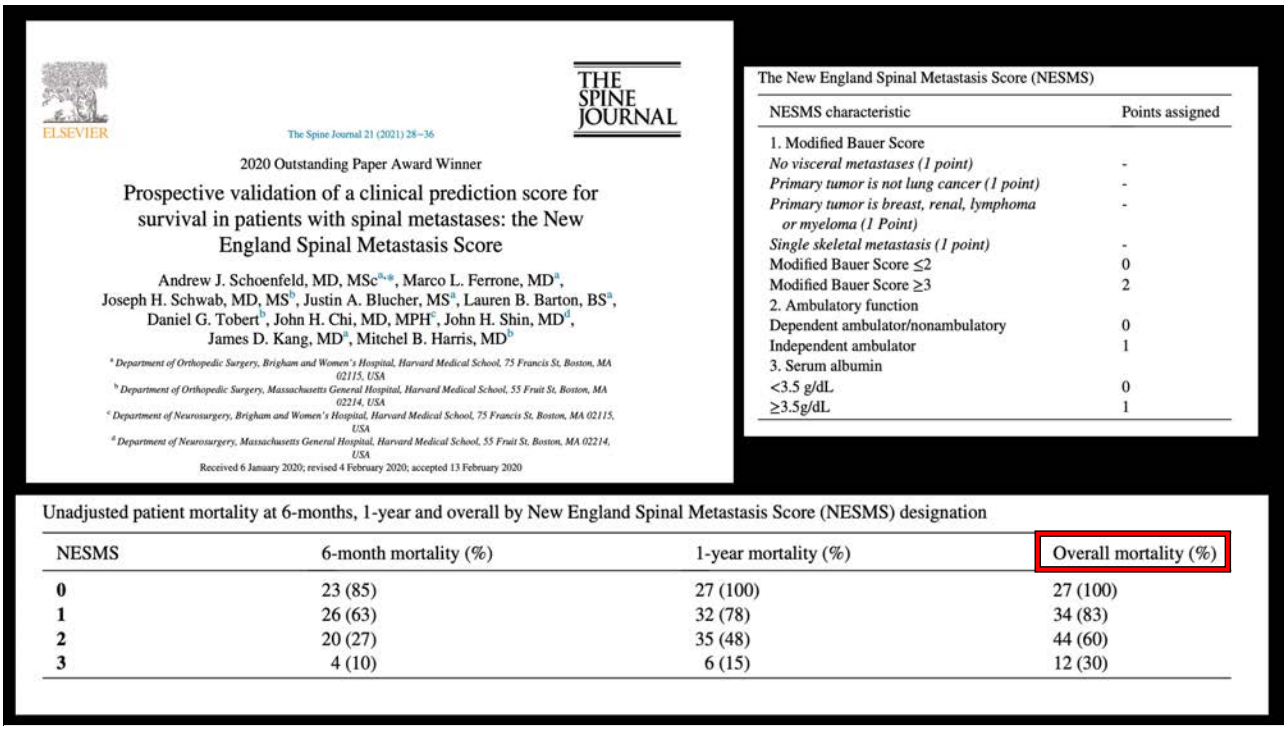

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The Spine Journal 21 (2021) 28–36
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2020 Outstanding Paper Award Winner

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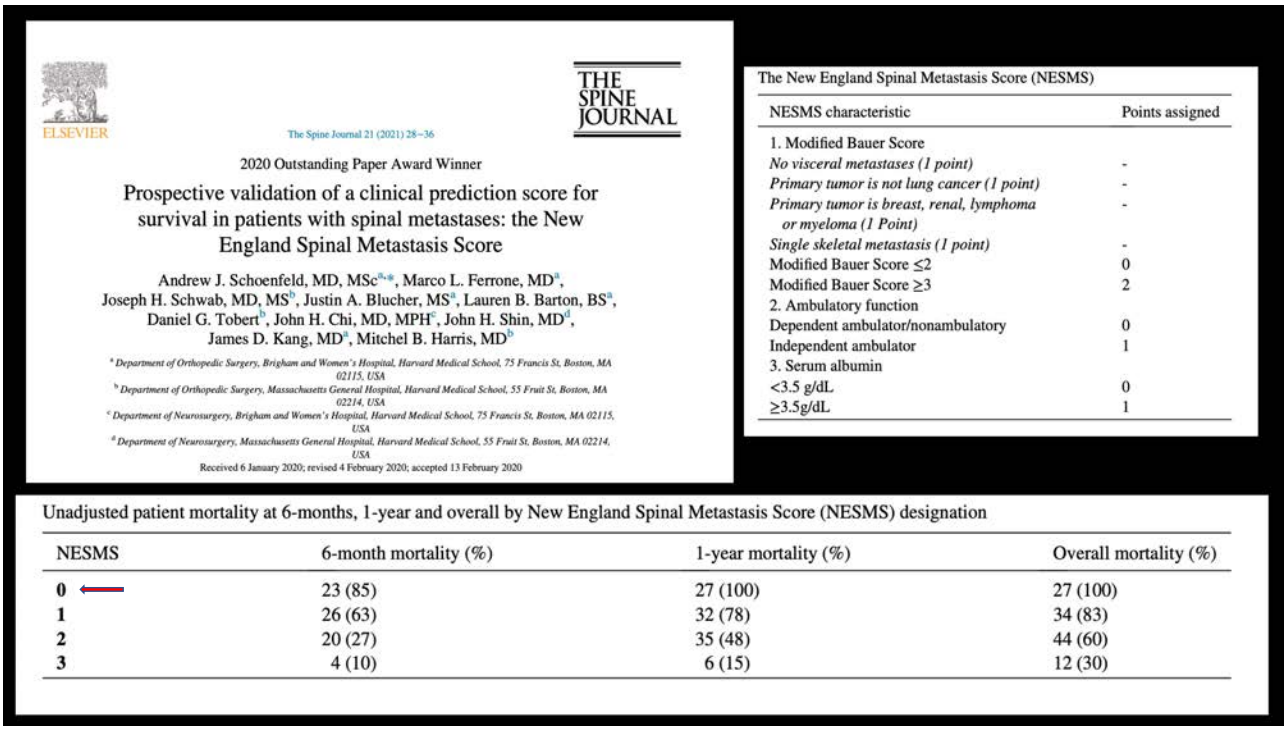

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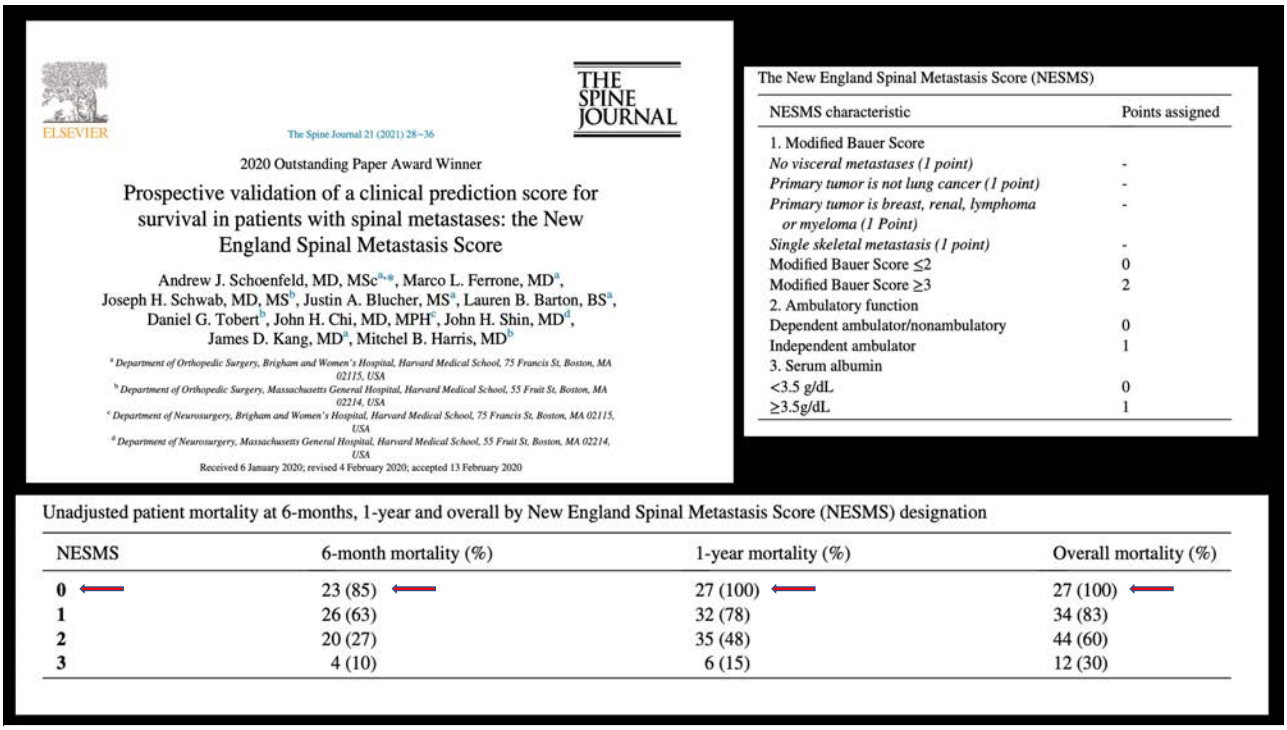

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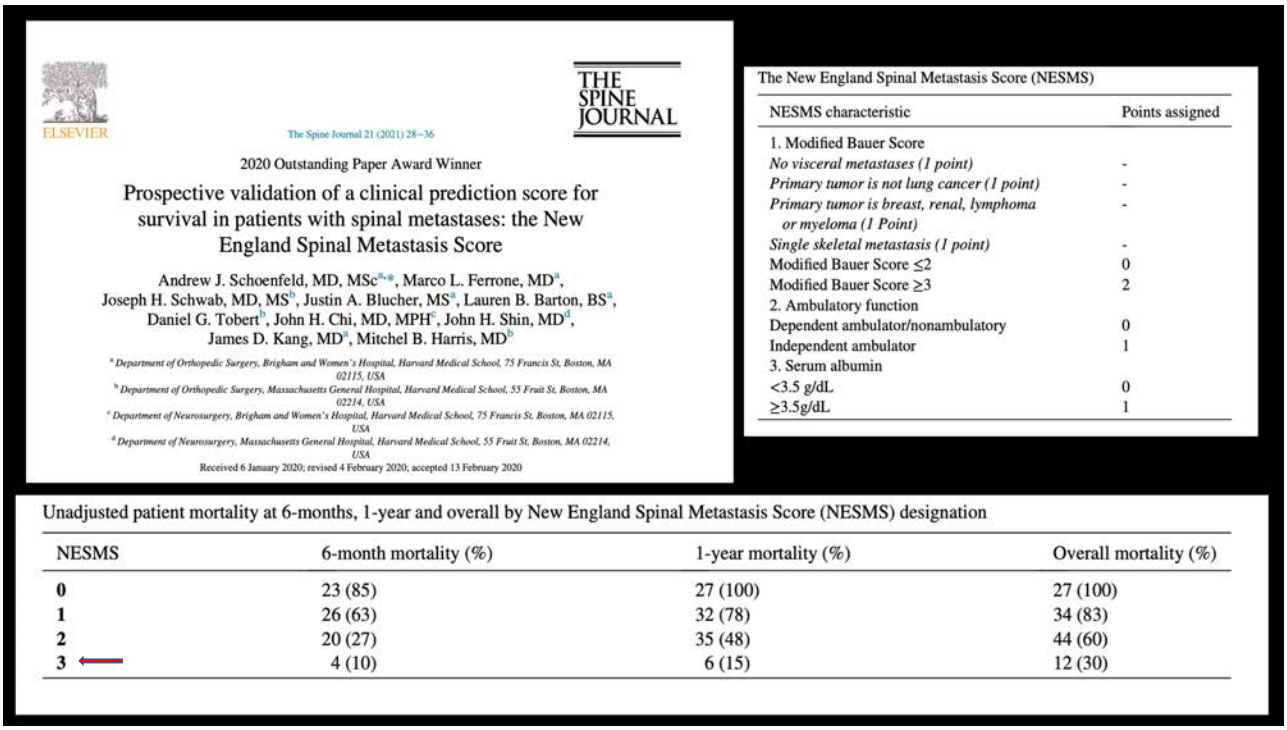

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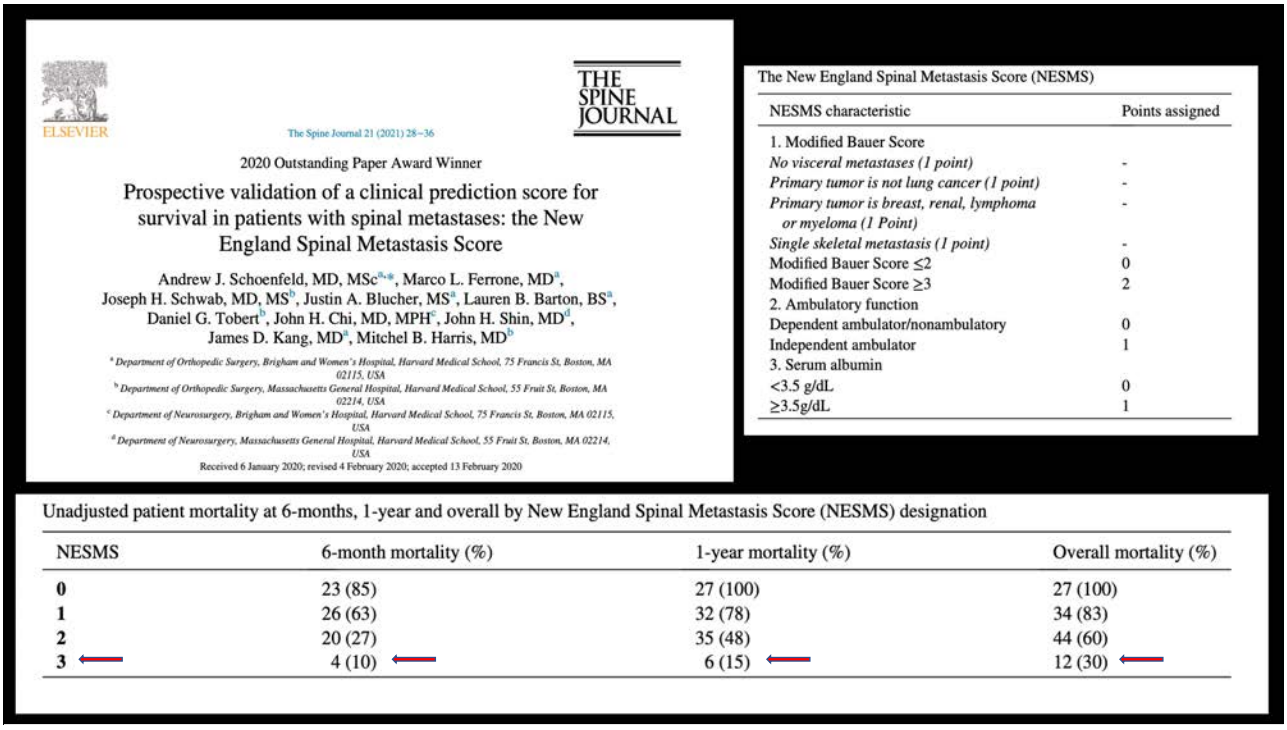

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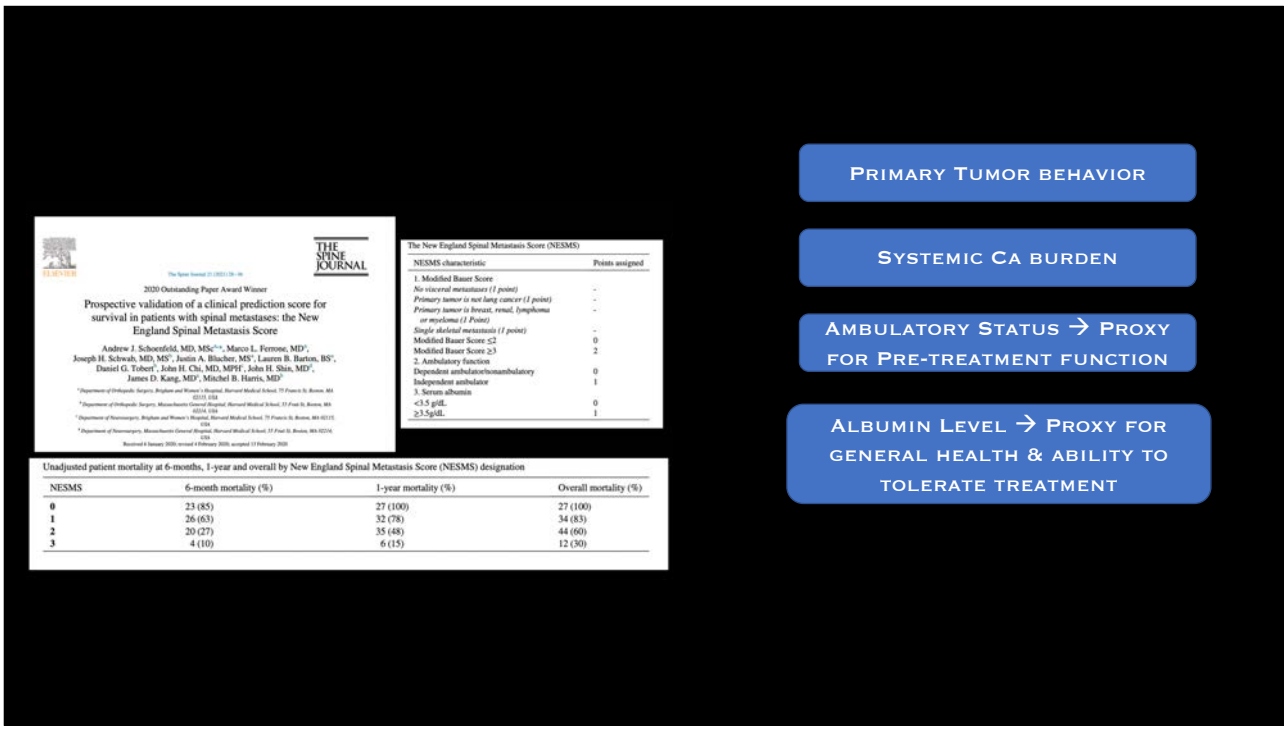
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AMBULATORY STATUS → PROXY FOR PRE-TREATMENT FUNCTION
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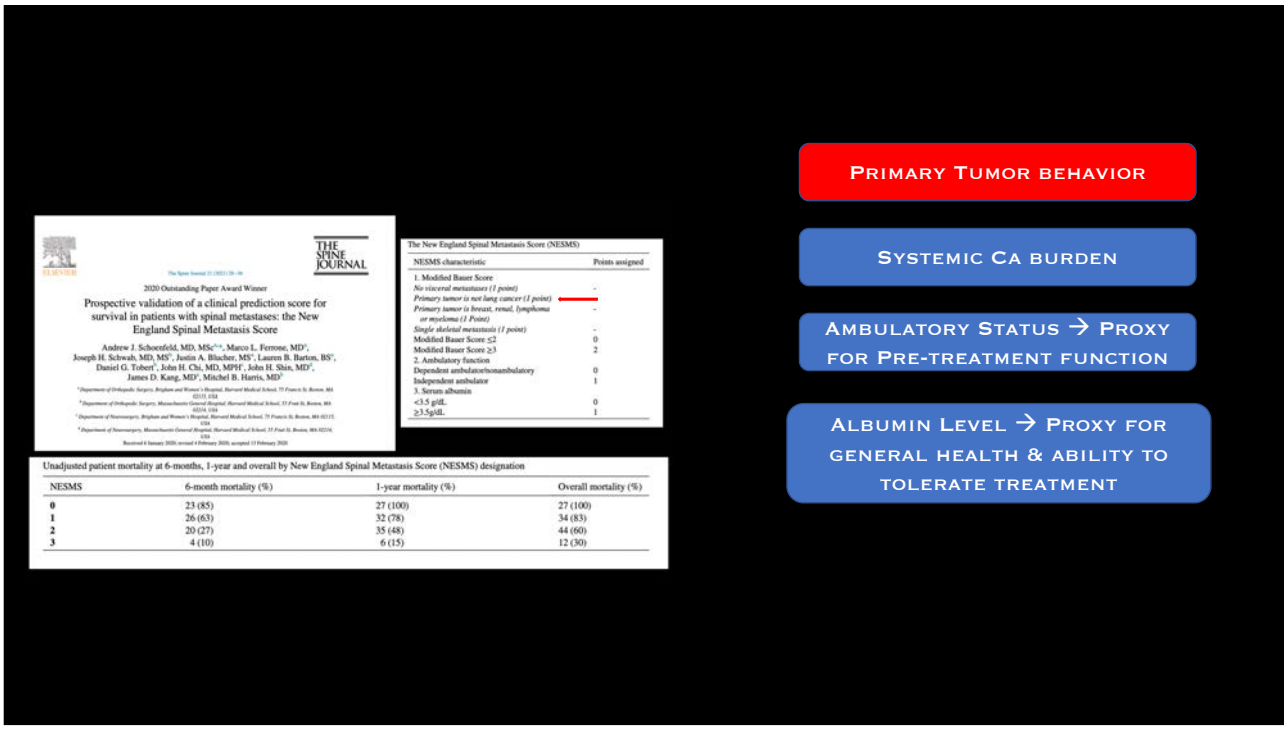
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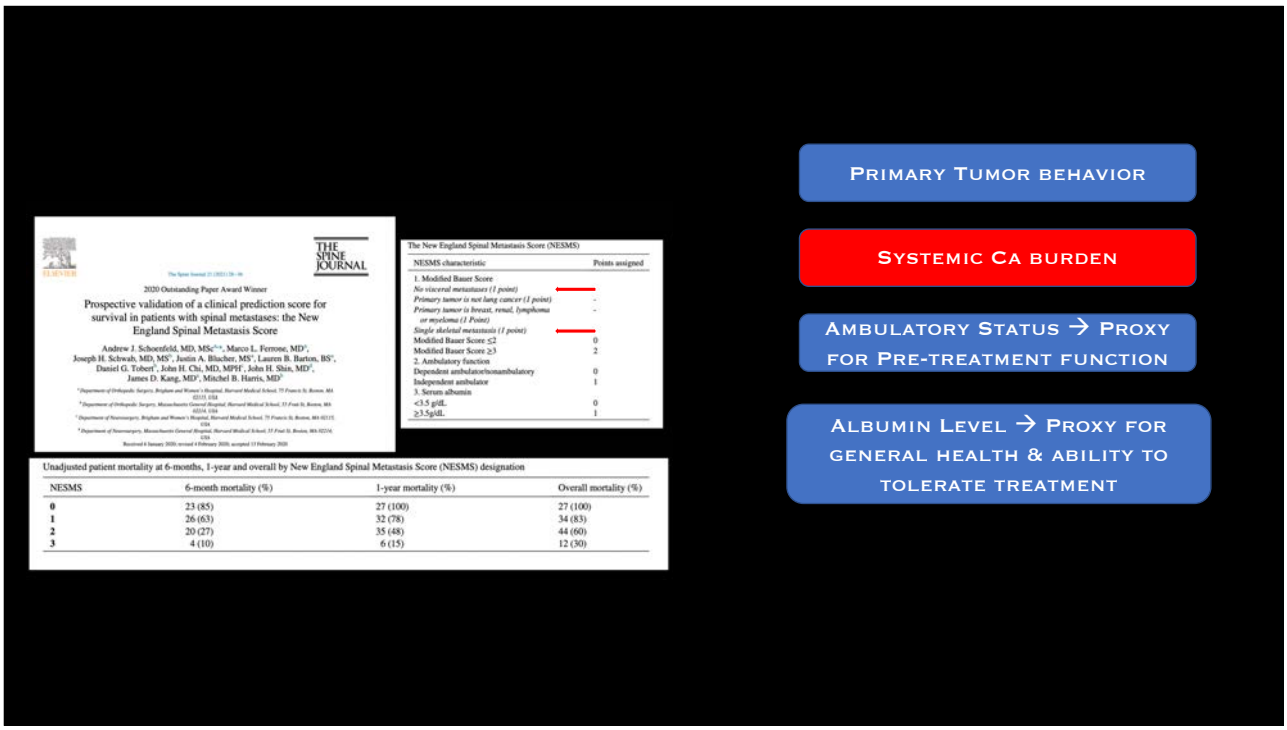
114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Albumin Level → Proxy for general health & ability to tolerate treatment

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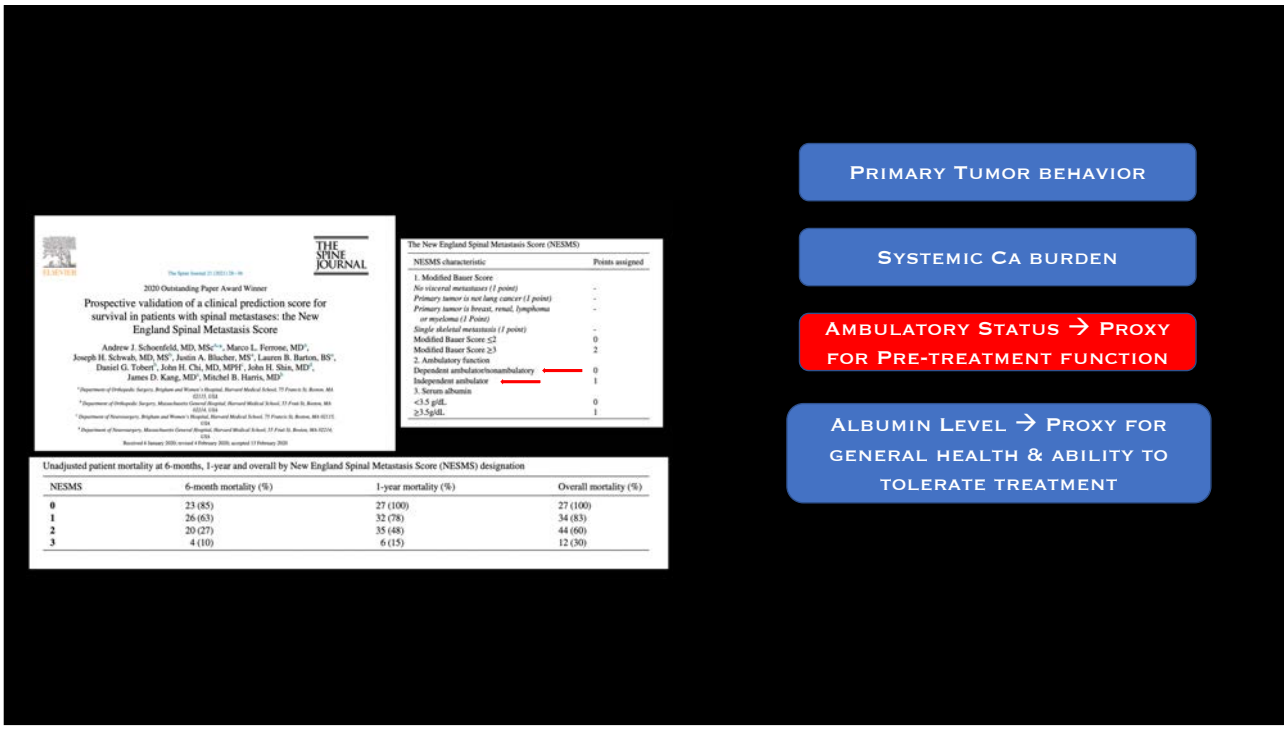
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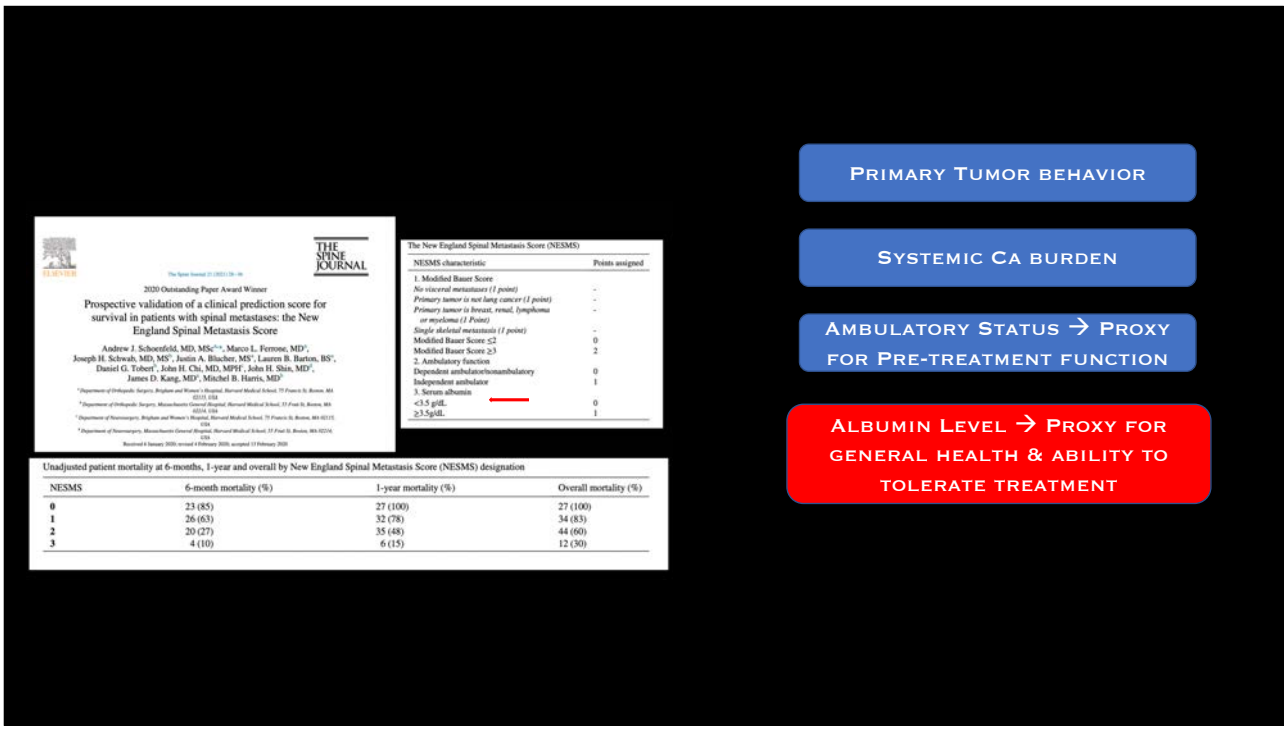
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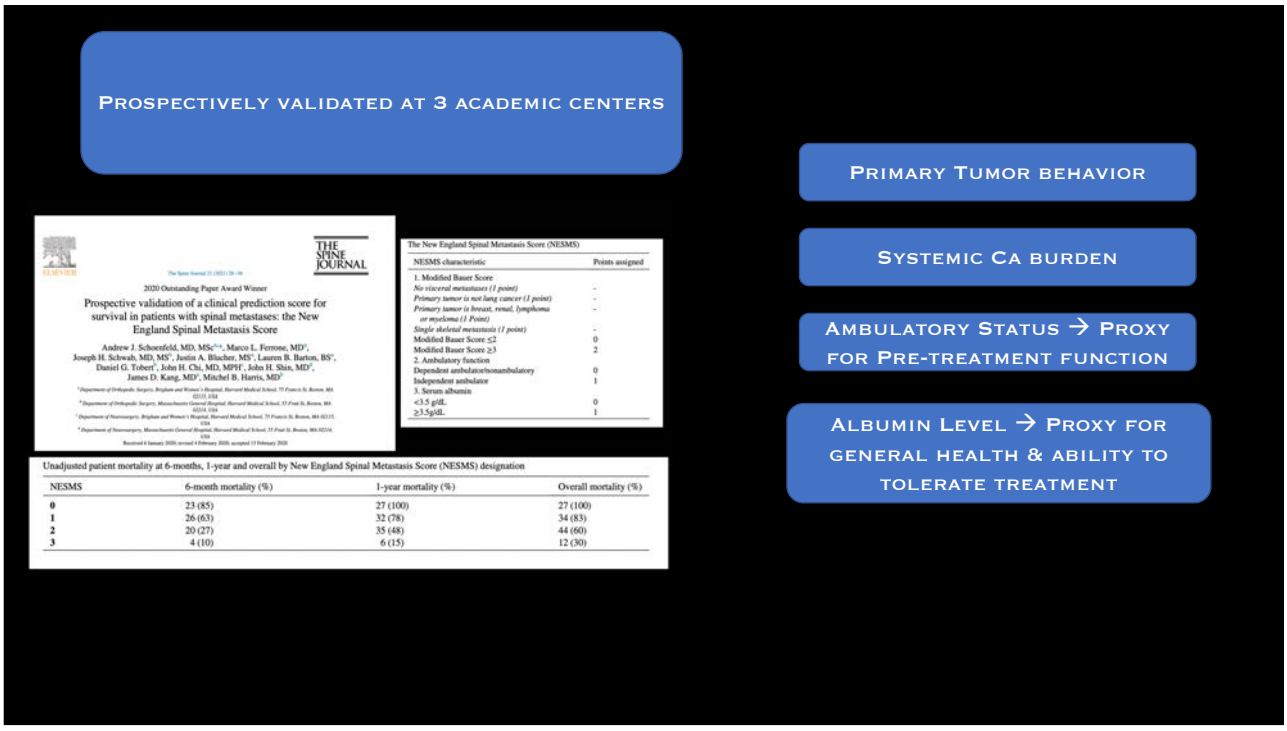
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PROSPECTIVELY VALIDATED AT 3 ACADEMIC CENTERS

2020 Outstanding Paper Award Winner

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- AMBULATORY STATUS → PROXY FOR PRE-TREATMENT FUNCTION
- ALBUMIN LEVEL → PROXY FOR GENERAL HEALTH & ABILITY TO TOLERATE TREATMENT

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PREDICTIVE FACTORS LEADING TO SURVIVORSHIP AT 1 YEAR

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- HIGHER PERFORMANCE STATUS
- BETTER NEUROLOGICAL STATUS
- ABSENCE OF VISCERAL METS

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Predictive Factors Leading to Survivorship at 1 year

2020 Outstanding Paper Award Winner

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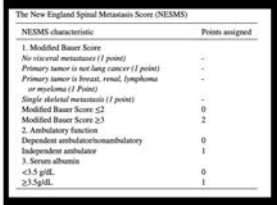
Andrew J. Schoenfeld, MD, MSc[a,*], Marco L. Ferrone, MD[b], Joseph H. Schwab, MD, MS[b], Justin A. Blucher, MS[b], Lauren B. Barton, BS[b], Daniel G. Tobert[b], John H. Chi, MD, MPH[c], John H. Shin, MD[d], James D. Kang, MD[c], Mitchel B. Harris, MD[b]



The New England Spinal Metastasis Score (NESMS)

NESMS characteristic	Points assigned
1. Modified Bauer Score	
No visceral metastases (1 point)	-
Primary tumor is not lung cancer (1 point)	-
Primary tumor is breast, renal, lymphoma or myeloma (1 Point)	-
Single skeletal metastasis (1 point)	-
Modified Bauer Score ≤2	0
Modified Bauer Score ≥3	2
2. Ambulatory function	
Dependent ambulator/nonambulatory	0
Independent ambulator	1
3. Serum albumin	
<3.5 g/dL	0
≥3.5g/dL	1

Unadjusted patient mortality at 6-months, 1-year and overall by New England Spinal Metastasis Score (NESMS) designation

NESMS	6-month mortality (%)	1-year mortality (%)	Overall mortality (%)
0	23 (85)	27 (100)	27 (100)
1	26 (63)	32 (78)	34 (83)
2	20 (27)	35 (48)	44 (60)
3	4 (10)	6 (15)	12 (30)

- Higher Performance Status
- Better Neurological Status
- Absence of Visceral Mets

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Predictive Factors Leading to Survivorship at 1 year

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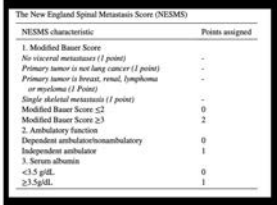

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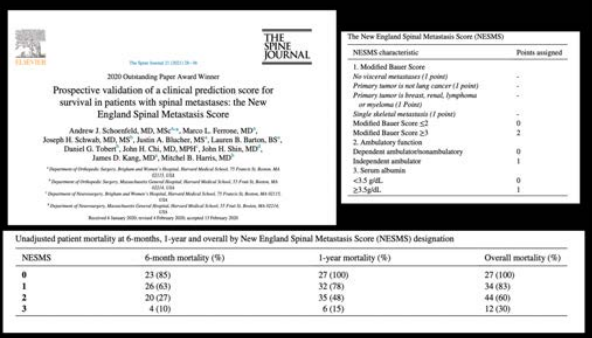

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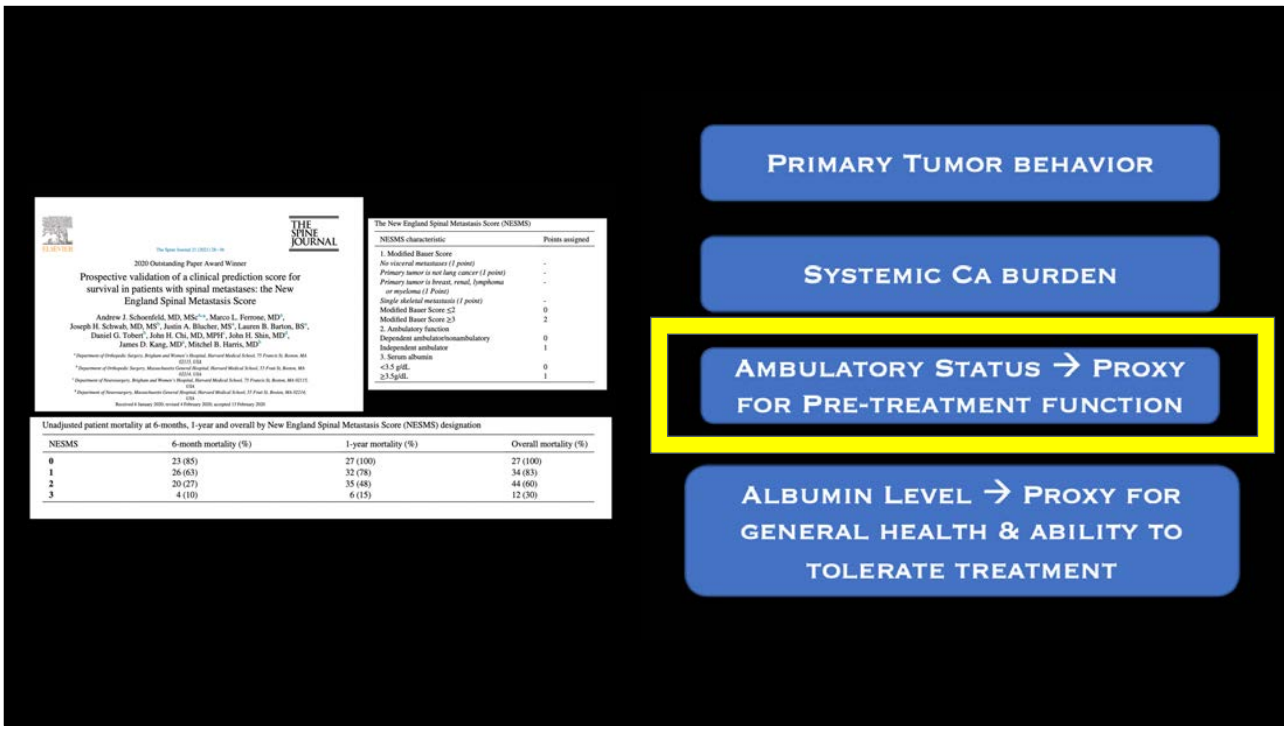
The New England Spinal Metastasis Score (NESMS)

Unadjusted patient mortality at 6-months, 1-year and overall by New England Spinal Metastasis Score (NESMS) designation

- Primary Tumor behavior
- Systemic Ca burden
- Ambulatory Status → Proxy for Pre-treatment function
- Albumin Level → Proxy for general health & ability to tolerate treatment

124


THE SPINE JOURNAL
2020 Outstanding Paper Award Winner
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NESMS characteristic
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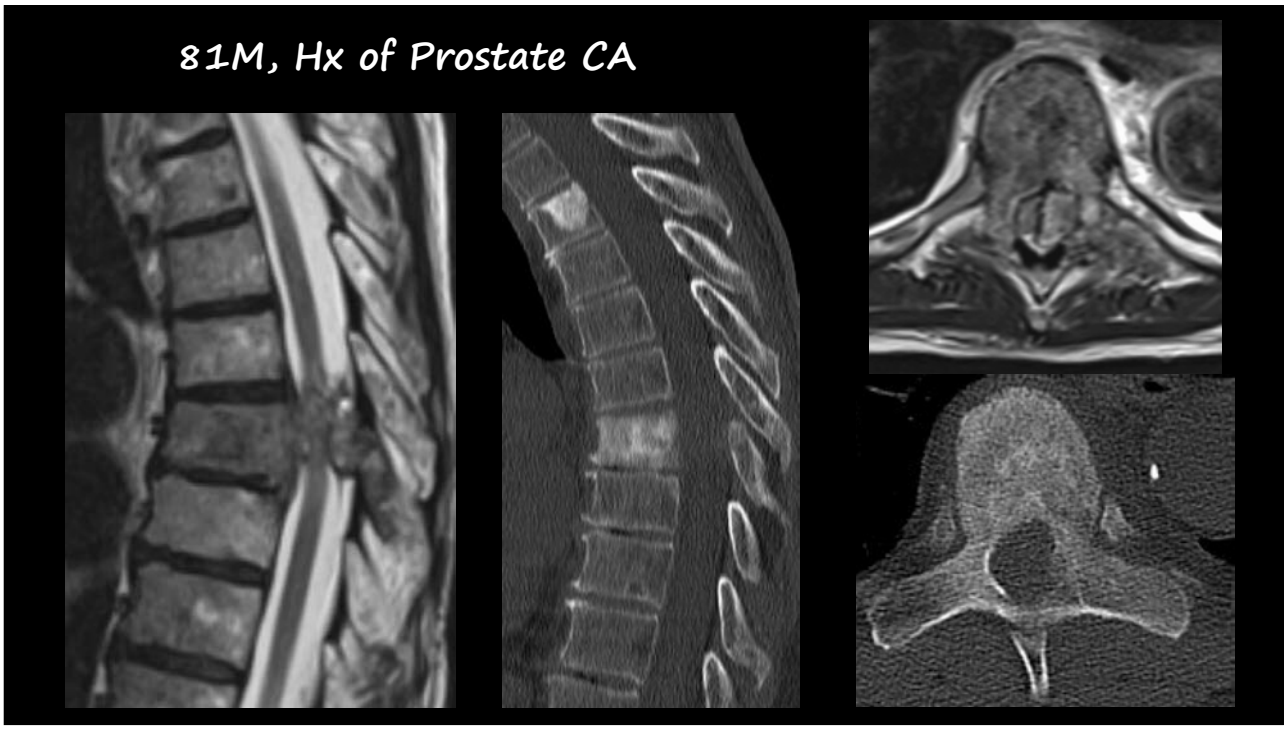
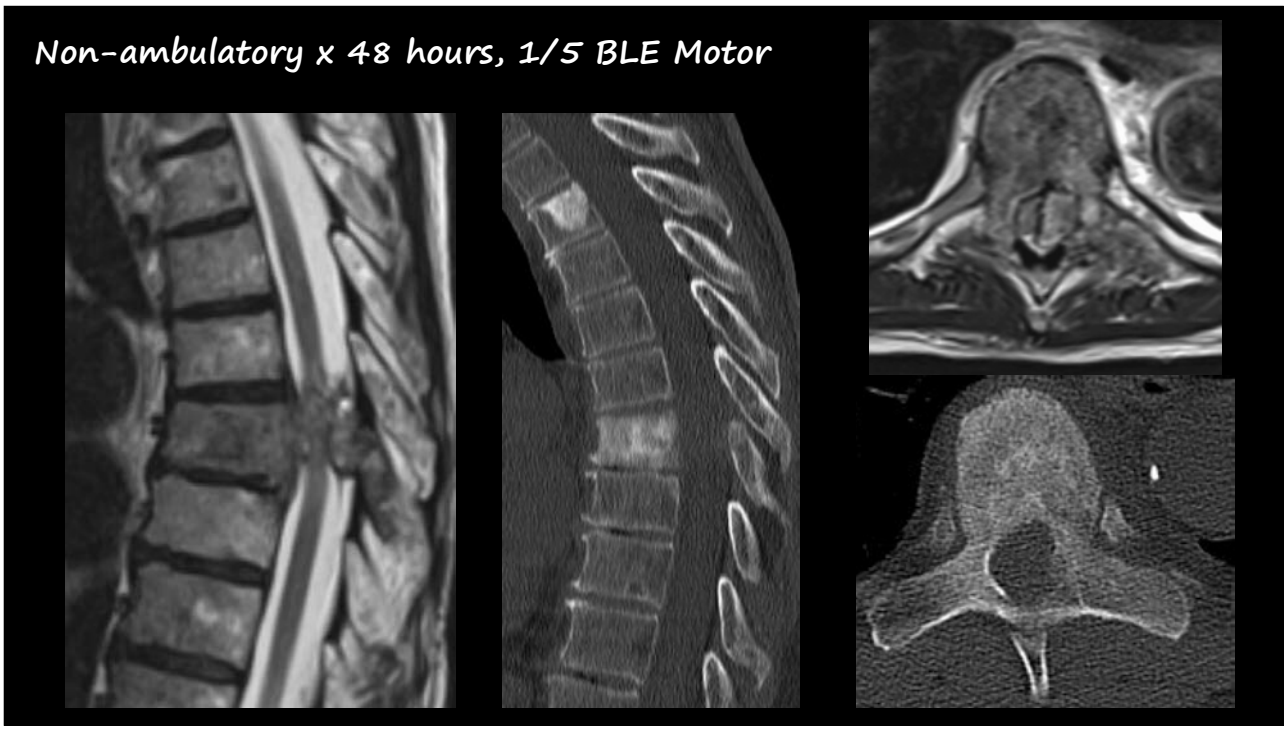
PRIMARY TUMOR BEHAVIOR
SYSTEMIC CA BURDEN
AMBULATORY STATUS → PROXY FOR PRE-TREATMENT FUNCTION
ALBUMIN LEVEL → PROXY FOR GENERAL HEALTH & ABILITY TO TOLERATE TREATMENT

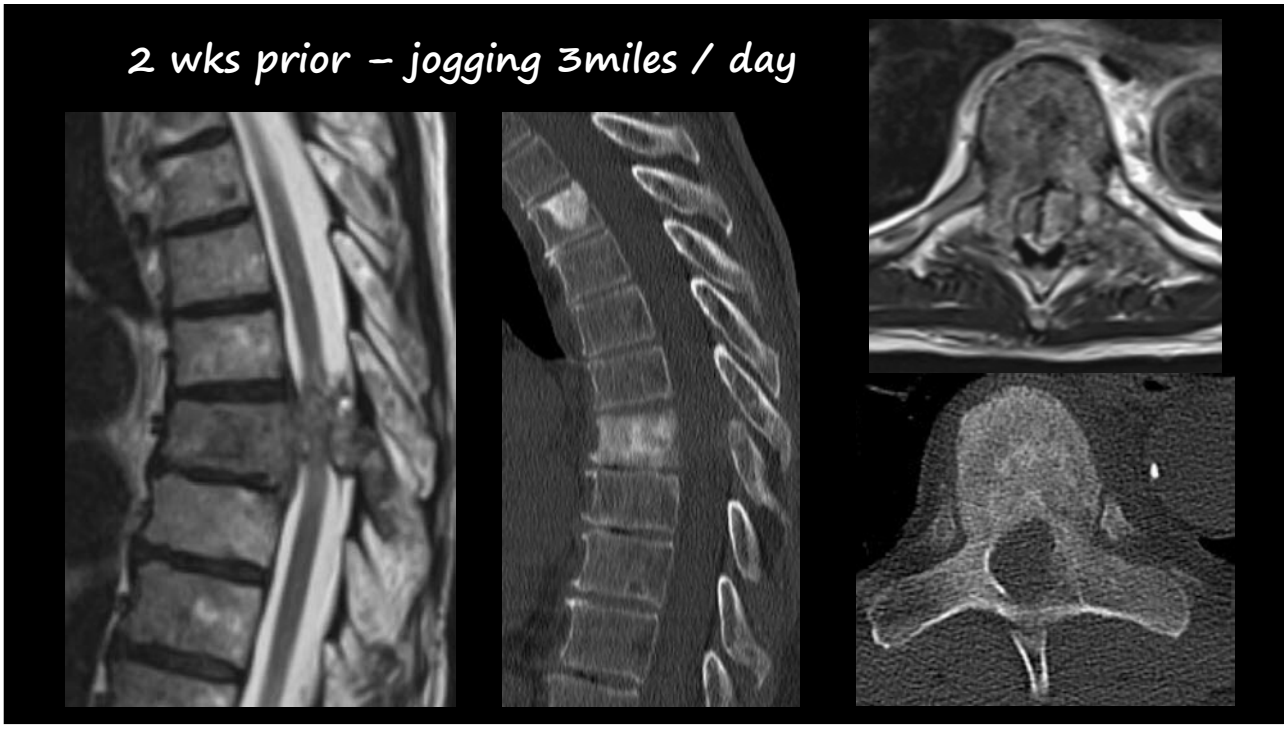
125


81M, Hx of Prostate CA

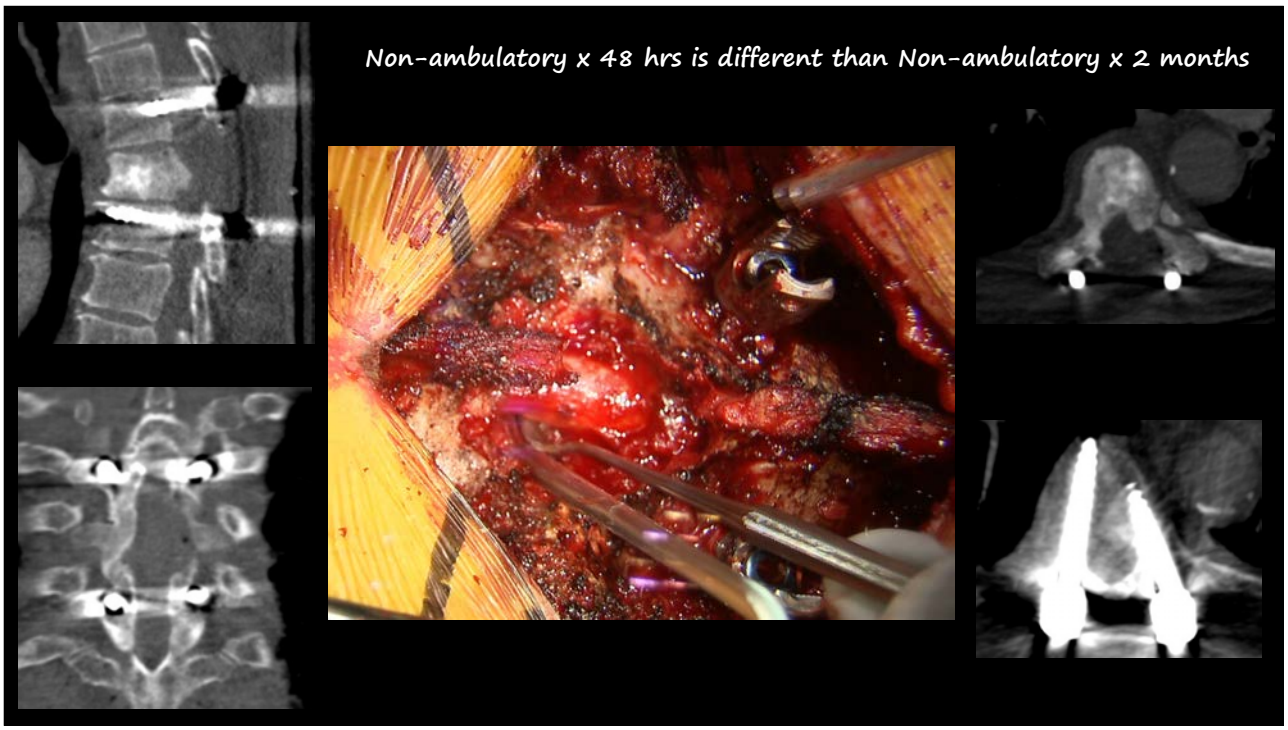
126


Non-ambulatory x 48 hours, 1/5 BLE Motor

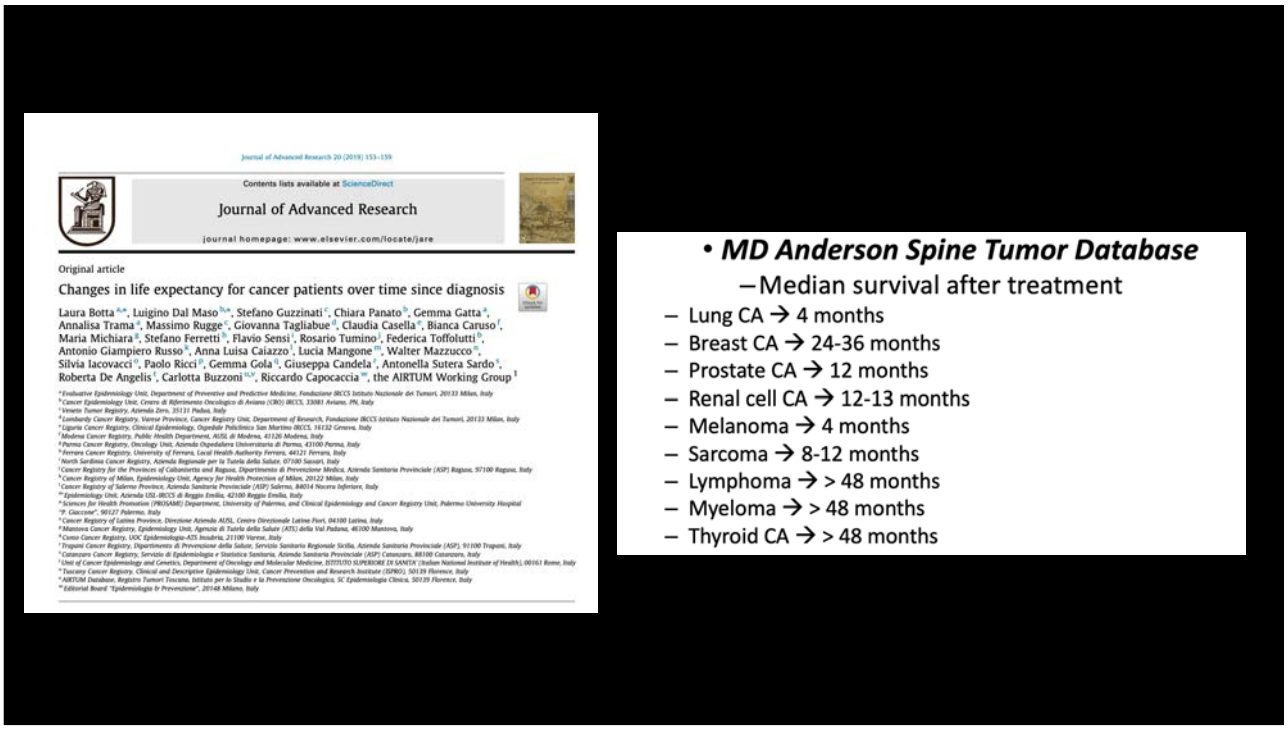
127


2 wks prior – jogging 3miles / day

128


Non-ambulatory x 48 hrs is different than Non-ambulatory x 2 months

129


Journal of Advanced Research 20 (2019) 153–159
Contents lists available at ScienceDirect
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journal homepage: www.elsevier.com/locate/jare
Original article
Changes in life expectancy for cancer patients over time since diagnosis
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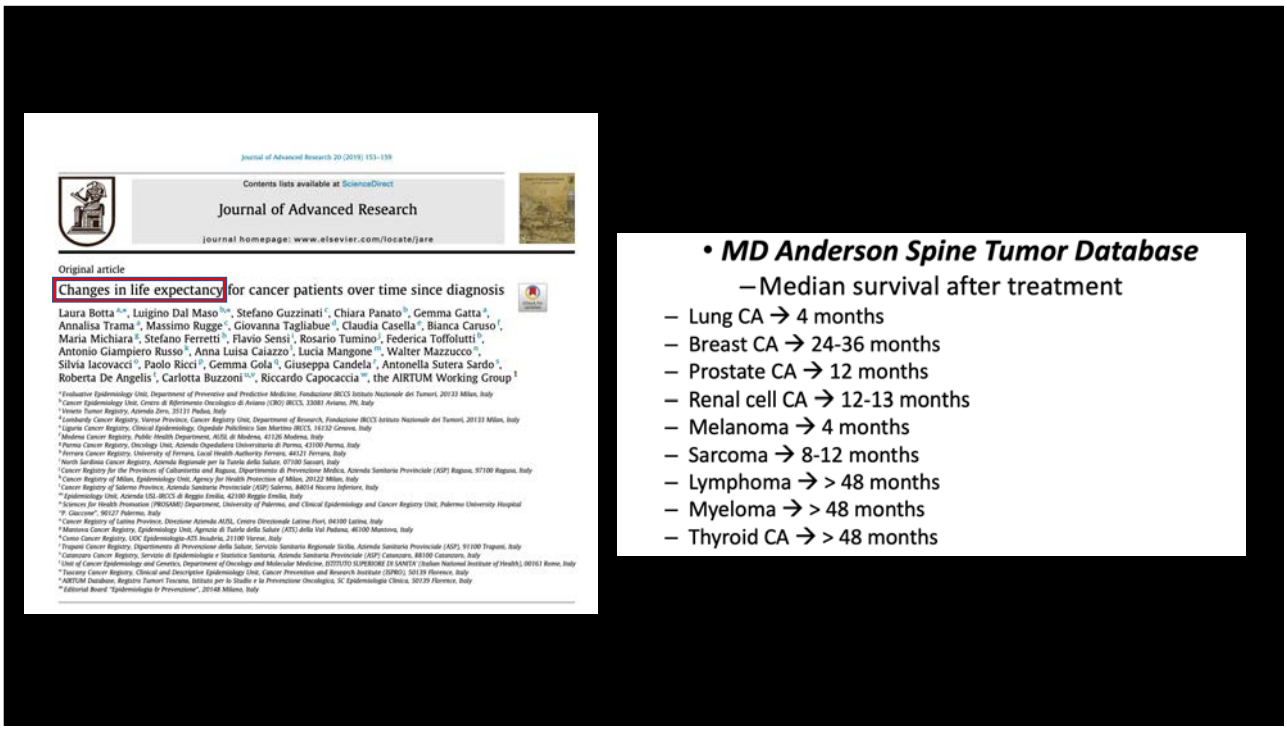
• MD Anderson Spine Tumor Database
–Median survival after treatment
– Lung CA → 4 months
– Breast CA → 24-36 months
– Prostate CA → 12 months
– Renal cell CA → 12-13 months
– Melanoma → 4 months
– Sarcoma → 8-12 months
– Lymphoma → > 48 months
– Myeloma → > 48 months
– Thyroid CA → > 48 months

130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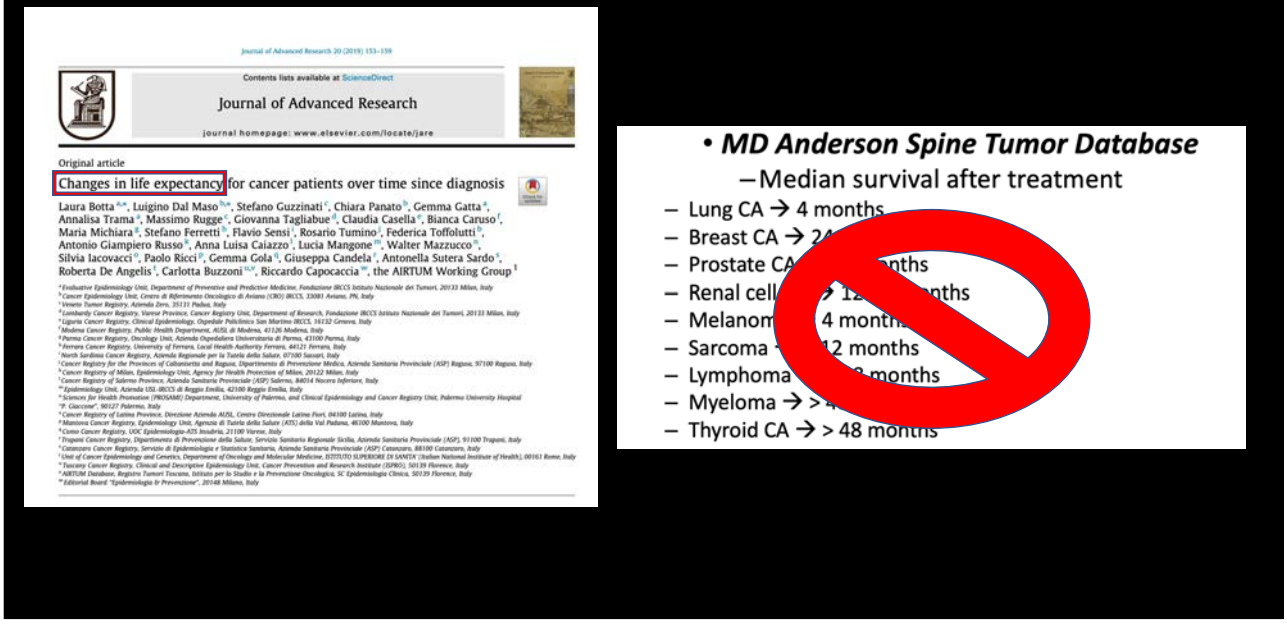
131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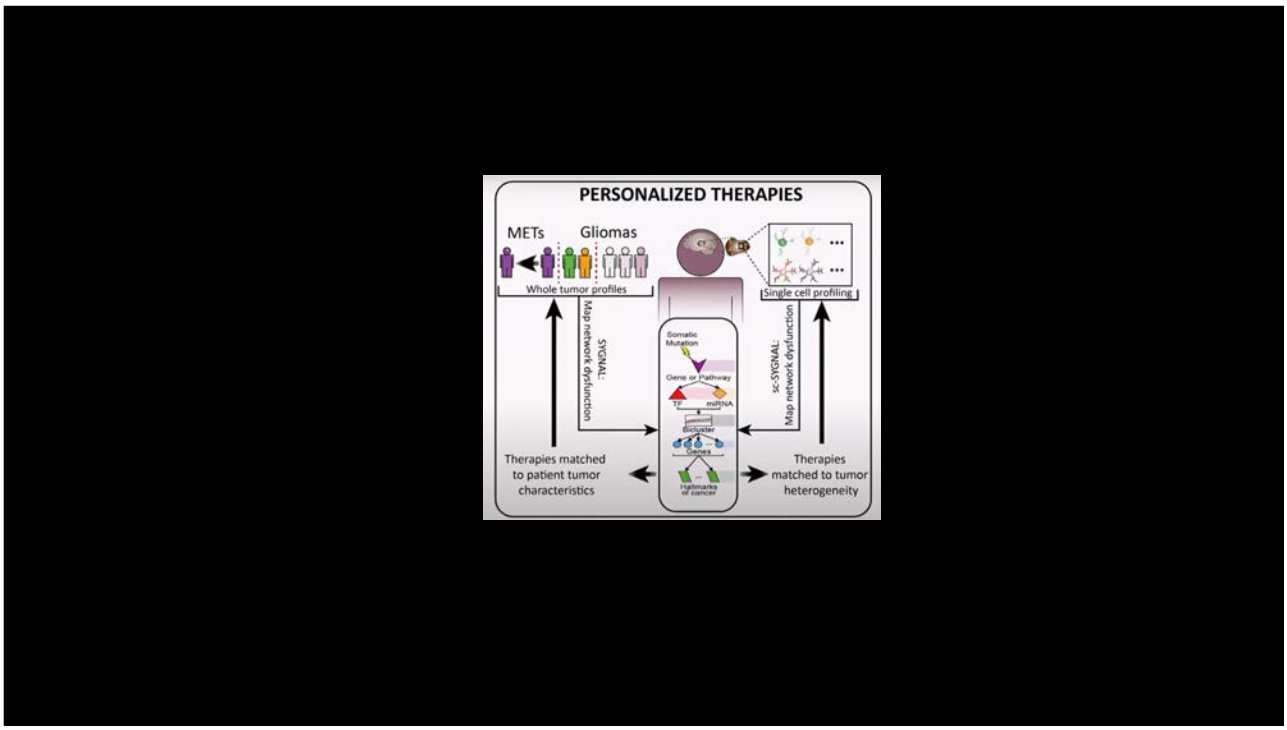
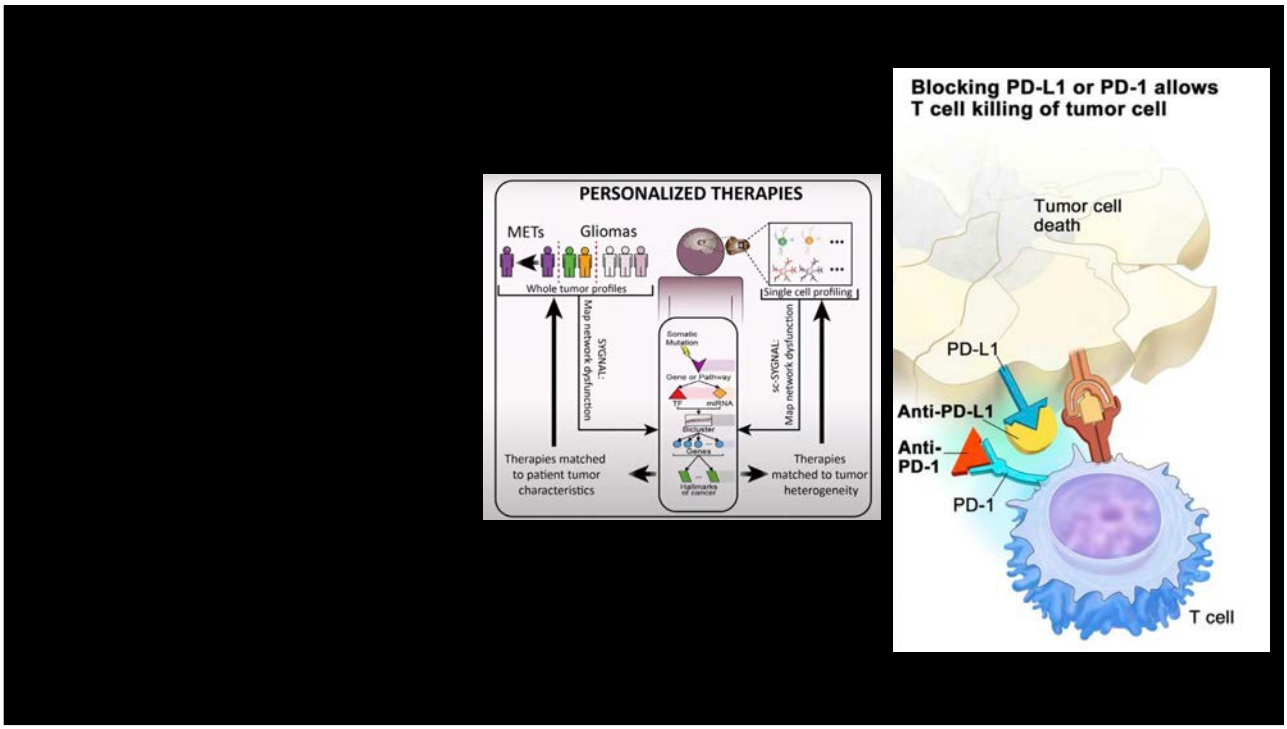
132


PERSONALIZED THERAPIES
METs
Gliomas
Whole tumor profiles
Single cell profiling
Map network dysfunction
SYGNAL:
sc-SYGNAL:
Map network dysfunction
Somatic Mutation
Gene or Pathway
TF
mRNA
Biocluster
Genes
Hallmarks of cancer
Therapies matched to patient tumor characteristics
Therapies matched to tumor heterogeneity

133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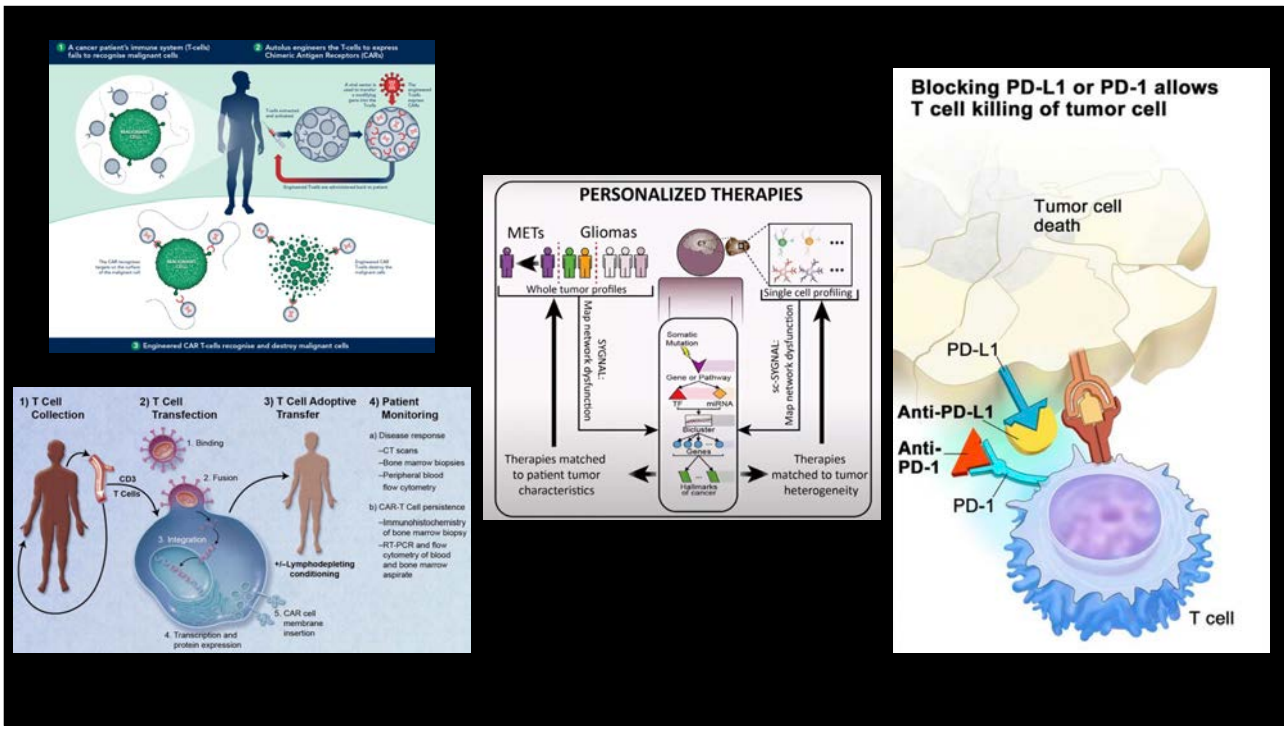
Blocking PD-L1 or PD-1 allows T cell killing of tumor cell
Tumor cell death
PD-L1
Anti-PD-L1
Anti-PD-1
PD-1
T cell

134


1) T Cell Collection
2) T Cell Transfection
3) T Cell Adoptive Transfer
4) Patient Monitoring
CD3 T Cells
1. Binding
2. Fusion
3. Integration
4. Transcription and protein expression
5. CAR cell membrane insertion
+/-Lymphodepleting conditioning
a) Disease response
–CT scans
–Bone marrow biopsies
–Peripheral blood flow cytometry
b) CAR-T Cell persistence
–Immunohistochemistry of bone marrow biopsy
–RT-PCR and flow cytometry of blood and bone marrow aspirate
PERSONALIZED THERAPIES
METs
Gliomas
Whole tumor profiles
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Map network dysfunction
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PD-L1
Anti-PD-L1
Anti-PD-1
PD-1
T cell

135


The Impact of Targetable Mutations on Clinical Outcomes of Metastatic Epidural Spinal Cord Compression in Patients With Non–Small-Cell Lung Cancer Treated With Hybrid Therapy (Surgery Followed by Stereotactic Body Radiation Therapy)
Spine
METASTATIC SPINE TUMORS
Molecular Markers and Targeted Therapeutics in Metastatic Tumors of the Spine
Changing the Treatment Paradigms
The Targeted Therapies Era Beyond the Surgical Point of View: What Spine Surgeons Should Know Before Approaching Spinal Metastases
nature communications
A transcriptional metastatic signature predicts survival in clear cell renal cell carcinoma
Can targeted therapy data be used for prognostication in spine metastatic spine disease?
• NSCLC: A systematic review including 27 studies found that median survival of patients with non-small cell lung cancer being treated with epidermal growth factor receptor (EGFR) inhibitors were improved.
• Melanoma: Retrospective small cohort of 18 patients found that failing prior immunotherapy treatment was associated with significantly shorter survival following spine surgery.

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Favorability of Mutations / Molecular Markers

138

Favorability of Mutations / Molecular Markers

Tumors w/ mutations amenable to targeted therapy tend to be associated with longer survival

139

Favorability of Mutations / Molecular Markers

Tumors w/ mutations amenable to targeted therapy tend to be associated with longer survival

Harboring favorable and actionable mutations generally makes a patient a more suitable surgical candidate

140

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Responsiveness to targeted therapy suggests that patients have options in the post-op period to control their systemic disease

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Favorability of Mutations / Molecular Markers

Tumors w/ mutations amenable to targeted therapy tend to be associated with longer survival

Harboring favorable and actionable mutations generally makes a patient a more suitable surgical candidate

Responsiveness to targeted therapy suggests that patients have options in the post-op period to control their systemic disease

Certain targeted therapies may negate the need for surgery >> Some treatments can rapidly stabilize the disease and buy time for other treatment options

Adapted from Dr. Rory Goodwin's Lecture at Spine Section 2024

142

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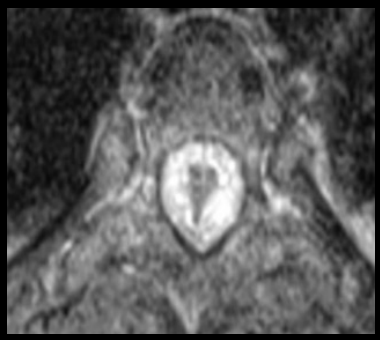
Certain targeted therapies may negate the need for surgery >> Some treatments can rapidly stabilize the disease and buy time for other treatment options



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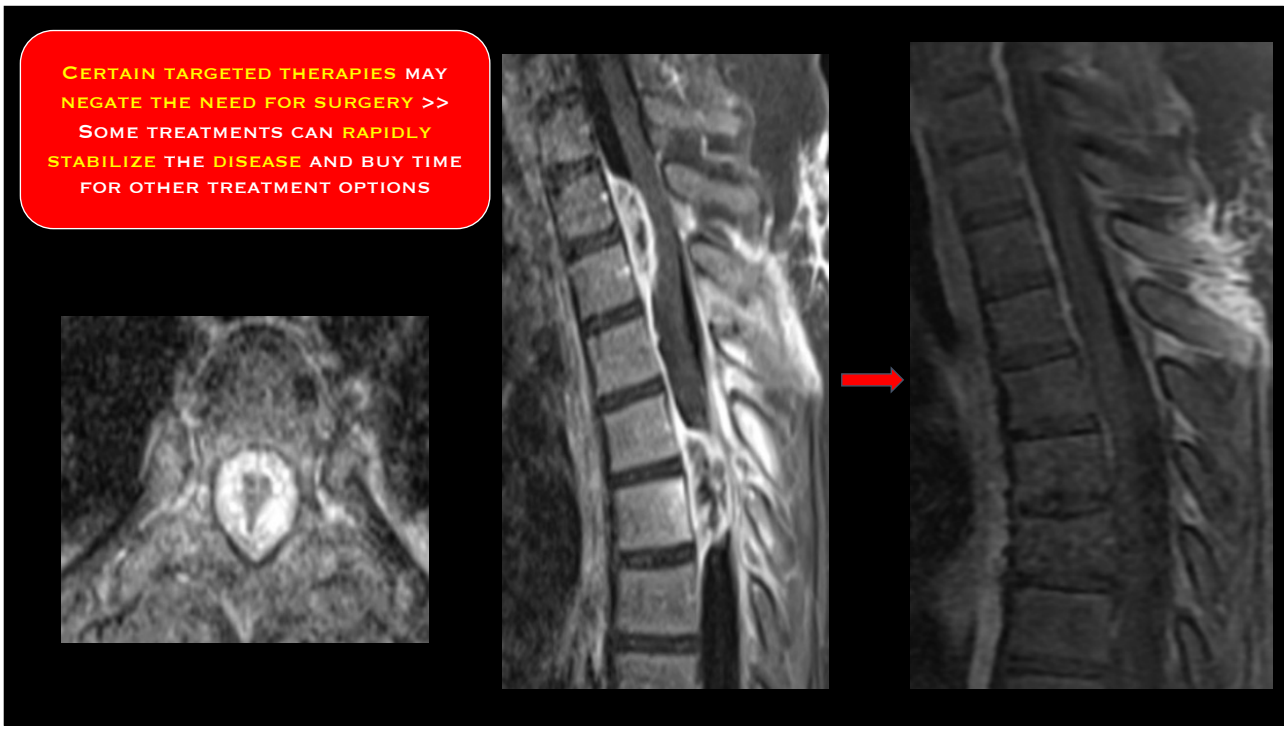
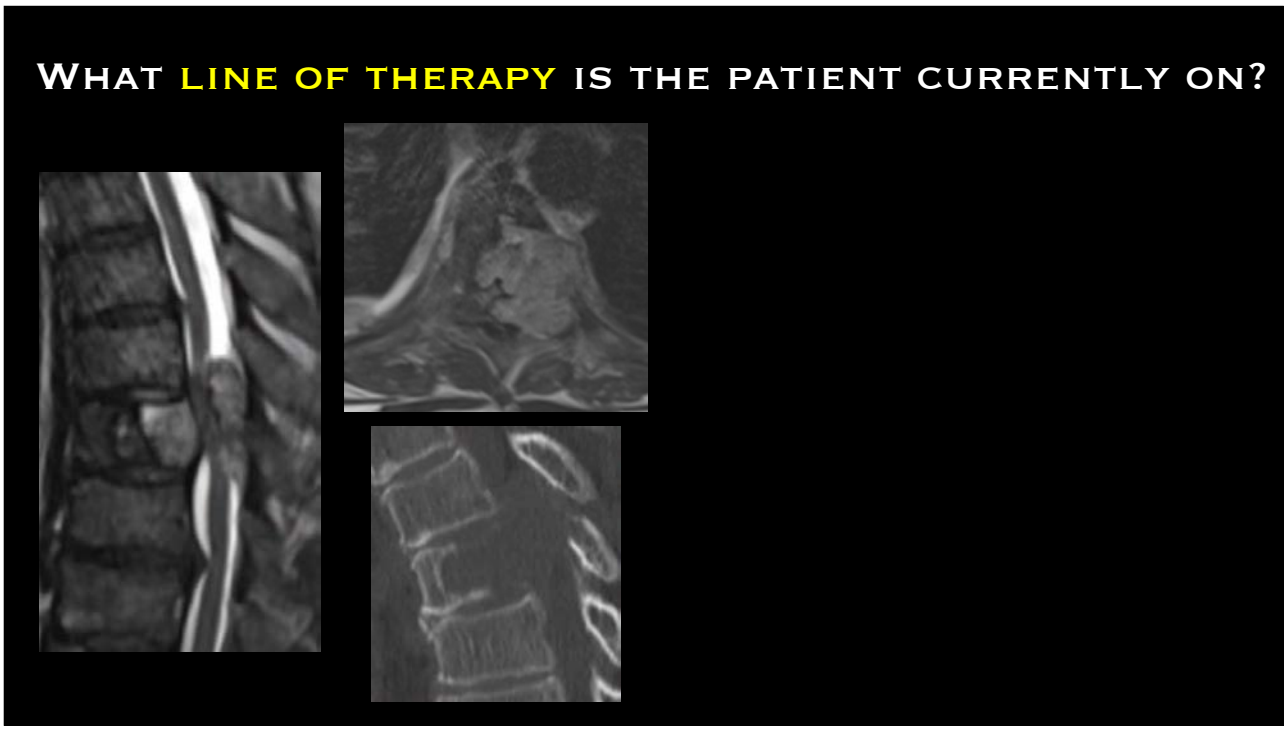


145

WHAT LINE OF THERAPY IS THE PATIENT CURRENTLY ON?

146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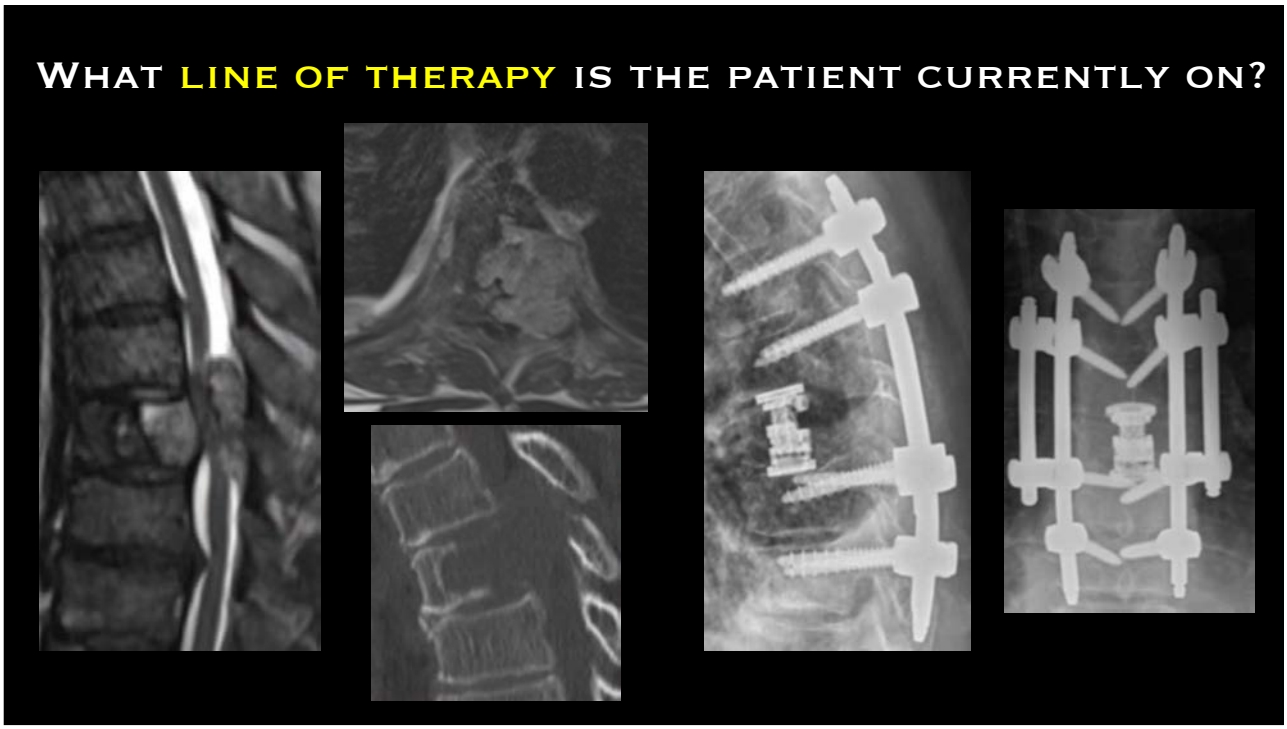
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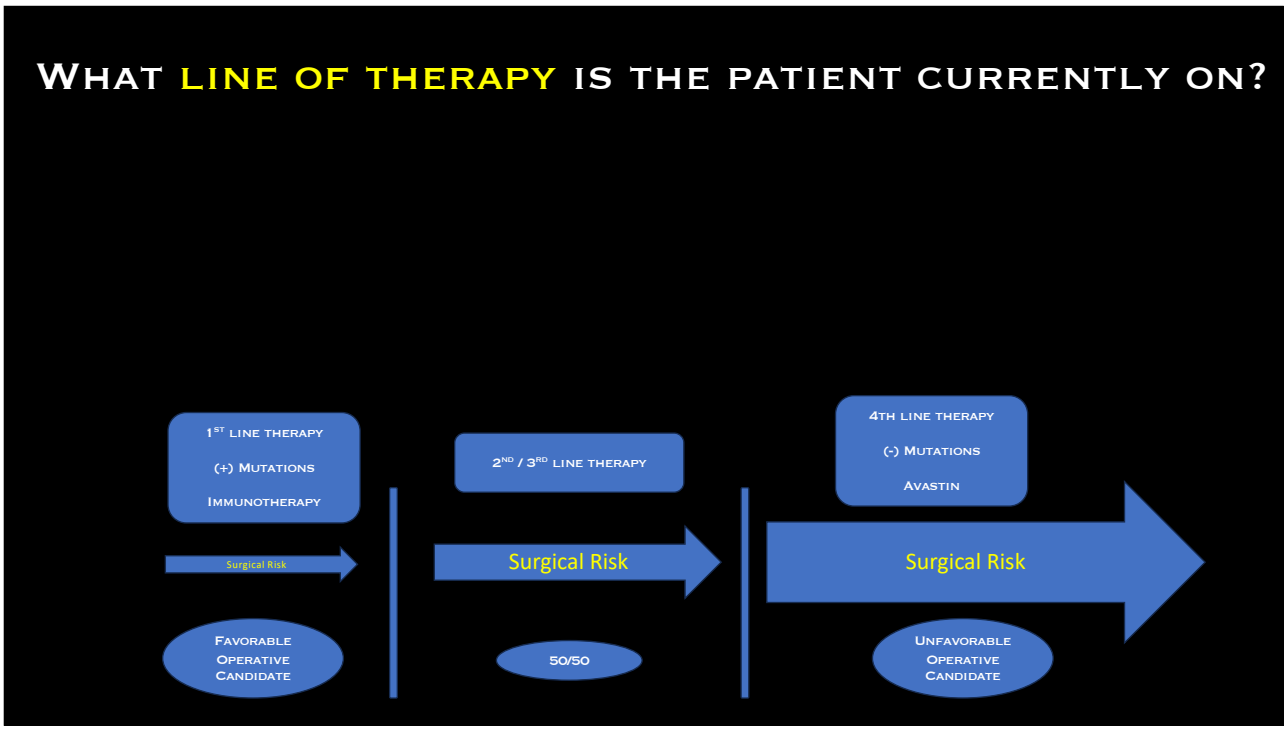
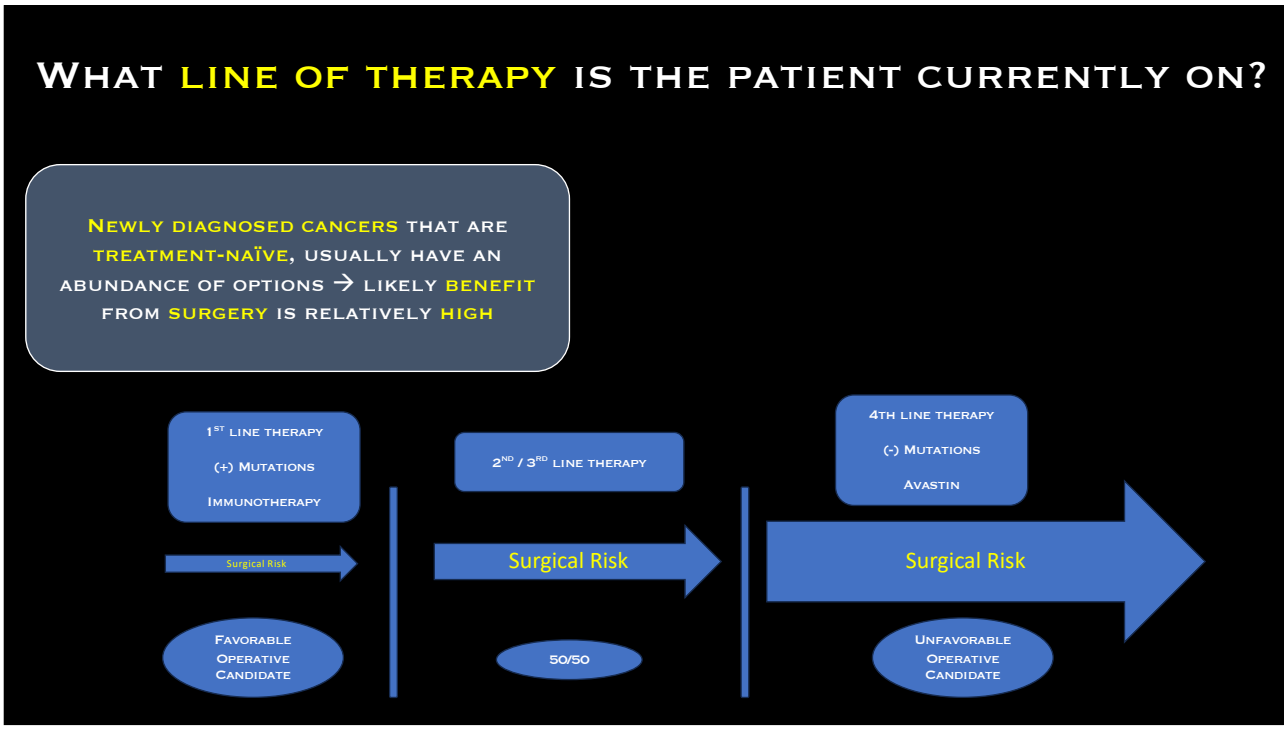
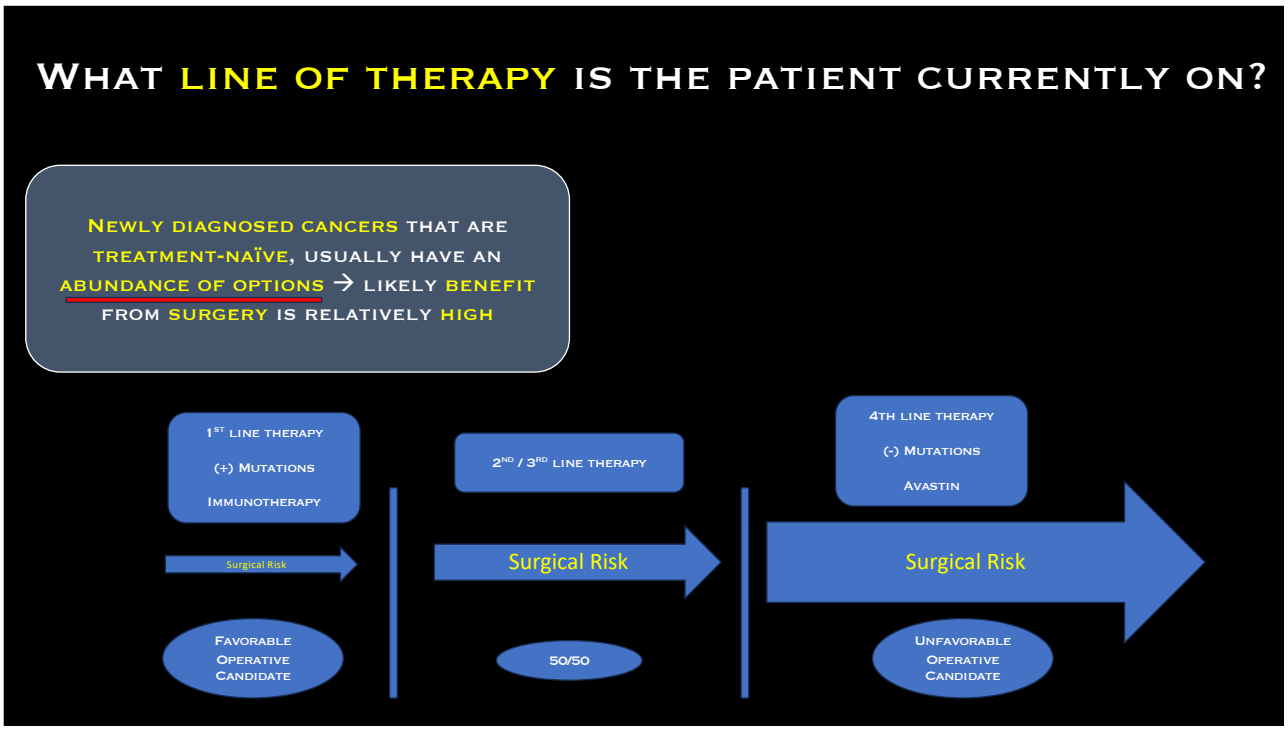

WHAT LINE OF THERAPY IS THE PATIENT CURRENTLY ON?
1ST LINE THERAPY
(+) MUTATIONS
IMMUNOTHERAPY
Surgical Risk
FAVORABLE OPERATIVE CANDIDATE
2ND / 3RD LINE THERAPY
Surgical Risk
50/50
4TH LINE THERAPY
(-) MUTATIONS
AVASTIN
Surgical Risk
UNFAVORABLE OPERATIVE CANDIDATE

149


WHAT LINE OF THERAPY IS THE PATIENT CURRENTLY ON?
NEWLY DIAGNOSED CANCERS THAT ARE TREATMENT-NAÏVE, USUALLY HAVE AN ABUNDANCE OF OPTIONS → LIKELY BENEFIT FROM SURGERY IS RELATIVELY HIGH
1ST LINE THERAPY
(+) MUTATIONS
IMMUNOTHERAPY
Surgical Risk
FAVORABLE OPERATIVE CANDIDATE
2ND / 3RD LINE THERAPY
Surgical Risk
50/50
4TH LINE THERAPY
(-) MUTATIONS
AVASTIN
Surgical Risk
UNFAVORABLE OPERATIVE CANDIDATE

150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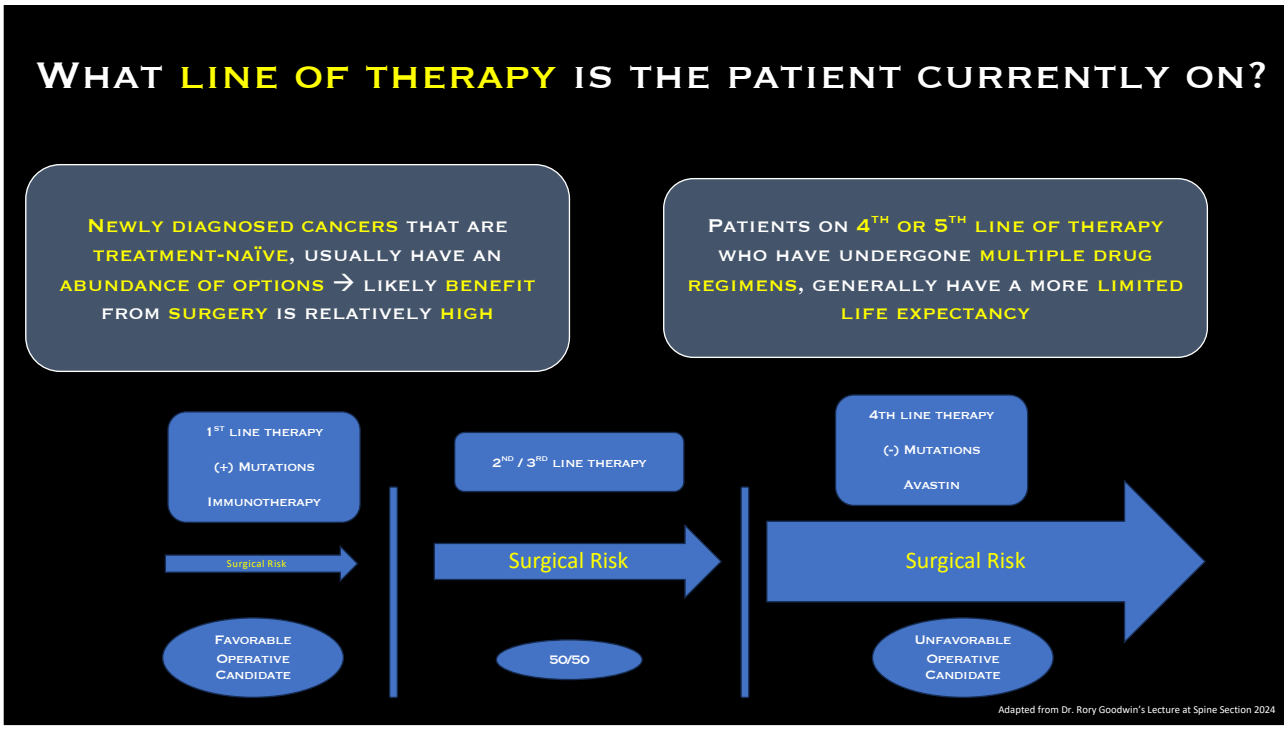
AVASTIN
Surgical Risk
UNFAVORABLE OPERATIVE CANDIDATE

151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NEWLY DIAGNOSED CANCERS THAT ARE TREATMENT-NAÏVE, USUALLY HAVE AN ABUNDANCE OF OPTIONS → LIKELY BENEFIT FROM SURGERY IS RELATIVELY HIGH
PATIENTS ON 4TH OR 5TH LINE OF THERAPY WHO HAVE UNDERGONE MULTIPLE DRUG REGIMENS, GENERALLY HAVE A MORE LIMITED LIFE EXPECTANCY
1ST LINE THERAPY
(+) MUTATIONS
IMMUNOTHERAPY
Surgical Risk
FAVORABLE OPERATIVE CANDIDATE
2ND / 3RD LINE THERAPY
Surgical Risk
50/50
4TH LINE THERAPY
(-) MUTATIONS
AVASTIN
Surgical Risk
UNFAVORABLE OPERATIVE CANDIDATE
Adapted from Dr. Rory Goodwin's Lecture at Spine Section 2024

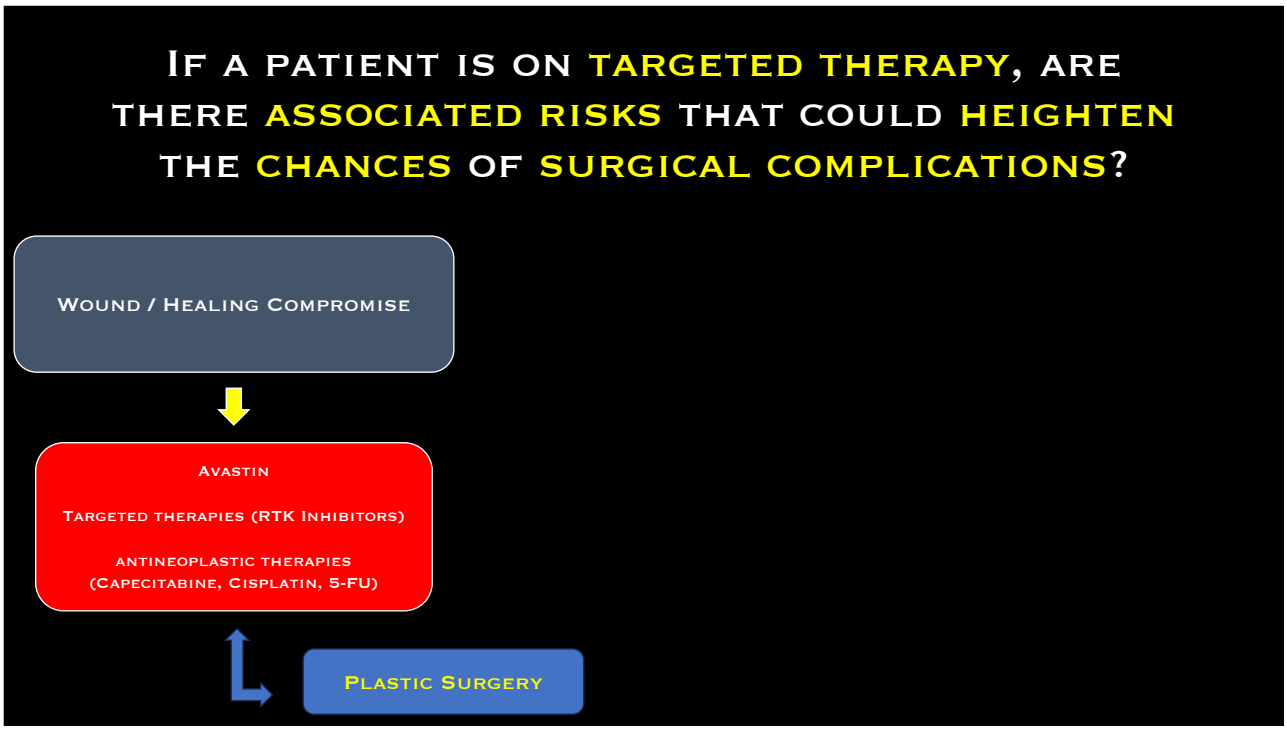
152

If a patient is on targeted therapy, are there associated risks that could heighten the chances of surgical complications?

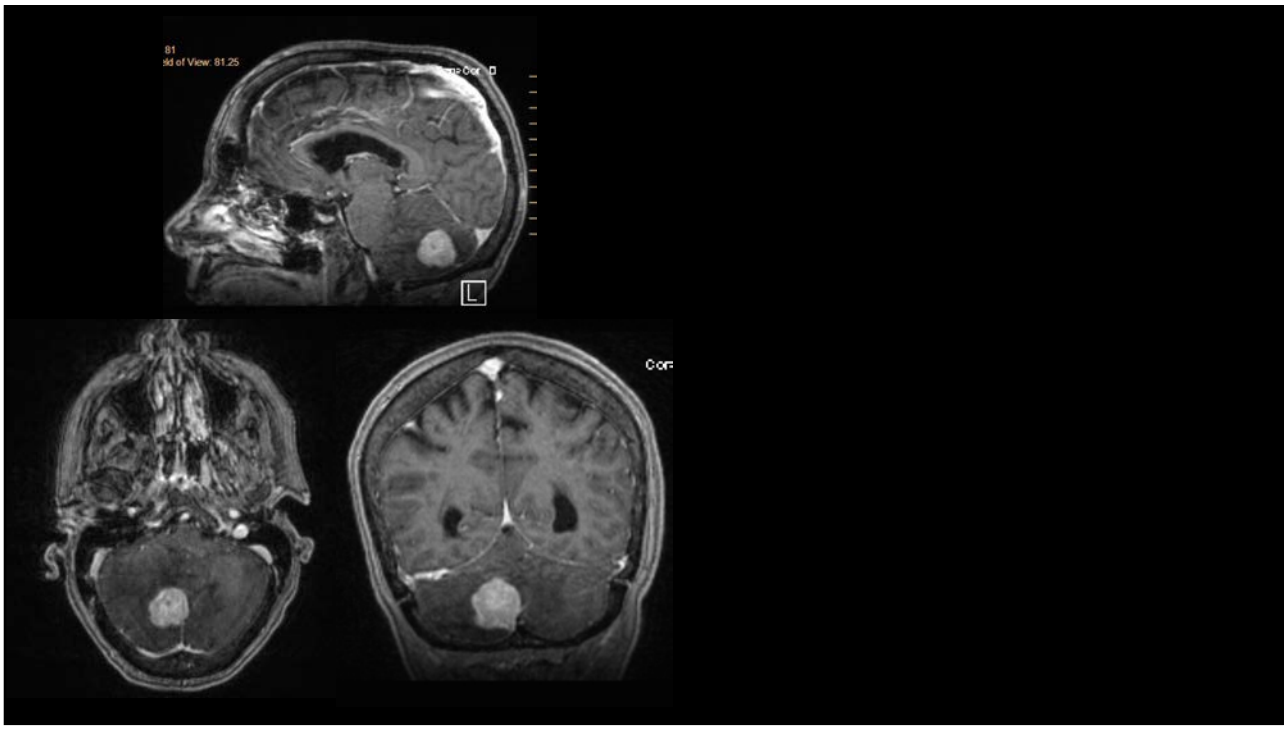
153

If a patient is on targeted therapy, are there associated risks that could heighten the chances of surgical complications?

154


If a patient is on targeted therapy, are there associated risks that could heighten the chances of surgical complications?
Wound / Healing Compromise
Avastin
Targeted therapies (RTK Inhibitors)
antineoplastic therapies (Capecitabine, Cisplatin, 5-FU)
Plastic Surgery

155



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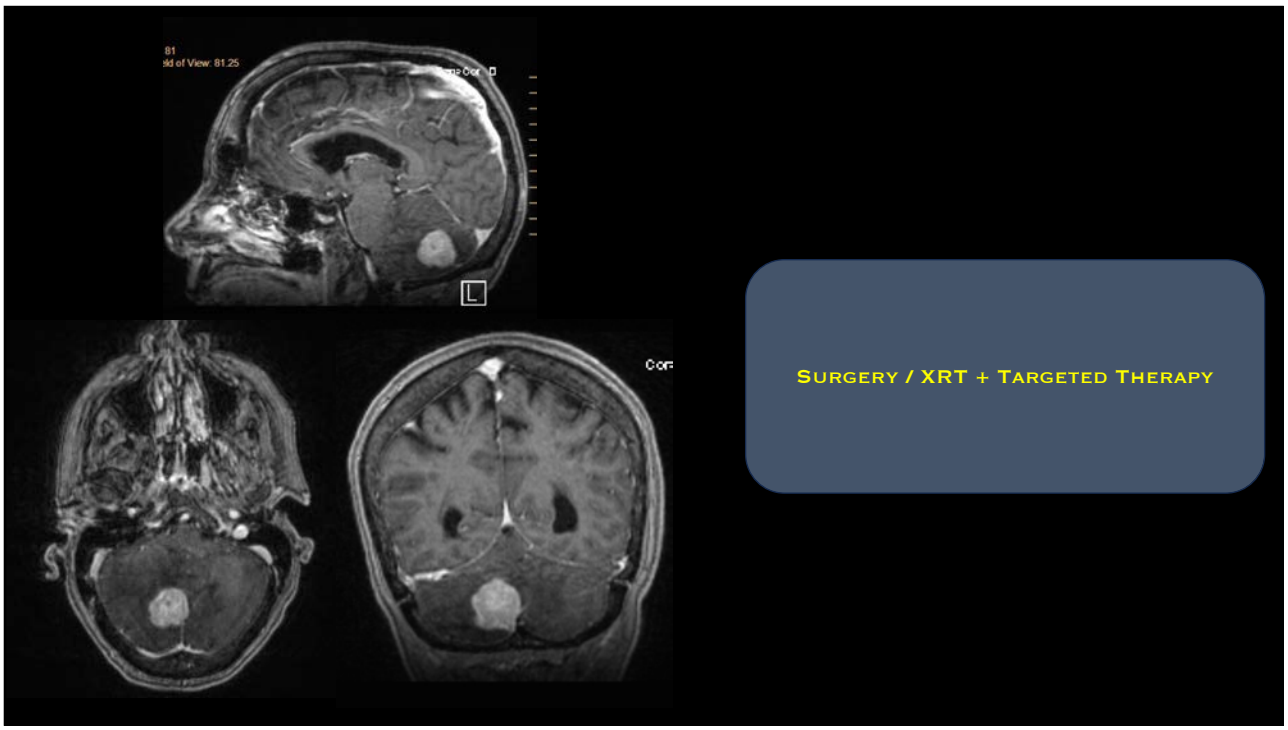

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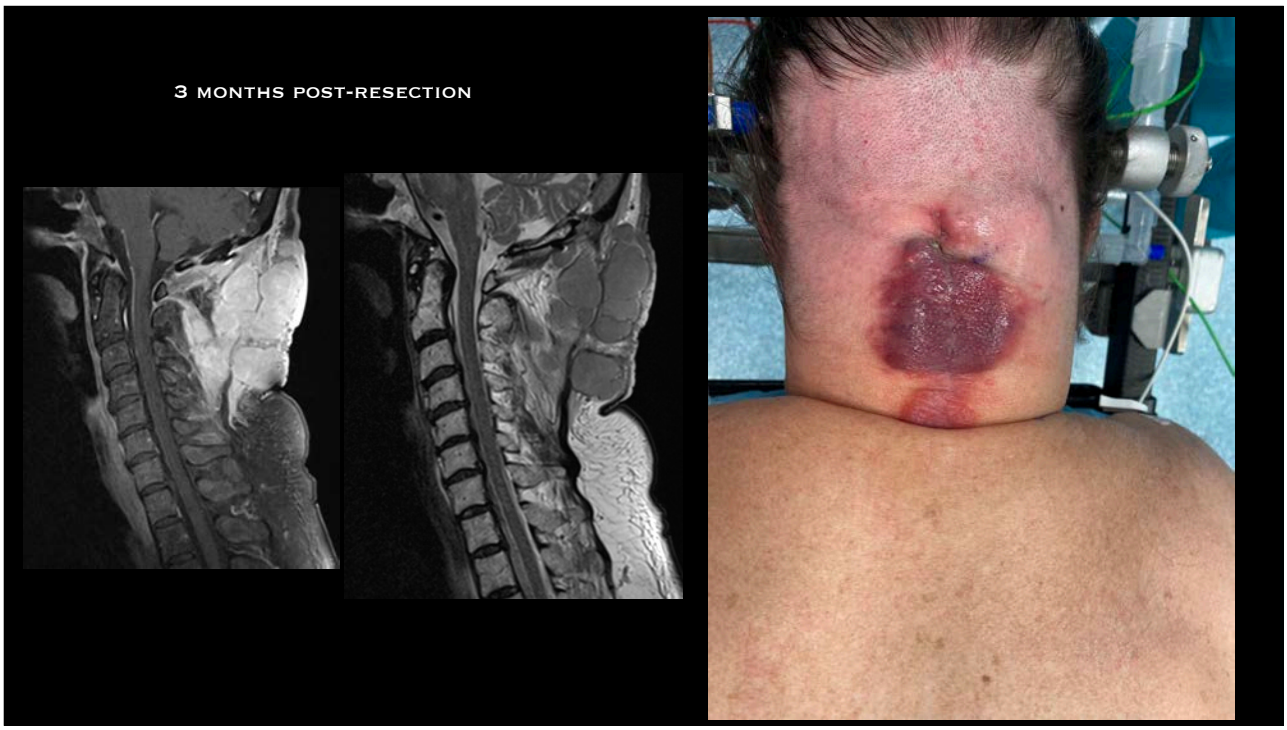

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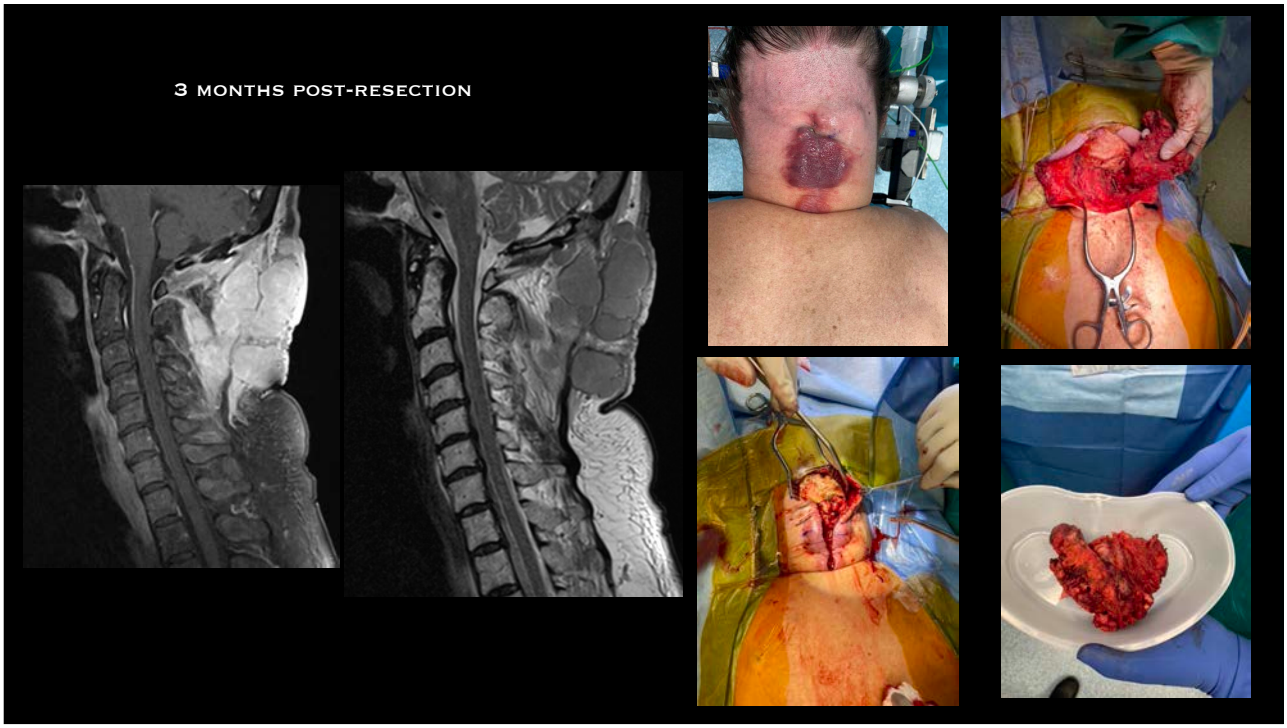

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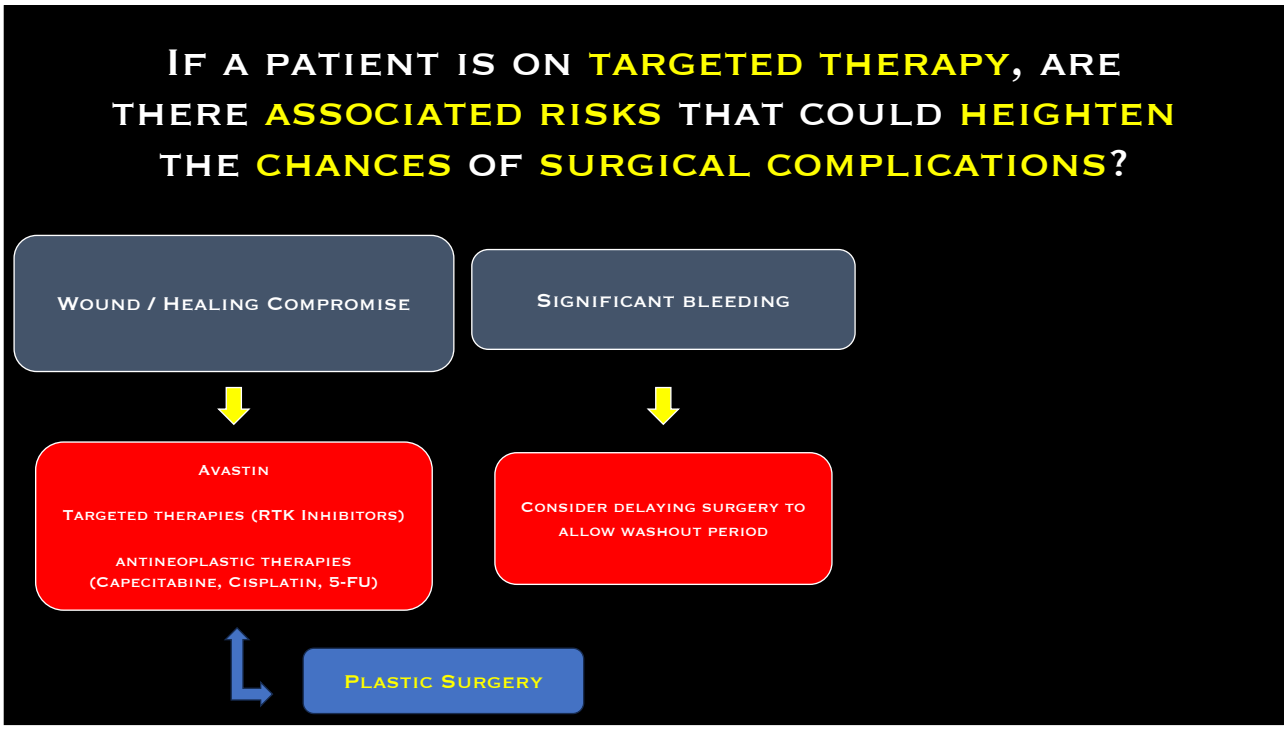
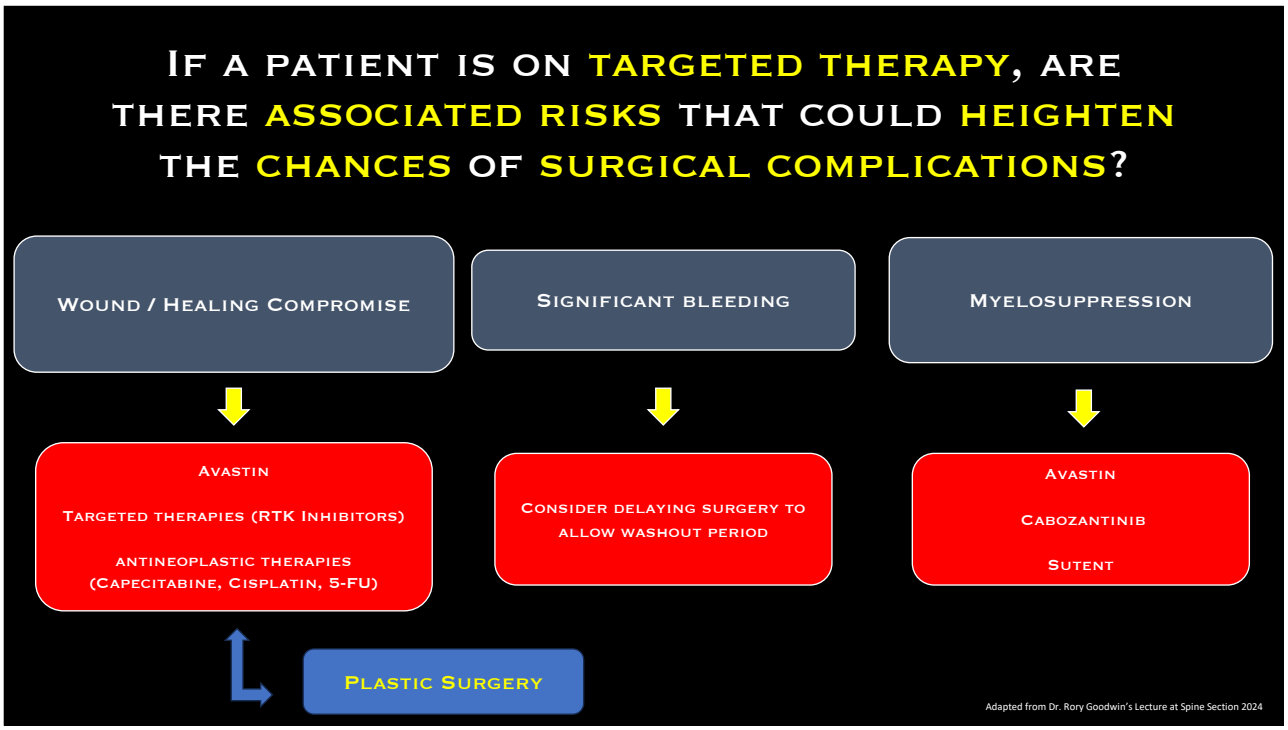

IF A PATIENT IS ON TARGETED THERAPY, ARE THERE ASSOCIATED RISKS THAT COULD HEIGHTEN THE CHANCES OF SURGICAL COMPLICATIONS?
WOUND / HEALING COMPROMISE
SIGNIFICANT BLEEDING
AVASTIN
TARGETED THERAPIES (RTK INHIBITORS)
ANTINEOPLASTIC THERAPIES (CAPECITABINE, CISPLATIN, 5-FU)
CONSIDER DELAYING SURGERY TO ALLOW WASHOUT PERIOD
PLASTIC SURGERY

162


If a patient is on targeted therapy, are there associated risks that could heighten the chances of surgical complications?
Wound / Healing Compromise
Significant bleeding
Myelosuppression
Avastin
Targeted therapies (RTK Inhibitors)
Antineoplastic therapies (Capecitabine, Cisplatin, 5-FU)
Consider delaying surgery to allow washout period
Avastin
Cabozantinib
Sutent
Plastic Surgery
Adapted from Dr. Rory Goodwin's Lecture at Spine Section 2024

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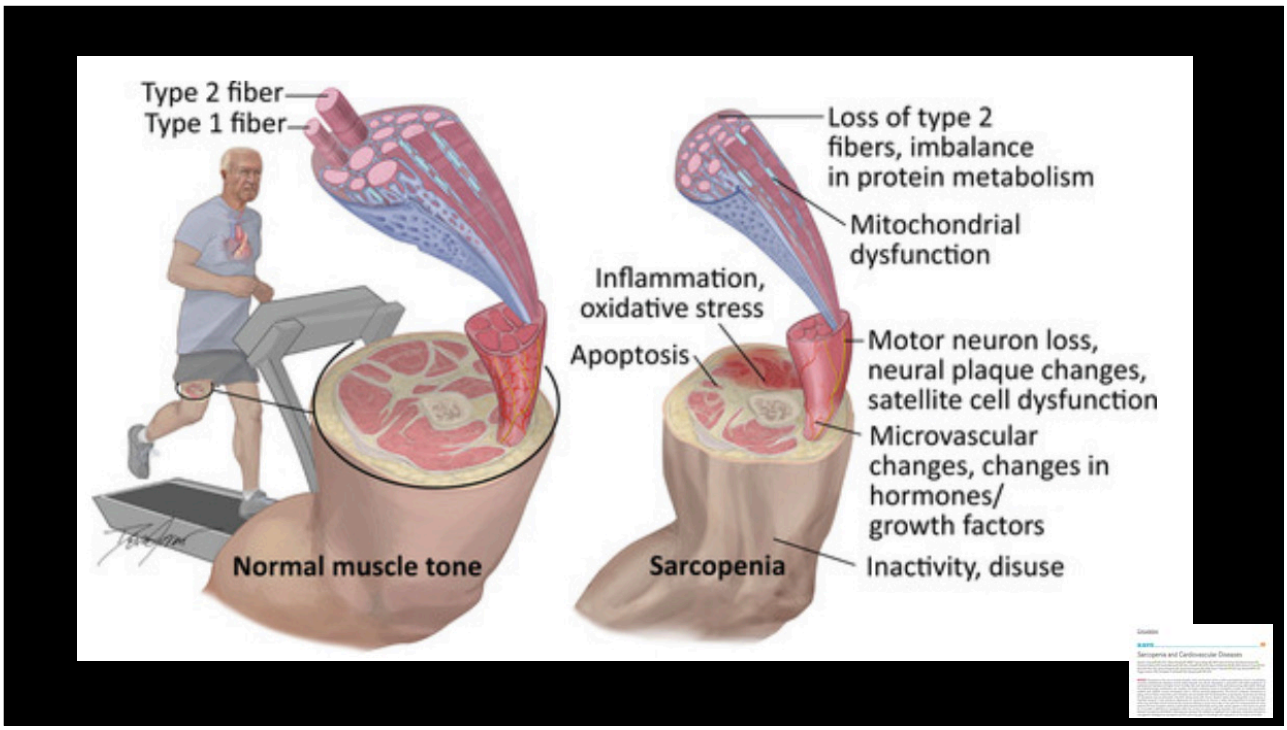
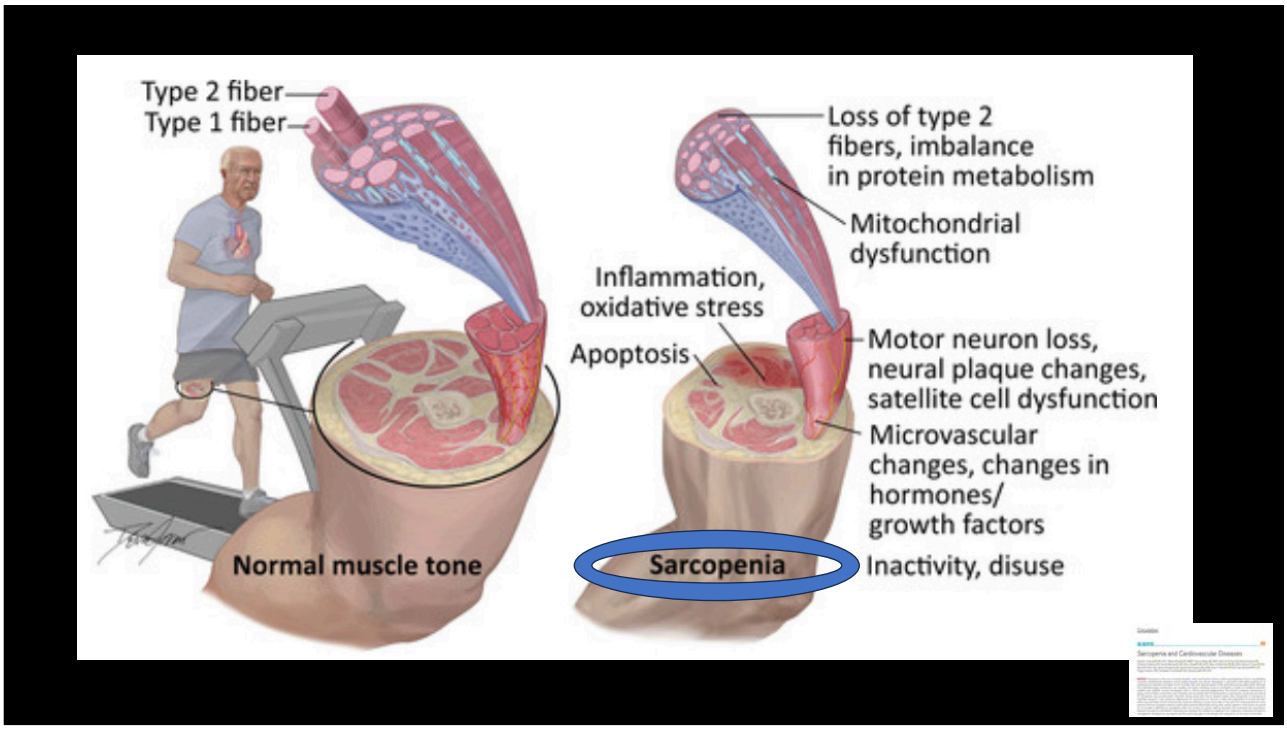
JNS SPINE
CLINICAL ARTICLE
Evaluating frailty, mortality, and complications associated with metastatic spine tumor surgery using machine learning–derived body composition analysis
THE SPINE JOURNAL
Clinical Study
Sarcopenia, but not frailty, predicts early mortality and adverse events after emergent surgery for metastatic disease of the spine
SURGICAL ONCOLOGY
ORTHOPEDICS
Impact of preoperative sarcopenia in patients undergoing sacral tumor resection
The Spine Journal
Available online 26 April 2023
In Press, Journal Pre-proof
Clinical Study
A novel scoring system incorporating sarcopenia to predict post-operative survival in spinal metastasis

164


Type 2 fiber
Type 1 fiber
Normal muscle tone
Loss of type 2 fibers, imbalance in protein metabolism
Mitochondrial dysfunction
Inflammation, oxidative stress
Apoptosis
Motor neuron loss, neural plaque changes, satellite cell dysfunction
Microvascular changes, changes in hormones/ growth factors
Sarcopenia
Inactivity, disuse

165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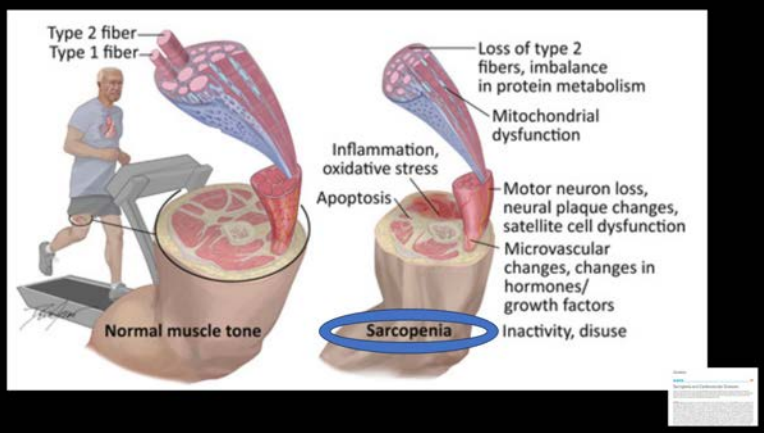
166

Sarcopenia

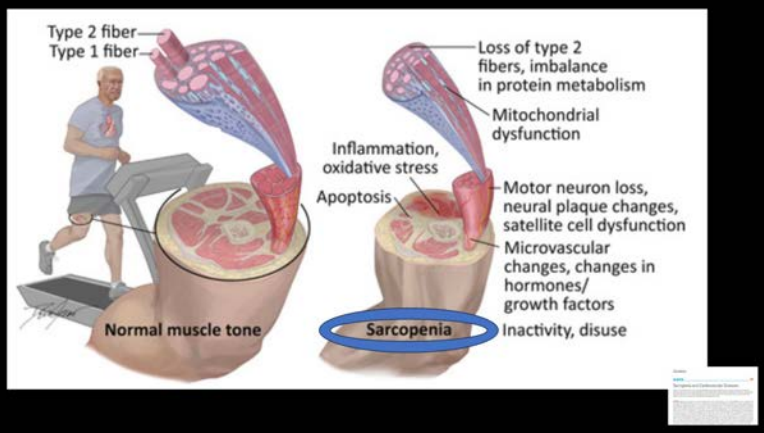


Loss of muscle mass

Loss of muscle Function

167

Sarcopenia

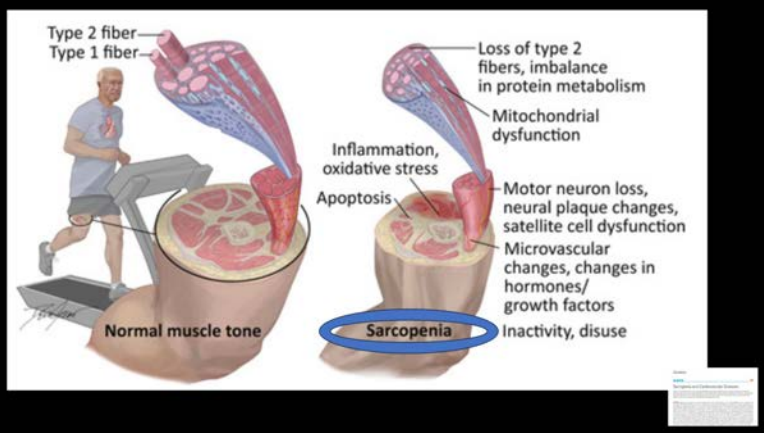


Loss of muscle mass

Loss of muscle Function

168

Sarcopenia



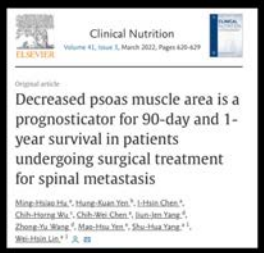
Loss of muscle mass

Loss of muscle Function

169


Journal of Clinical Neuroscience

Prognostic value of low psoas muscle mass in patients with cervical spine metastasis

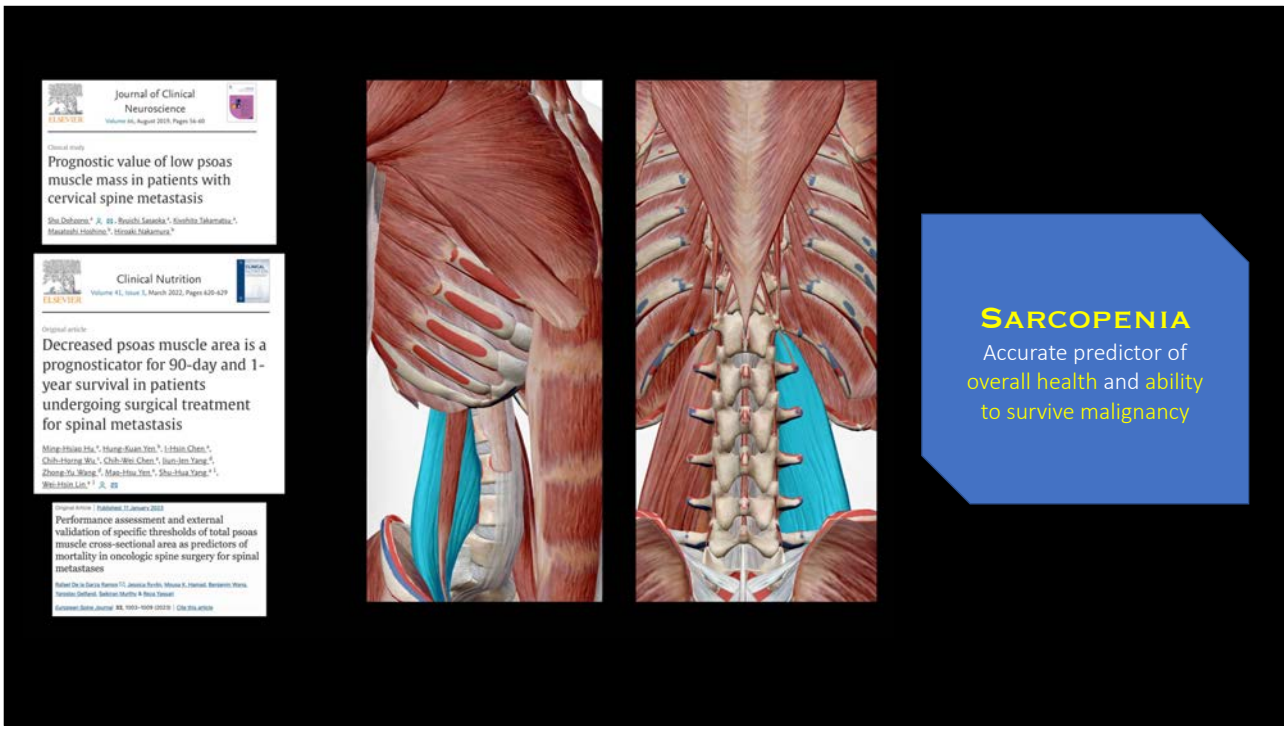

Clinical Nutrition

Decreased psoas muscle area is a prognosticator for 90-day and 1-year survival in patients undergoing surgical treatment for spinal metastasis


Performance assessment and external validation of specific thresholds of total psoas muscle cross-sectional area as predictors of mortality in oncologic spine surgery for spinal metastases

Sarcopenia
Accurate predictor of overall health and ability to survive malignancy

170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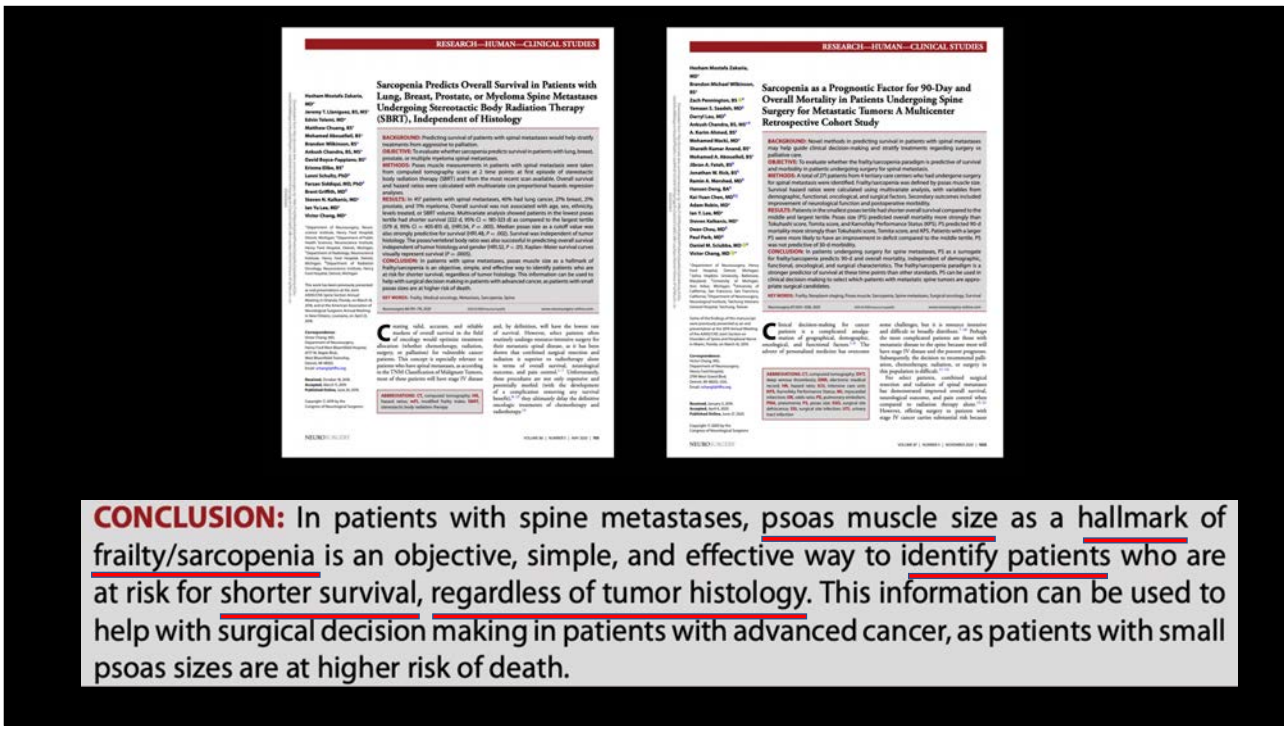
RESEARCH—HUMAN—CLINICAL STUDIES
Sarcopenia Predicts Overall Survival in Patients with Lung, Breast, Prostate, or Myeloma Spine Metastases Undergoing Stereotactic Body Radiation Therapy (SBRT), Independent of Histology
RESEARCH—HUMAN—CLINICAL STUDIES
Sarcopenia as a Prognostic Factor for 90-Day and Overall Mortality in Patients Undergoing Spine Surgery for Metastatic Tumors: A Multicenter Retrospective Cohort Study

172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RESEARCH—HUMAN—CLINICAL STUDIES
Sarcopenia as a Prognostic Factor for 90-Day and Overall Mortality in Patients Undergoing Spine Surgery for Metastatic Tumors: A Multicenter Retrospective Cohort Study
CONCLUSION: In patients with spine metastases, psoas muscle size as a hallmark of frailty/sarcopenia is an objective, simple, and effective way to identify patients who are at risk for shorter survival, regardless of tumor histology. This information can be used to help with surgical decision making in patients with advanced cancer, as patients with small psoas sizes are at higher risk of death.

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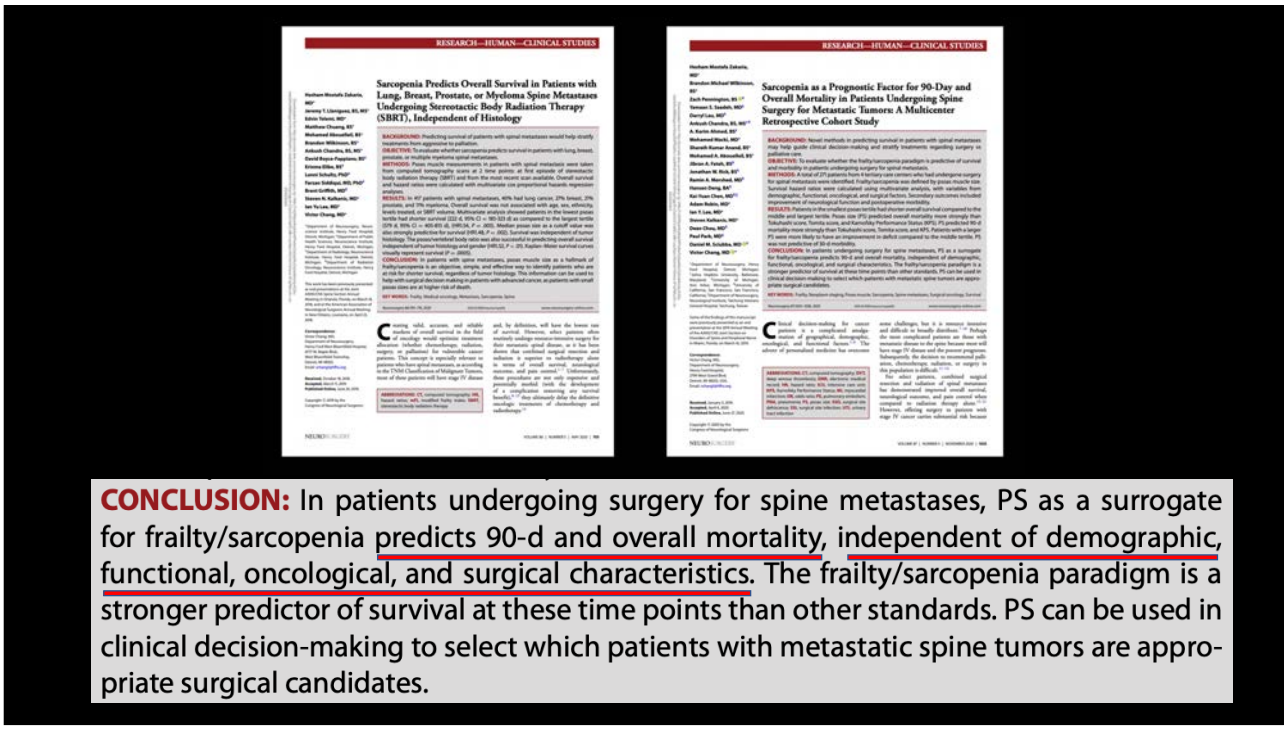
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CONCLUSION: In patients undergoing surgery for spine metastases, PS as a surrogate for frailty/sarcopenia predicts 90-d and overall mortality, independent of demographic, functional, oncological, and surgical characteristics. The frailty/sarcopenia paradigm is a stronger predictor of survival at these time points than other standards. PS can be used in clinical decision-making to select which patients with metastatic spine tumors are appropriate surgical candidates.

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How can we Quantify sarcopenia?

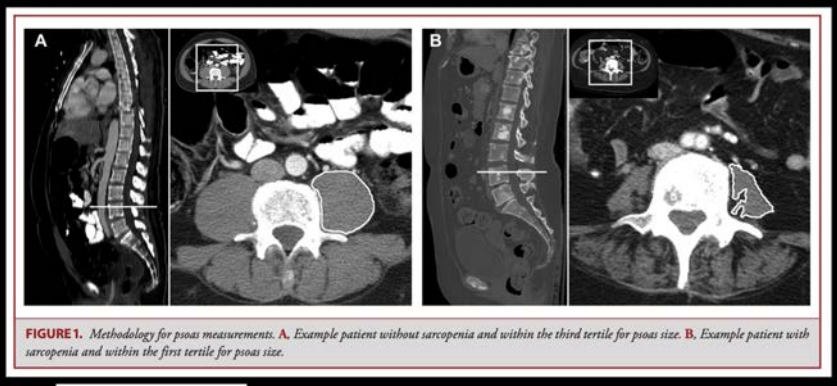

FIGURE 1. *Methodology for psoas measurements.* **A**, *Example patient without sarcopenia and within the third tertile for psoas size.* **B**, *Example patient with sarcopenia and within the first tertile for psoas size.*

Measurements of the PS (a continuous variable) were divided into 3 equal tertiles to provide a clinically meaningful interpretation of the associated odds ratio (OR) and HR. To account for differences in gender differences, the 3 tertiles were calculated independently for males and females. The male mean PS ± standard deviation, with minimum and maximum (range), were 8.59 cm^2 ± 1.31, 5.45-10.47 cm^2 for tertile 1 (T1); 11.99 cm^2 ± 0.80, 10.50-13.36 cm^2 for tertile 2 (T2); and 15.50 cm^2 ± 1.87, 13.37-21.08 cm^2 for tertile 3 (T3). For females, measurements were 6.13 cm^2 ± 0.80, 4.20-7.22 cm^2 for T1; 8.04 cm^2 ± 0.51, 7.24-9.05 cm^2 for T2; and 10.68 cm^2 ± 1.61, 9.06-14.95 cm^2 for T3. Table 1 compares the 3 psoas tertiles

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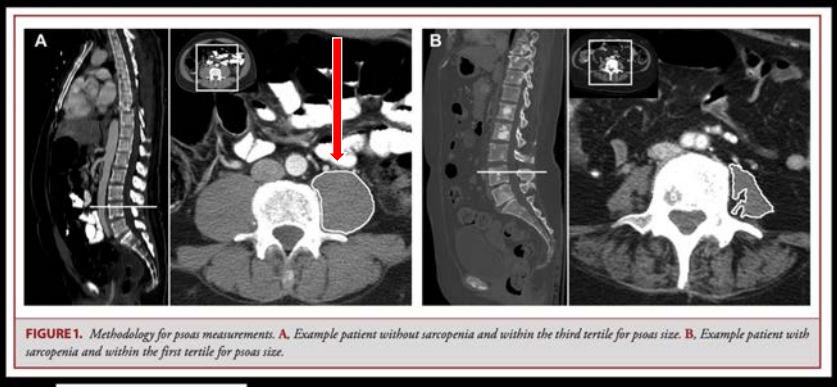

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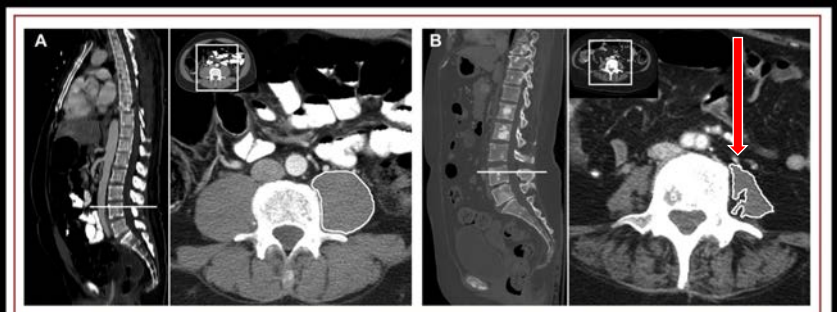

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VIDEO. *Movie illustrating the technique used to measure psoas muscle area using the electronic image viewing system. After opening a computed tomography (CT) scan, a free-hand region of interest tool was selected and used to outline the psoas muscle at the L3/4 disc space on the L4 pedicle, which calculates the cross-sectional area (Video). The CT scan selected was the one closest to the date of surgery, and measurements obtained >200 days from surgery were excluded.*

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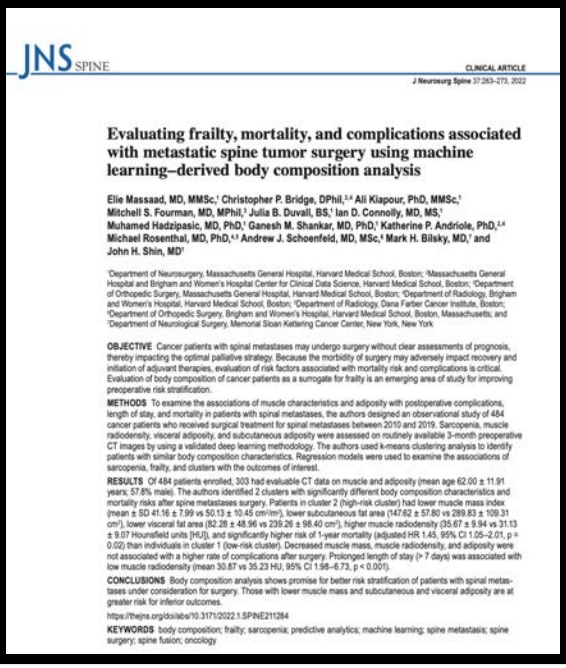
Is there a more granular approach to measuring sarcopenia?



JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 37:263–273, 2022

Evaluating frailty, mortality, and complications associated with metastatic spine tumor surgery using machine learning–derived body composition analysis

Elie Massaad, MD, MMSc,[1] Christopher P. Bridge, DPhil,[2,4] Ali Kiapour, PhD, MMSc,[1] Mitchell S. Fourman, MD, MPhil,[3] Julia B. Duvall, BS,[1] Ian D. Connolly, MD, MS,[1] Muhamed Hadzipasic, MD, PhD,[1] Ganesh M. Shankar, MD, PhD,[1] Katherine P. Andriole, PhD,[2,4] Michael Rosenthal, MD, PhD,[4,5] Andrew J. Schoenfeld, MD, MSc,[6] Mark H. Bilsky, MD,[7] and John H. Shin, MD[1]

[1]Department of Neurosurgery, Massachusetts General Hospital, Harvard Medical School, Boston; [2]Massachusetts General Hospital and Brigham and Women's Hospital Center for Clinical Data Science, Harvard Medical School, Boston; [3]Department of Orthopedic Surgery, Massachusetts General Hospital, Harvard Medical School, Boston; [4]Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston; [5]Department of Radiology, Dana Farber Cancer Institute, Boston; [6]Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts; and [7]Department of Neurological Surgery, Memorial Sloan Kettering Cancer Center, New York, New York

OBJECTIVE Cancer patients with spinal metastases may undergo surgery without clear assessments of prognosis, thereby impacting the optimal palliative strategy. Because the morbidity of surgery may adversely impact recovery and initiation of adjuvant therapies, evaluation of risk factors associated with mortality risk and complications is critical. Evaluation of body composition of cancer patients as a surrogate for frailty is an emerging area of study for improving preoperative risk stratification.

METHODS To examine the associations of muscle characteristics and adiposity with postoperative complications, length of stay, and mortality in patients with spinal metastases, the authors designed an observational study of 484 cancer patients who received surgical treatment for spinal metastases between 2010 and 2019. Sarcopenia, muscle radiodensity, visceral adiposity, and subcutaneous adiposity were assessed on routinely available 3-month preoperative CT images by using a validated deep learning methodology. The authors used k-means clustering analysis to identify patients with similar body composition characteristics. Regression models were used to examine the associations of sarcopenia, frailty, and clusters with the outcomes of interest.

RESULTS Of 484 patients enrolled, 303 had evaluable CT data on muscle and adiposity (mean age 62.00 ± 11.91 years; 57.8% male). The authors identified 2 clusters with significantly different body composition characteristics and mortality risks after spine metastases surgery. Patients in cluster 2 (high-risk cluster) had lower muscle mass index (mean ± SD 41.16 ± 7.99 vs 50.13 ± 10.45 cm^2/m^2), lower subcutaneous fat area (147.62 ± 57.80 vs 289.83 ± 109.31 cm^2), lower visceral fat area (82.28 ± 48.96 vs 239.26 ± 98.40 cm^2), higher muscle radiodensity (35.67 ± 9.94 vs 31.13 ± 9.07 Hounsfield units [HU]), and significantly higher risk of 1-year mortality (adjusted HR 1.45, 95% CI 1.05–2.01, p = 0.02) than individuals in cluster 1 (low-risk cluster). Decreased muscle mass, muscle radiodensity, and adiposity were not associated with a higher rate of complications after surgery. Prolonged length of stay (> 7 days) was associated with low muscle radiodensity (mean 30.87 vs 35.23 HU, 95% CI 1.98–6.73, p < 0.001).

CONCLUSIONS Body composition analysis shows promise for better risk stratification of patients with spinal metastases under consideration for surgery. Those with lower muscle mass and subcutaneous and visceral adiposity are at greater risk for inferior outcomes.

https://thejns.org/doi/abs/10.3171/2022.1.SPINE211284

KEYWORDS body composition; frailty; sarcopenia; predictive analytics; machine learning; spine metastasis; spine surgery; spine fusion; oncology

Body Composition

- Skeletal muscle mass
- Skeletal Muscle Radiodensity → Muscle Quality
- Visceral adiposity
- Subcutaneous adiposity

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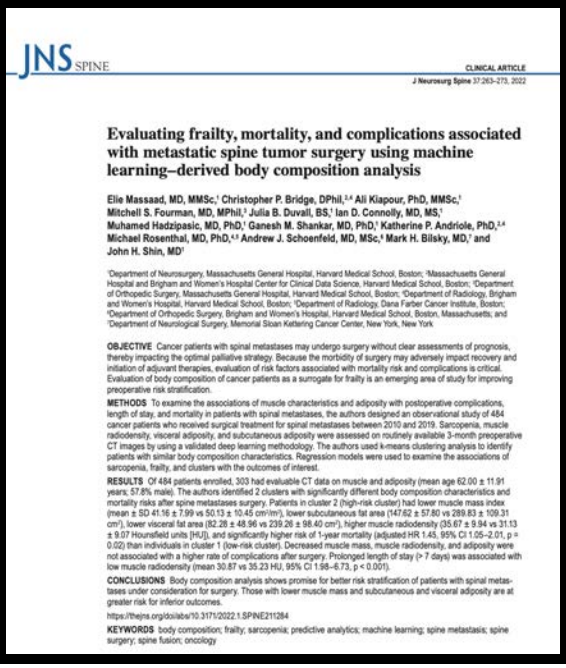

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Decreased 1-year Survival

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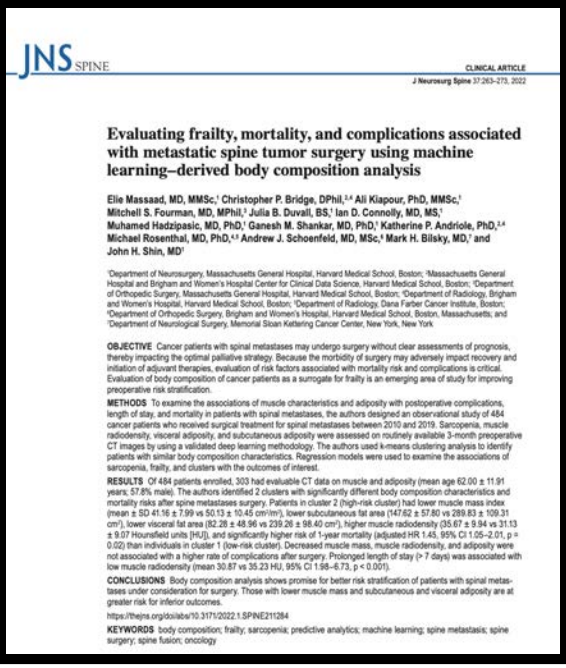

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CONCLUSIONS Body composition analysis shows promise for better risk stratification of patients with spinal metastases under consideration for surgery. Those with lower muscle mass and subcutaneous and visceral adiposity are at greater risk for inferior outcomes.

https://thejns.org/doi/abs/10.3171/2022.1.SPINE211284

KEYWORDS body composition; frailty; sarcopenia; predictive analytics; machine learning; spine metastasis; spine surgery; spine fusion; oncology

Decreased 1-year Survival

Body Composition

- Skeletal muscle mass
- Skeletal Muscle Radiodensity → Muscle Quality
- Visceral adiposity
- Subcutaneous adiposity

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Is there a more granular approach to measuring sarcopenia?

JNS SPINE

CLINICAL ARTICLE

J Neurosurg Spine 37:263–273, 2022

Evaluating frailty, mortality, and complications associated with metastatic spine tumor surgery using machine learning–derived body composition analysis

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OBJECTIVE Cancer patients with spinal metastases may undergo surgery without clear assessments of prognosis, thereby impacting the optimal palliative strategy. Because the morbidity of surgery may adversely impact recovery and initiation of adjuvant therapies, evaluation of risk factors associated with mortality risk and complications is critical. Evaluation of body composition of cancer patients as a surrogate for frailty is an emerging area of study for improving preoperative risk stratification.

METHODS To examine the associations of muscle characteristics and adiposity with postoperative complications, length of stay, and mortality in patients with spinal metastases, the authors designed an observational study of 484 cancer patients who received surgical treatment for spinal metastases between 2010 and 2019. Sarcopenia, muscle radiodensity, visceral adiposity, and subcutaneous adiposity were assessed on routinely available 3-month preoperative CT images by using a validated deep learning methodology. The authors used k-means clustering analysis to identify patients with similar body composition characteristics. Regression models were used to examine the associations of sarcopenia, frailty, and clusters with the outcomes of interest.

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- Decreased 1-year Survival
- **Body Composition**
  - Skeletal muscle mass ↓
  - Skeletal Muscle Radiodensity → Muscle Quality ↓
  - Visceral adiposity ↓
  - Subcutaneous adiposity ↓
- Quantification of Cachexia

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Artificial Intelligence and Machine Learning Applications in Spine Surgery

NATHAN J. LEE, MD[1]; JOSEPH M. LOMBARDI, MD[1]; AND RONALD A. LEHMAN, MD[1]

[1]Department of Orthopaedics, Columbia University Medical Center, The Och Spine Hospital at New York-Presbyterian, New York, NY, USA

ABSTRACT

The complexity of patients with spine pathology and high rates of complications has driven extensive research directed toward optimizing outcomes and reducing complications. Traditional statistical analysis has been limited both in validity and in the number of predictor variables considered. Over the past decade, artificial intelligence and machine learning have taken center stage as the possible solution to creating more accurate and applicable patient-centered predictive models in spine surgery. This review discusses the current published machine learning applications on preoperative optimization, risk stratification, and predictive modeling for the cervical, lumbar, and adult spinal deformity populations.

Focus Issue Article

Keywords: machine learning, artificial intelligence, cervical spine, lumbar spine, adult spinal deformity, predictive model

INTRODUCTION

The development of predictive models is not a novel concept in spine surgery. For decades, surgeons have relied on various statistical analyses to identify risk factors for complications with the hope of creating a valid model. A popular technique is the use of multivariate logistic regression (LR), which produces odds ratios for independent variables on the outcomes of interest. The advantage of such analysis includes the relative ease of interpretation and application. However, an important limitation of predictive models is the limited number of predictive variables included. Furthermore, these traditional analyses are static in nature, assume a "linear" relationship between the input and output variables, and may have minimal applicability for addressing the intricacies of patient-specific needs as new data are introduced.

Over the past decade, health care providers have gained access to an immense amount of patient information through the digitation of electronic medical records. As a result, artificial intelligence (AI) and machine learning (ML) have taken center stage as the potential solution for implementing more accurate and generalizable predictive models. The major reasons for the increasing attraction toward AI and ML include the potential to process large amounts of data quickly, create models that adapt to new data, and understand complex, nonlinear relationships that conventional regression models might fail to comprehend. Spine studies are already showing promise in the ability of ML methods to provide improved preoperative risk stratification and diagnostics as well as leverage imaging data for better clinical prognostication.[1–3] The purpose of this review is to highlight the current applications of ML in spine surgery, compare the performance of common ML models, and explore the potential of ML in future studies.

WHAT IS ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING?

AI is the broader concept of applying systems to simulate human learning and thinking. One of the main applications of AI is ML, which utilizes various computational techniques to continuously learn and self-adjust from past data in order to determine mathematical relationships inherent in the data. The majority of prior outcomes research in spine have involved statistical analyses to characterize relationships between independent and dependent variables. By doing so, the focus of these statistical analyses has been to identify the parameters of a model and understand how each impacts the prediction. Although these analyses are valuable and often offer the researcher an ease of interpretability, they are static in nature and are often subject to selection bias and limited external validity. In contrast, the focus of ML is less about the parameters of a model and more about the prediction. This often leads to "black box" algorithms, which may be difficult to conceptualize. However, ML has the potential to process an inordinate amount of data, learn and adapt to varying

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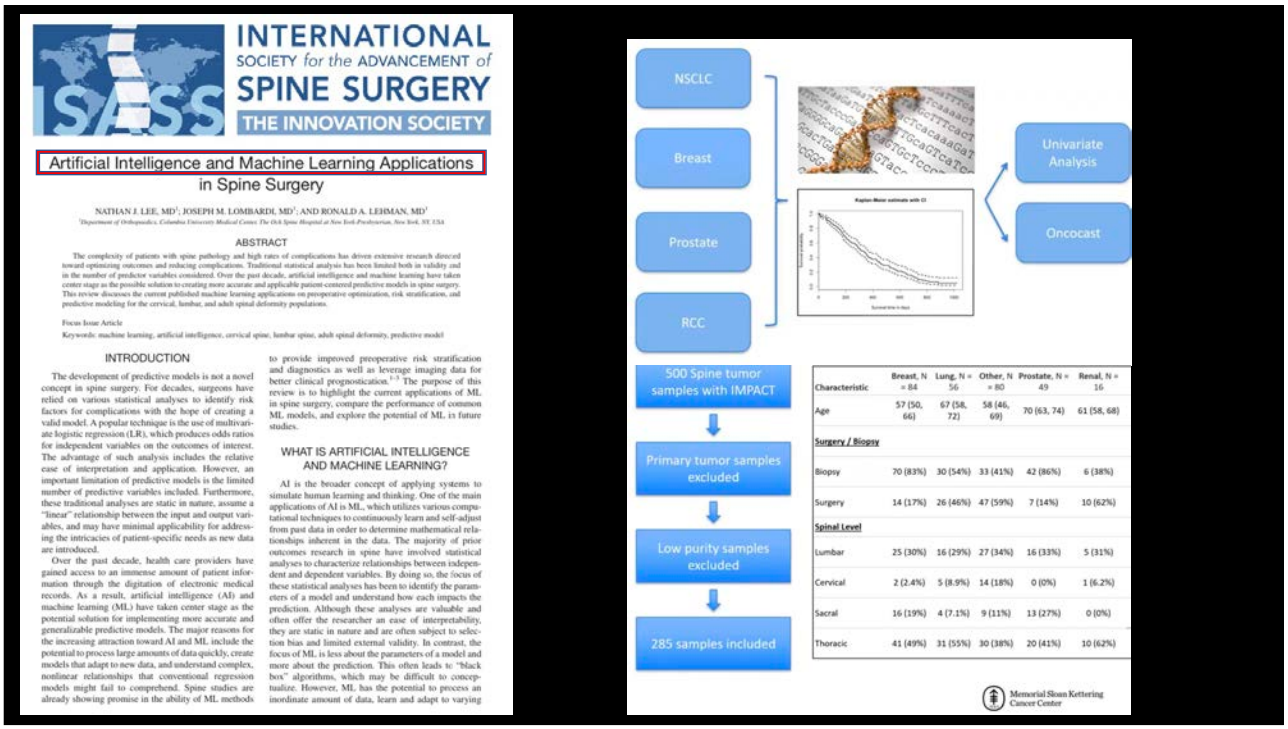

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Characteristic	Breast, N = 84	Lung, N = 56	Other, N = 80	Prostate, N = 49	Renal, N = 16
Age	57 (50, 66)	67 (58, 72)	58 (46, 69)	70 (63, 74)	61 (58, 68)
Surgery / Biopsy					
Biopsy	70 (83%)	30 (54%)	33 (41%)	42 (86%)	6 (38%)
Surgery	14 (17%)	26 (46%)	47 (59%)	7 (14%)	10 (62%)
Spinal Level					
Lumbar	25 (30%)	16 (29%)	27 (34%)	16 (33%)	5 (31%)
Cervical	2 (2.4%)	5 (8.9%)	14 (18%)	0 (0%)	1 (6.2%)
Sacral	16 (19%)	4 (7.1%)	9 (11%)	13 (27%)	0 (0%)
Thoracic	41 (49%)	31 (55%)	30 (38%)	20 (41%)	10 (62%)

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500 Spine tumor samples with IMPACT
Primary tumor samples excluded
Low purity samples excluded
285 samples included
OncoCast

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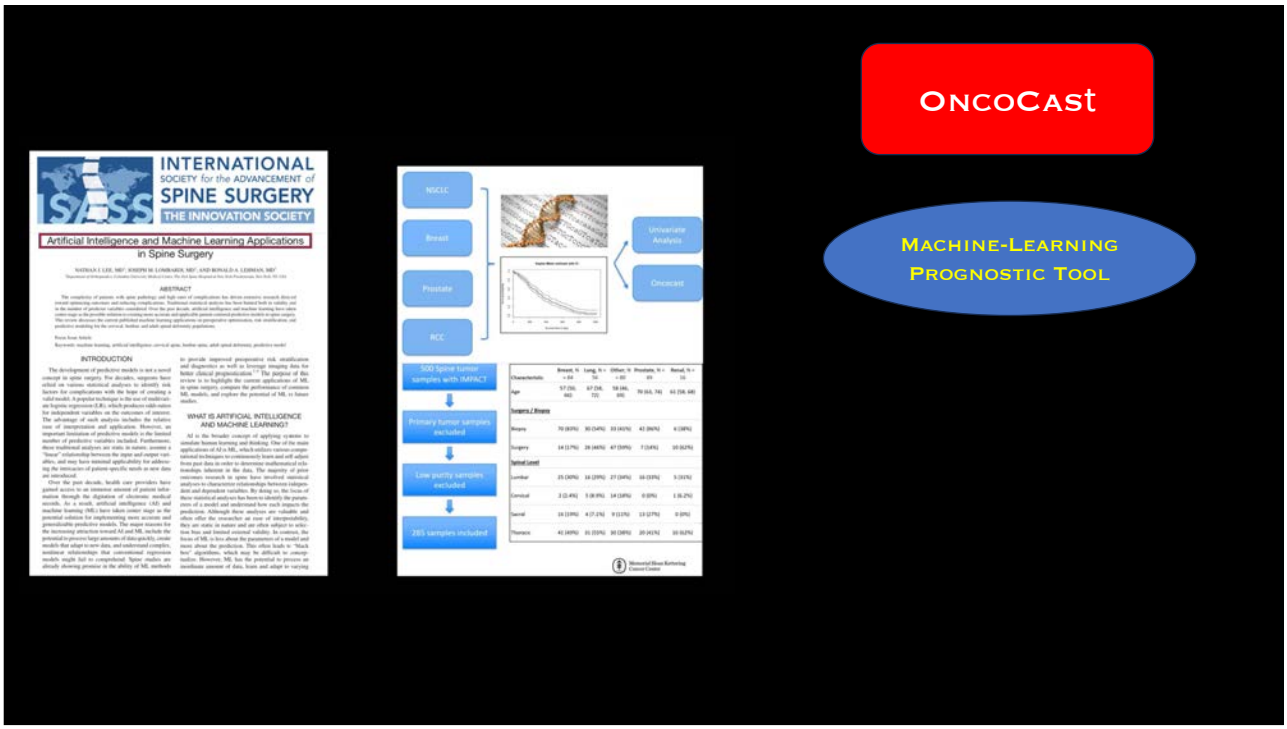
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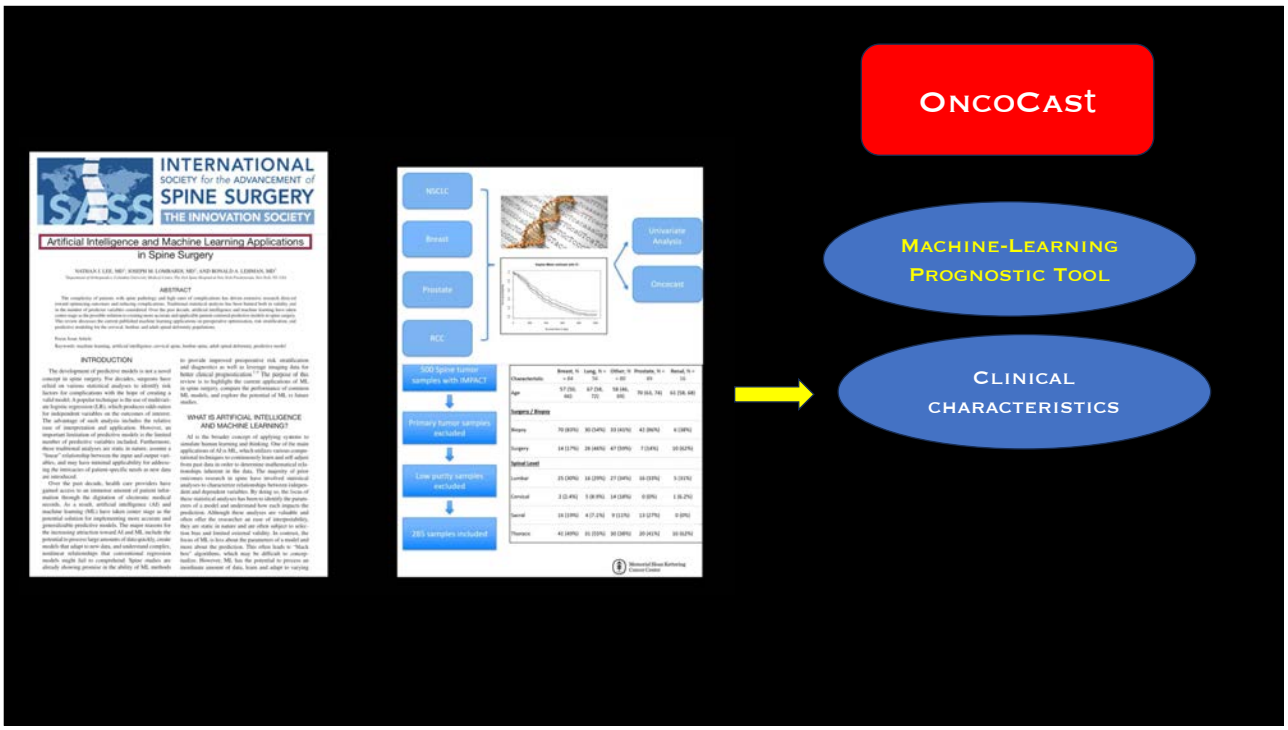
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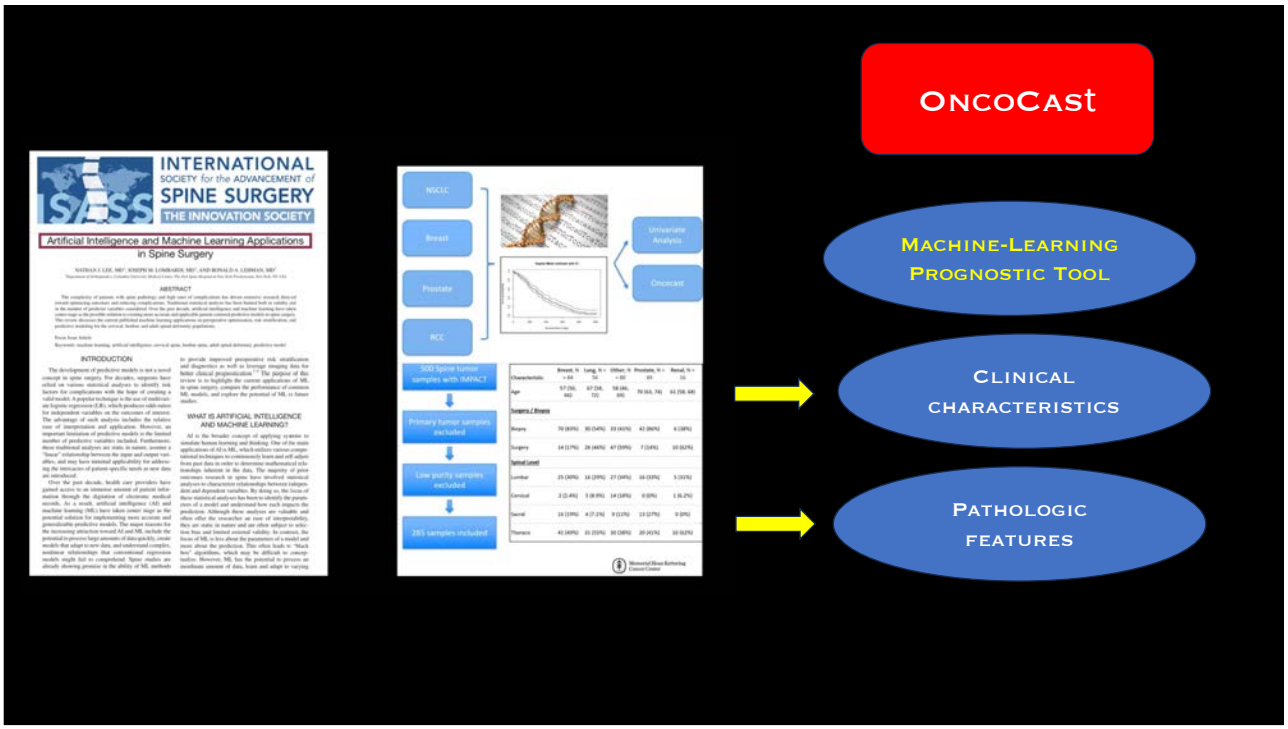
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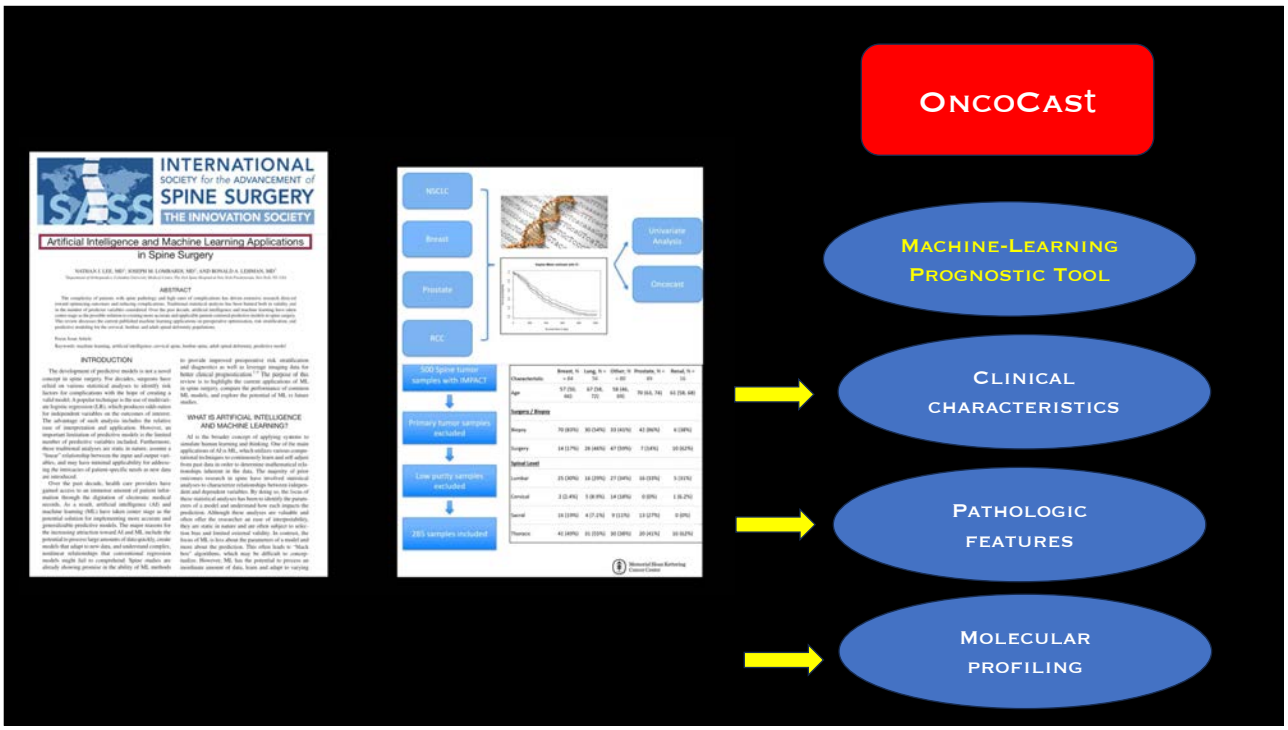
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Machine-Learning Prognostic Tool
Clinical characteristics
Pathologic features
Molecular profiling

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RESEARCH—HUMAN—CLINICAL STUDIES
Survival Trends After Surgery for Spinal Metastatic Tumors: 20-Year Cancer Center Experience
Robert J. Rothrock, MD
Ori Barzilai, MD
Anne S. Reiner, MPH
Eric Lis, MD
Adam M. Schmitt, MD
Daniel S. Higginson, MD
Yoshiya Yamada, MD
Mark H. Bilsky, MD
Ilya Laufer, MD
BACKGROUND: Over the last 2 decades, advances in systemic therapy have increased the expected overall survival for patients with cancer. It is unclear whether the same survival benefit has been conferred to patients requiring surgery for metastatic spinal disease.
OBJECTIVE: To examine trends in postoperative survival over a 20-yr period for patients surgically treated for spinal metastatic disease.
METHODS: Data were obtained for 1515 patients who underwent surgery for metastatic epidural spinal cord compression or tumor-related mechanical instability. Postoperative overall survival was calculated for all included patients using Kaplan-Meier methodology from date of surgery until death or last follow-up for those who were censored. Trends were analyzed using Cox proportional hazards modeling.
RESULTS: Patients with renal, breast, lung, and colon cancers experienced a statistically significant improvement in survival over time based on the year of surgery (40%-100% improvement over the study period), whereas the overall survival trend for the entire cohort did not reach statistical significance ($P = .12$, median survival 0.71 yr, 95% CI 0.63-0.78). Patients presenting with synchronous metastatic disease had better survival compared to those presenting with metachronous disease (median overall survival: 0.94 vs 0.63 yr, respectively; log-rank P-value = .00001).
CONCLUSION: The postoperative survival among patients with spinal metastases has improved over the past 20 yr, particularly in patients with kidney, breast, lung, and colon tumors metastatic to the spine. The observed survival improvement emphasizes the need for long-term outcome consideration in treatment decisions for patients undergoing surgery for spinal metastatic tumors.
KEY WORDS: Survival for spinal metastases, Trends in survival, Separation surgery, Hybrid therapy
Over the last 2 decades, advances in treatment and early diagnosis have increased the expected overall survival for patients with cancer.[1] The 5-yr relative survival among patients diagnosed with cancer improved from 35% in 1950 to 1954 to 70% for the 2009 to 2015 time interval.[2] However, these composite survival statistics include patients with local, regional, and metastatic stages of cancer, with less information available for the survival trends specific to patients with metastatic cancer.
The spine represents one of the most common sites of metastatic disease. Decisions regarding treatment strategy selection require consideration of the expected survival. Although the general cancer statistics indicate that patients diagnosed with cancer live longer, it is unclear whether the same survival benefit has been conferred to patients requiring surgery for metastatic spinal disease because these patients present at various stages of treatment.[3] As more therapeutic agents and potential salvage therapies become available for patients with metastatic cancer, it has been assumed that longer overall survival for cancer patients has translated into longer postoperative survival, leading to greater emphasis on the maintenance of quality of life (QOL) and durable local tumor control in the treatment of spinal metastatic disease.[4-8]
ABBREVIATIONS: CI, confidence interval; OS, overall survival; RPA, recursive partitioning analysis

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RESEARCH—HUMAN—CLINICAL STUDIES

Survival Trends After Surgery for Spinal Metastatic Tumors: 20-Year Cancer Center Experience

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Yoshiya Yamada, MD
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KEY WORDS: Survival for spinal metastases, Trends in survival, Separation surgery, Hybrid therapy

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1ST YEAR IN PRACTICE

- EXAMPLE:
  - NEUROLOGY – 3/5 BLE
  - ONCOLOGIC – UROTHELIAL CARCINOMA
  - MECHANICAL STABILITY – SINS 13

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- Example:
  - Neurology – 3/5 BLE
  - Oncologic – Urothelial Carcinoma
  - Mechanical Stability – SINS 13

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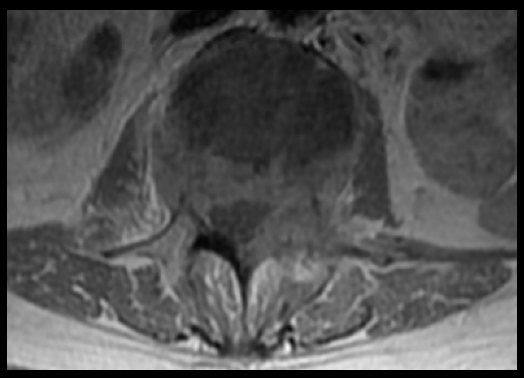
- Example:
  - Neurology – 3/5 BLE
  - Oncologic – Urothelial Carcinoma
  - Mechanical Stability – SINS 13



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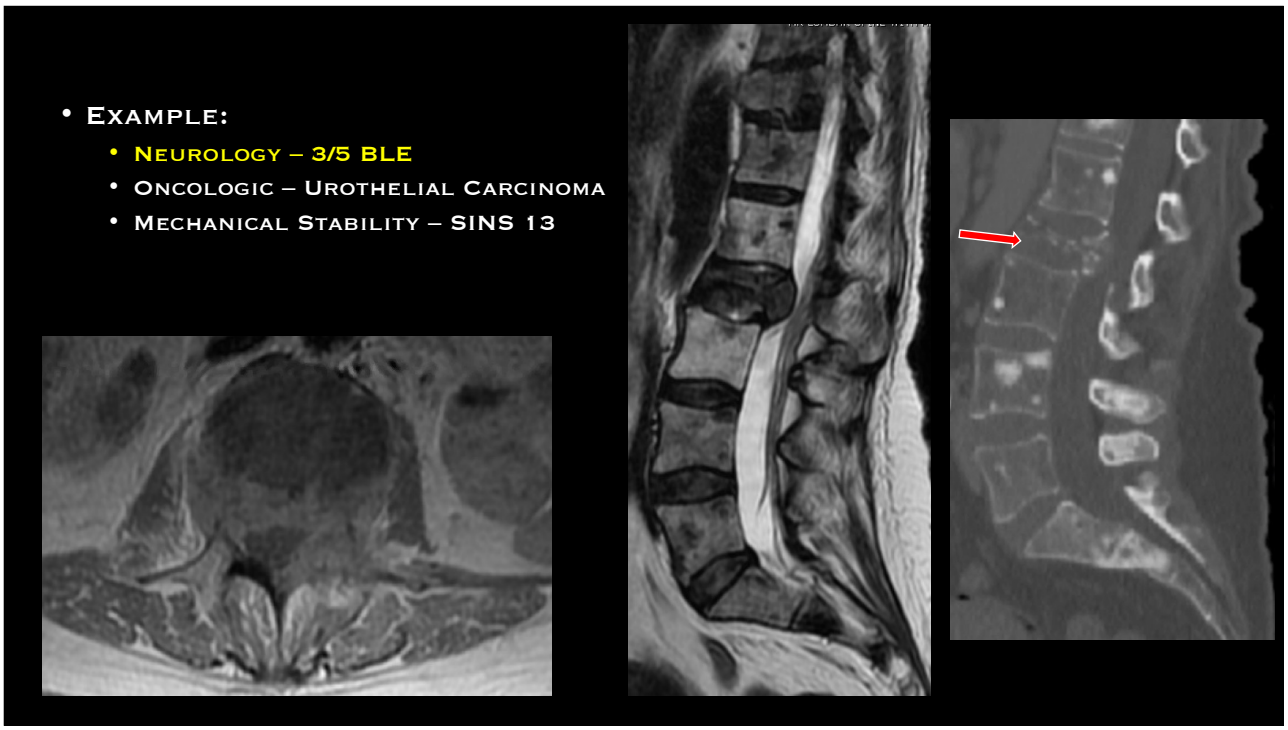
• Example:
• Neurology – 3/5 BLE
• Oncologic – Urothelial Carcinoma
• Mechanical Stability – SINS 13

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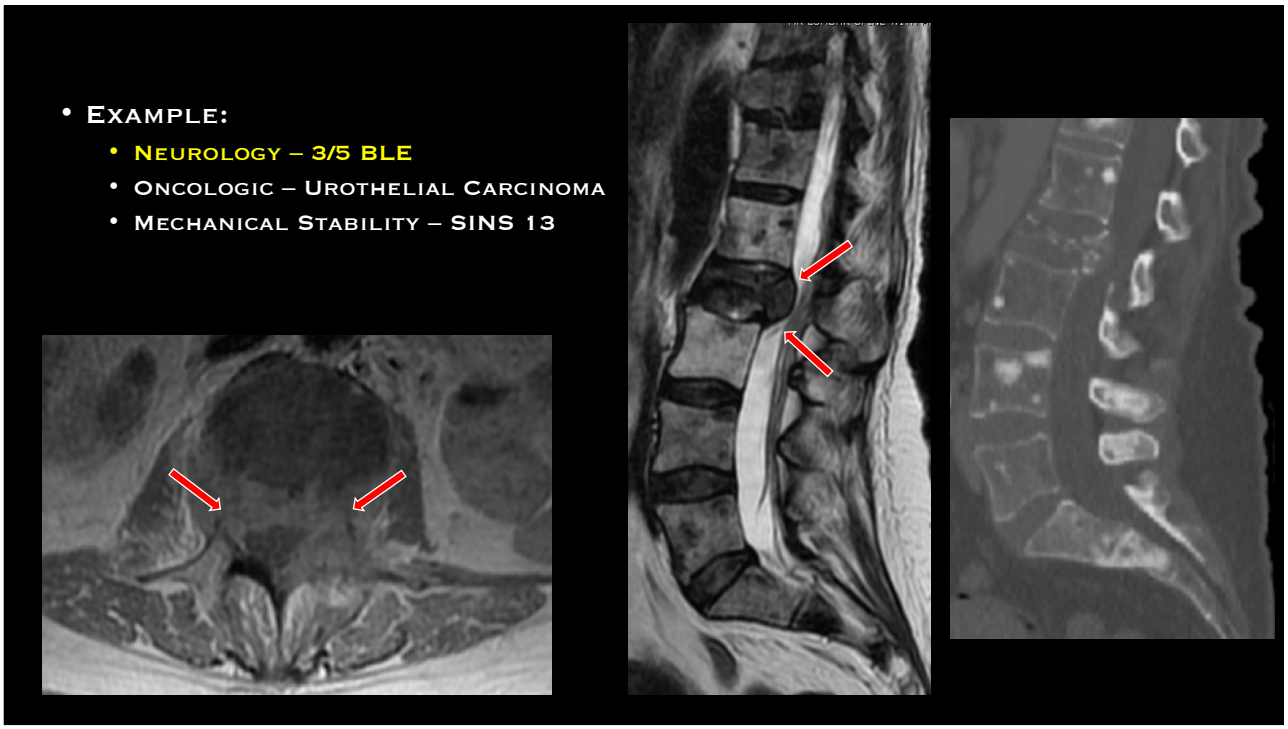
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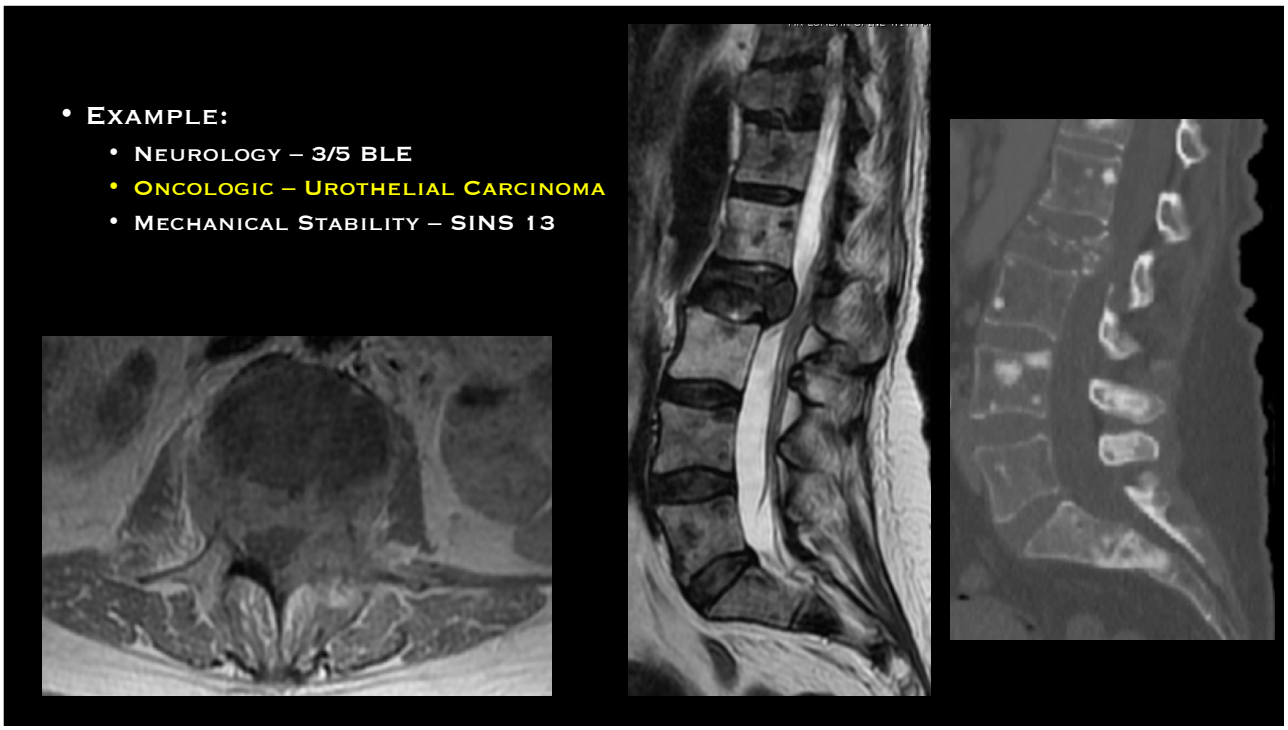
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• Mechanical Stability – SINS 13

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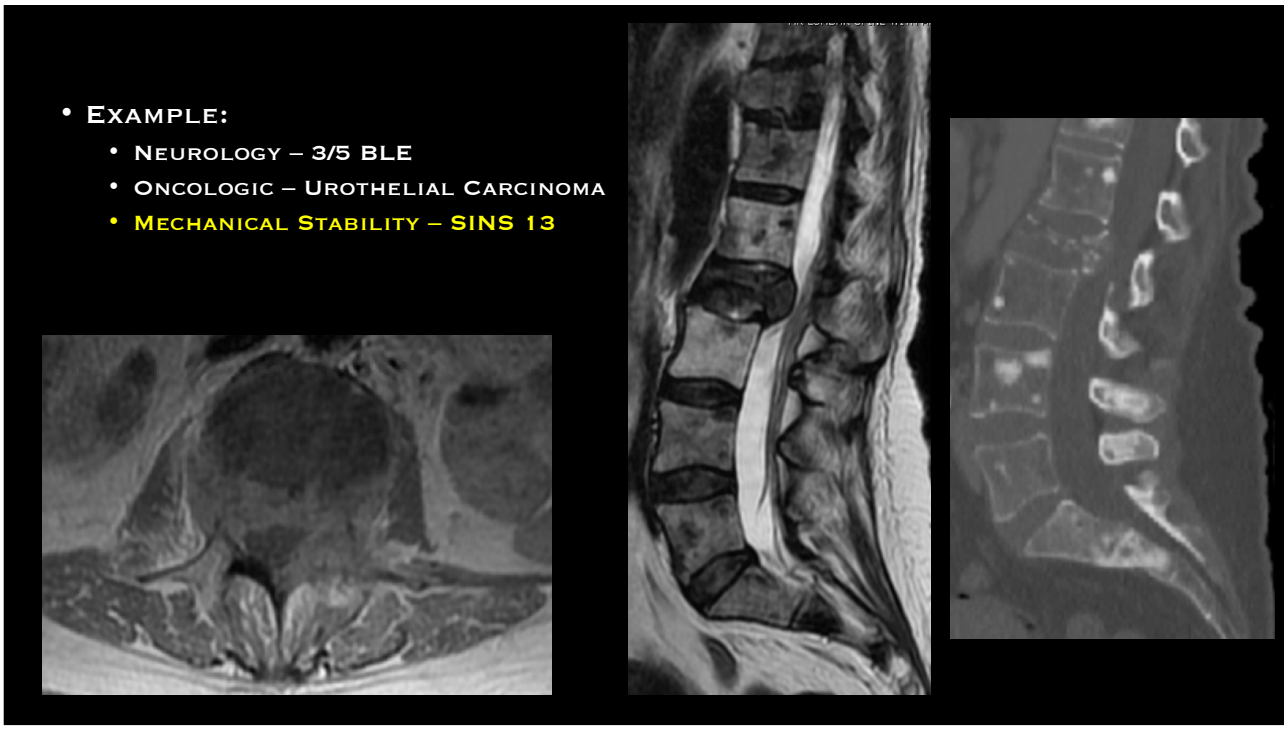
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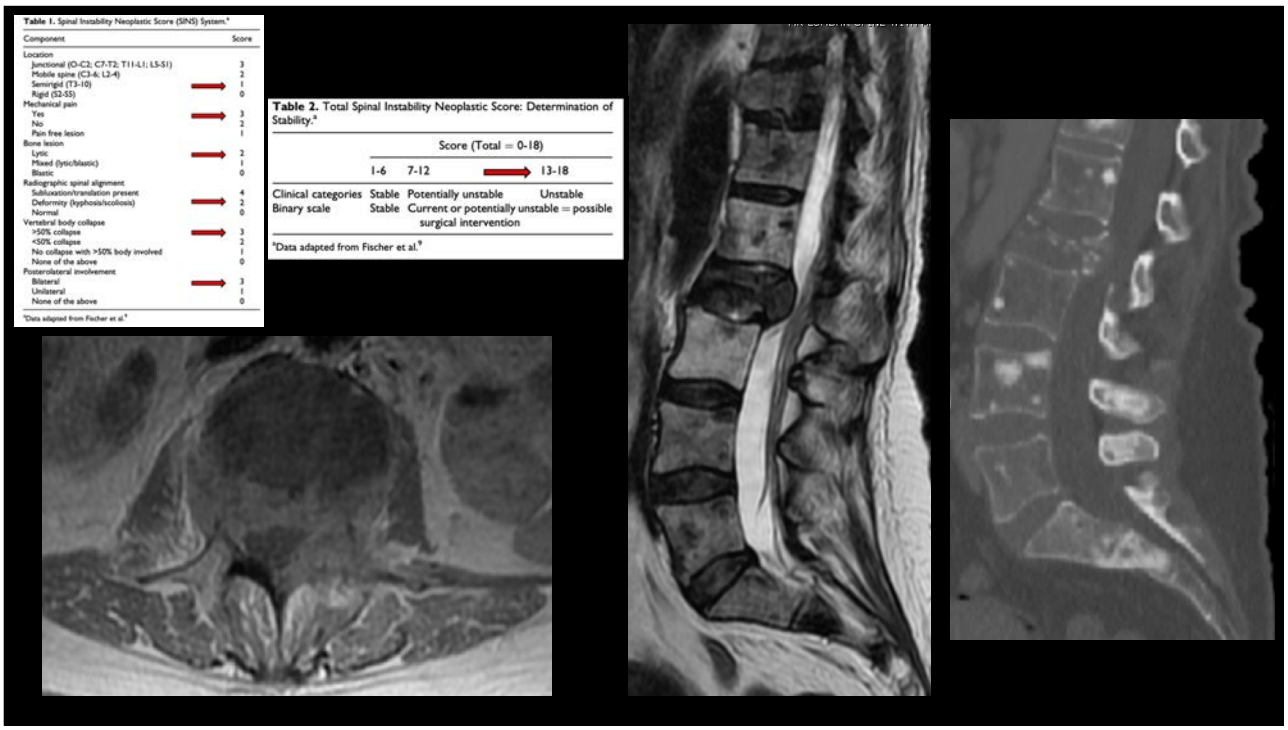
• Neurology – 3/5 BLE
• Oncologic – Urothelial Carcinoma
• Mechanical Stability – SINS 13

198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Component
Score
Location
Junctional (O-C2; C7-T2; T11-L1; L5-S1)
3
Mobile spine (C3-6; L2-4)
2
Semirigid (T3-10)
1
Rigid (S2-S5)
0
Mechanical pain
Yes
3
No
2
Pain free lesion
1
Bone lesion
Lytic
2
Mixed (lytic/blastic)
1
Blastic
0
Radiographic spinal alignment
Subluxation/translation present
4
Deformity (kyphosis/scoliosis)
2
Normal
0
Vertebral body collapse
>50% collapse
3
<50% collapse
2
No collapse with >50% body involved
1
None of the above
0
Posterolateral involvement
Bilateral
3
Unilateral
1
None of the above
0
*Data adapted from Fischer et al.[9]
Table 2. Total Spinal Instability Neoplastic Score: Determination of Stability.*
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
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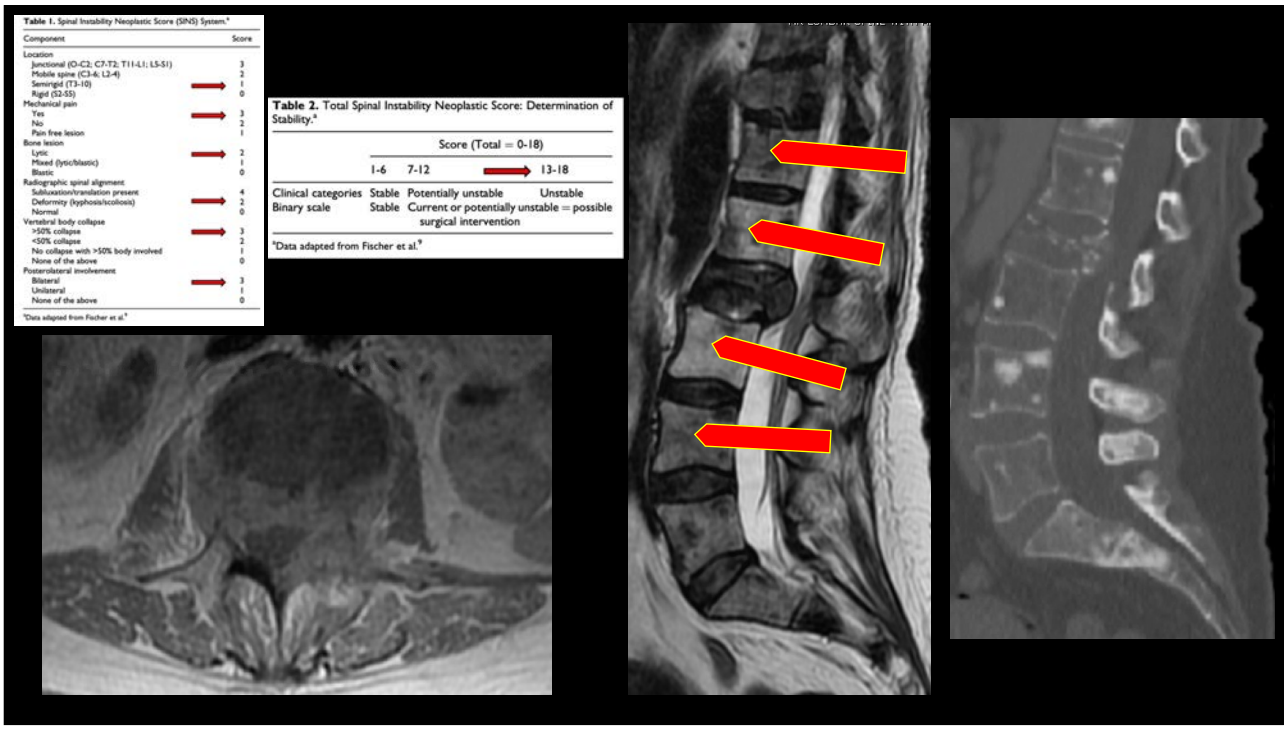
199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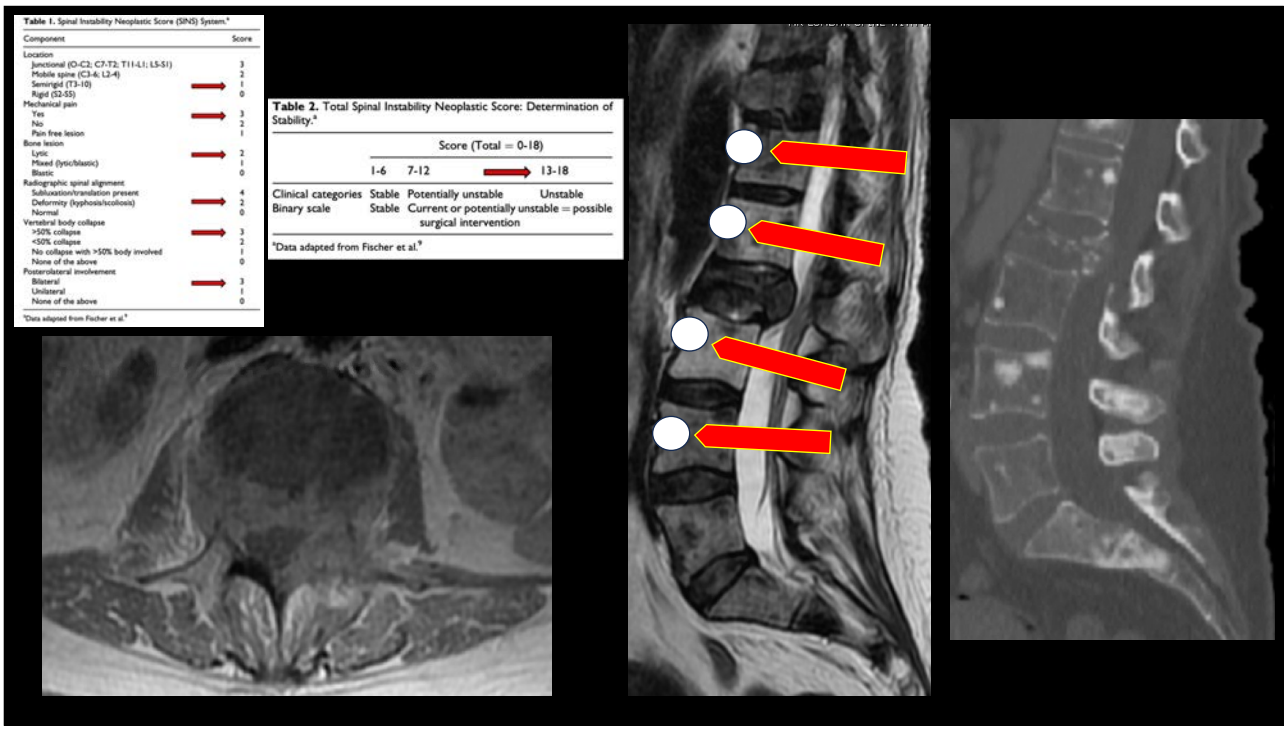
200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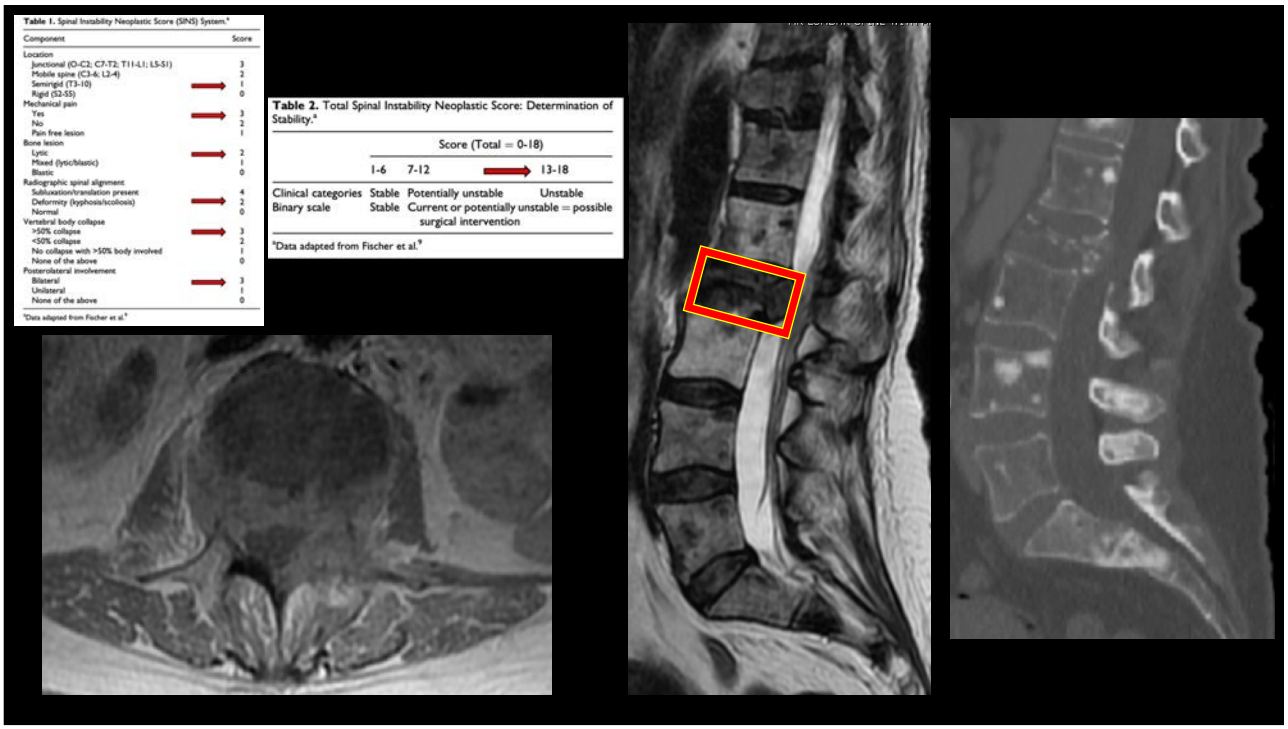
201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202

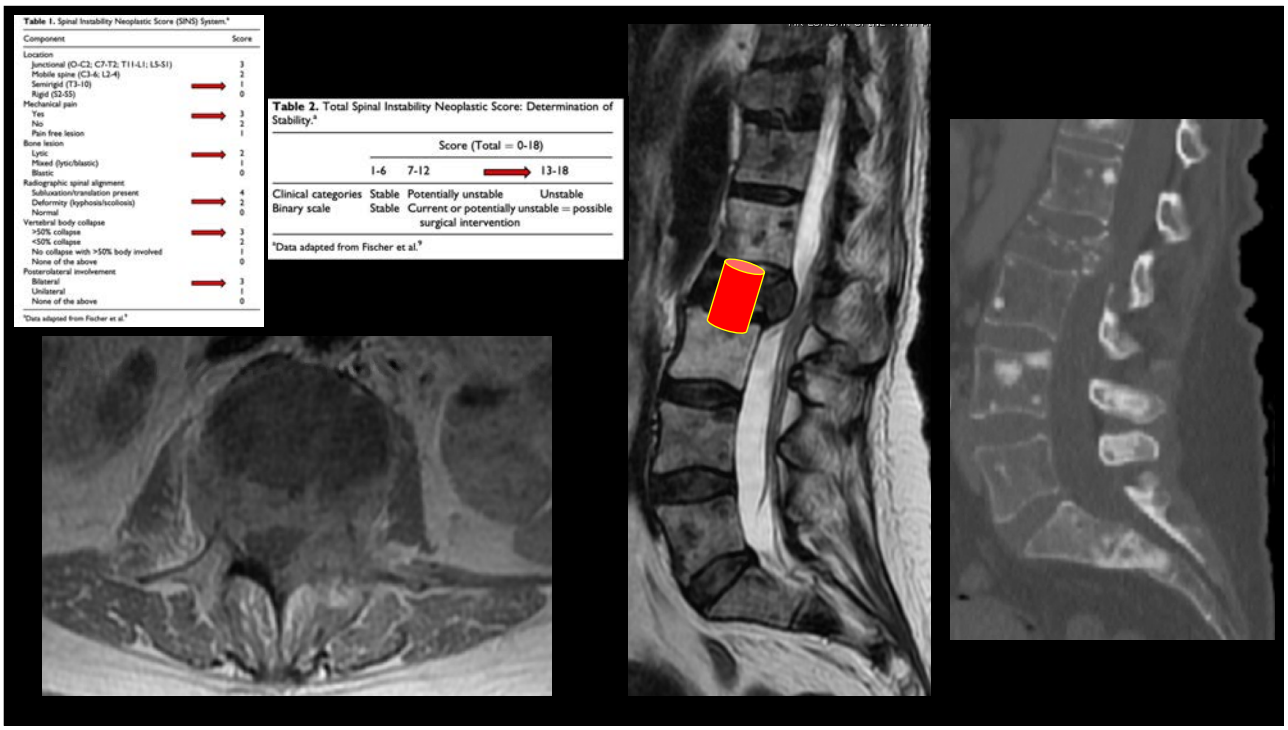

Table 1. Spinal Instability Neoplastic Score (SINS) System.*

Component	Score
Location	
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Mobile spine (C3-6; L2-4)	2
Semirigid (T3-10)	1
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Mechanical pain	
Yes	3
No	2
Pain free lesion	1
Bone lesion	
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Mixed (lytic/blastic)	1
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Radiographic spinal alignment	
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>50% collapse	3
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Posterolateral involvement	
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	1-6	7-12	13-18
Clinical categories	Stable	Potentially unstable	Unstable
Binary scale	Stable	Current or potentially unstable = possible surgical intervention	

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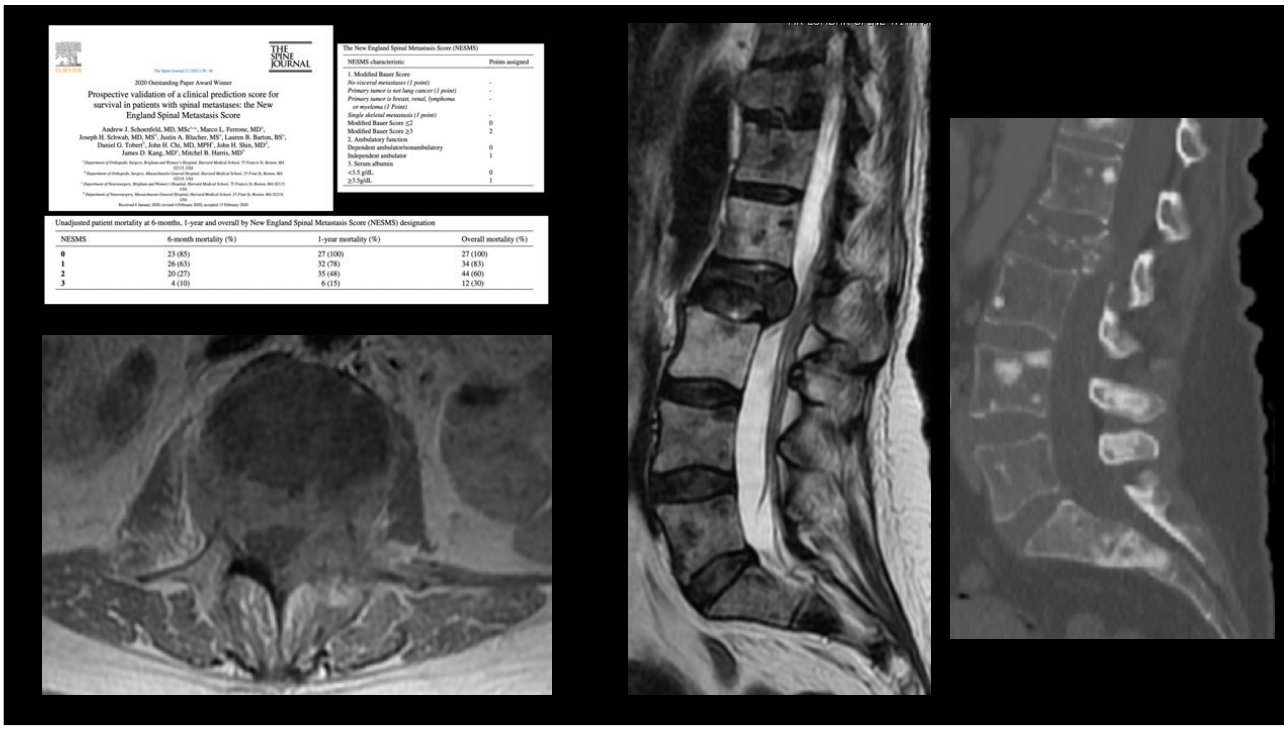
203



THE SPINE JOURNAL

2020 Outstanding Paper Award Winner

Prospective validation of a clinical prediction score for survival in patients with spinal metastases: the New England Spinal Metastasis Score

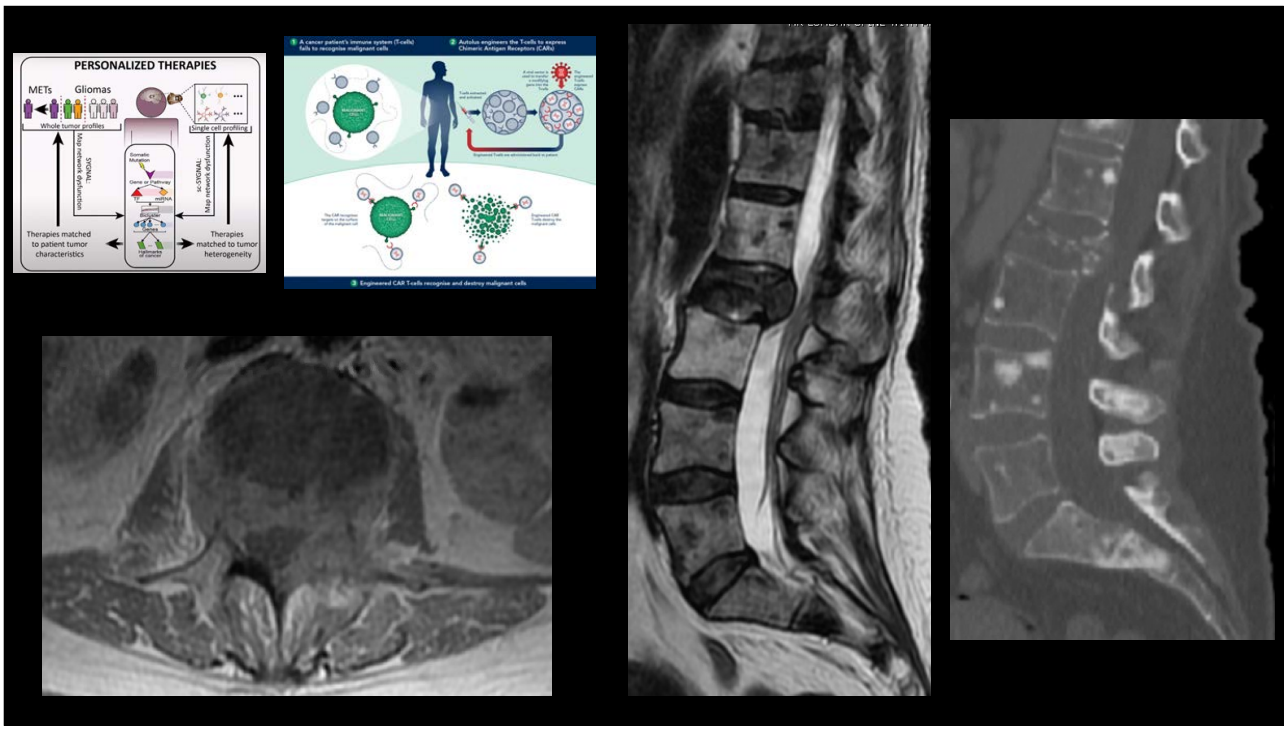
The New England Spinal Metastasis Score (NESMS)

NESMS characteristic	Points assigned
1. Modified Bauer Score	
No visceral metastases (1 point)	-
Primary tumor is not lung cancer (1 point)	-
Primary tumor is breast, renal, lymphoma or myeloma (1 Point)	-
Single skeletal metastasis (1 point)	-
Modified Bauer Score ≤2	0
Modified Bauer Score ≥3	2
2. Ambulatory function	
Dependent ambulator/nonambulatory	0
Independent ambulator	1
3. Serum albumin	
<3.5 g/dL	0
≥3.5g/dL	1

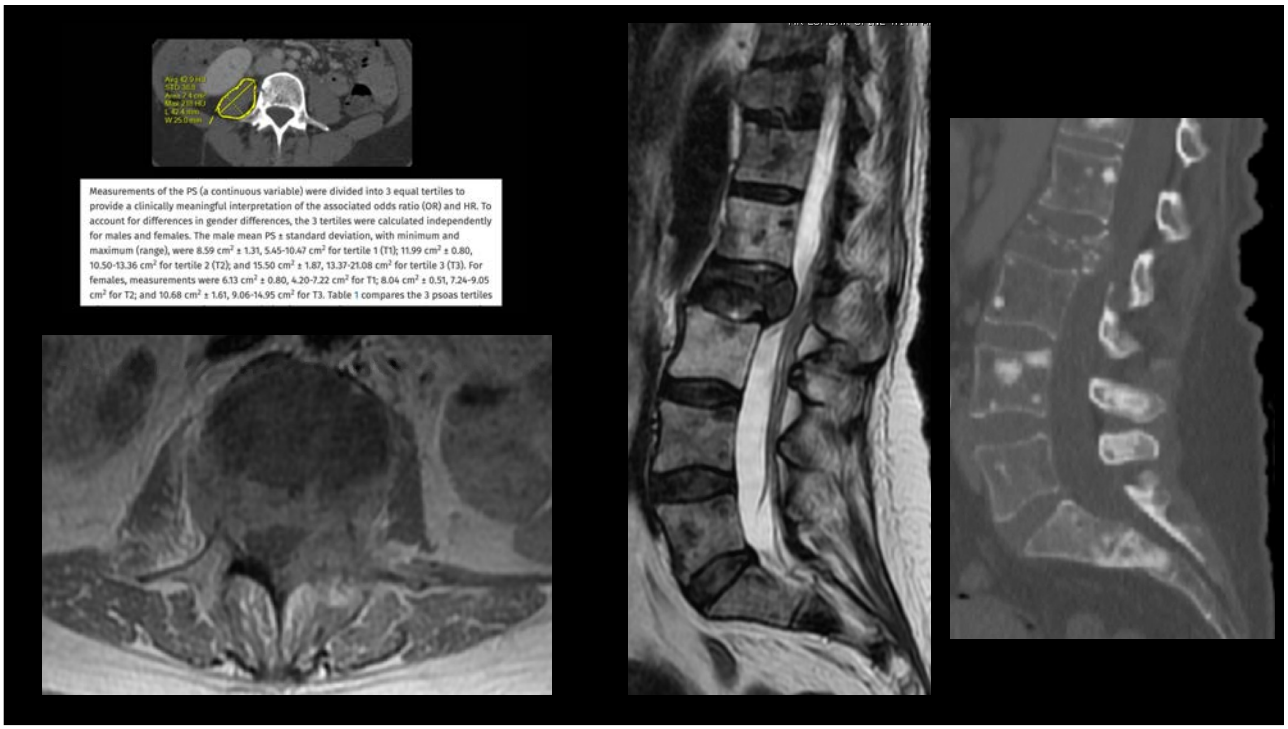
Unadjusted patient mortality at 6-months, 1-year and overall by New England Spinal Metastasis Score (NESMS) designation

NESMS	6-month mortality (%)	1-year mortality (%)	Overall mortality (%)
0	23 (85)	27 (100)	27 (100)
1	26 (63)	32 (78)	34 (83)
2	20 (27)	35 (48)	44 (60)
3	4 (10)	6 (15)	12 (30)

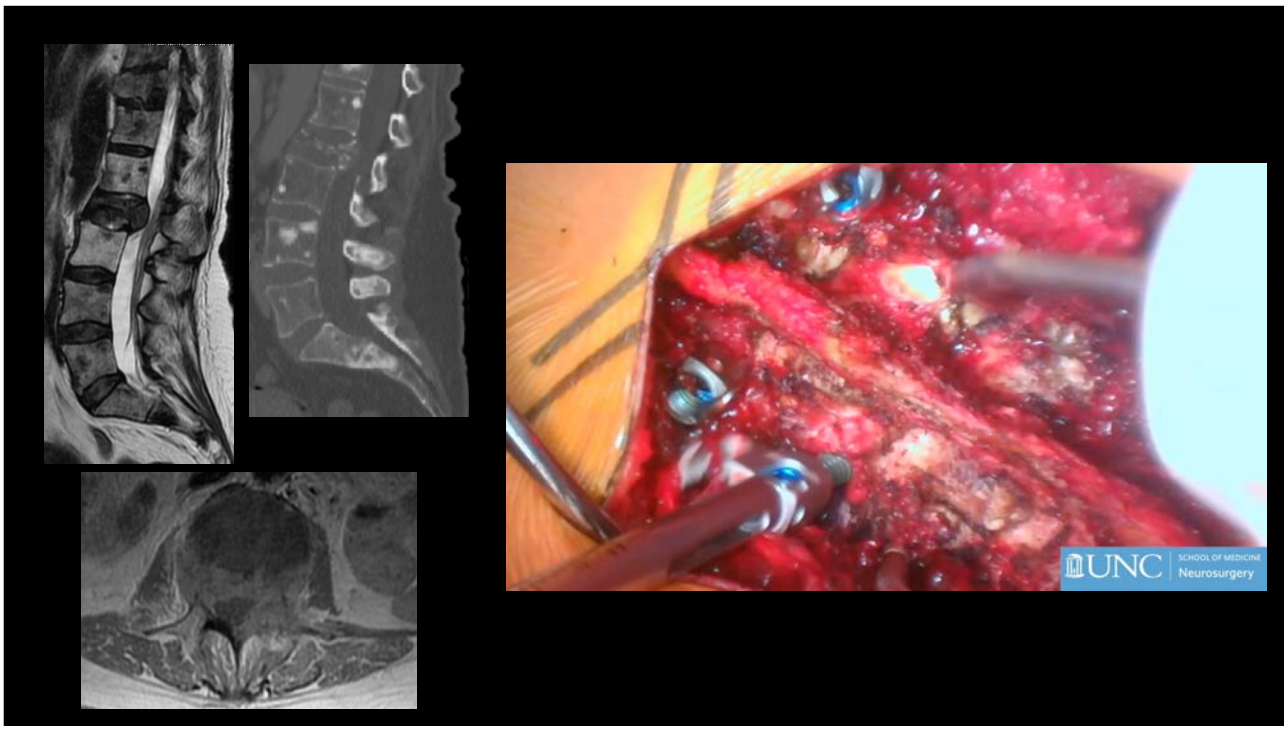
204


PERSONALIZED THERAPIES
METs
Gliomas
Whole tumor profiles
Single cell profiling
Therapies matched to patient tumor characteristics
Therapies matched to tumor heterogeneity

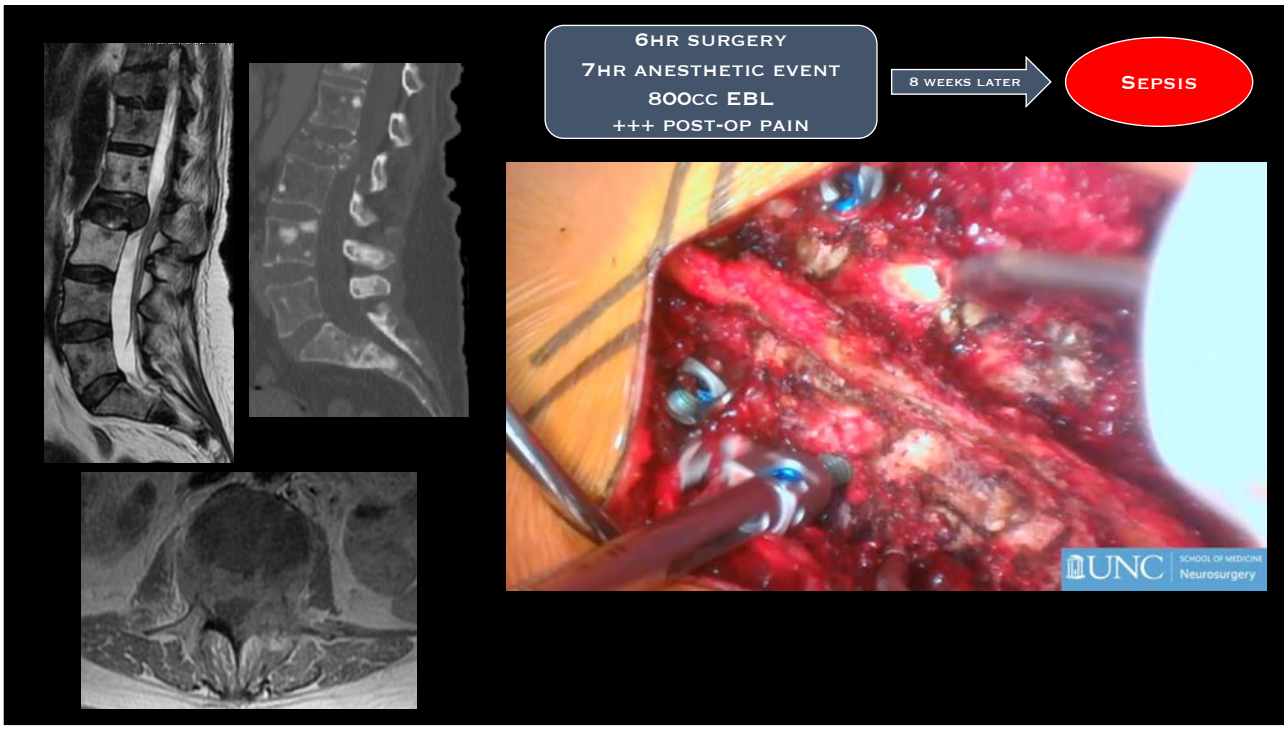
205


Measurements of the PS (a continuous variable) were divided into 3 equal tertiles to provide a clinically meaningful interpretation of the associated odds ratio (OR) and HR. To account for differences in gender differences, the 3 tertiles were calculated independently for males and females. The male mean PS ± standard deviation, with minimum and maximum (range), were 8.59 cm² ± 1.31, 5.45-10.47 cm² for tertile 1 (T1); 11.99 cm² ± 0.80, 10.50-13.36 cm² for tertile 2 (T2); and 15.50 cm² ± 1.87, 13.37-21.08 cm² for tertile 3 (T3). For females, measurements were 6.13 cm² ± 0.80, 4.20-7.22 cm² for T1; 8.04 cm² ± 0.51, 7.24-9.05 cm² for T2; and 10.68 cm² ± 1.61, 9.06-14.95 cm² for T3. Table 1 compares the 3 psoas tertiles

206

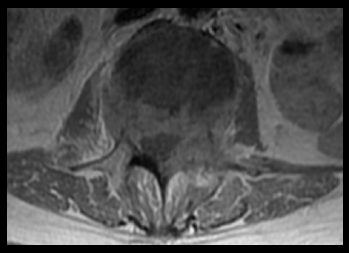

UNC
SCHOOL OF MEDICINE
Neurosurgery

207


6HR SURGERY
7HR ANESTHETIC EVENT
800CC EBL
+++ POST-OP PAIN
8 WEEKS LATER
SEPSIS
UNC
SCHOOL OF MEDICINE
Neurosurgery

208

- Example:
  - Neurology – 3/5 BLE
  - Oncologic – Urothelial Carcinoma
  - Mechanical Stability – SINS 13
  - Systemic Disease – NESMS Score 0


209

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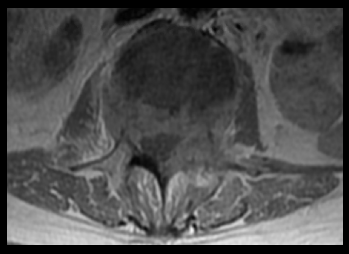


210

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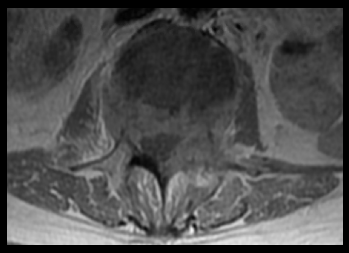

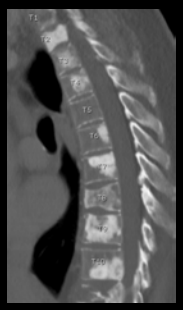
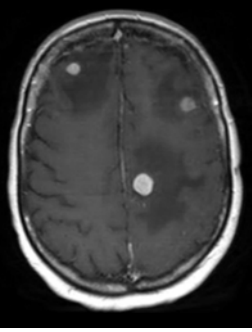

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ELSEVIER
The Spine Journal 21 (2021) 28–36
THE SPINE JOURNAL

2020 Outstanding Paper Award Winner

Prospective validation of a clinical prediction score for survival in patients with spinal metastases: the New England Spinal Metastasis Score

Andrew J. Schoenfeld, MD, MSc[a,*], Marco L. Ferrone, MD[a], Joseph H. Schwab, MD, MS[b], Justin A. Blucher, MS[a], Lauren B. Barton, BS[a], Daniel G. Tobert[b], John H. Chi, MD, MPH[c], John H. Shin, MD[d], James D. Kang, MD[a], Mitchel B. Harris, MD[b]

[a] Department of Orthopedic Surgery, Brigham and Women's Hospital, Harvard Medical School, 75 Francis St, Boston, MA 02115, USA
[b] Department of Orthopedic Surgery, Massachusetts General Hospital, Harvard Medical School, 55 Fruit St, Boston, MA 02214, USA
[c] Department of Neurosurgery, Brigham and Women's Hospital, Harvard Medical School, 75 Francis St, Boston, MA 02115, USA
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Received 6 January 2020; revised 4 February 2020; accepted 13 February 2020

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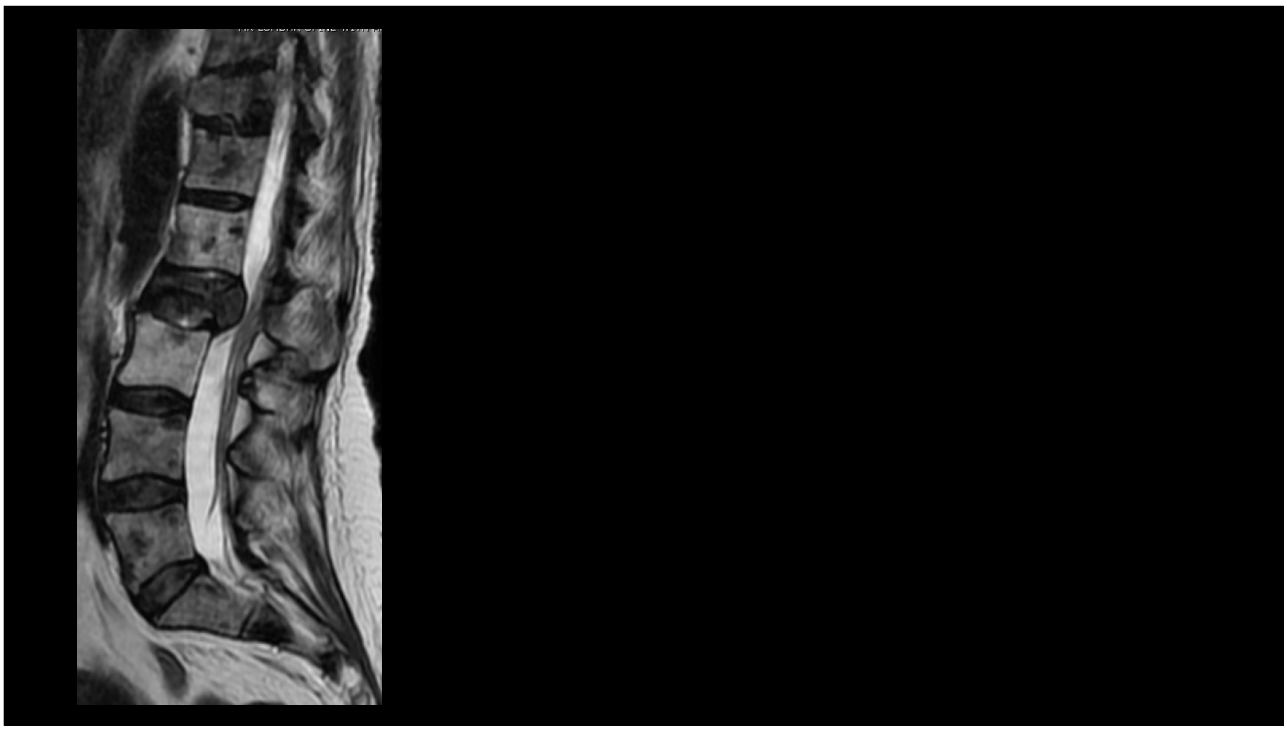
212



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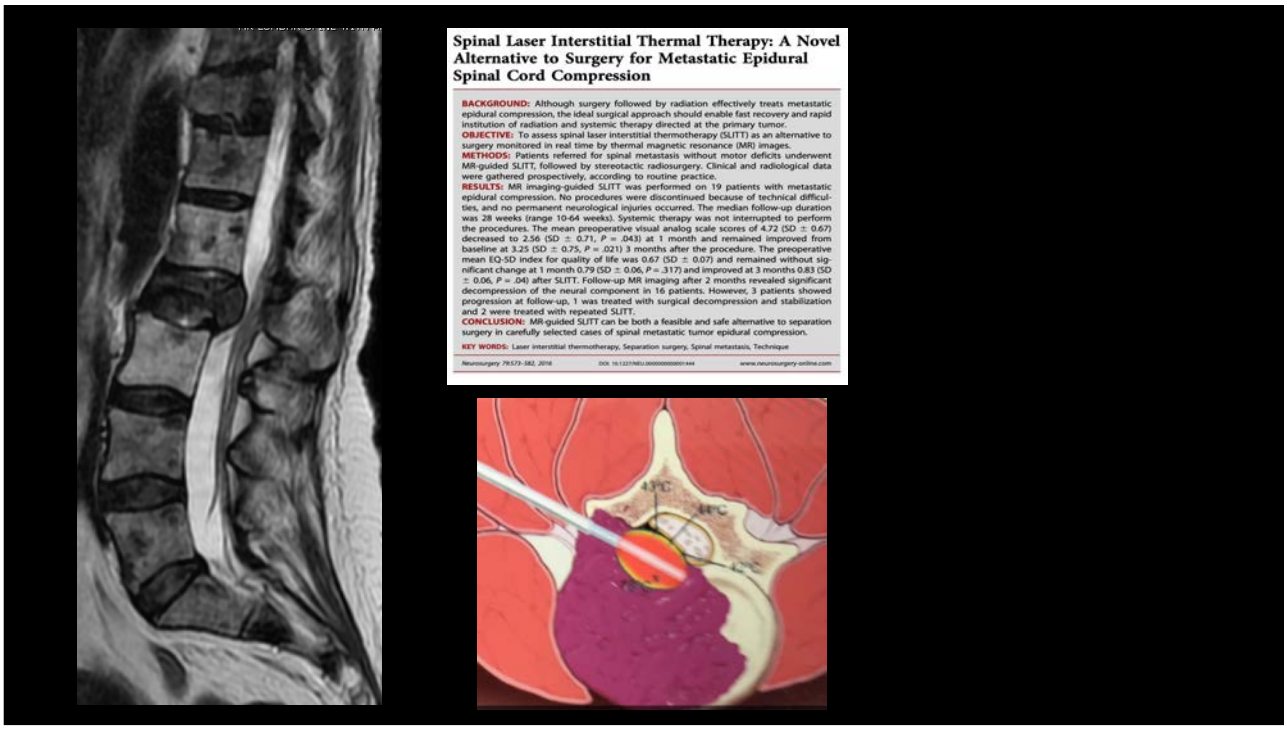
Spinal Laser Interstitial Thermal Therapy: A Novel Alternative to Surgery for Metastatic Epidural Spinal Cord Compression
BACKGROUND: Although surgery followed by radiation effectively treats metastatic epidural compression, the ideal surgical approach should enable fast recovery and rapid institution of radiation and systemic therapy directed at the primary tumor.
OBJECTIVE: To assess spinal laser interstitial thermotherapy (SLITT) as an alternative to surgery monitored in real time by thermal magnetic resonance (MR) images.
METHODS: Patients referred for spinal metastasis without motor deficits underwent MR-guided SLITT, followed by stereotactic radiosurgery. Clinical and radiological data were gathered prospectively, according to routine practice.
RESULTS: MR imaging-guided SLITT was performed on 19 patients with metastatic epidural compression. No procedures were discontinued because of technical difficulties, and no permanent neurological injuries occurred. The median follow-up duration was 28 weeks (range 10-64 weeks). Systemic therapy was not interrupted to perform the procedures. The mean preoperative visual analog scale scores of 4.72 (SD ± 0.67) decreased to 2.56 (SD ± 0.71, P = .043) at 1 month and remained improved from baseline at 3.25 (SD ± 0.75, P = .021) 3 months after the procedure. The preoperative mean EQ-SD index for quality of life was 0.67 (SD ± 0.07) and remained without significant change at 1 month 0.79 (SD ± 0.06, P = .317) and improved at 3 months 0.83 (SD ± 0.06, P = .04) after SLITT. Follow-up MR imaging after 2 months revealed significant decompression of the neural component in 16 patients. However, 3 patients showed progression at follow-up, 1 was treated with surgical decompression and stabilization and 2 were treated with repeated SLITT.
CONCLUSION: MR-guided SLITT can be both a feasible and safe alternative to separation surgery in carefully selected cases of spinal metastatic tumor epidural compression.
KEY WORDS: Laser interstitial thermotherapy, Separation surgery, Spinal metastasis, Technique
Neurosurgery 79:573–582, 2016
www.neurosurgery-online.com

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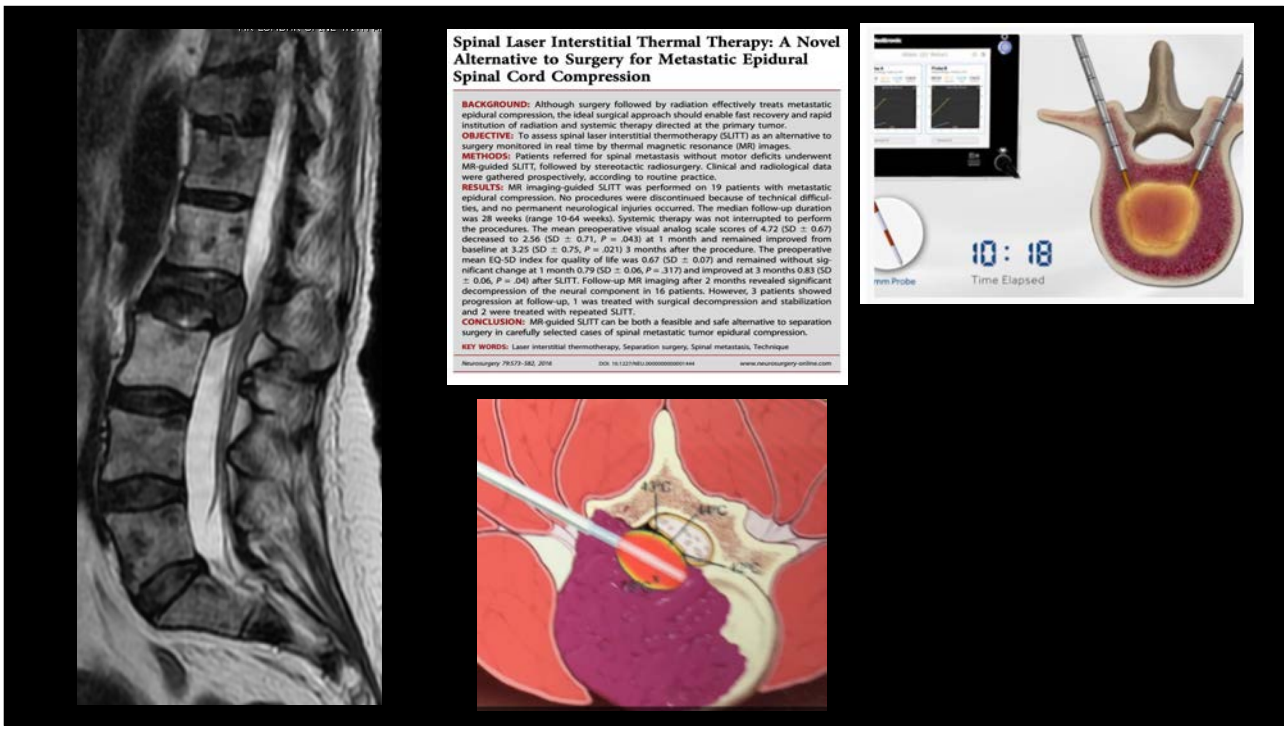
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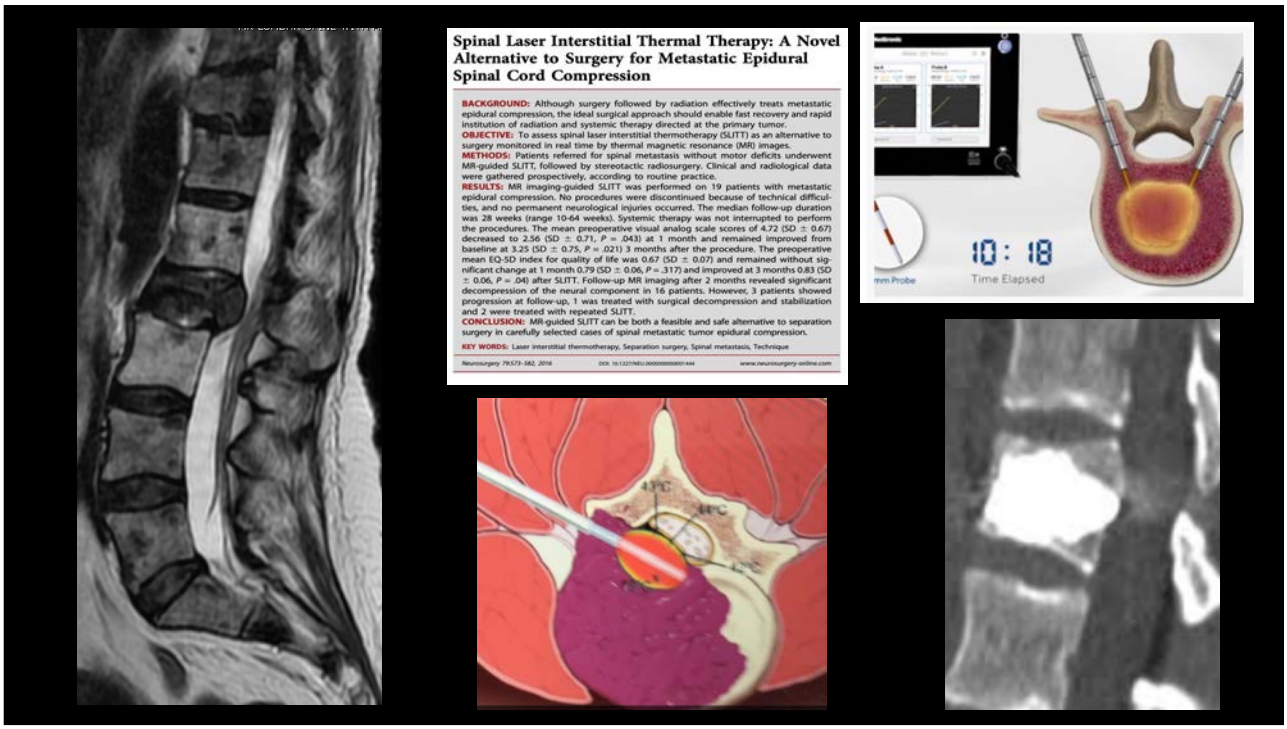
10 : 18
Time Elapsed

215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10 : 18
Time Elapsed

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Journal of Neuro-Oncology (2022) 157:277–283
https://doi.org/10.1007/s11060-022-03982-0

TOPIC REVIEW

Evolution of surgical treatment of metastatic spine tumors

Patricia Zadnik Sullivan[1] · Tianyi Niu[1] · Jose Fernandez Abinader[1] · Sohail Syed[1] · Prakash Sampath[1] · Albert Telfeian[1] · Jared Fridley[1] · Petra Klinge[1] · Joaquin Camara[1] · Adetokunbo Oyelese[1] · Ziya L. Gokaslan[1]

Received: 31 December 2021 / Accepted: 4 March 2022 / Published online: 20 March 2022

Abstract
Purpose The treatment of cancer has transformed over the past 40 years, with medical oncologists, radiation oncologists and surgeons working together to prolong survival times and minimize treatment related morbidity. With each advancement, the risk–benefit scale has been calibrated to provide an accurate assessment of surgical hazard. The goal of this review is to look back at how the role of surgery has evolved with each new medical advance, and to explore the role of surgeons in the future of cancer care.
Methods A literature review was conducted, highlighting the key papers guiding surgical management of spinal metastatic lesions.
Conclusion The roles of surgery, medical therapy, and radiation have evolved over the past 40 years, with new advances requiring complex multidisciplinary care.

REVIEWS

Paradigm changes in spine surgery —evolution of minimally invasive techniques

Zachary A. Smith and Richard G. Fessler

Abstract | Minimally invasive spine surgery (MISS) techniques were developed to address morbidities associated with open spinal surgery approaches. MISS was initially applied for indications such as the microendoscopic decompression of stenosis (MEDS)—an operation that has become widely implemented in modern spine surgery practice. Minimally invasive surgery for MEDS is an excellent example of how an MISS technique has improved outcomes compared with the use of traditional open surgical procedures. In parallel with reports of surgeon experience, accumulating clinical evidence suggests that MISS is favoured over open surgery, and one could argue that the role of MISS techniques will continue to expand. As the field of minimally invasive surgery has developed, MISS has been implemented for the treatment of increasingly difficult and complex pathologies, including trauma, spinal malignancies and spinal deformity in adults. In this Review, we present the accumulating evidence in support of minimally invasive techniques for established MISS indications, such as lumbar stenosis, and discuss the need for additional level I and level II data to demonstrate the benefit of MISS over traditional open surgery. The expanding utility of MISS techniques to address an increasingly broad range of spinal pathologies is also highlighted.

Smith, Z. A. & Fessler, R. G. Nat. Rev. Neurol. 8, 443–450 (2012); published online 19 June 2012; doi:10.1038/nrneurol.2012.110

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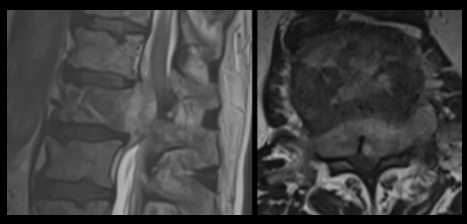
Relevance of Separation Surgery & CF Instrumentation



Radiolucent Hardware

218

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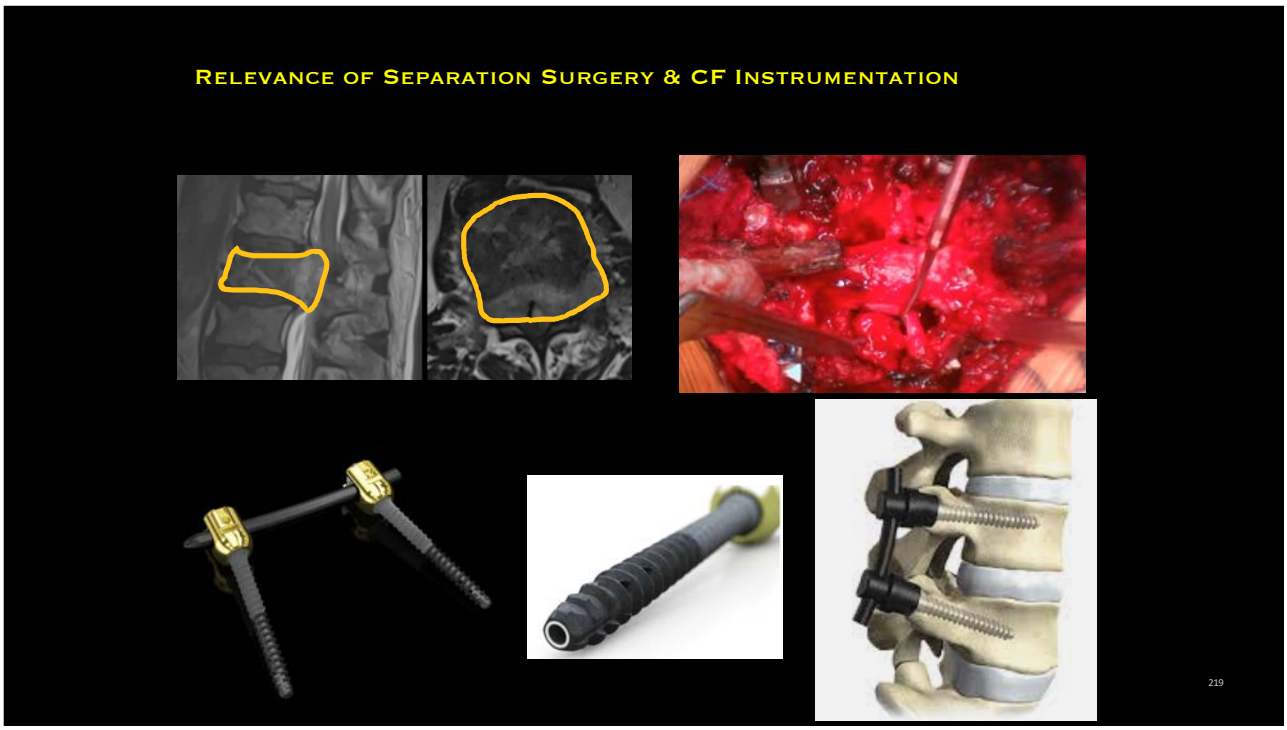
Relevance of Separation Surgery & CF Instrumentation
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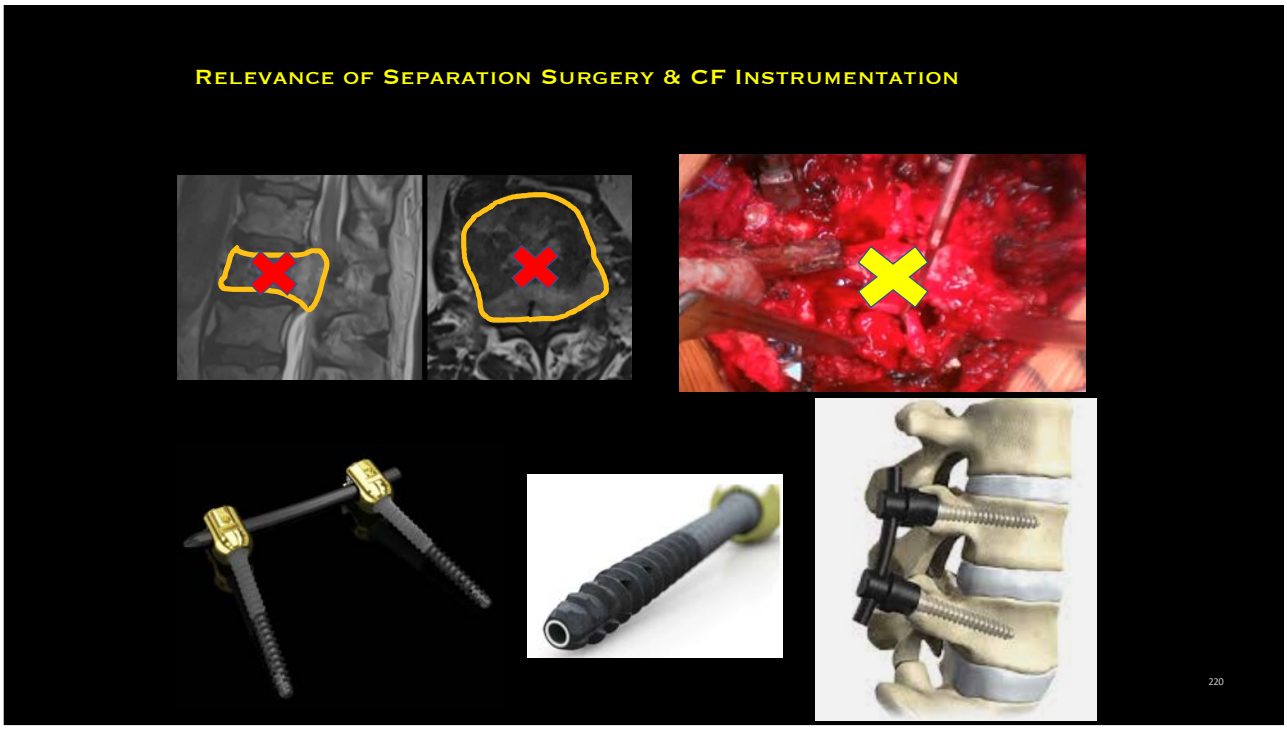
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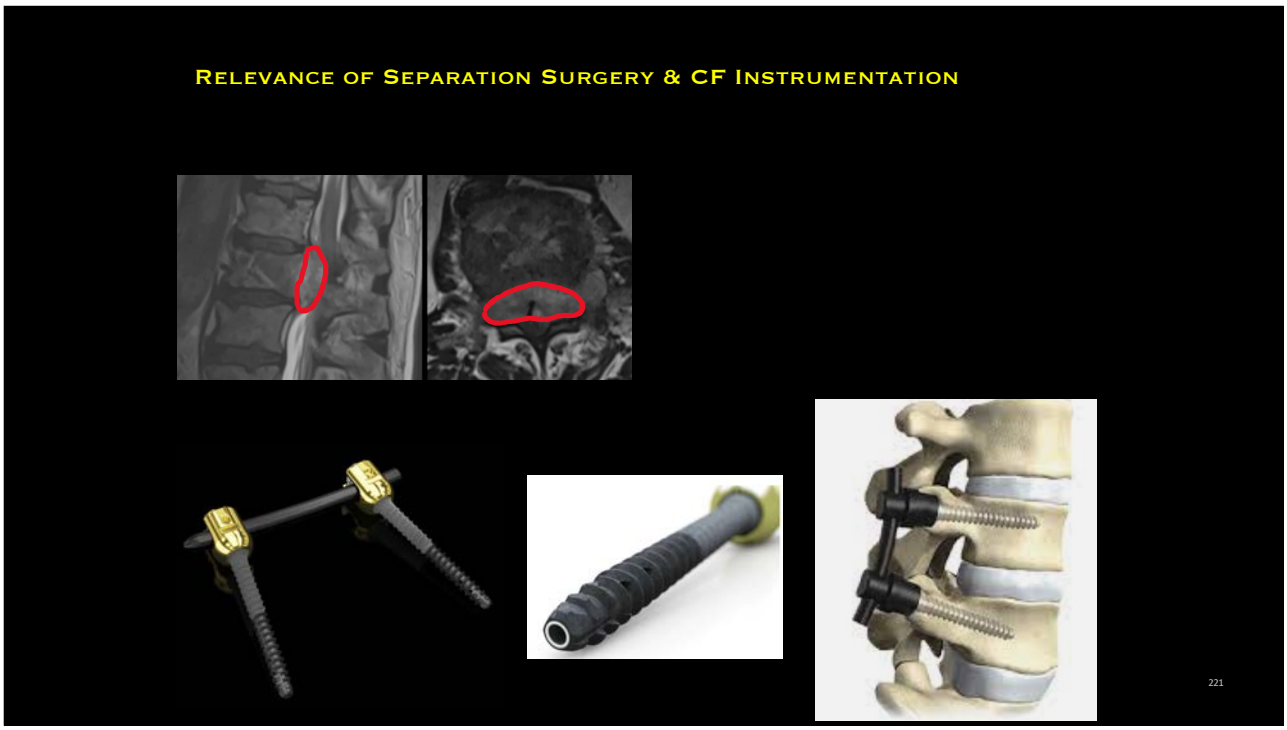
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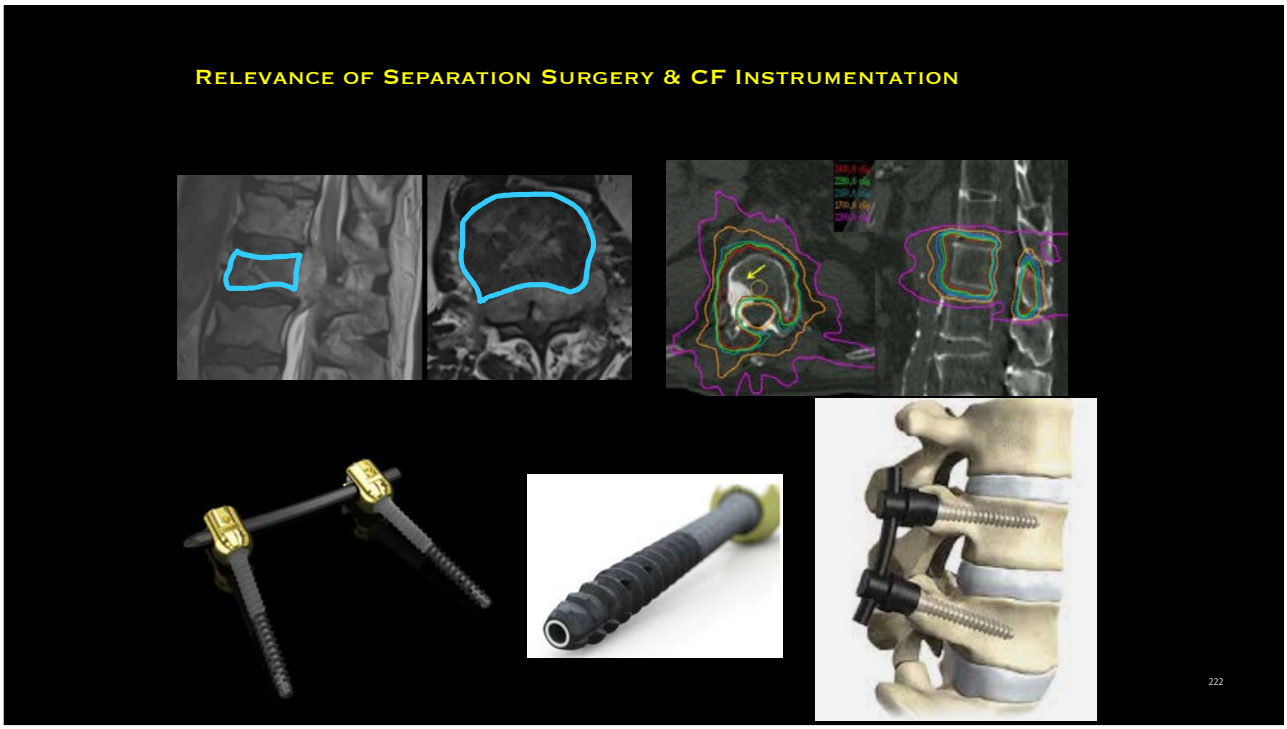
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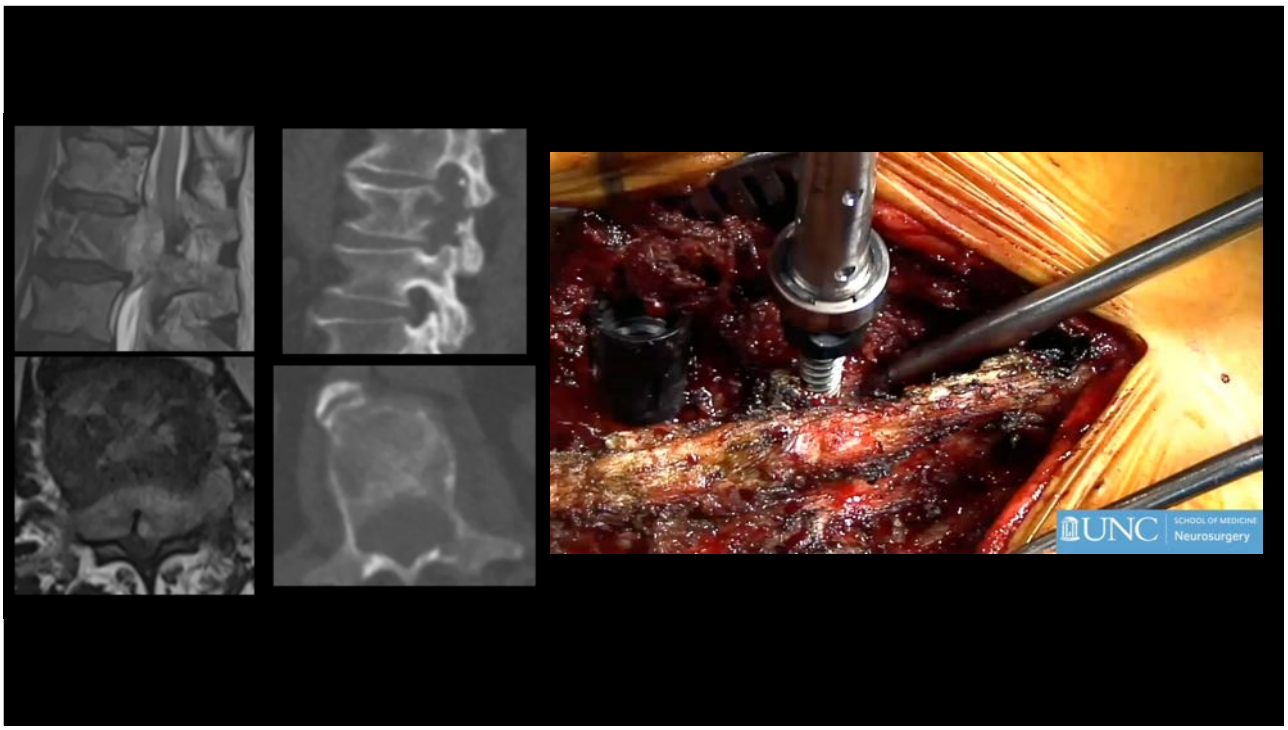

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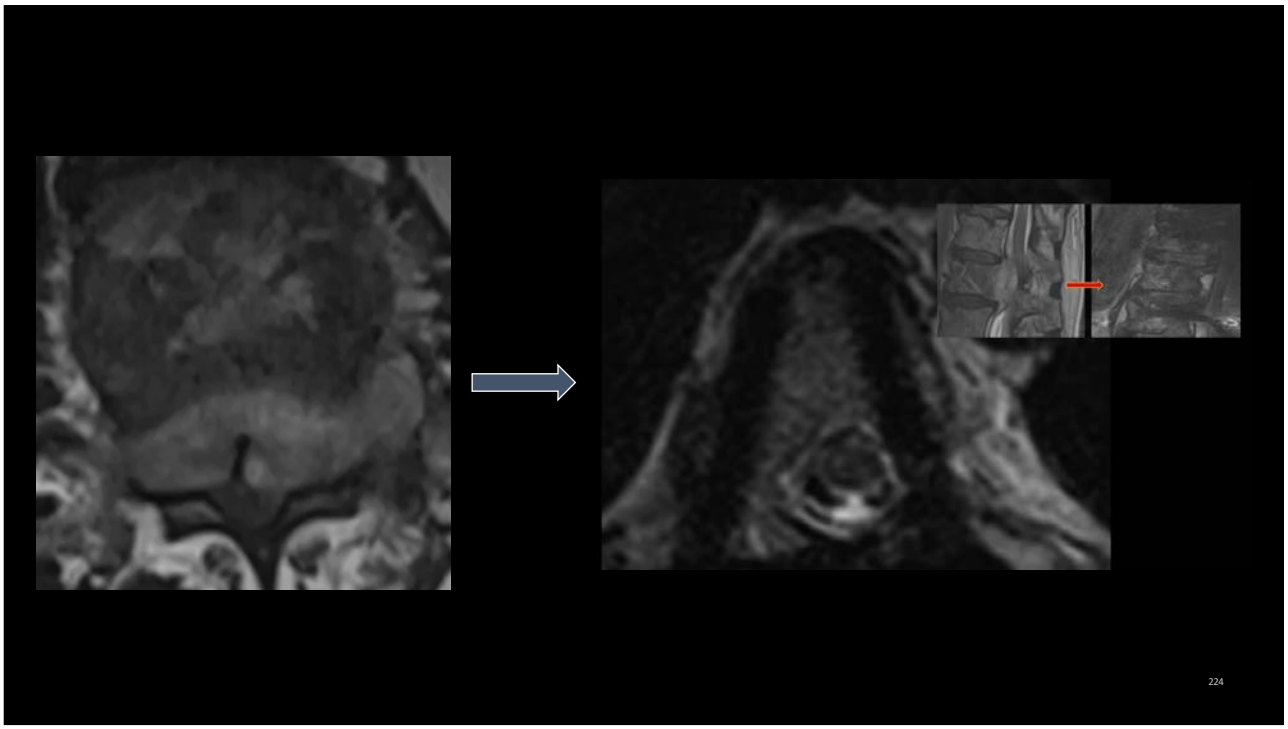

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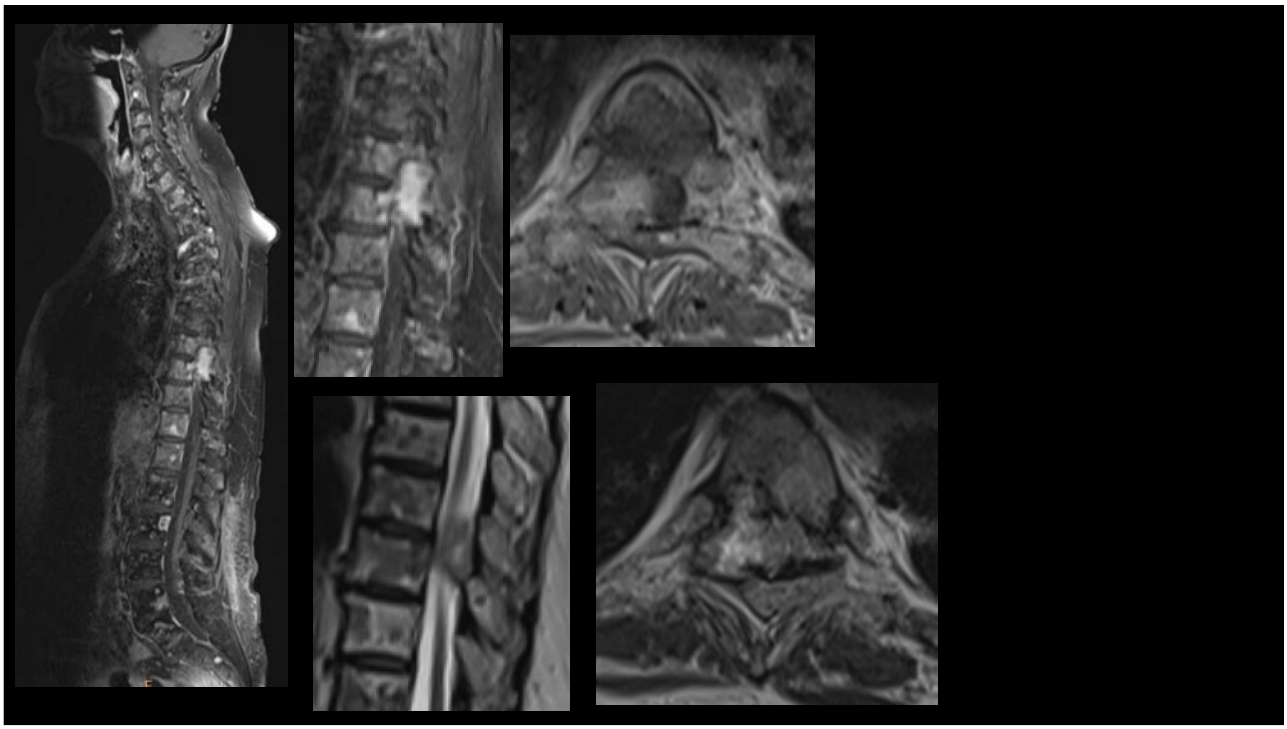

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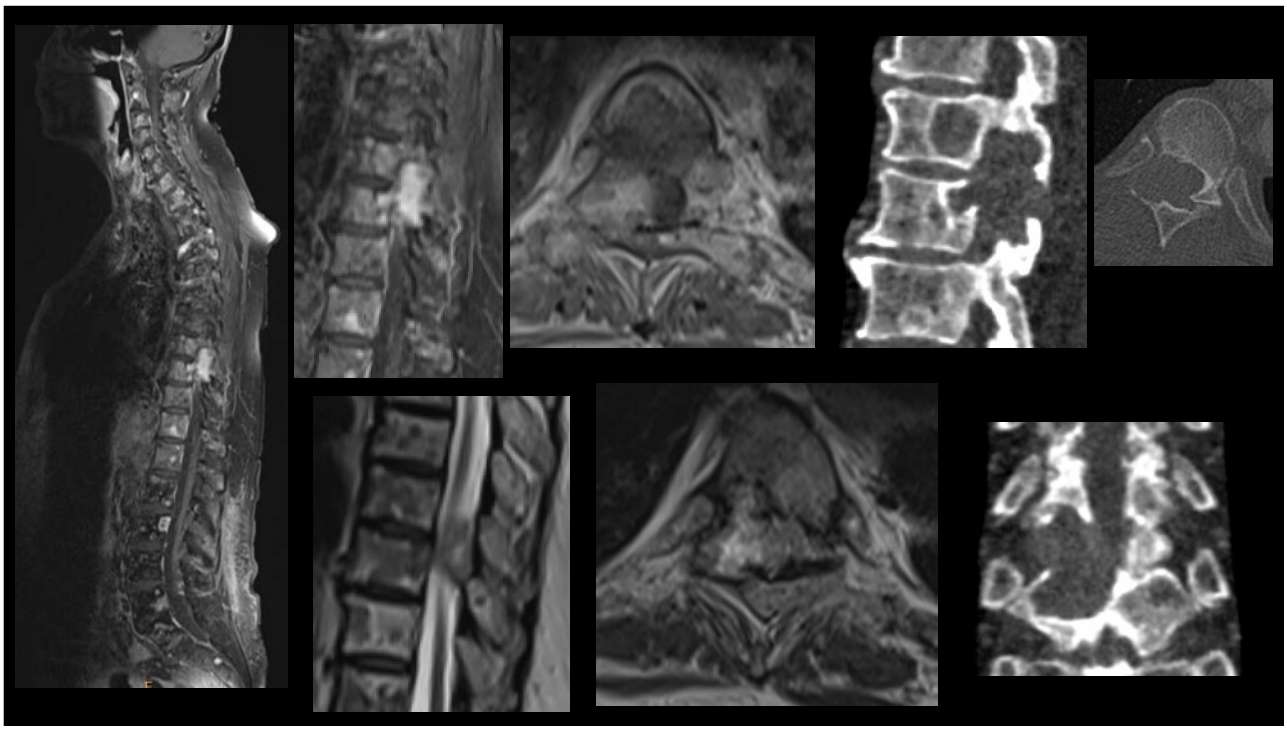

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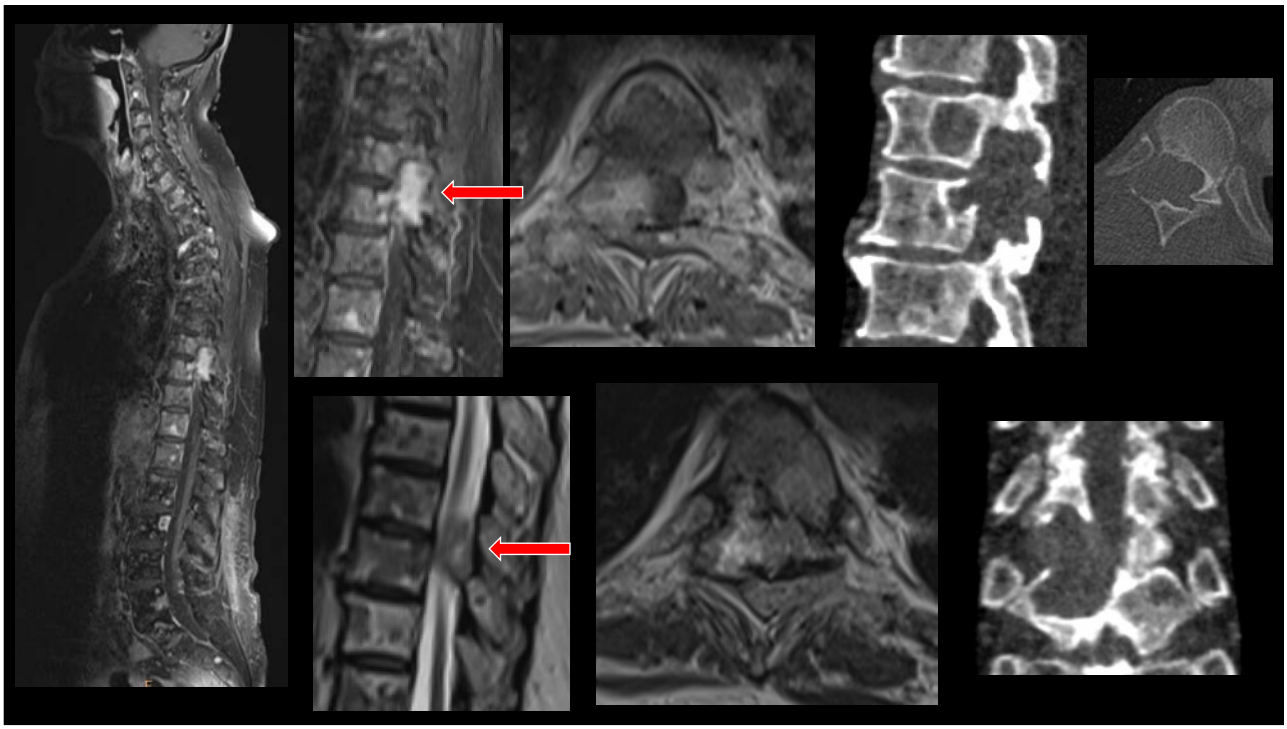

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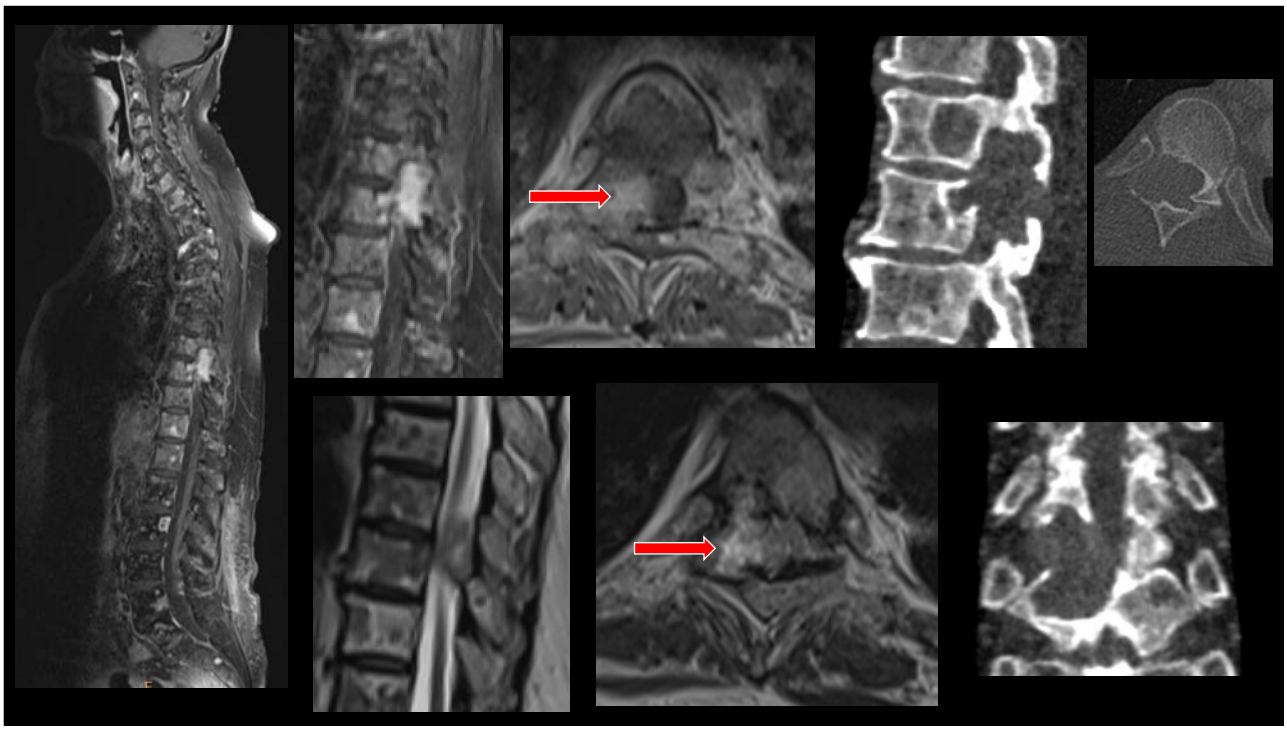

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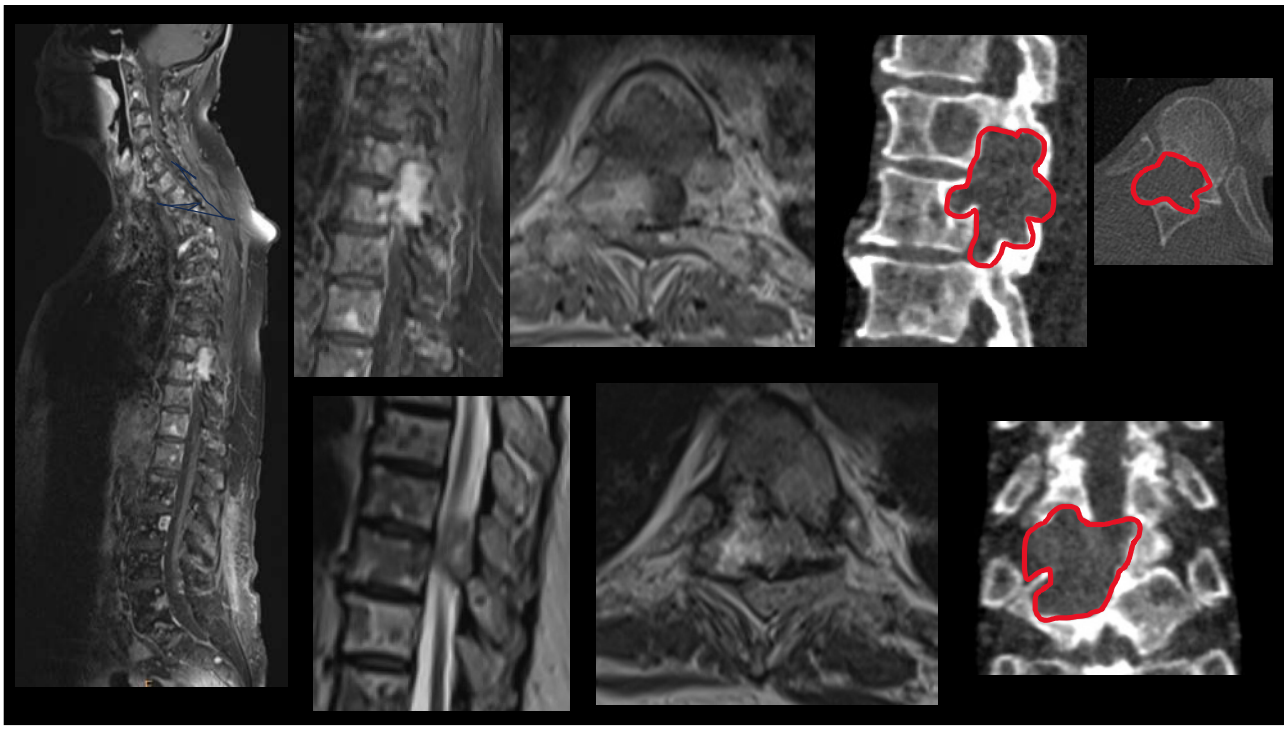

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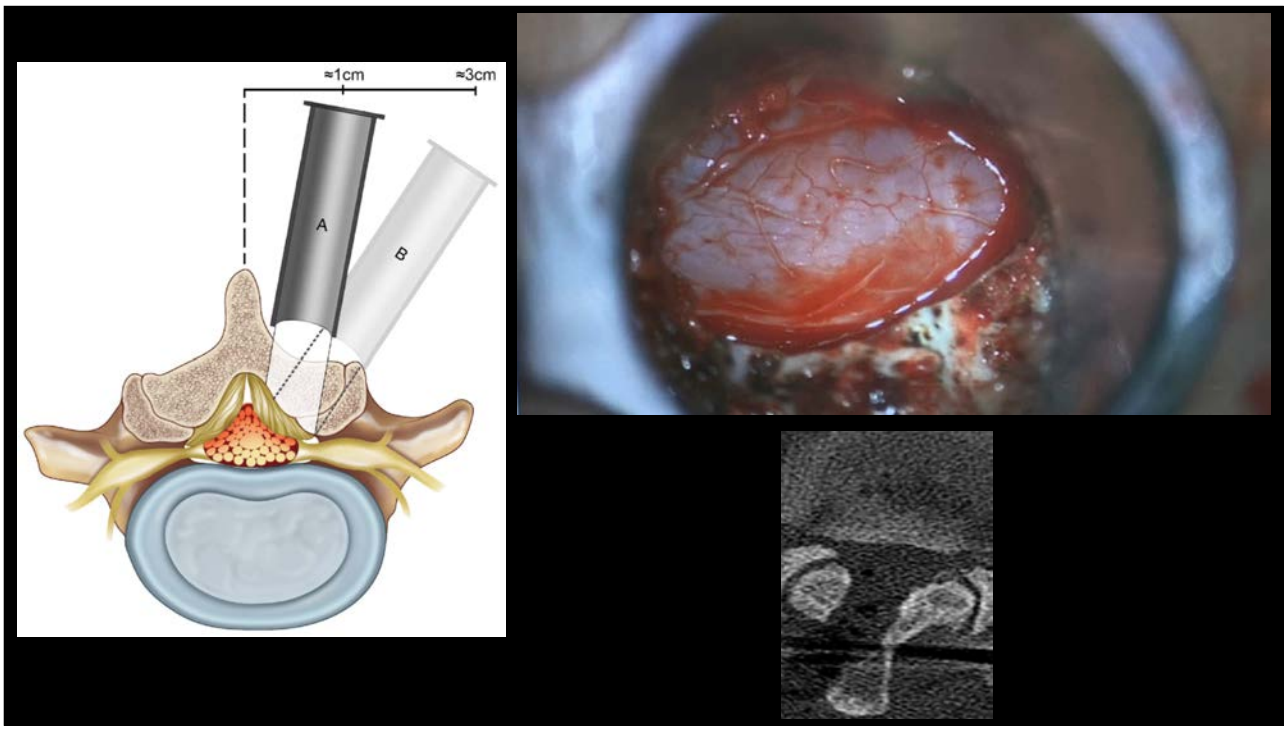

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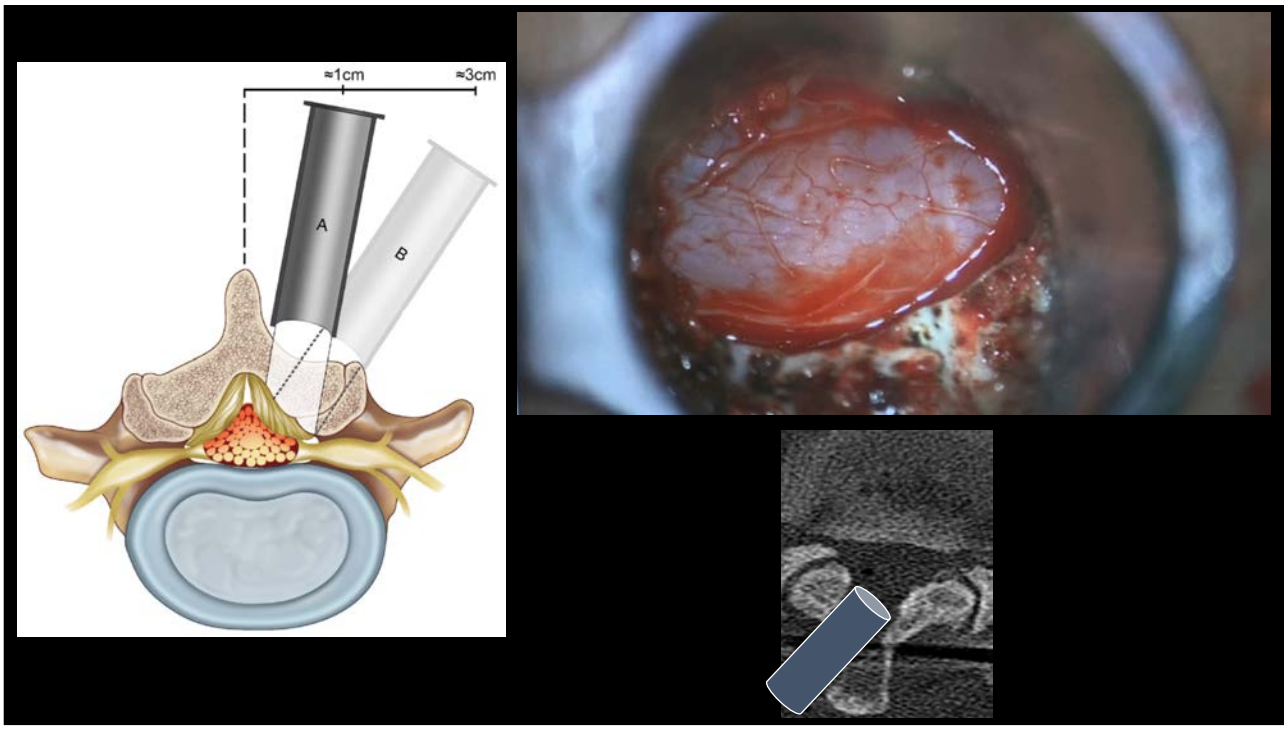

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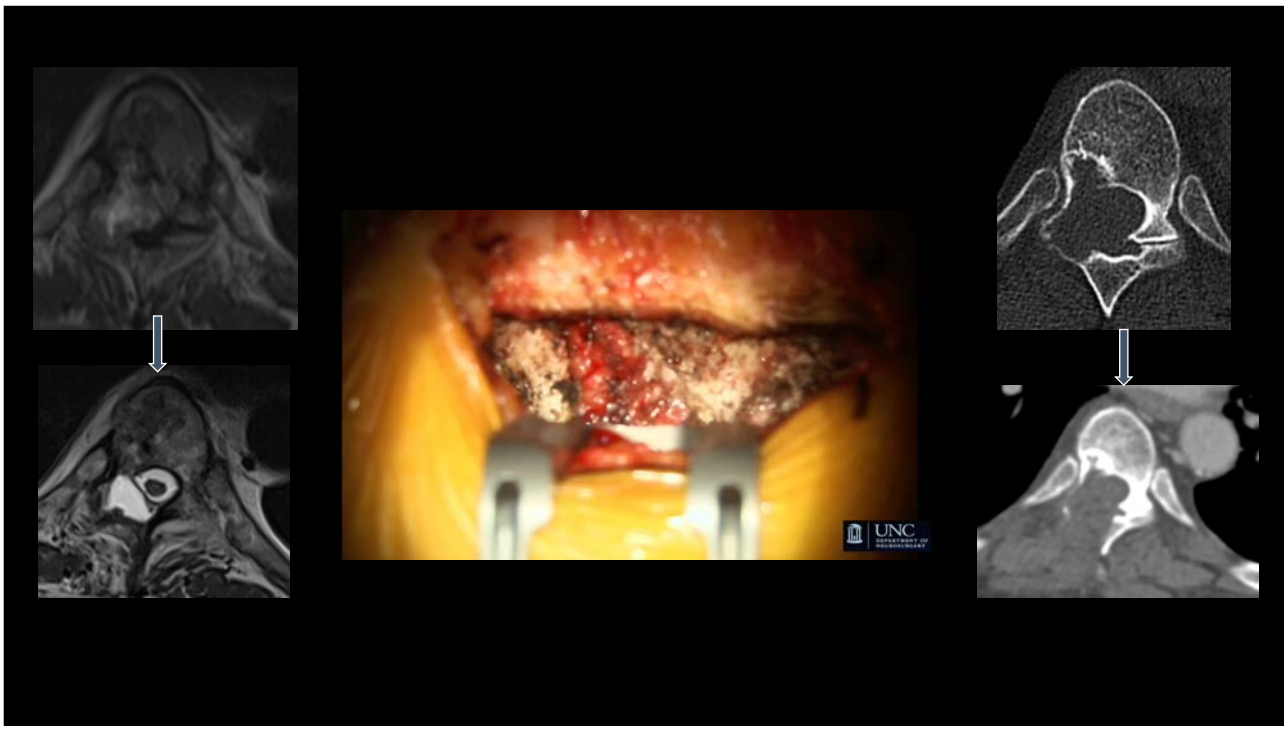
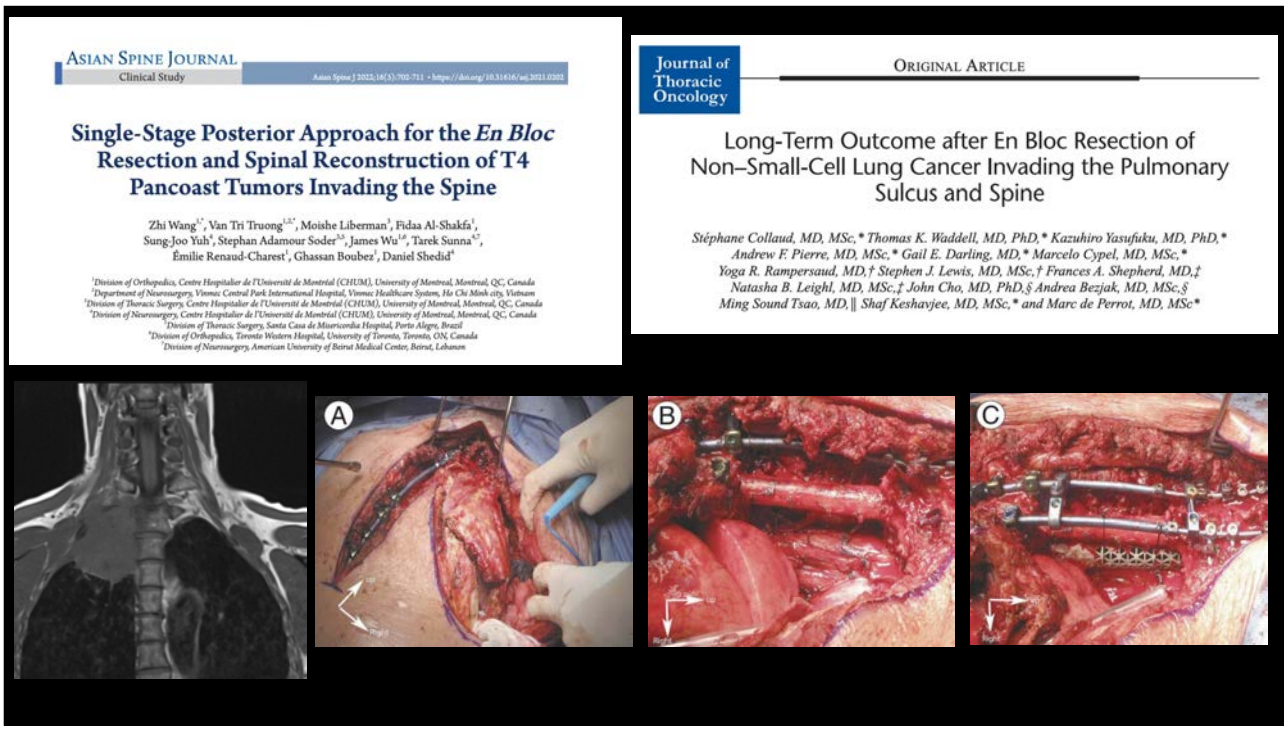


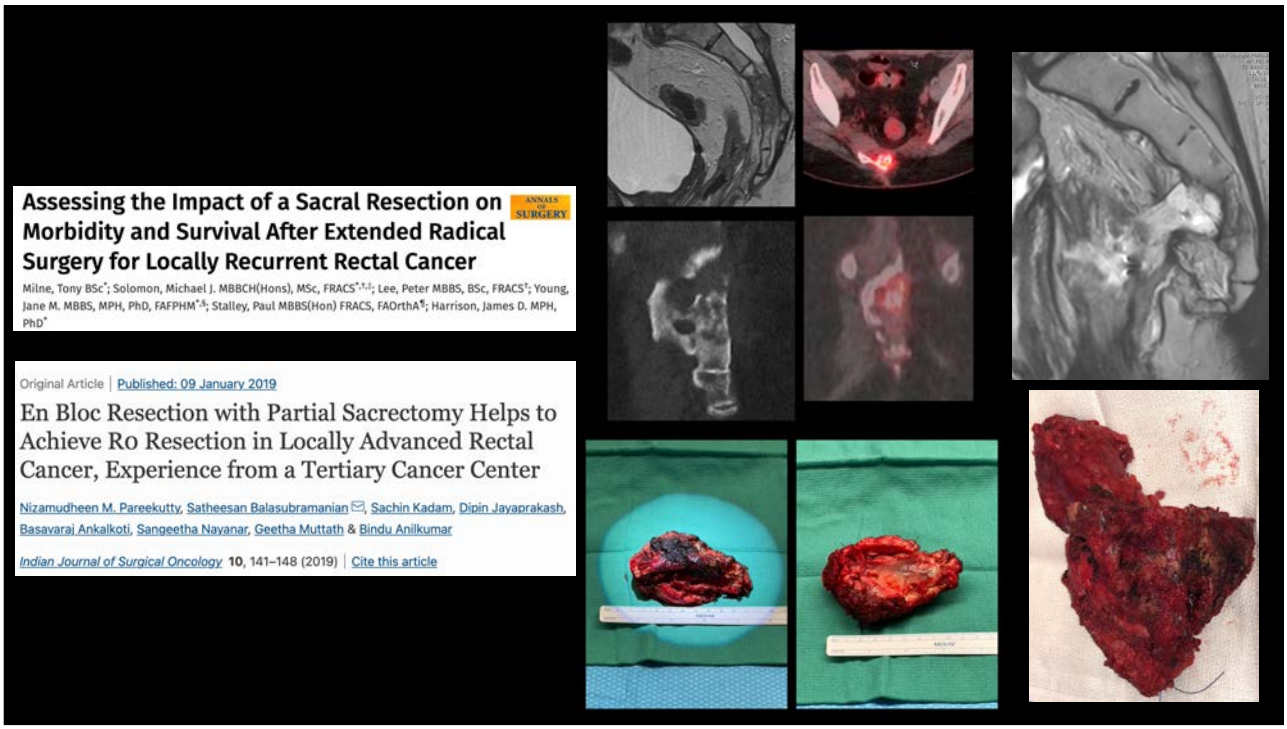
233

Can Surgery ever Influence the metastatic potential of cancer?

234


ASIAN SPINE JOURNAL
Clinical Study
Single-Stage Posterior Approach for the En Bloc Resection and Spinal Reconstruction of T4 Pancoast Tumors Invading the Spine
Journal of Thoracic Oncology
ORIGINAL ARTICLE
Long-Term Outcome after En Bloc Resection of Non–Small-Cell Lung Cancer Invading the Pulmonary Sulcus and Spine
A
B
C

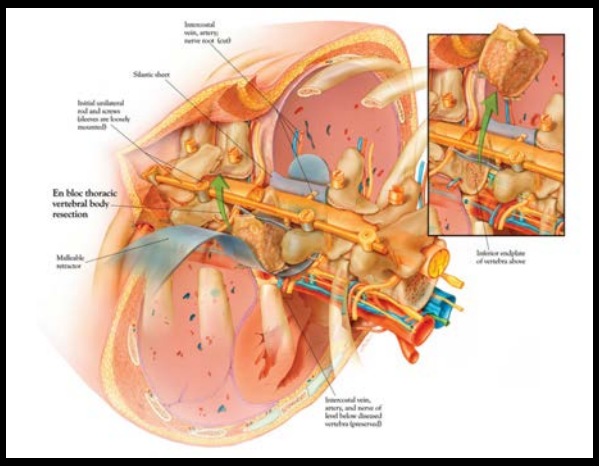
235


Assessing the Impact of a Sacral Resection on Morbidity and Survival After Extended Radical Surgery for Locally Recurrent Rectal Cancer
ANNALS OF SURGERY
Original Article | Published: 09 January 2019
En Bloc Resection with Partial Sacrectomy Helps to Achieve Ro Resection in Locally Advanced Rectal Cancer, Experience from a Tertiary Cancer Center
Indian Journal of Surgical Oncology 10, 141–148 (2019) | Cite this article

236

Primary Vertebral Column Tumors

- Osteochondroma
- Aneurysmal Bone Cyst (ABC)
- Hemangioma
- Osteoid osteoma
- Osteoblastoma
- Chondromyxoid fibroma
- *Giant Cell Tumor*
- Osteogenic sarcoma
- Ewing's sarcoma
- Plasmacytoma / Myeloma
- Chordoma
- Chrondrosarcoma



237

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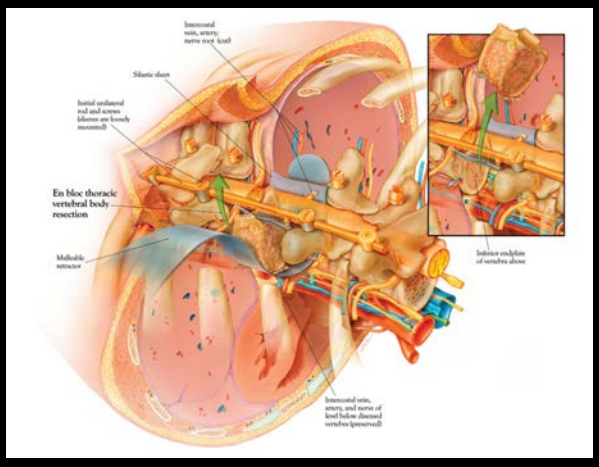

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Primary Vertebral Column Tumors

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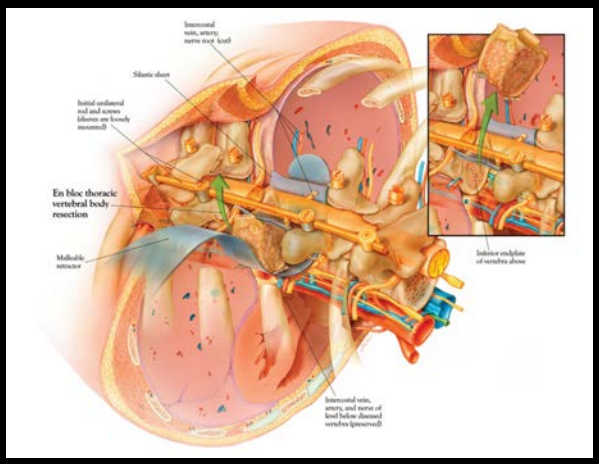
Locally-Aggressive



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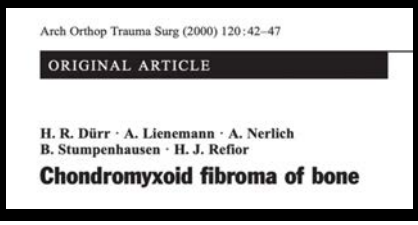
Chondromyxoid Fibroma


Arch Orthop Trauma Surg (2000) 120:42–47

ORIGINAL ARTICLE

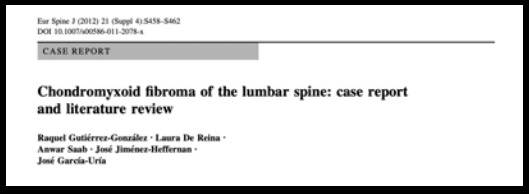
H. R. Dürr · A. Lienemann · A. Nerlich
B. Stumpenhausen · H. J. Refior

Chondromyxoid fibroma of bone


Chondromyxoid Fibroma: First Report of Occurrence of This Tumor in Vertebral Column

Walter R. Benson, M.D., Spencer Bass, Jr., M.D.

American Journal of Clinical Pathology, Volume 25, Issue 11, 1 November 1955, Pages 1290–1292, https://doi.org/10.1093/ajcp/25.11.1290


Eur Spine J (2012) 21 (Suppl 4):S458–S462

CASE REPORT

Chondromyxoid fibroma of the lumbar spine: case report and literature review

Raquel Gutiérrez-González · Laura De Reina · Anwar Saab · José Jiménez-Heffernan · José García-Uría

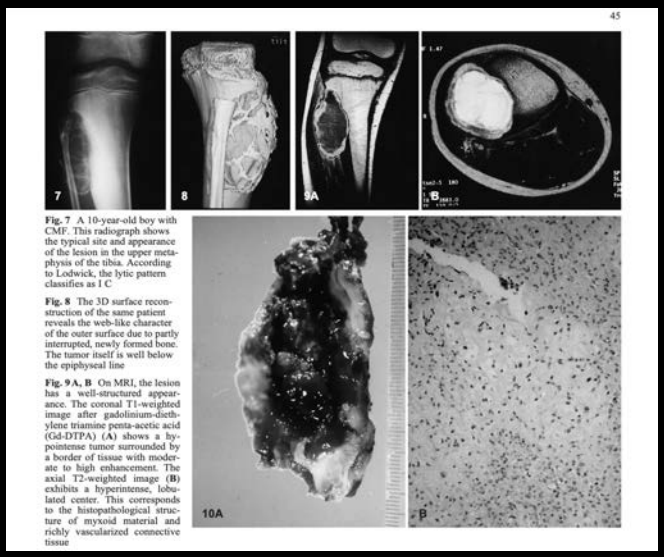
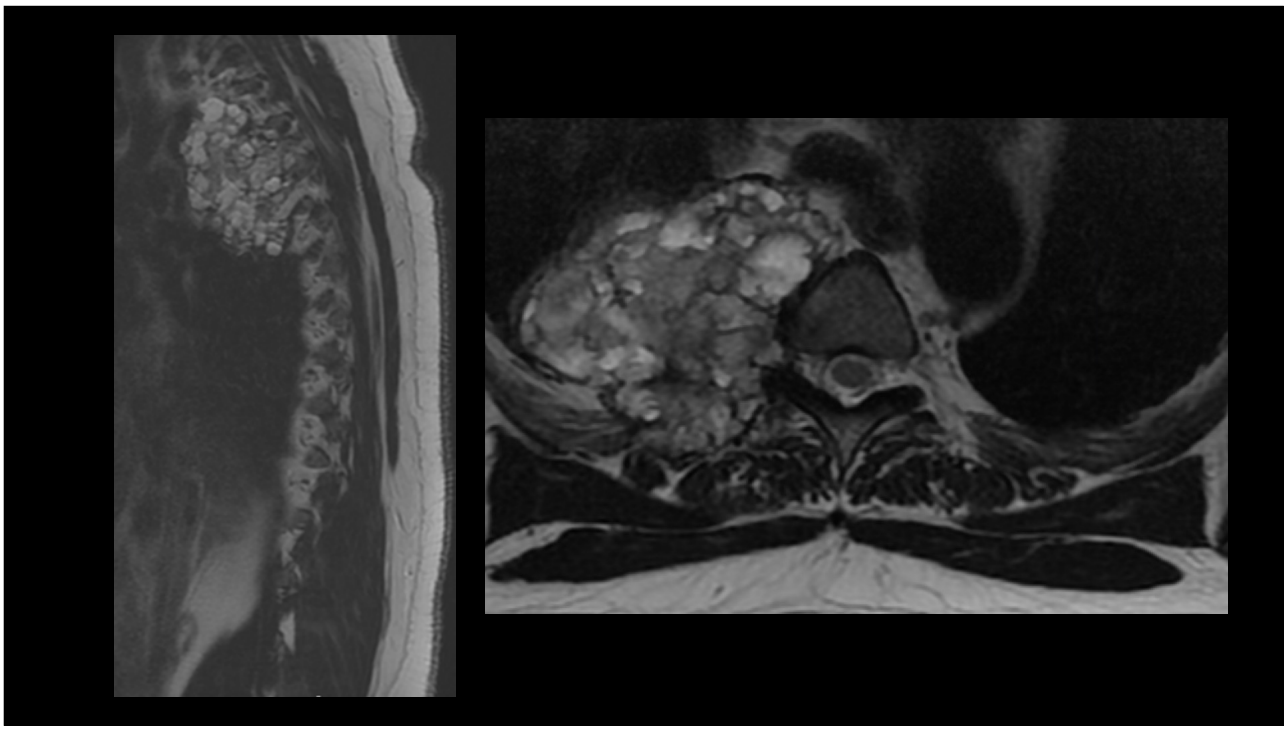

45

Fig. 7 A 10-year-old boy with CMF. This radiograph shows the typical site and appearance of the lesion in the upper metaphysis of the tibia. According to Lodwick, the lytic pattern classifies as 1 C

Fig. 8 The 3D surface reconstruction of the same patient reveals the web-like character of the outer surface due to partly interrupted, newly formed bone. The tumor itself is well below the epiphyseal line

Fig. 9 A, B On MRI, the lesion has a well-structured appearance. The coronal T1-weighted image after gadolinium-diethylene triamine penta-acetic acid (Gd-DTPA) (A) shows a hypointense tumor surrounded by a border of tissue with moderate to high enhancement. The axial T2-weighted image (B) exhibits a hyperintense, lobulated center. This corresponds to the histopathological structure of myxoid material and richly vascularized connective tissue

240



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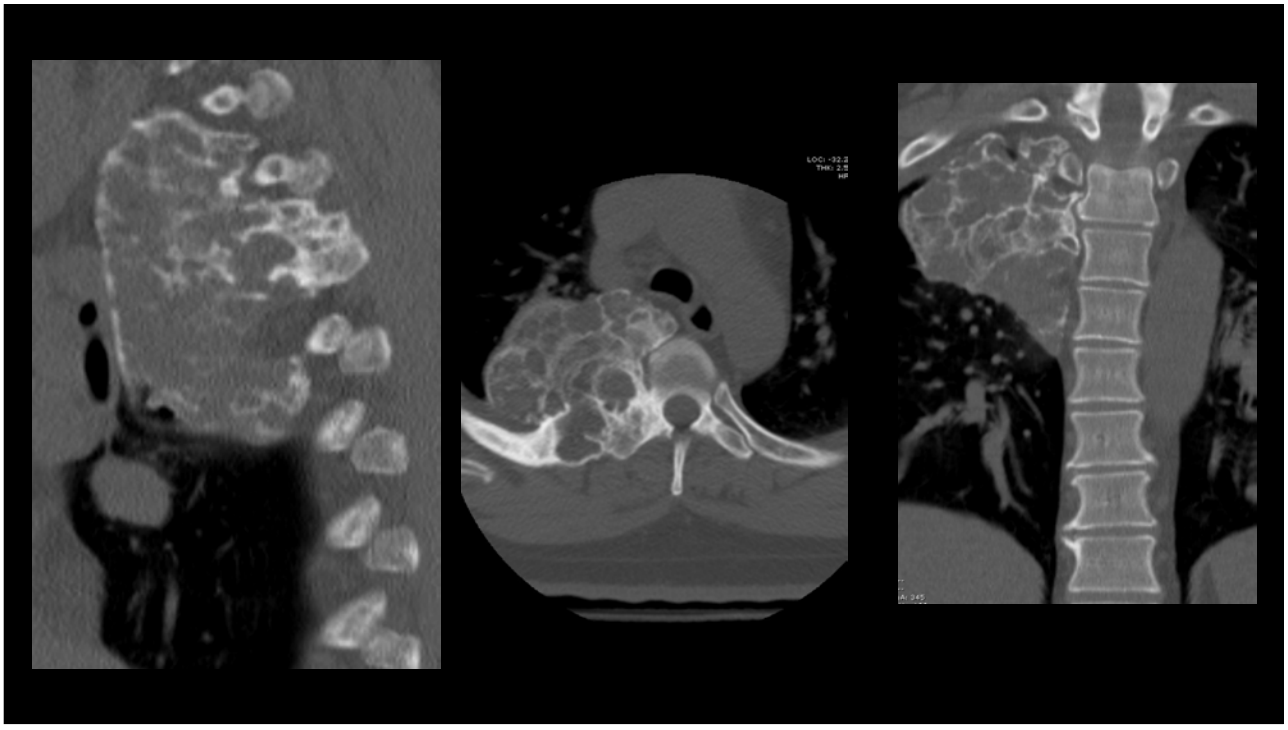

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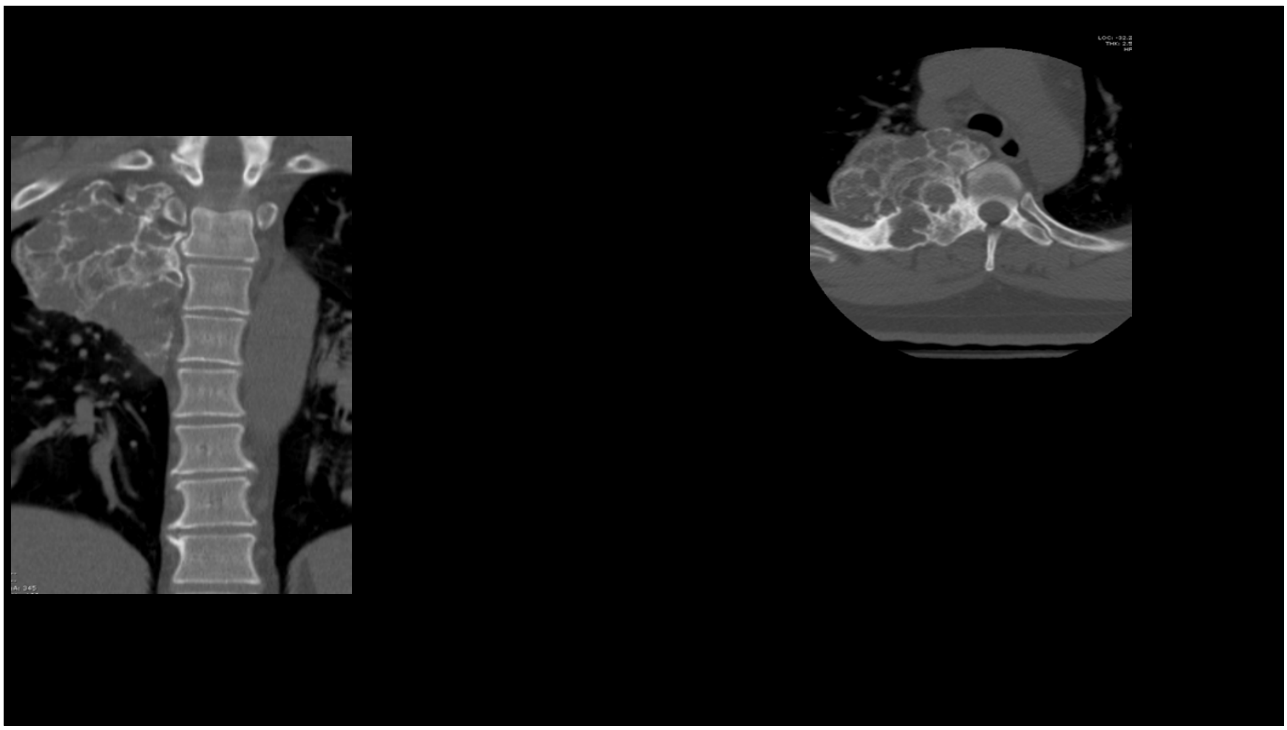

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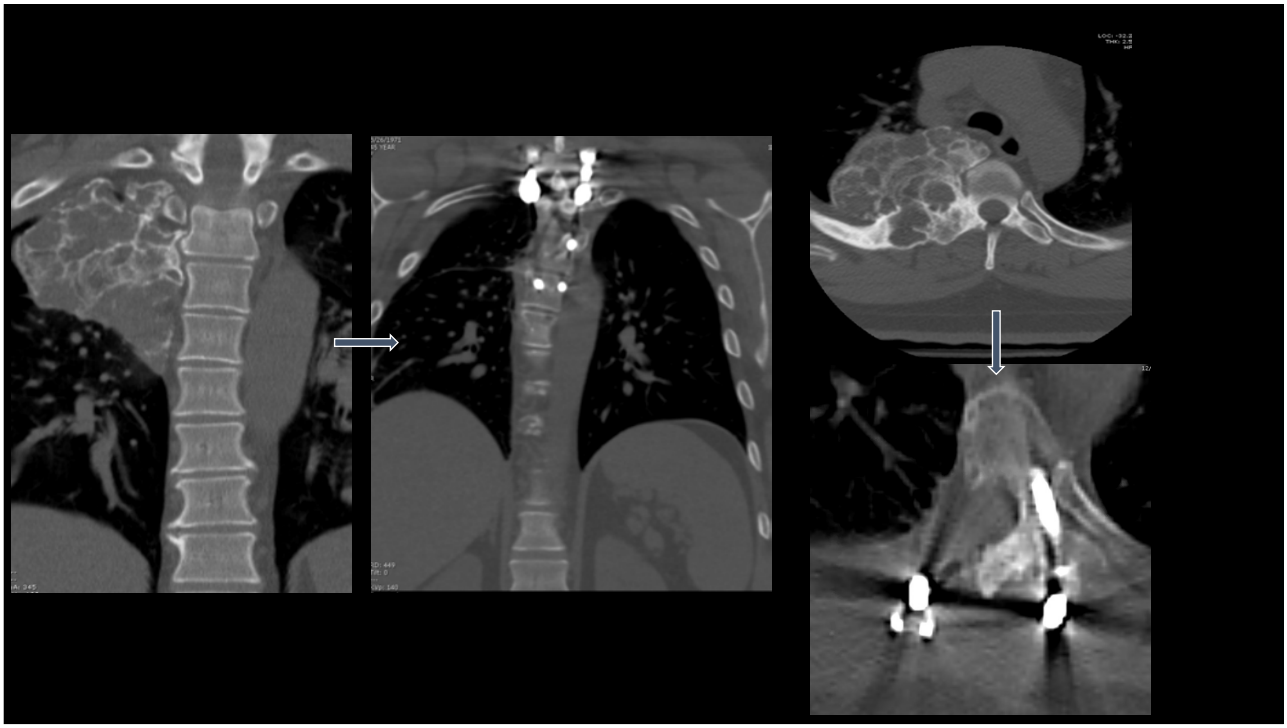

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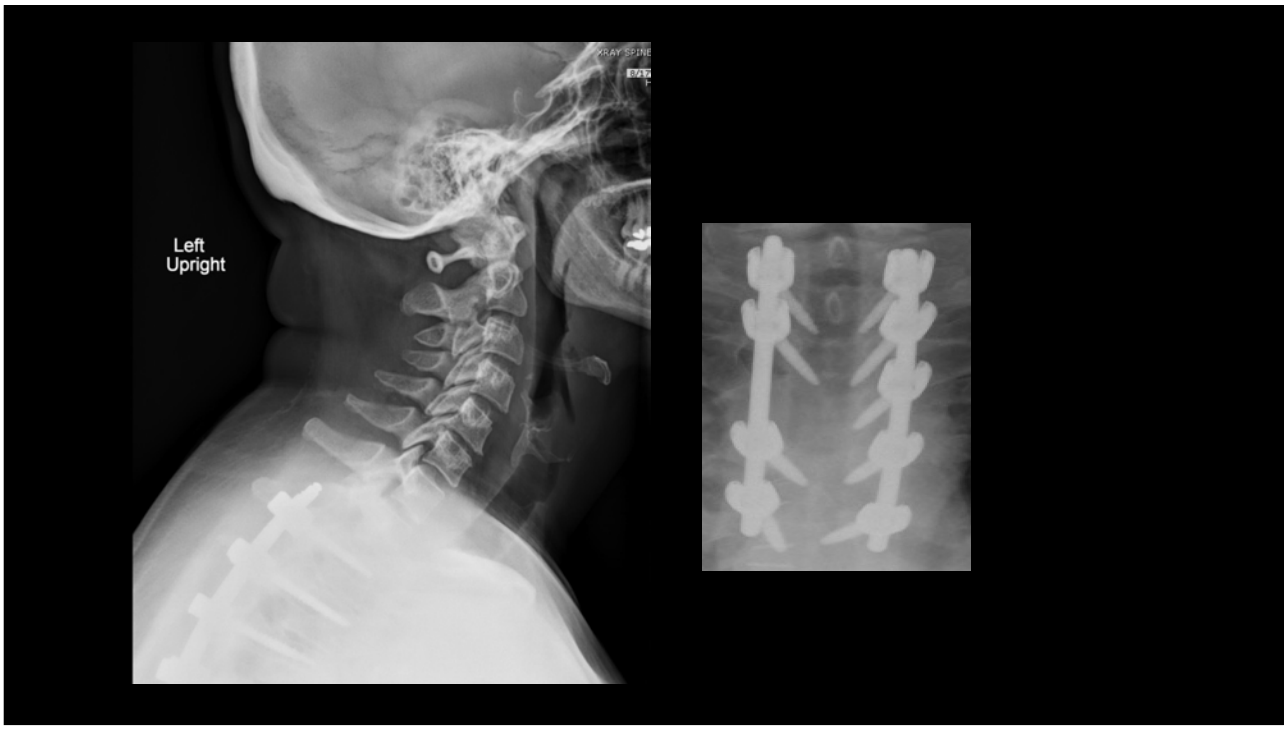
Left
Upright

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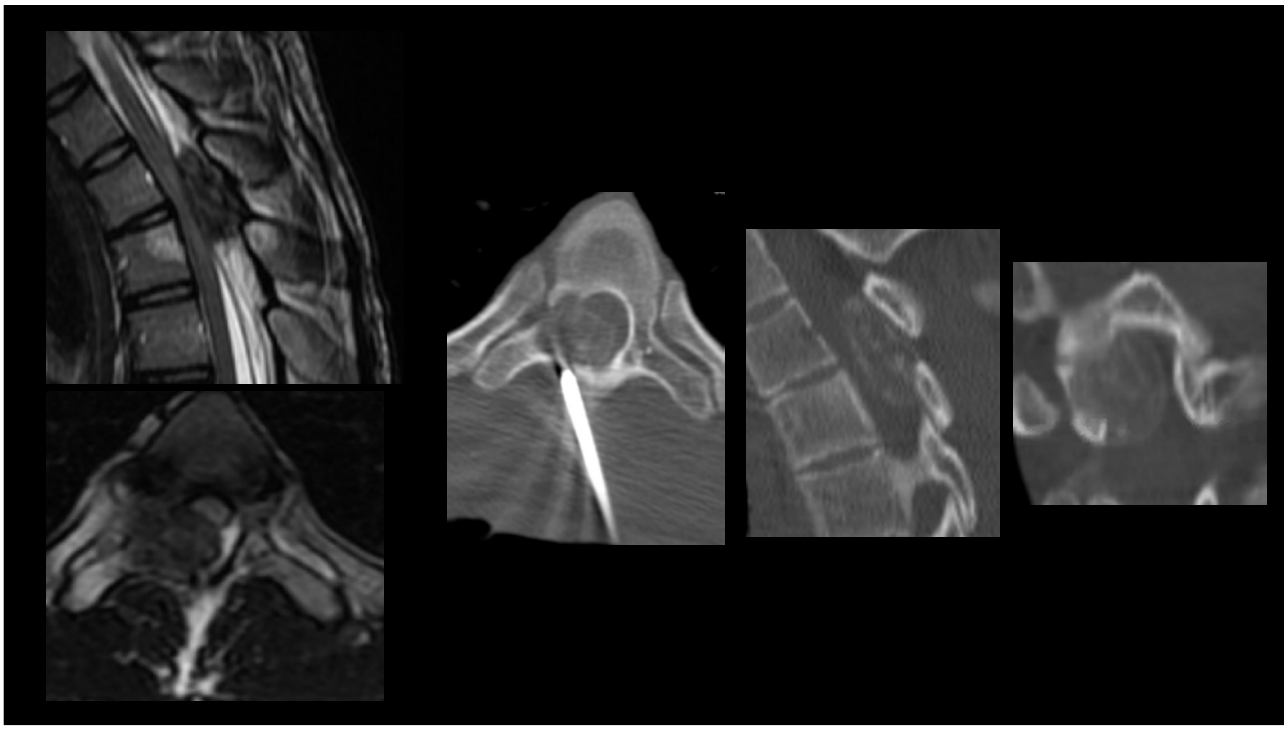

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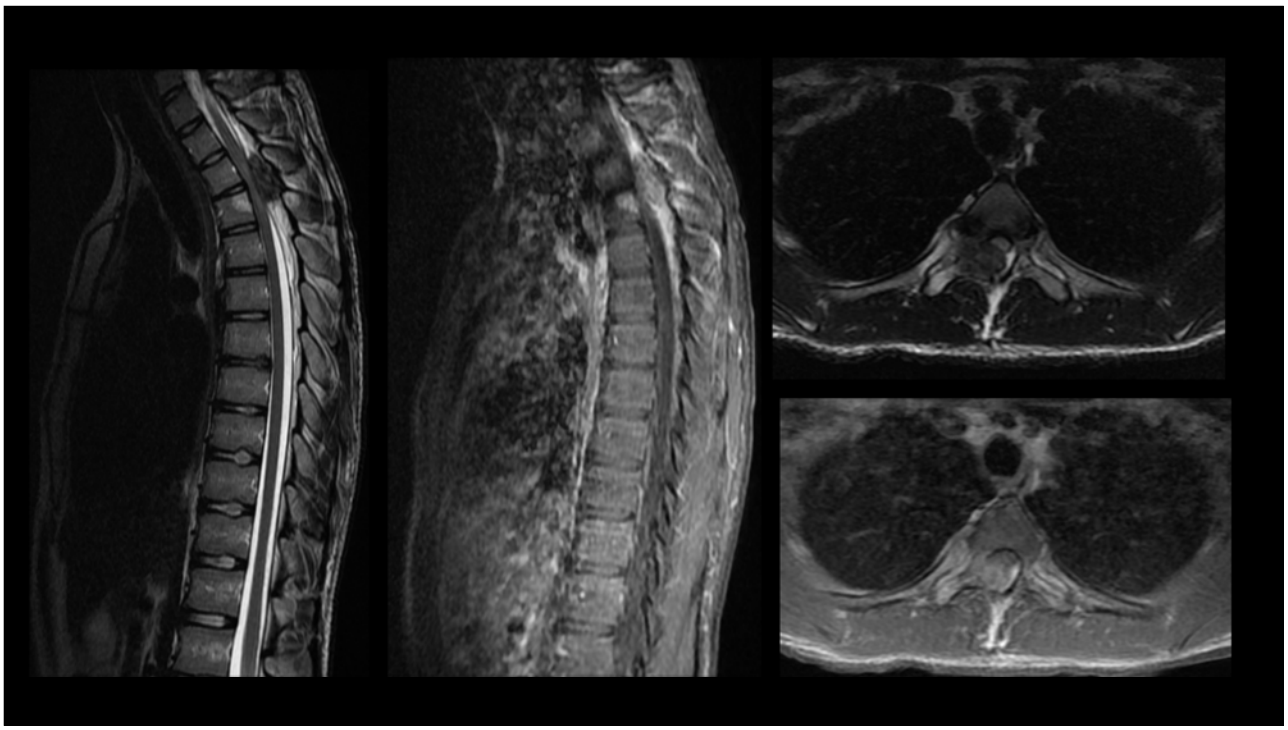

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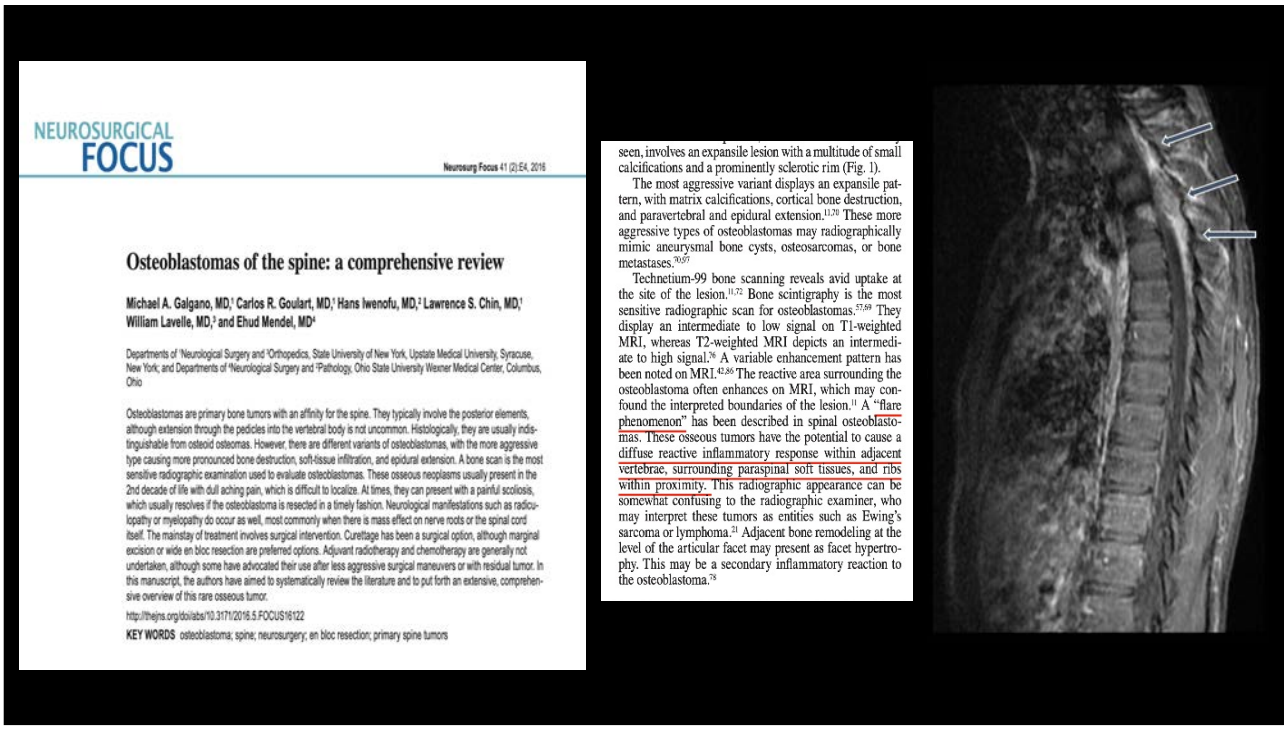


NEUROSURGICAL FOCUS

Neurosurg Focus 41 (2):E4, 2016

Osteoblastomas of the spine: a comprehensive review

Michael A. Galgano, MD,[1] Carlos R. Goulart, MD,[1] Hans Iwenofu, MD,[2] Lawrence S. Chin, MD,[1] William Lavelle, MD,[3] and Ehud Mendel, MD[4]

Departments of [1]Neurological Surgery and [3]Orthopedics, State University of New York, Upstate Medical University, Syracuse, New York; and Departments of [2]Neurological Surgery and [4]Pathology, Ohio State University Wexner Medical Center, Columbus, Ohio

Osteoblastomas are primary bone tumors with an affinity for the spine. They typically involve the posterior elements, although extension through the pedicles into the vertebral body is not uncommon. Histologically, they are usually indistinguishable from osteoid osteomas. However, there are different variants of osteoblastomas, with the more aggressive type causing more pronounced bone destruction, soft-tissue infiltration, and epidural extension. A bone scan is the most sensitive radiographic examination used to evaluate osteoblastomas. These osseous neoplasms usually present in the 2nd decade of life with dull aching pain, which is difficult to localize. At times, they can present with a painful scoliosis, which usually resolves if the osteoblastoma is resected in a timely fashion. Neurological manifestations such as radiculopathy or myelopathy do occur as well, most commonly when there is mass effect on nerve roots or the spinal cord itself. The mainstay of treatment involves surgical intervention. Curettage has been a surgical option, although marginal excision or wide en bloc resection are preferred options. Adjuvant radiotherapy and chemotherapy are generally not undertaken, although some have advocated their use after less aggressive surgical maneuvers or with residual tumor. In this manuscript, the authors have aimed to systematically review the literature and to put forth an extensive, comprehensive overview of this rare osseous tumor.

http://thejns.org/doi/abs/10.3171/2016.5.FOCUS16122

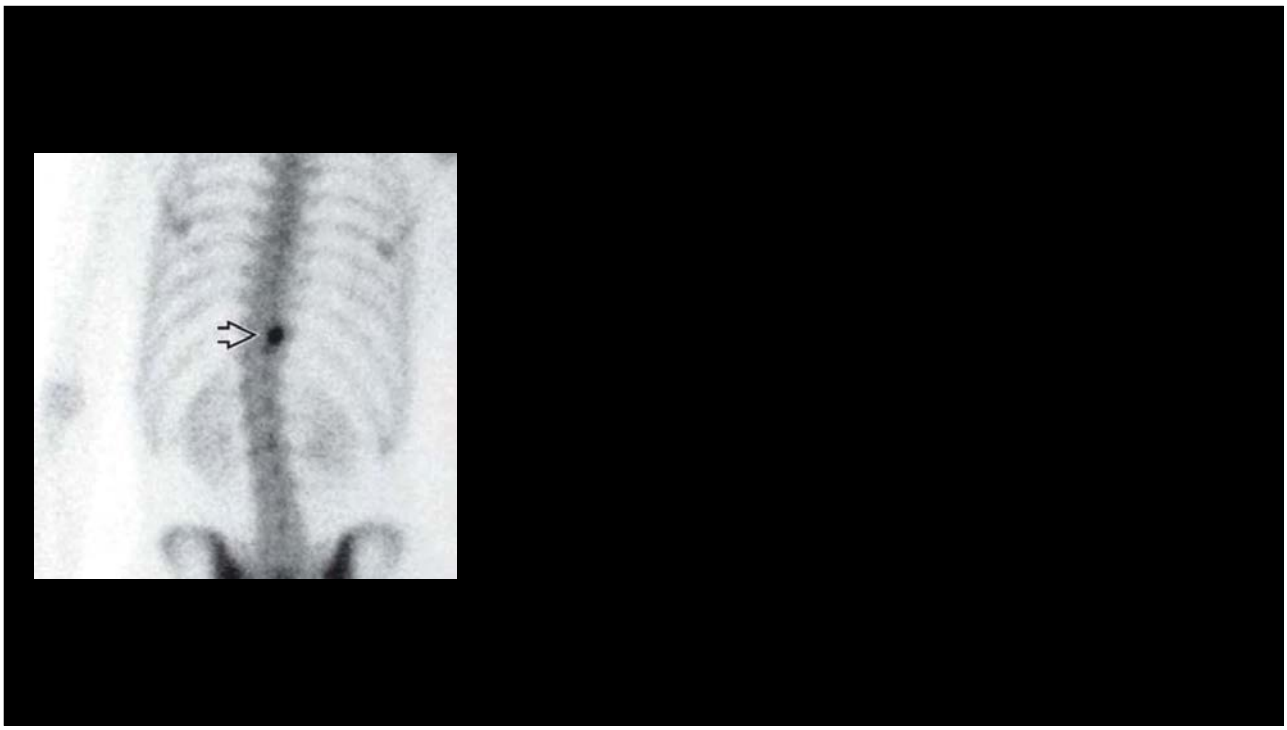
KEY WORDS osteoblastoma; spine; neurosurgery; en bloc resection; primary spine tumors

seen, involves an expansile lesion with a multitude of small calcifications and a prominently sclerotic rim (Fig. 1).

The most aggressive variant displays an expansile pattern, with matrix calcifications, cortical bone destruction, and paravertebral and epidural extension.[11,70] These more aggressive types of osteoblastomas may radiographically mimic aneurysmal bone cysts, osteosarcomas, or bone metastases.[70,97]

Technetium-99 bone scanning reveals avid uptake at the site of the lesion.[11,72] Bone scintigraphy is the most sensitive radiographic scan for osteoblastomas.[57,69] They display an intermediate to low signal on T1-weighted MRI, whereas T2-weighted MRI depicts an intermediate to high signal.[76] A variable enhancement pattern has been noted on MRI.[42,86] The reactive area surrounding the osteoblastoma often enhances on MRI, which may confound the interpreted boundaries of the lesion.[11] A "flare phenomenon" has been described in spinal osteoblastomas. These osseous tumors have the potential to cause a diffuse reactive inflammatory response within adjacent vertebrae, surrounding paraspinal soft tissues, and ribs within proximity. This radiographic appearance can be somewhat confusing to the radiographic examiner, who may interpret these tumors as entities such as Ewing's sarcoma or lymphoma.[21] Adjacent bone remodeling at the level of the articular facet may present as facet hypertrophy. This may be a secondary inflammatory reaction to the osteoblastoma.[78]

250



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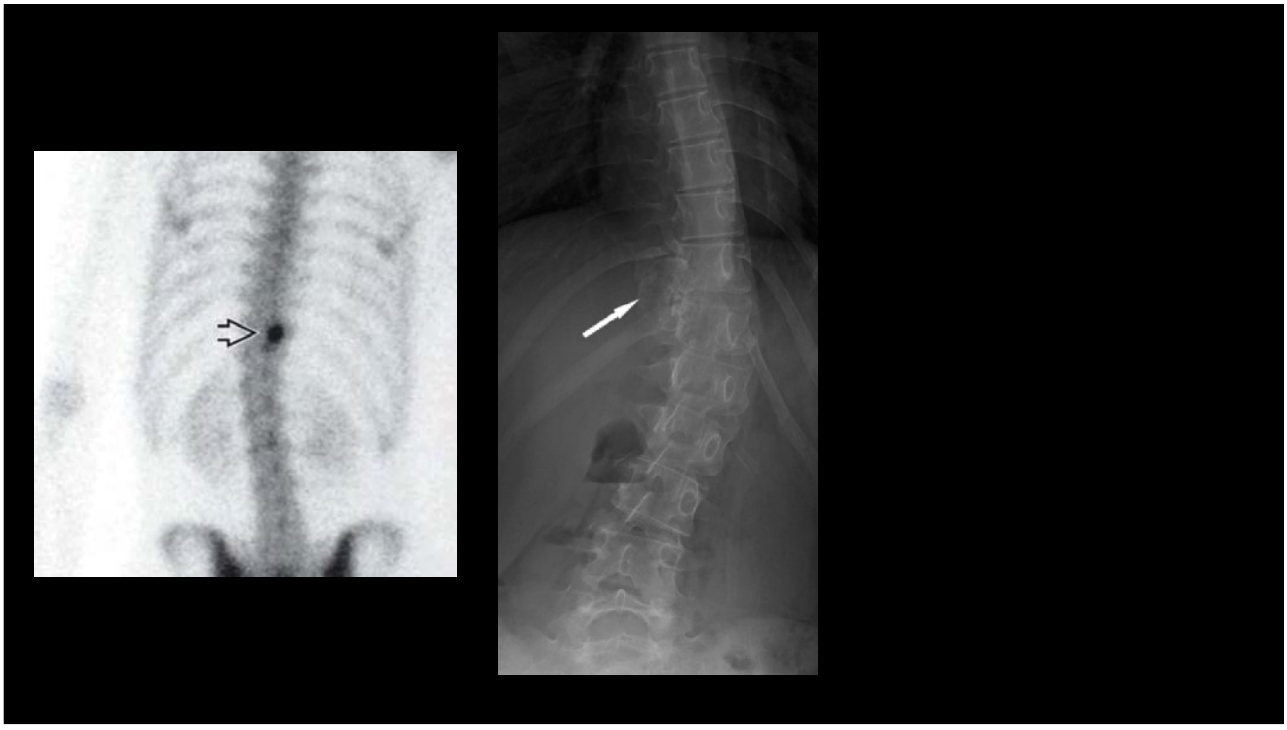

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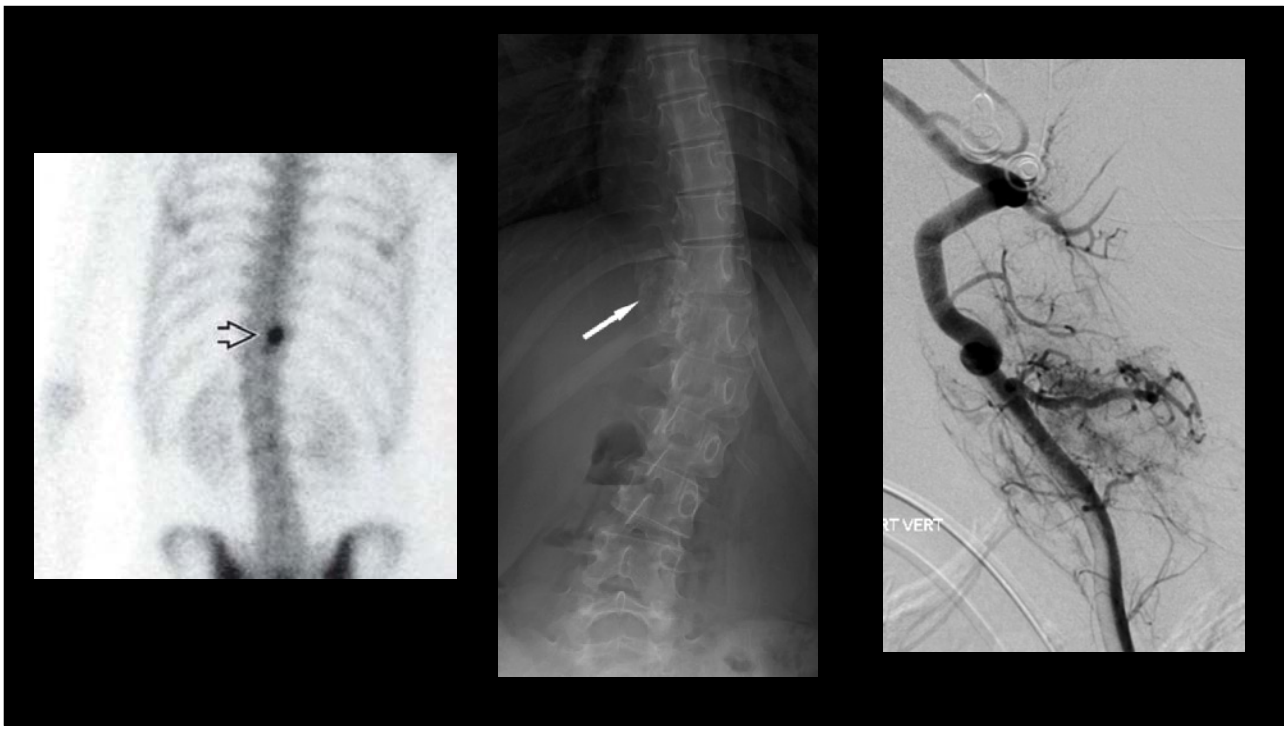
RT VERT

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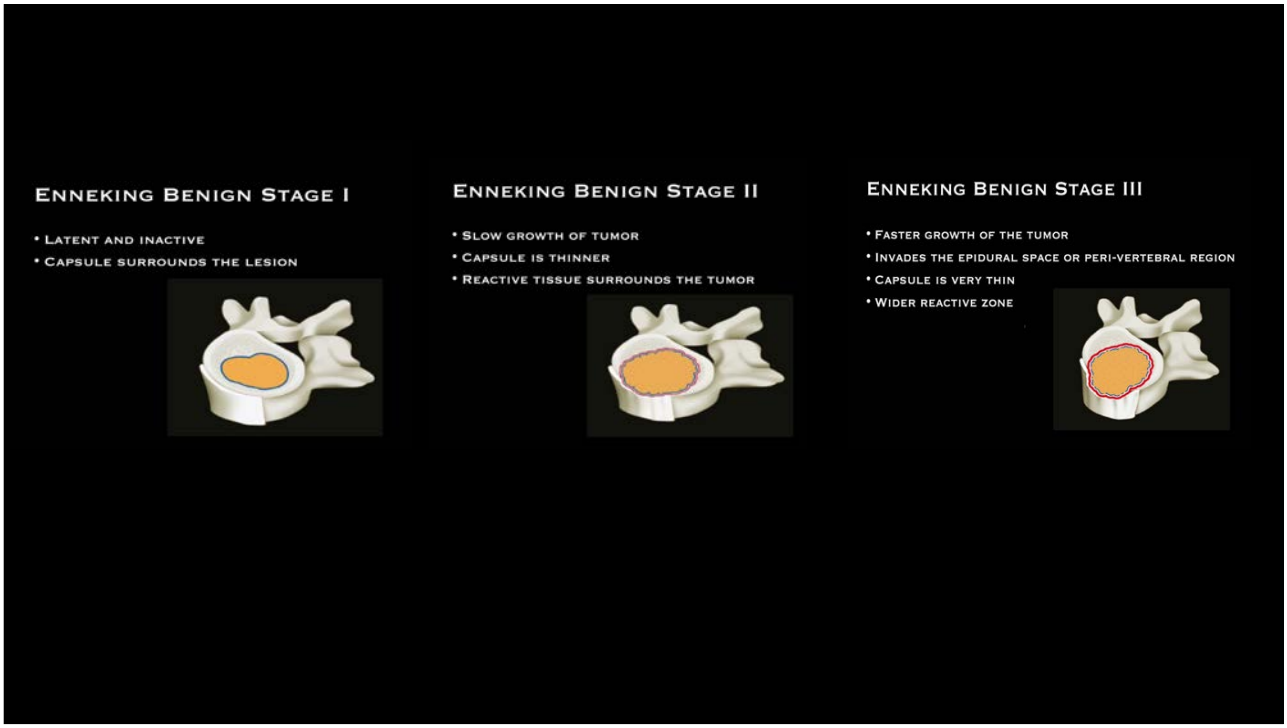
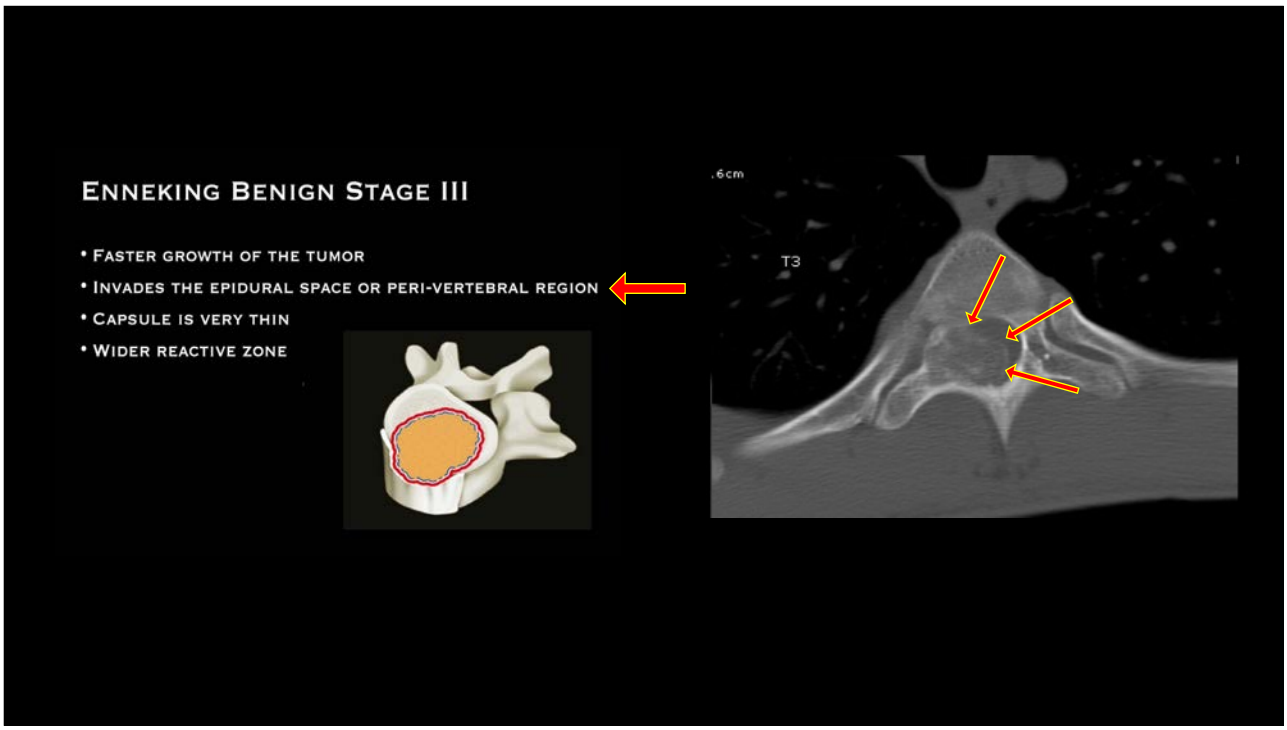
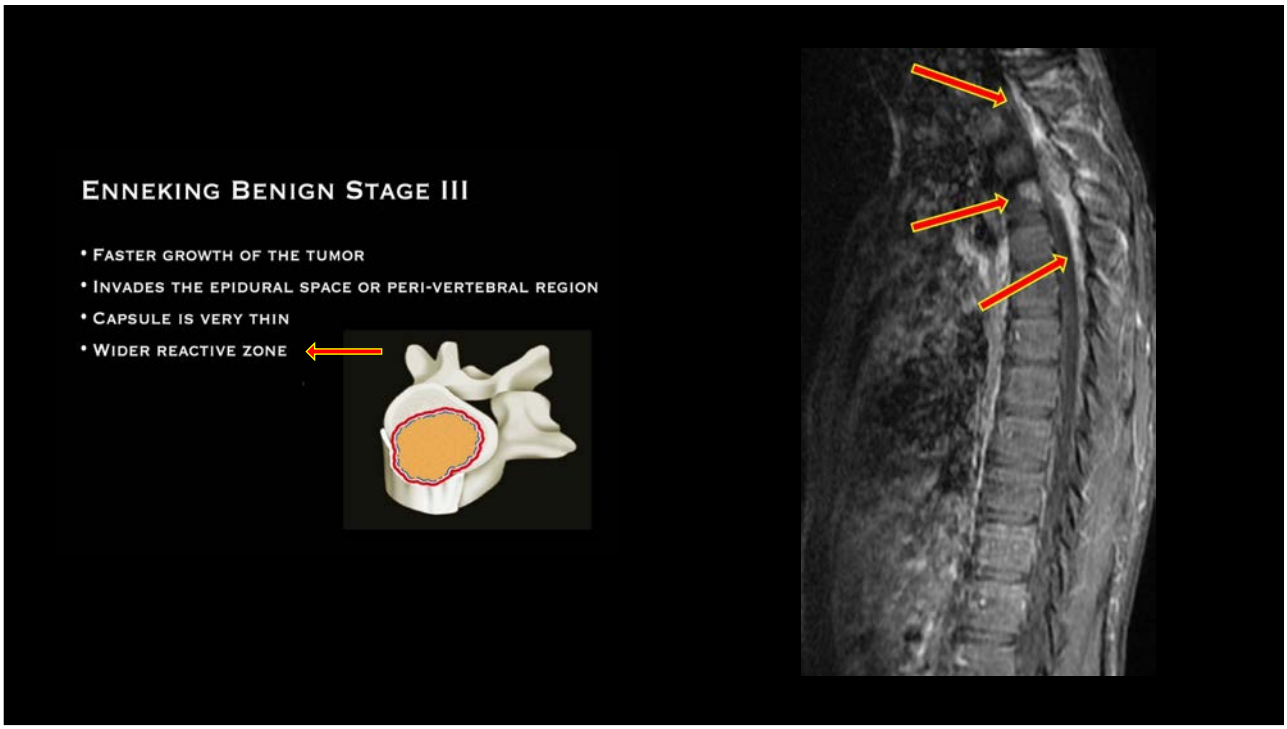

ENNEKING BENIGN STAGE I
• LATENT AND INACTIVE
• CAPSULE SURROUNDS THE LESION
ENNEKING BENIGN STAGE II
• SLOW GROWTH OF TUMOR
• CAPSULE IS THINNER
• REACTIVE TISSUE SURROUNDS THE TUMOR
ENNEKING BENIGN STAGE III
• FASTER GROWTH OF THE TUMOR
• INVADES THE EPIDURAL SPACE OR PERI-VERTEBRAL REGION
• CAPSULE IS VERY THIN
• WIDER REACTIVE ZONE

254


ENNEKING BENIGN STAGE III
• FASTER GROWTH OF THE TUMOR
• INVADES THE EPIDURAL SPACE OR PERI-VERTEBRAL REGION
• CAPSULE IS VERY THIN
• WIDER REACTIVE ZONE
.6cm
T3

255


ENNEKING BENIGN STAGE III
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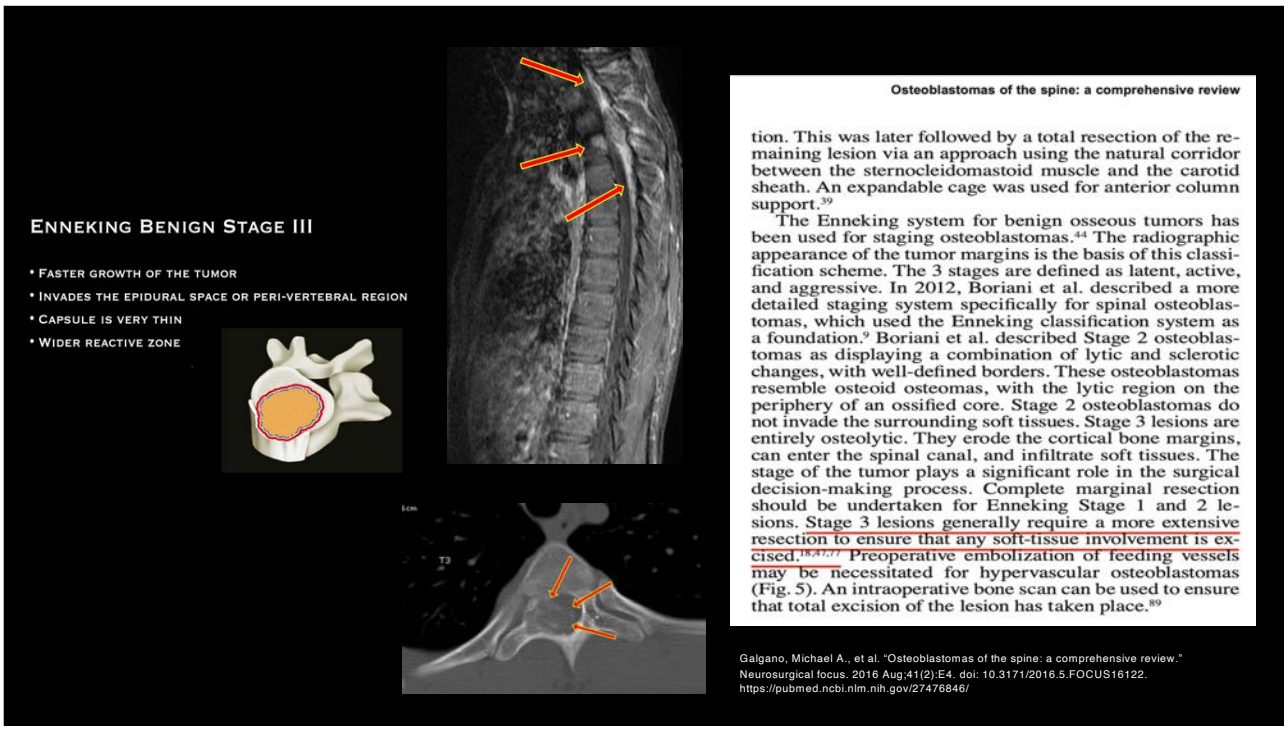
• INVADES THE EPIDURAL SPACE OR PERI-VERTEBRAL REGION
• CAPSULE IS VERY THIN
• WIDER REACTIVE ZONE

256


ENNEKING BENIGN STAGE III
• FASTER GROWTH OF THE TUMOR
• INVADES THE EPIDURAL SPACE OR PERI-VERTEBRAL REGION
• CAPSULE IS VERY THIN
• WIDER REACTIVE ZONE
T3
Osteoblastomas of the spine: a comprehensive review
tion. This was later followed by a total resection of the remaining lesion via an approach using the natural corridor between the sternocleidomastoid muscle and the carotid sheath. An expandable cage was used for anterior column support.[39]
The Enneking system for benign osseous tumors has been used for staging osteoblastomas.[44] The radiographic appearance of the tumor margins is the basis of this classification scheme. The 3 stages are defined as latent, active, and aggressive. In 2012, Boriani et al. described a more detailed staging system specifically for spinal osteoblastomas, which used the Enneking classification system as a foundation.[9] Boriani et al. described Stage 2 osteoblastomas as displaying a combination of lytic and sclerotic changes, with well-defined borders. These osteoblastomas resemble osteoid osteomas, with the lytic region on the periphery of an ossified core. Stage 2 osteoblastomas do not invade the surrounding soft tissues. Stage 3 lesions are entirely osteolytic. They erode the cortical bone margins, can enter the spinal canal, and infiltrate soft tissues. The stage of the tumor plays a significant role in the surgical decision-making process. Complete marginal resection should be undertaken for Enneking Stage 1 and 2 lesions. Stage 3 lesions generally require a more extensive resection to ensure that any soft-tissue involvement is excised.[18,47,77] Preoperative embolization of feeding vessels may be necessitated for hypervascular osteoblastomas (Fig. 5). An intraoperative bone scan can be used to ensure that total excision of the lesion has taken place.[89]
Galgano, Michael A., et al. "Osteoblastomas of the spine: a comprehensive review."
Neurosurgical focus. 2016 Aug;41(2):E4. doi: 10.3171/2016.5.FOCUS16122.
https://pubmed.ncbi.nlm.nih.gov/27476846/

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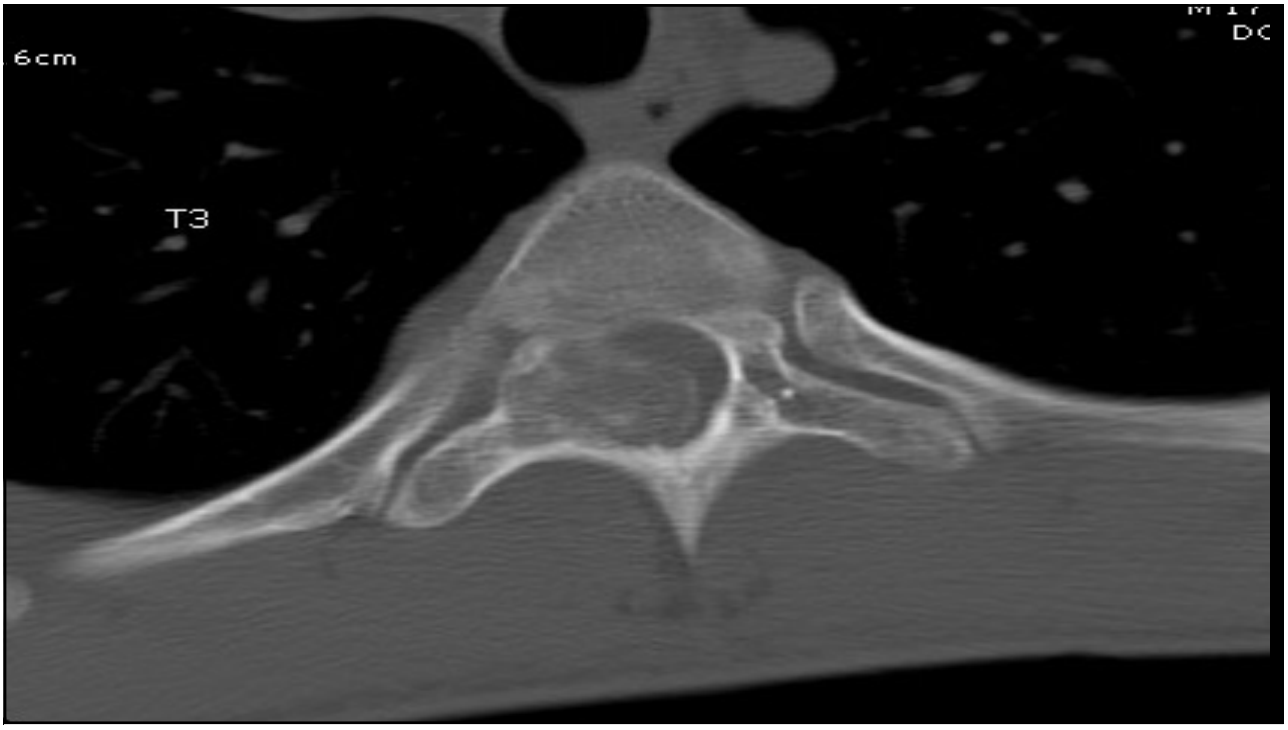
6cm
T3

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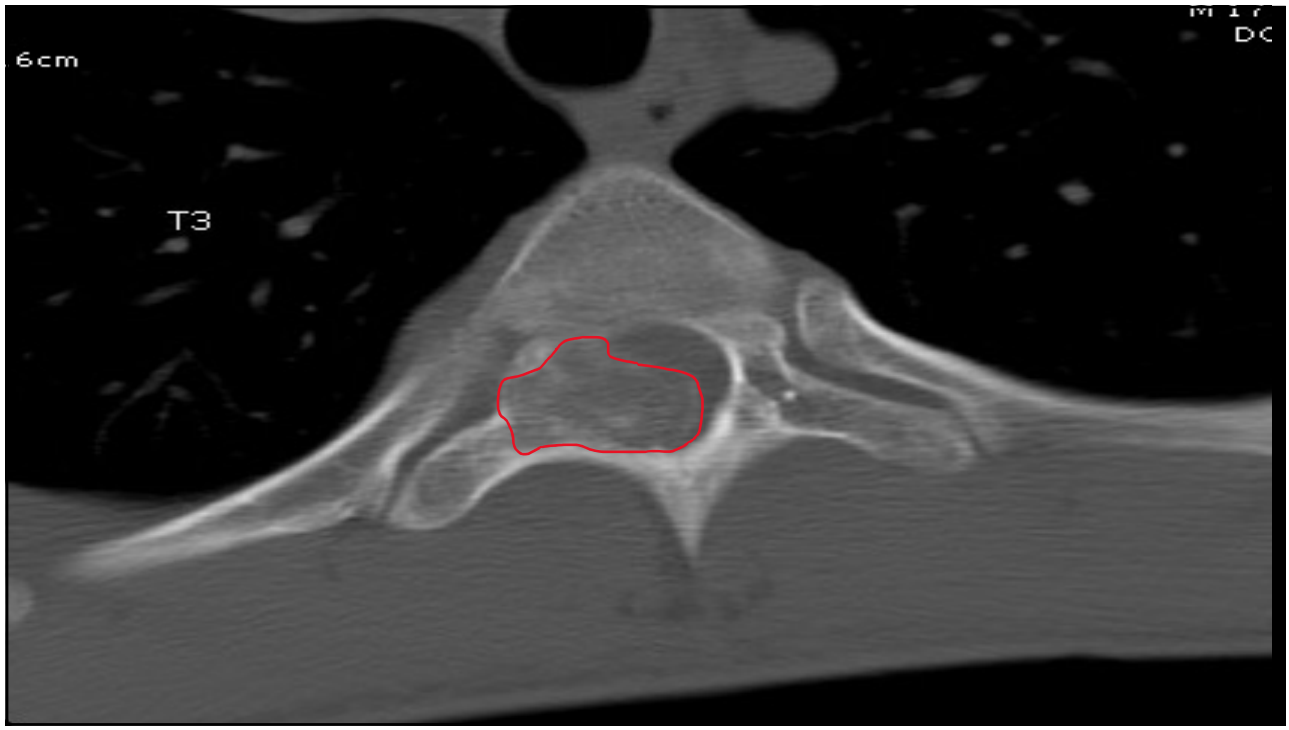

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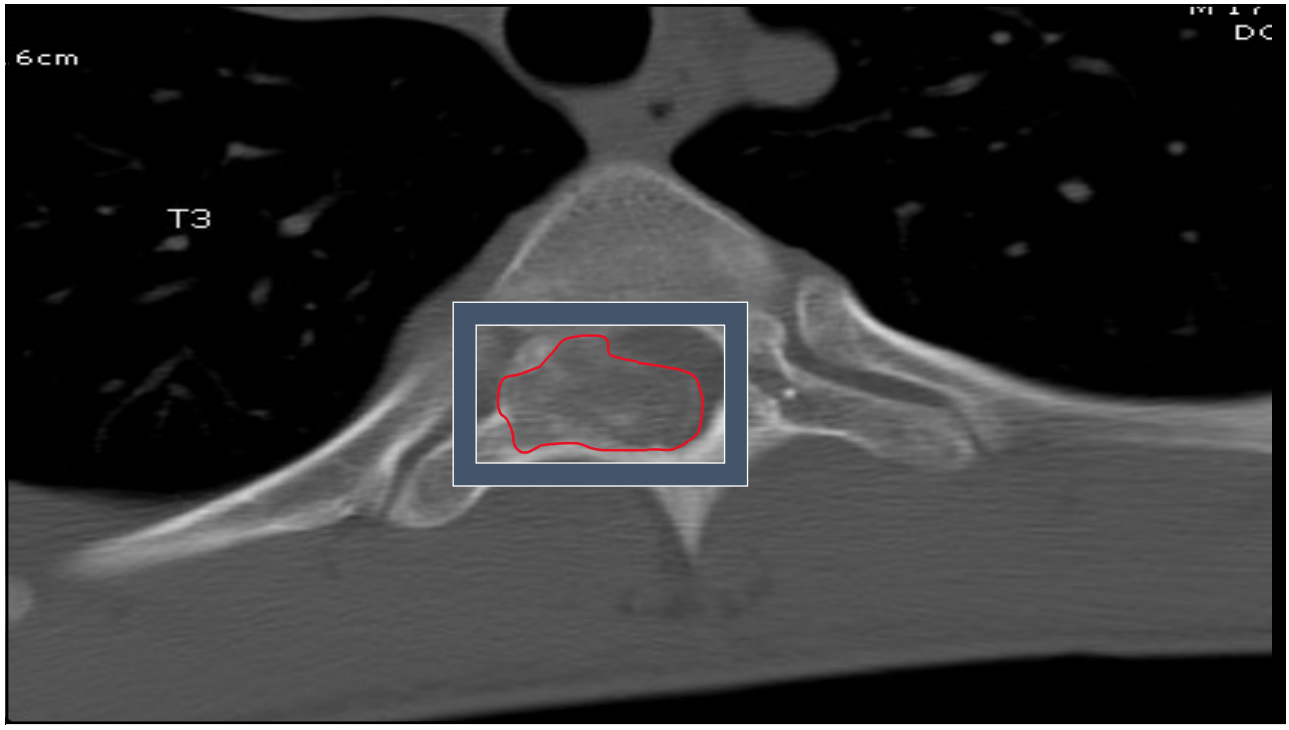

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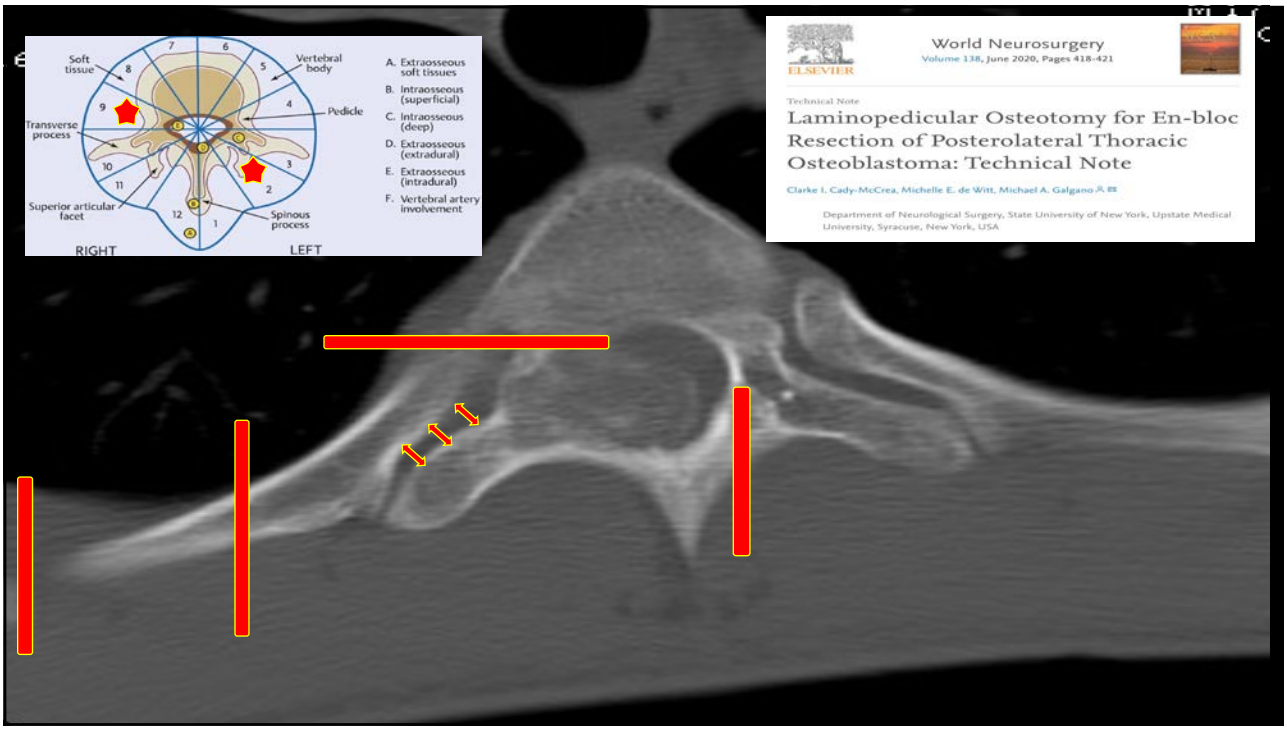
Soft tissue
Vertebral body
Transverse process
Pedicle
Superior articular facet
Spinous process
RIGHT
LEFT
A. Extraosseous soft tissues
B. Intraosseous (superficial)
C. Intraosseous (deep)
D. Extraosseous (extradural)
E. Extraosseous (intradural)
F. Vertebral artery involvement
World Neurosurgery
Volume 138, June 2020, Pages 418-421
Technical Note
Laminopedicular Osteotomy for En-bloc Resection of Posterolateral Thoracic Osteoblastoma: Technical Note
Clarke I. Cady-McCrea, Michelle E. de Witt, Michael A. Galgano
Department of Neurological Surgery, State University of New York, Upstate Medical University, Syracuse, New York, USA

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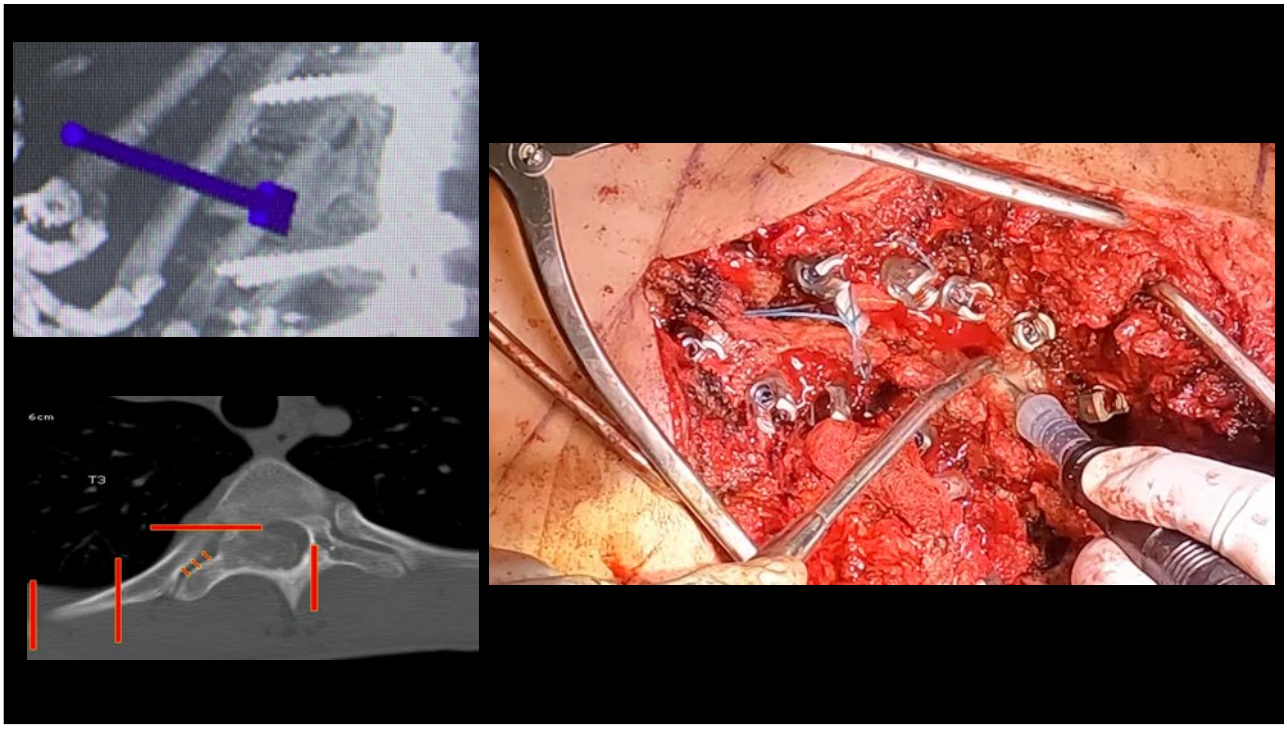
6cm
T3

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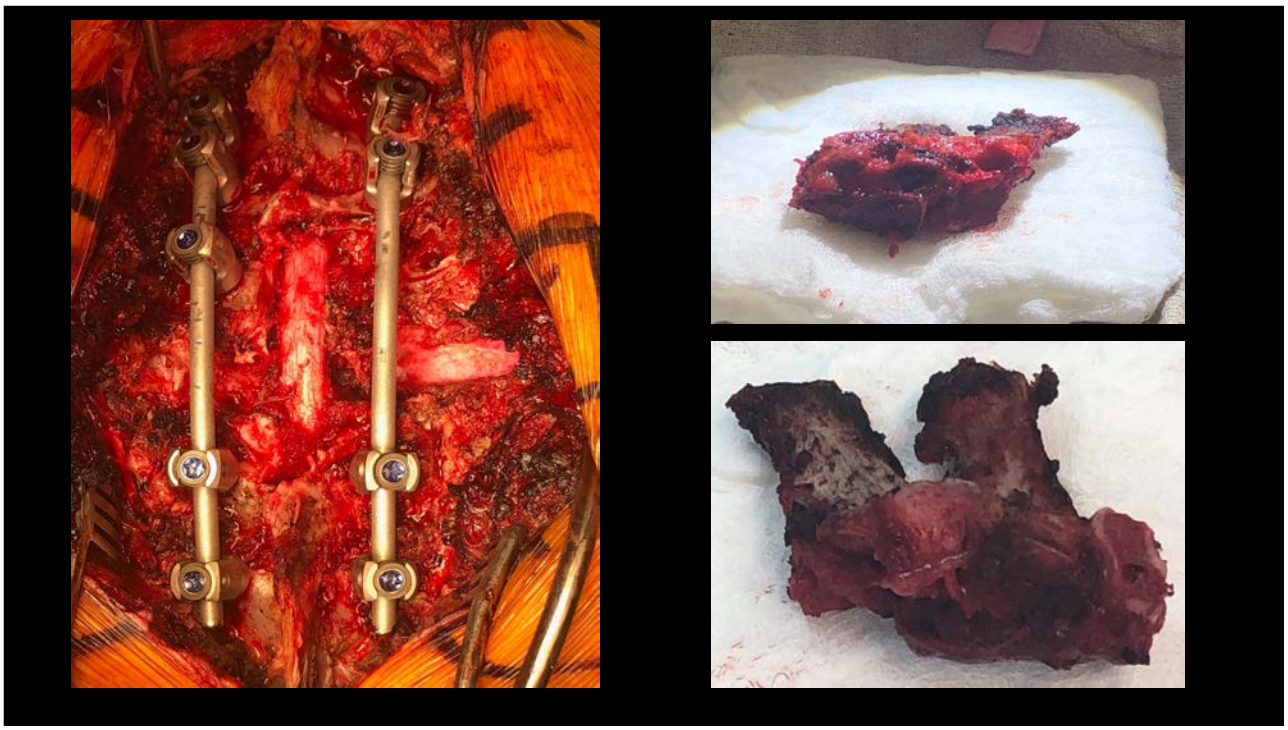

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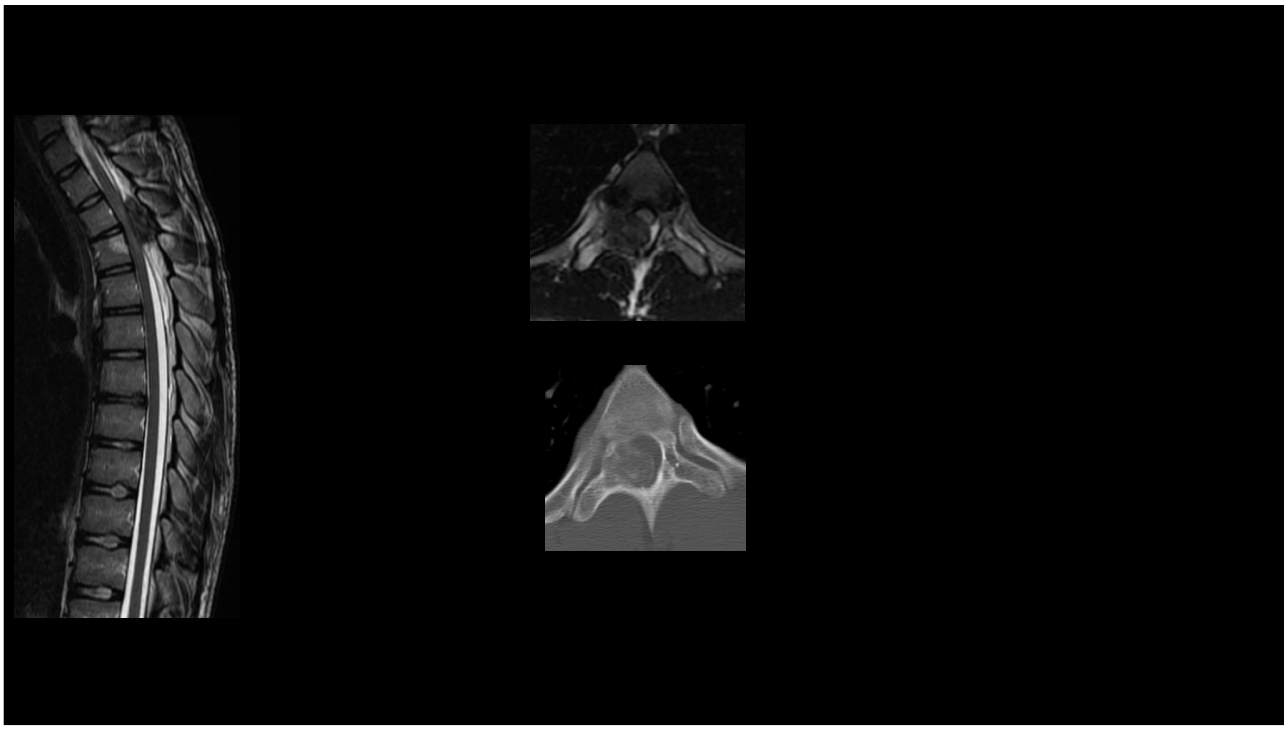

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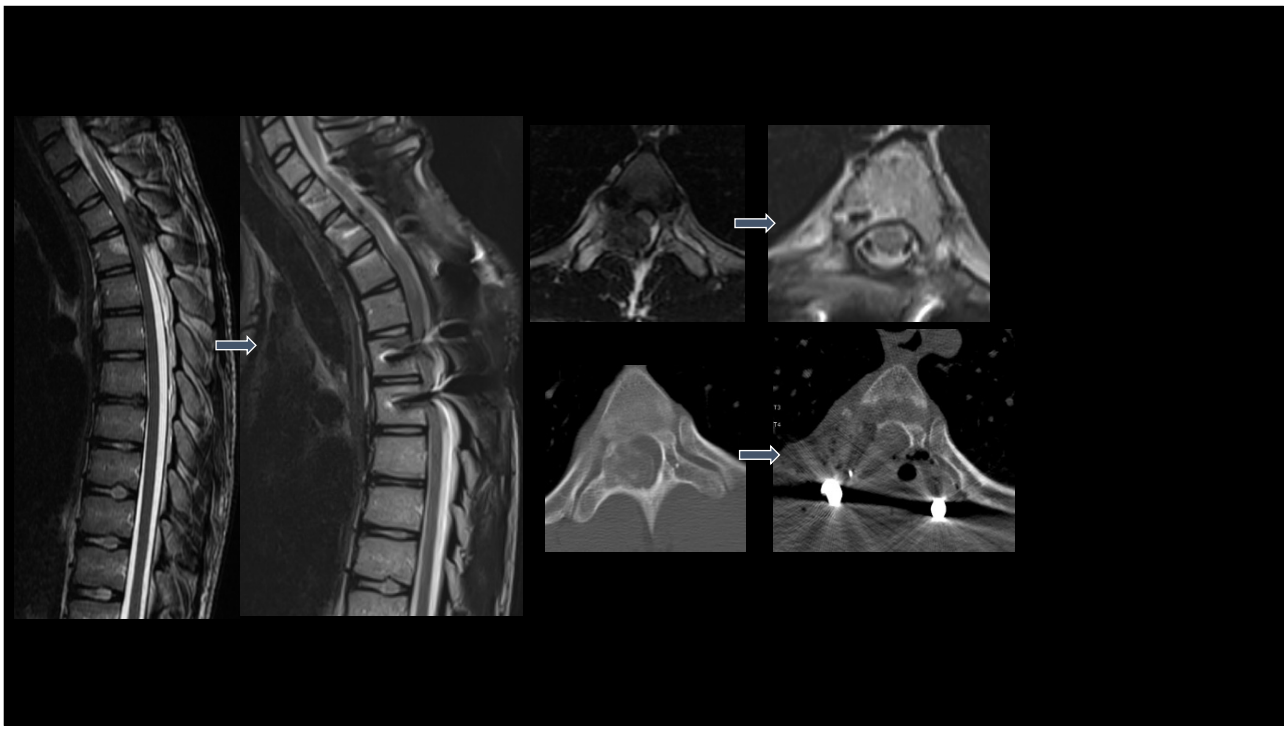

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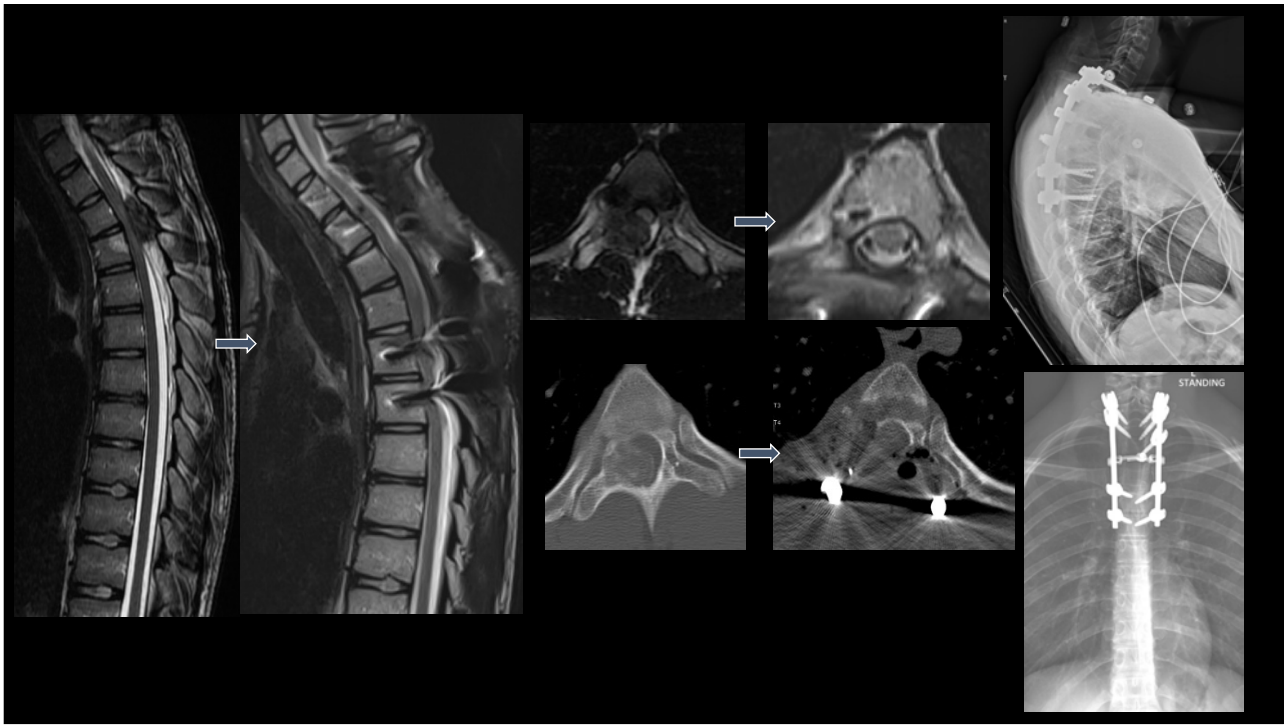

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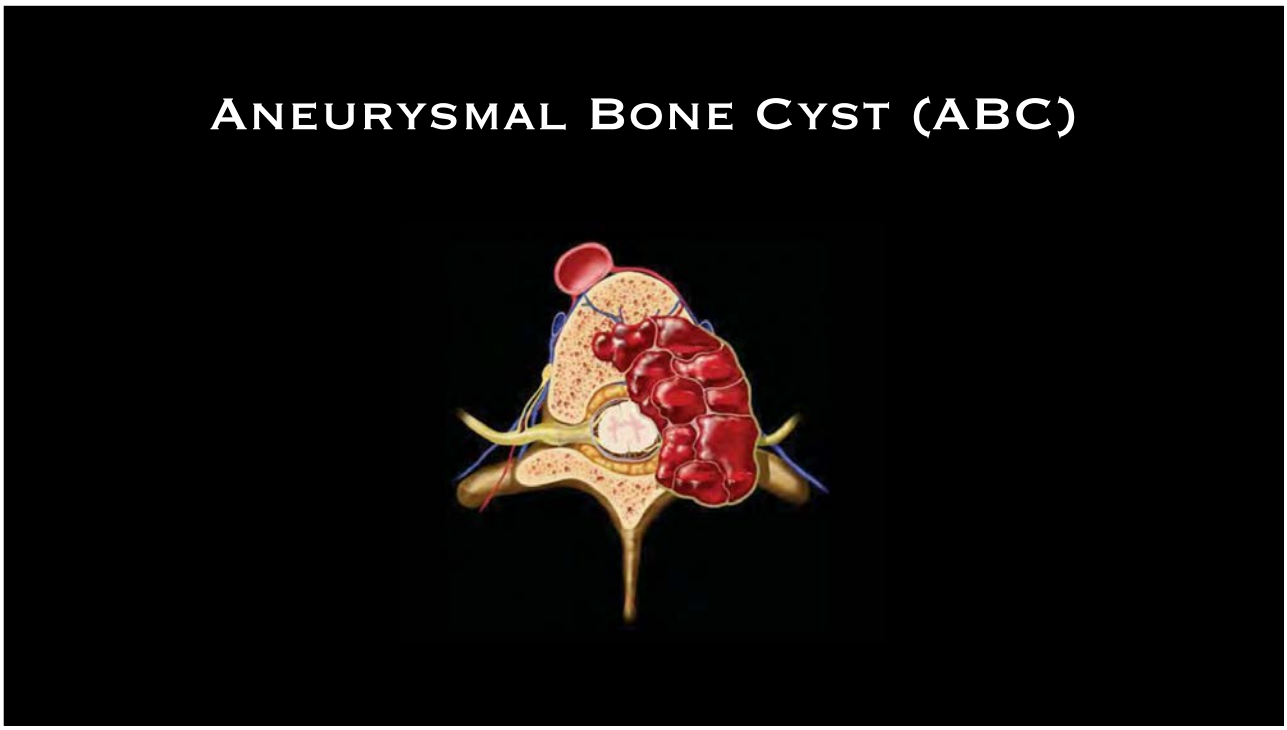

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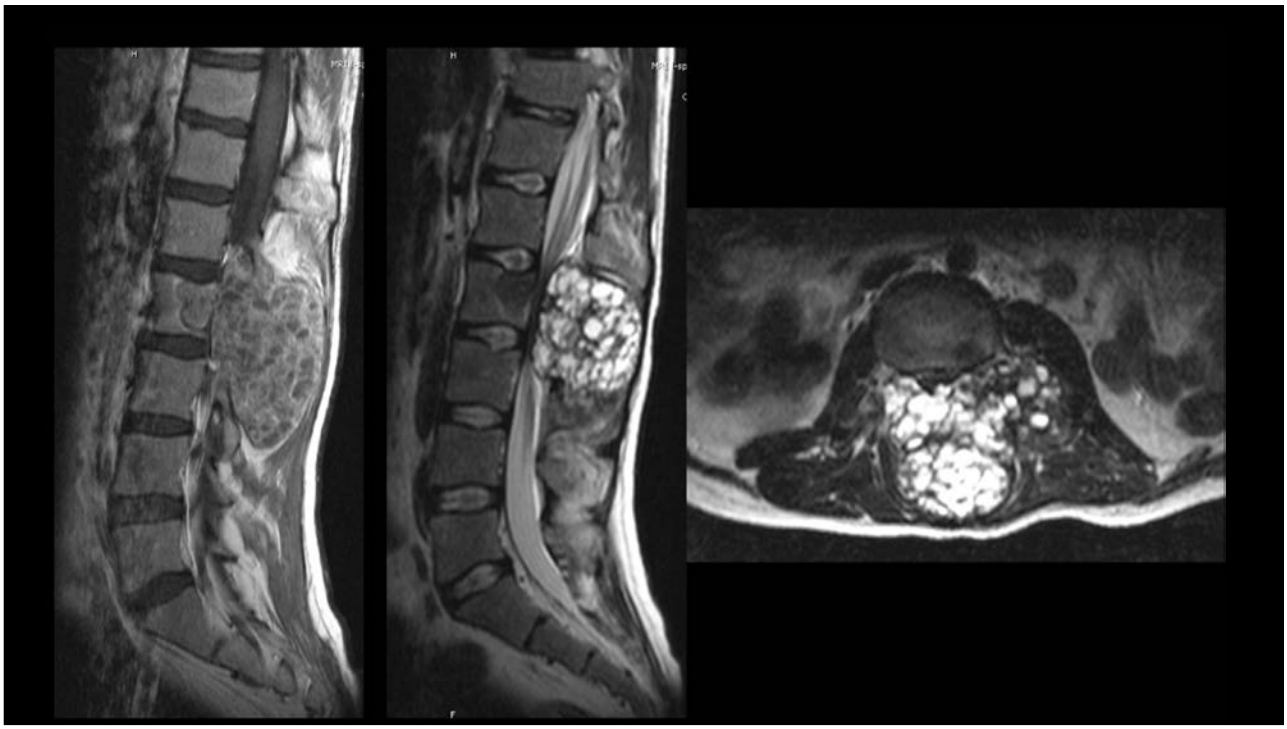

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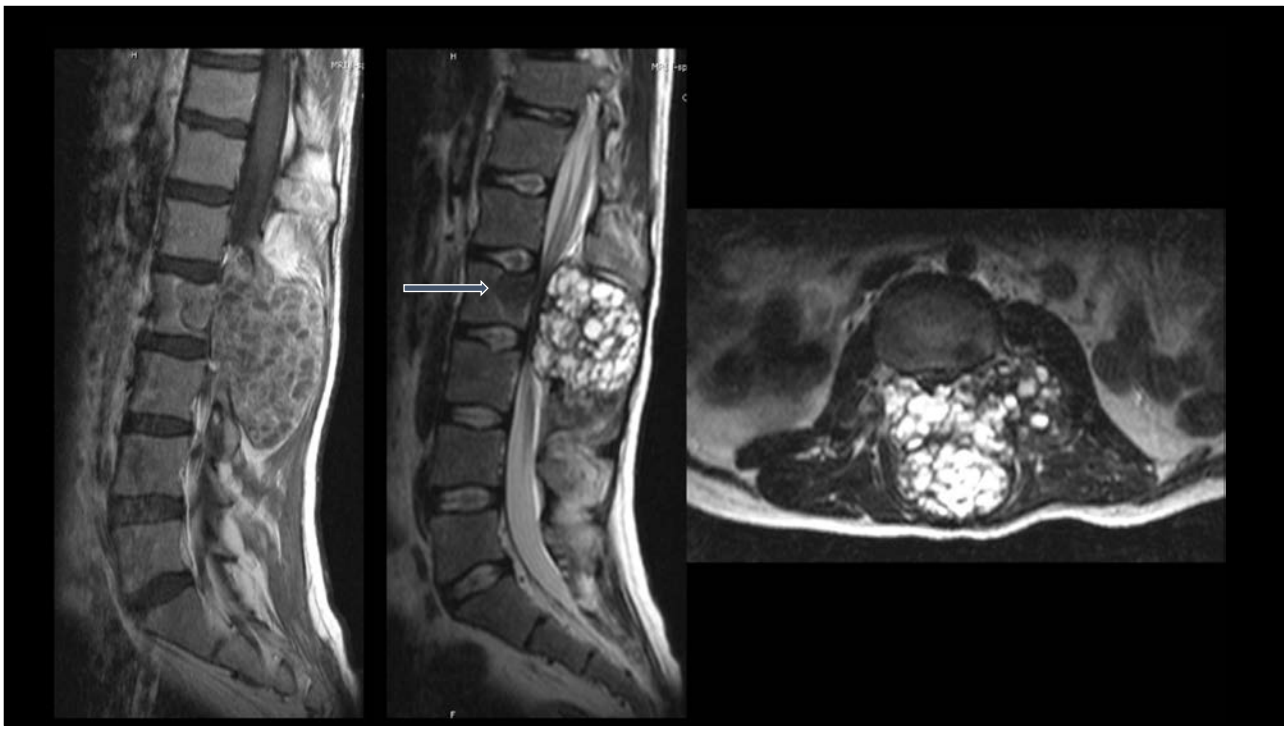

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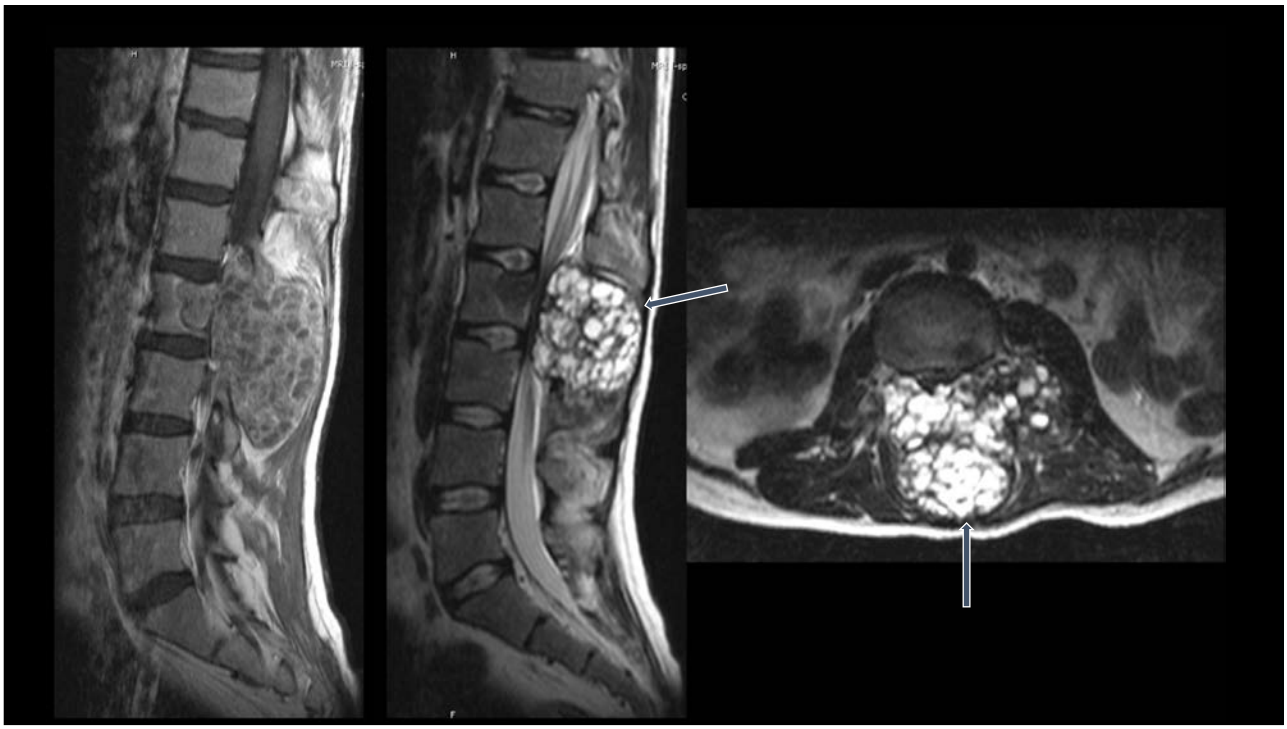

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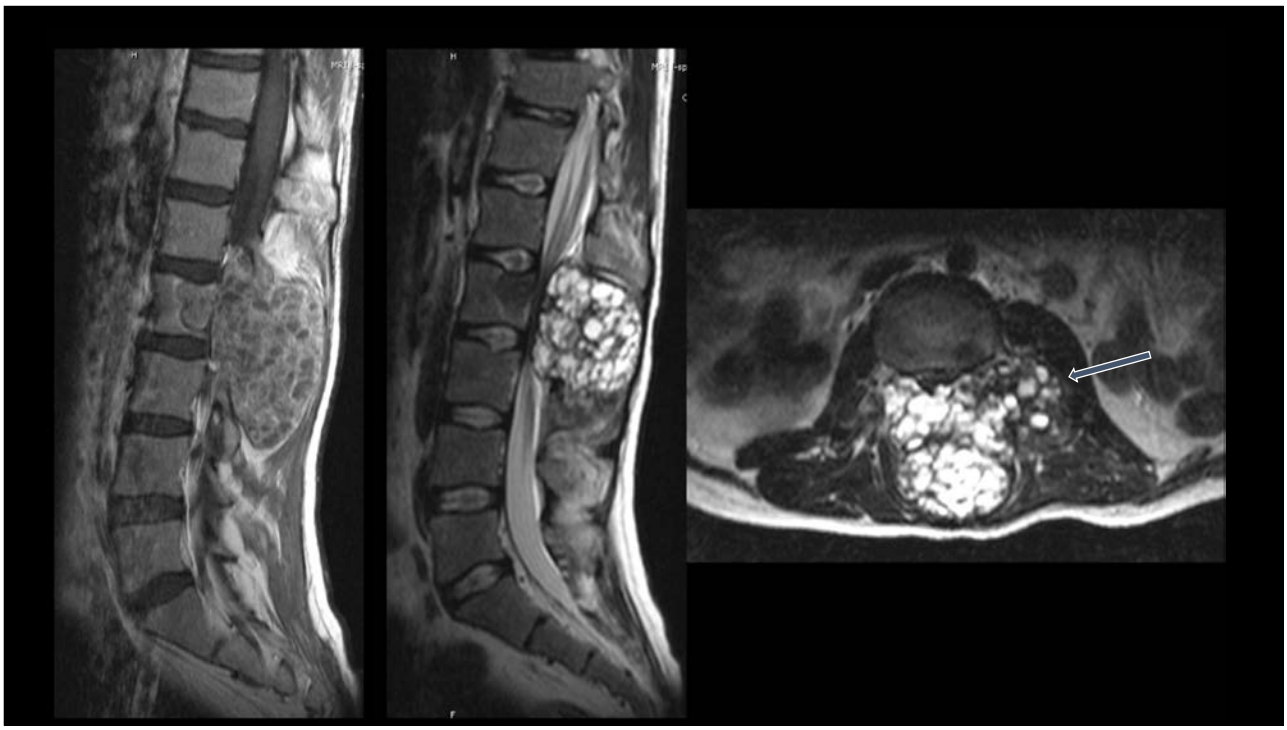

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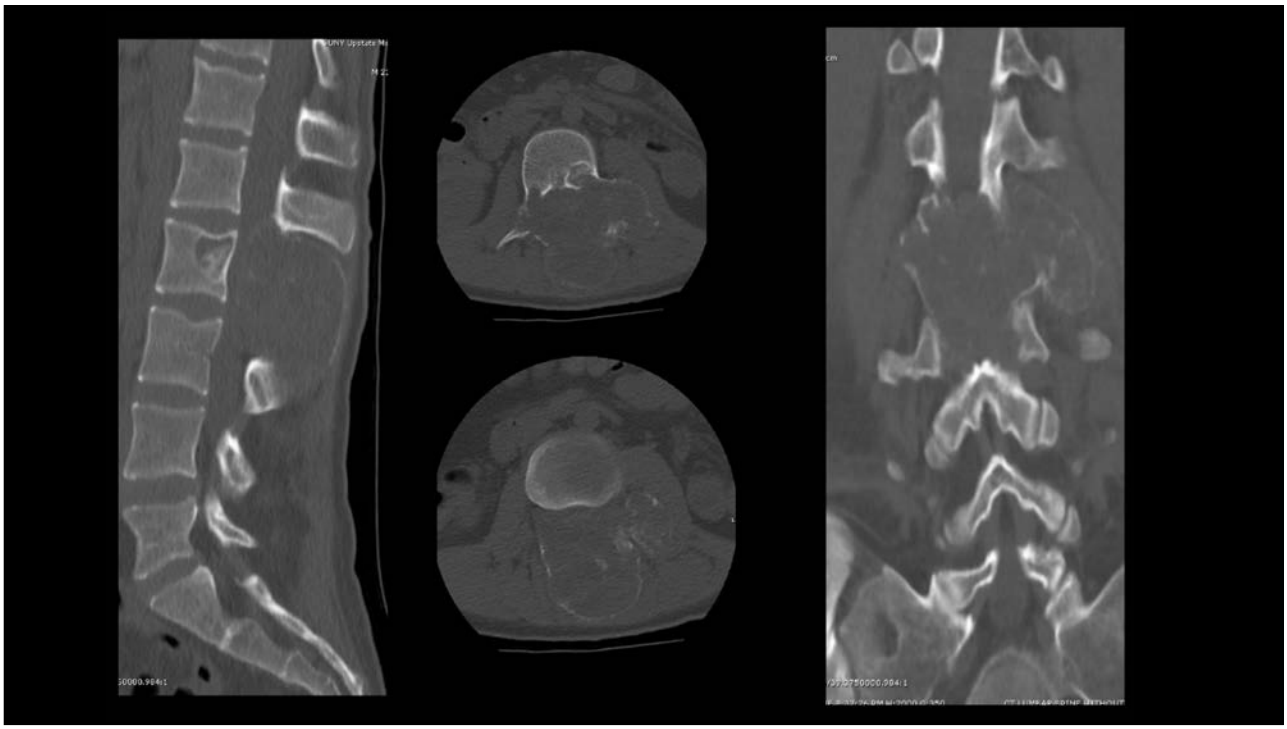

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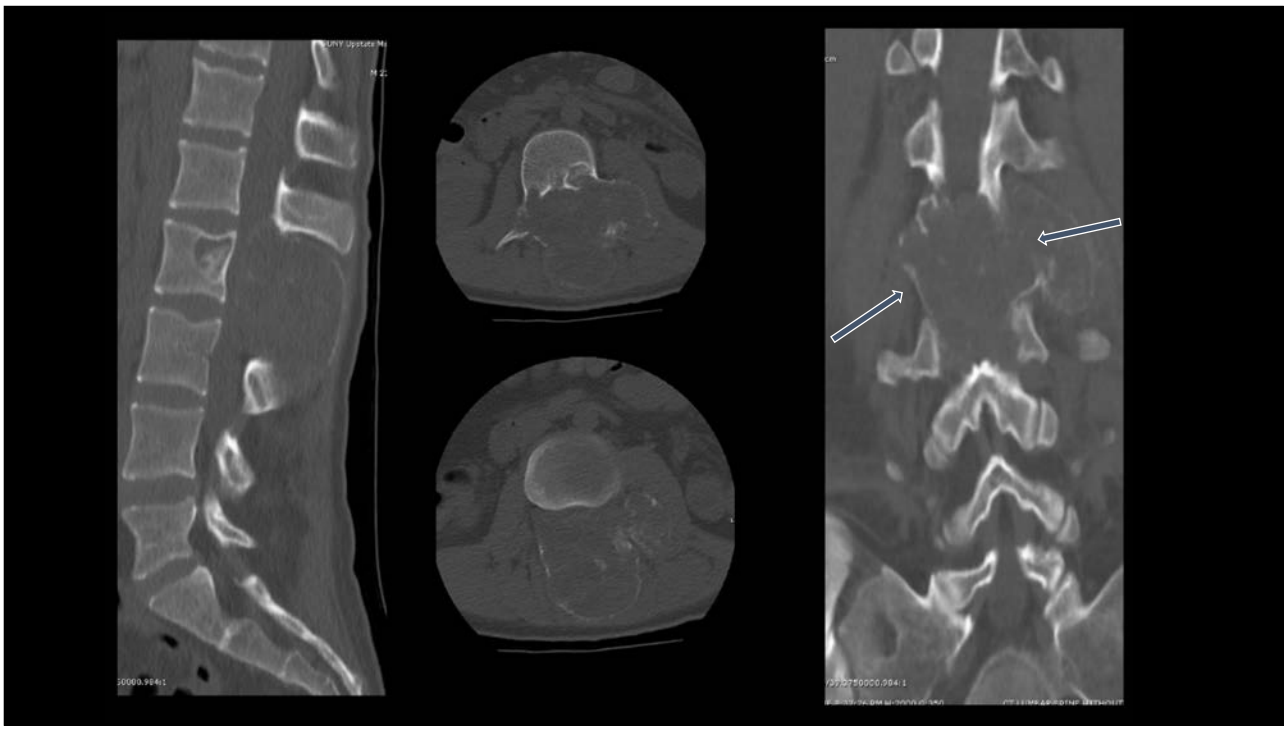

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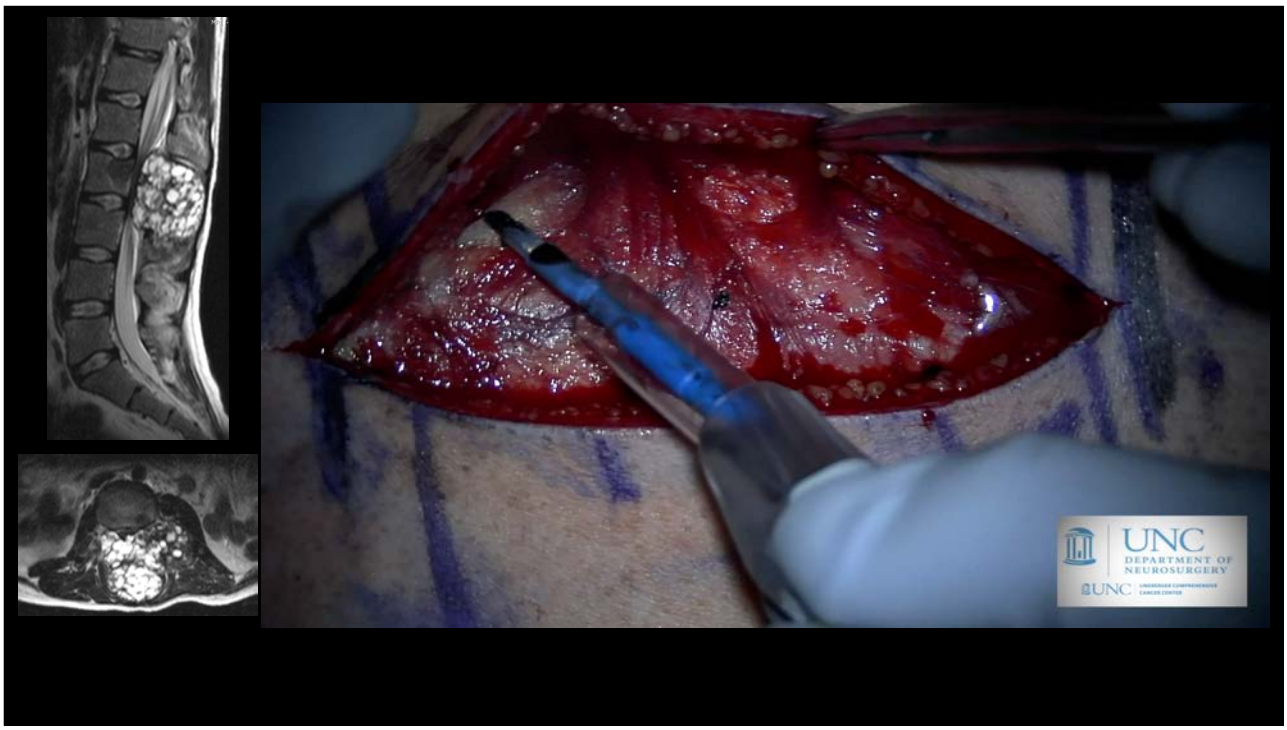

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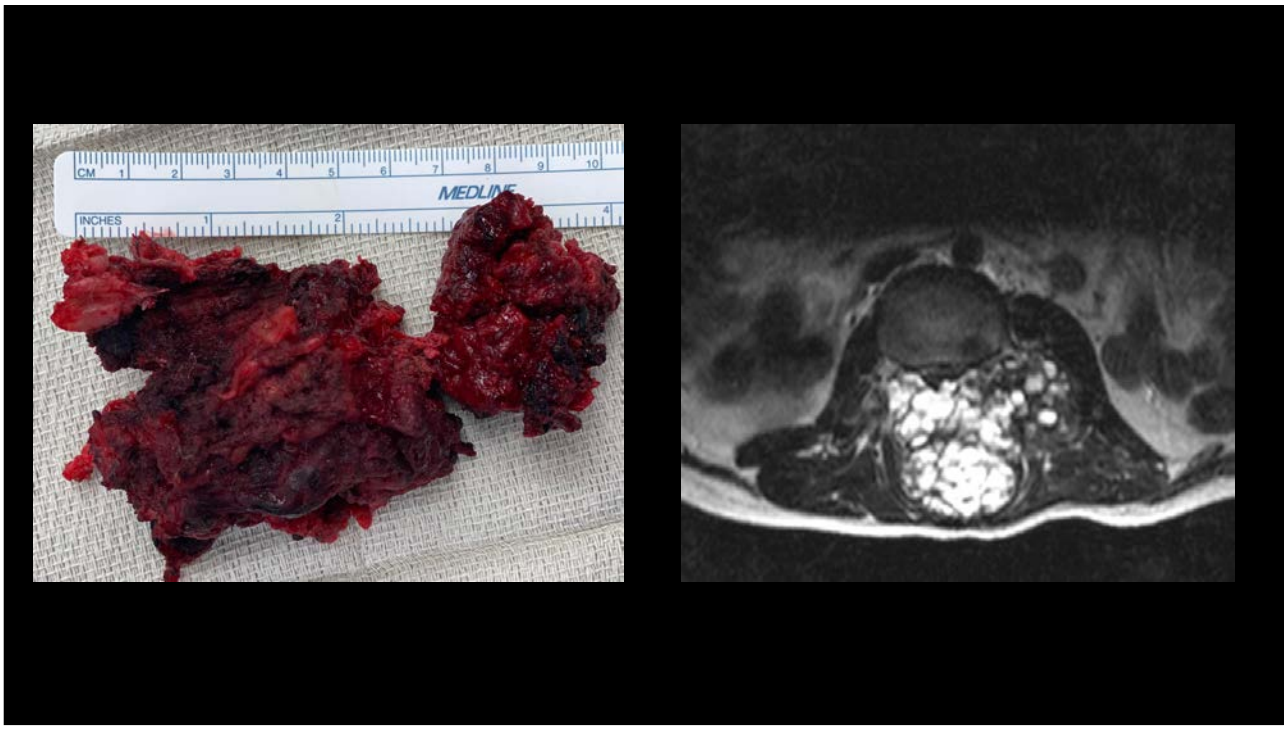

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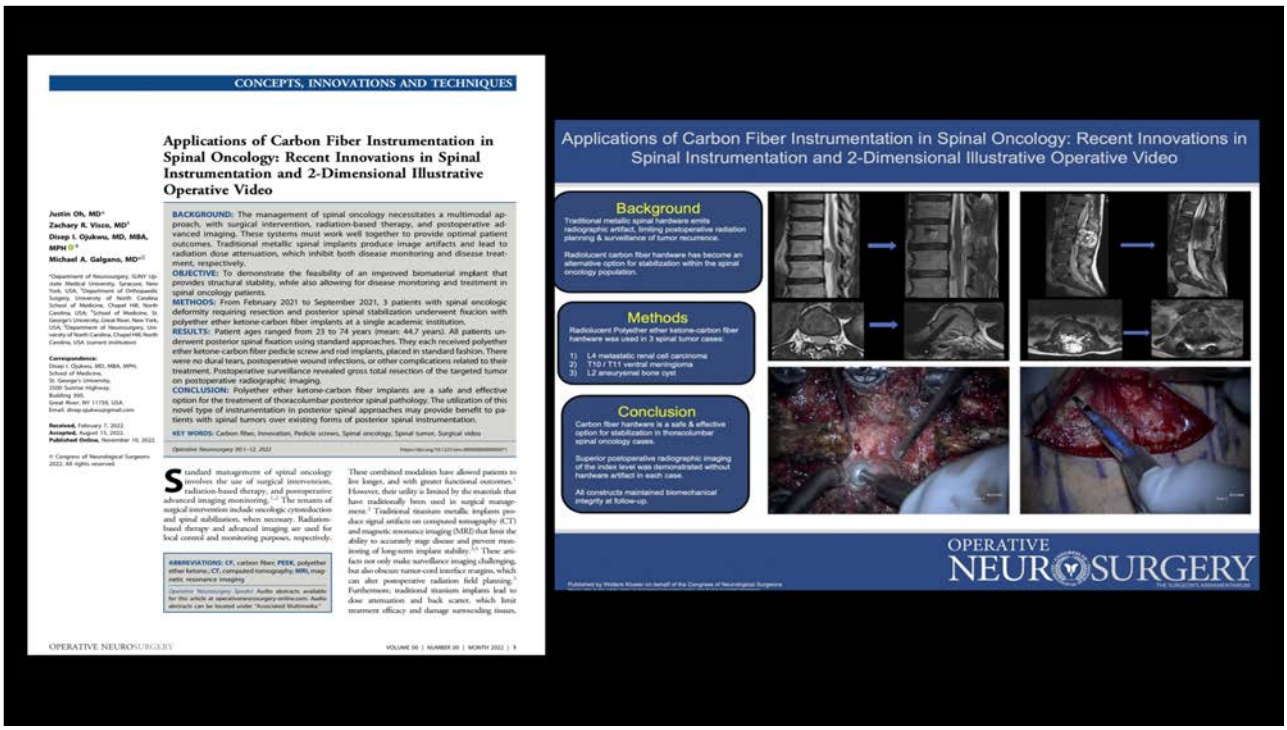
CONCEPTS, INNOVATIONS AND TECHNIQUES
Applications of Carbon Fiber Instrumentation in Spinal Oncology: Recent Innovations in Spinal Instrumentation and 2-Dimensional Illustrative Operative Video
Justin Oh, MD
Zachary R. Visco, MD
Disep I. Ojukwu, MD, MBA, MPH
Michael A. Galgano, MD
BACKGROUND: The management of spinal oncology necessitates a multimodal approach, with surgical intervention, radiation-based therapy, and postoperative advanced imaging. These systems must work well together to provide optimal patient outcomes. Traditional metallic spinal implants produce image artifacts and lead to radiation dose attenuation, which inhibit both disease monitoring and disease treatment, respectively.
OBJECTIVE: To demonstrate the feasibility of an improved biomaterial implant that provides structural stability, while also allowing for disease monitoring and treatment in spinal oncology patients.
METHODS: From February 2021 to September 2021, 3 patients with spinal oncologic deformity requiring resection and posterior spinal stabilization underwent fixation with polyether ether ketone-carbon fiber implants at a single academic institution.
RESULTS: Patient ages ranged from 23 to 74 years (mean: 44.7 years). All patients underwent posterior spinal fixation using standard approaches. They each received polyether ether ketone-carbon fiber pedicle screw and rod implants, placed in standard fashion. There were no dural tears, postoperative wound infections, or other complications related to their treatment. Postoperative surveillance revealed gross total resection of the targeted tumor on postoperative radiographic imaging.
CONCLUSION: Polyether ether ketone-carbon fiber implants are a safe and effective option for the treatment of thoracolumbar posterior spinal pathology. The utilization of this novel type of instrumentation in posterior spinal approaches may provide benefit to patients with spinal tumors over existing forms of posterior spinal instrumentation.
KEY WORDS: Carbon fiber, Innovation, Pedicle screws, Spinal oncology, Spinal tumor, Surgical video
Standard management of spinal oncology involves the use of surgical intervention, radiation-based therapy, and postoperative advanced imaging monitoring.
ABBREVIATIONS: CF, carbon fiber; PEEK, polyether ether ketone; CT, computed tomography; MRI, magnetic resonance imaging
OPERATIVE NEUROSURGERY
Applications of Carbon Fiber Instrumentation in Spinal Oncology: Recent Innovations in Spinal Instrumentation and 2-Dimensional Illustrative Operative Video
Background
Traditional metallic spinal hardware emits radiographic artifact, limiting postoperative radiation planning & surveillance of tumor recurrence.
Radiolucent carbon fiber hardware has become an alternative option for stabilization within the spinal oncology population.
Methods
Radiolucent Polyether ether ketone-carbon fiber hardware was used in 3 spinal tumor cases:
1) L4 metastatic renal cell carcinoma
2) T10 / T11 ventral meningioma
3) L2 aneurysmal bone cyst
Conclusion
Carbon fiber hardware is a safe & effective option for stabilization in thoracolumbar spinal oncology cases.
Superior postoperative radiographic imaging of the index level was demonstrated without hardware artifact in each case.
All constructs maintained biomechanical integrity at follow-up.
OPERATIVE NEUROSURGERY

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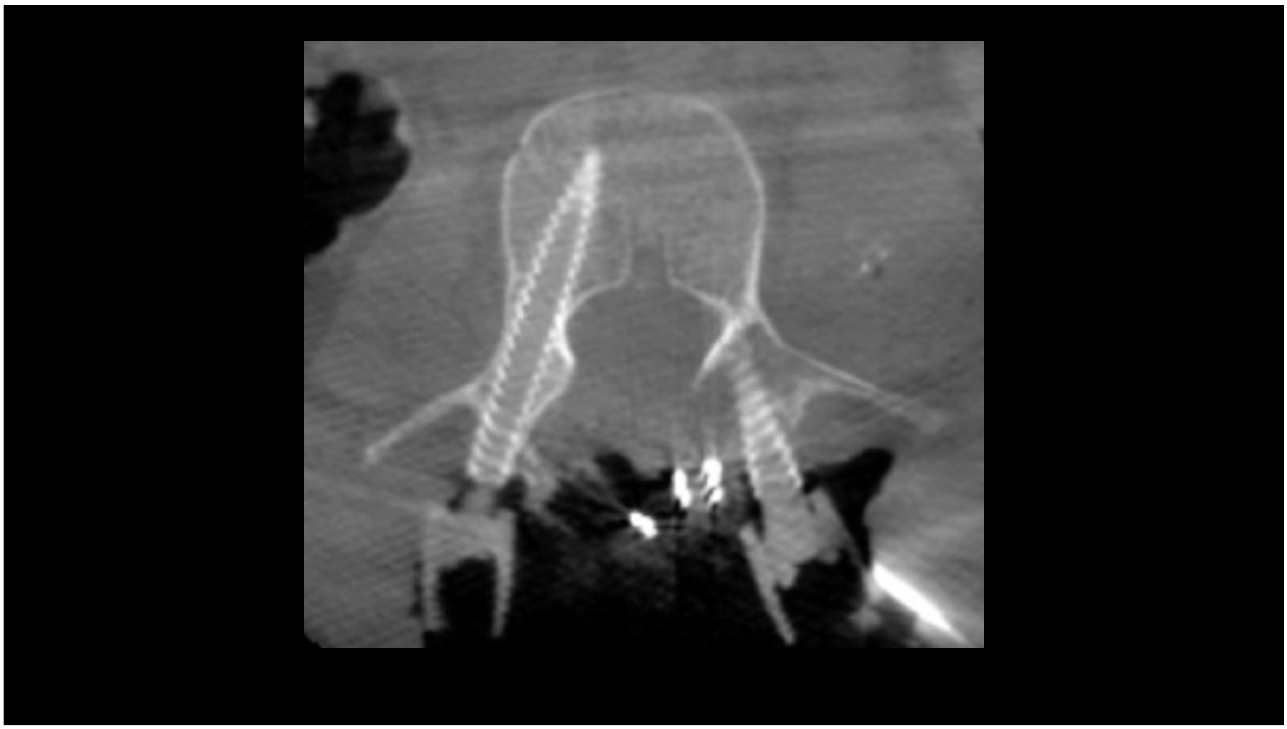

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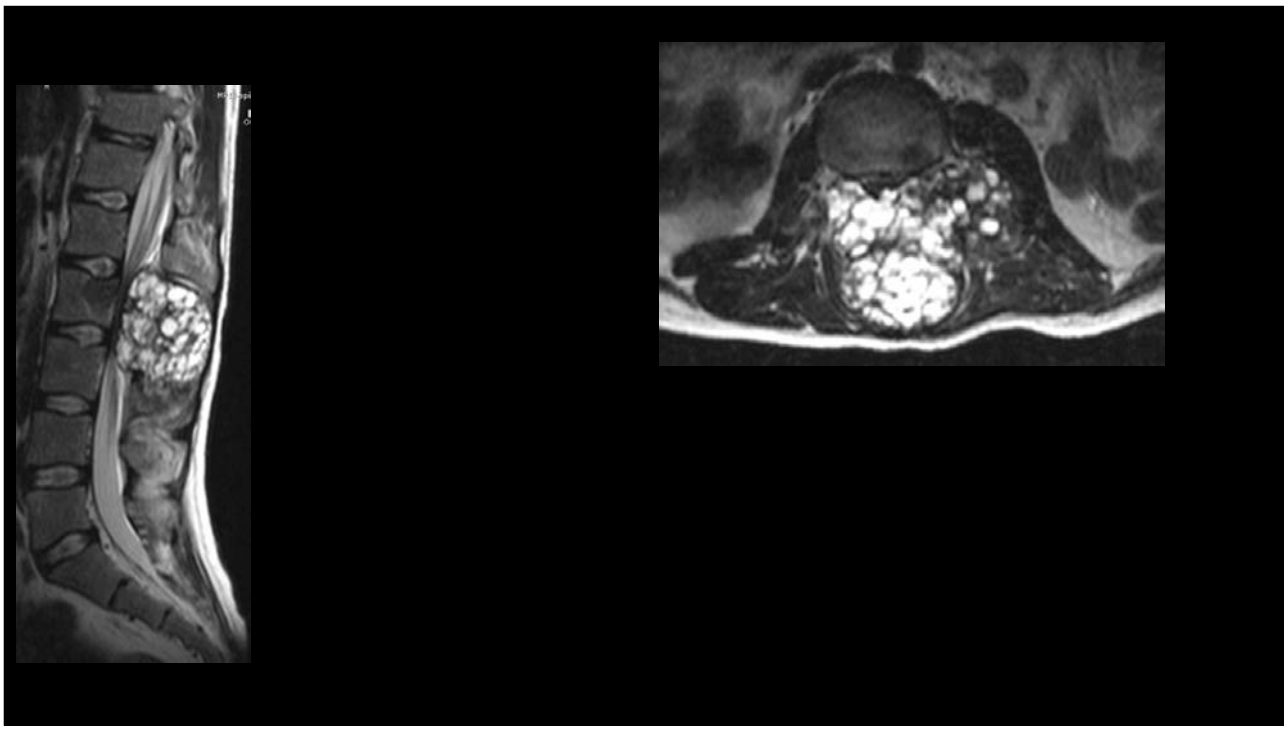

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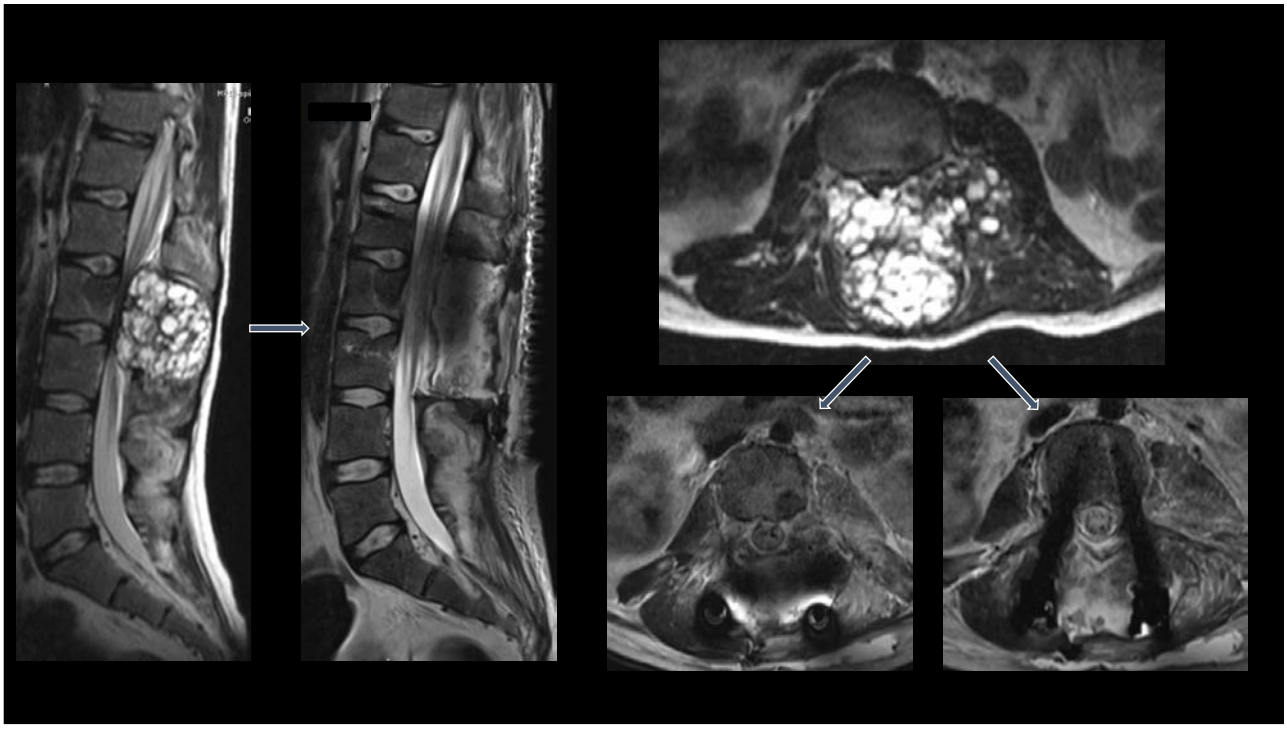

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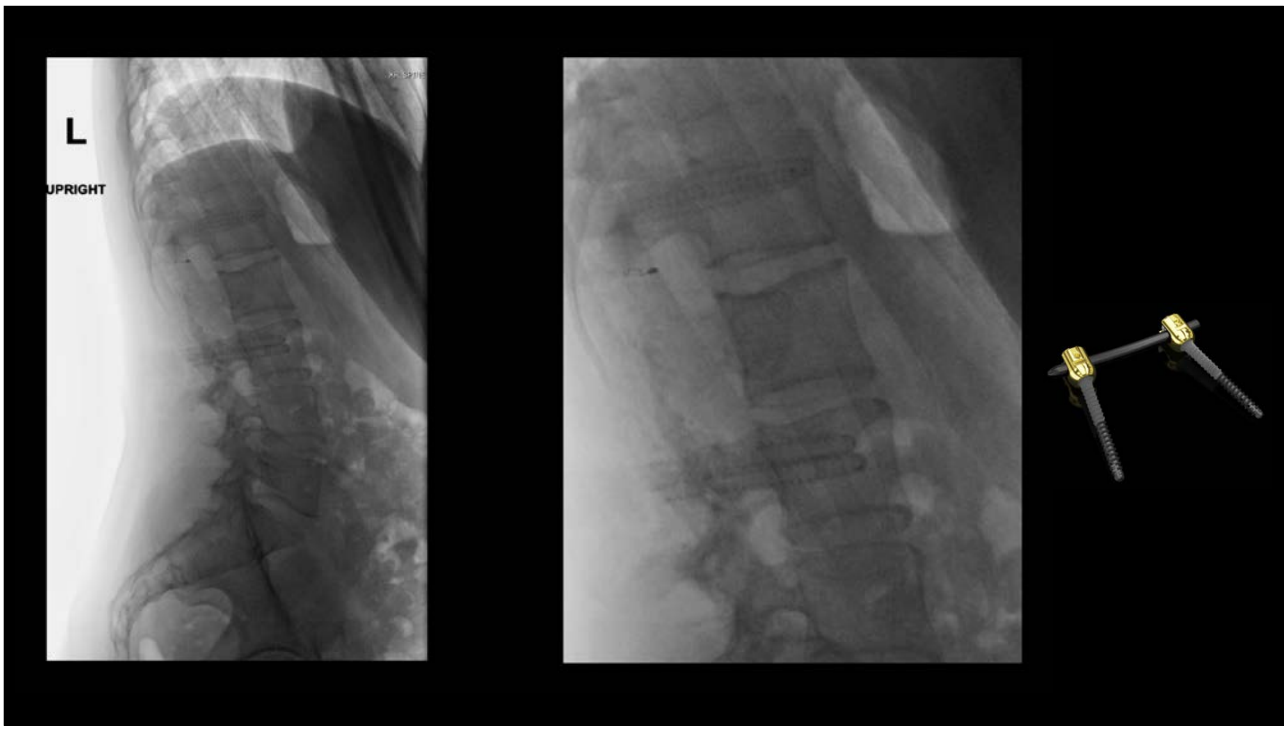

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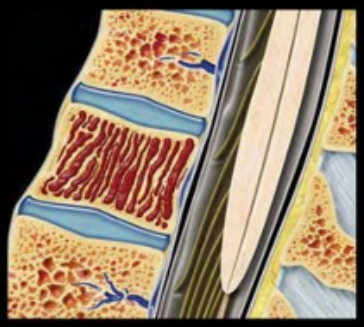
Hemangiomas



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"Neuro-Aggressive" Hemangioma

NEUROSURGICAL FOCUS

Neurosurg Focus 41 (2):E7, 2016

Surgical treatment of aggressive vertebral hemangiomas

Viren S. Vasudeva, MD,[1] John H. Chi, MD, MPH,[1,2] and Michael W. Groff, MD[1,2]

[1]Brigham and Women's Hospital, Harvard Medical School; and [2]Center for Neuro-Oncology, Dana-Farber Cancer Institute, Boston, Massachusetts

OBJECTIVE Vertebral hemangiomas are common tumors that are benign and generally asymptomatic. Occasionally these lesions can exhibit aggressive features such as bony expansion and erosion into the epidural space resulting in neurological symptoms. Surgery is often recommended in these cases, especially if symptoms are severe or rapidly progressive. Some surgeons perform decompression alone, others perform gross-total resection, while others perform en bloc resection. Radiation, embolization, vertebroplasty, and ethanol injection have also been used in combination with surgery. Despite the variety of available treatment options, the optimal management strategy is unclear because aggressive vertebral hemangiomas are uncommon lesions, making it difficult to perform large trials. For this reason, the authors chose instead to report their institutional experience along with a comprehensive review of the literature.

METHODS A departmental database was searched for patients with a pathological diagnosis of "hemangioma" between 2008 and 2015. Medical records were reviewed to identify patients with aggressive vertebral hemangiomas, and these cases were reviewed in detail.

RESULTS Five patients were identified who underwent surgery for treatment of aggressive vertebral hemangiomas during the specified time period. There were 2 lumbar and 3 thoracic lesions. One patient underwent en bloc spondylectomy, 2 patients had piecemeal gross-total resection, and the remaining 2 had subtotal tumor resection. Intraoperative vertebroplasty was used in 3 cases to augment the anterior column or to obliterate residual tumor. Adjuvant radiation was used in 1 case where there was residual tumor as well. The patient who underwent en bloc spondylectomy experienced several postoperative complications requiring additional medical care and reoperation. At an average follow-up of 31 months (range 3–65 months), no patient had any recurrence of disease and all were clinically asymptomatic, except the patient who underwent en bloc resection who continued to have back pain.

CONCLUSIONS Gross-total resection or subtotal resection in combination with vertebroplasty or adjuvant radiation therapy to treat residual tumor seems sufficient in the treatment of aggressive vertebral hemangiomas. En bloc resection appears to provide a similar oncological benefit, but it carries higher morbidity to the patient.

http://thejns.org/doi/abs/10.3171/2016.5.FOCUS16169

KEY WORDS aggressive vertebral hemangioma; vertebral hemangioma; cavernous hemangioma; vertebral angioma; primary spinal column tumor

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Review Article

Surgical management of symptomatic vertebral hemangiomas: A case report and literature review

Harman Chopra[1], Haydn Hoffman[1], Timothy E. Richardson[2], Michael A. Galgano[1]

Departments of [1]Neurosurgery, [2]Pathology, SUNY Upstate, Syracuse, New York, United States.

E-mail: Harman Chopra - chopra h@upstate.edu; *Haydn Hoffman - hoffmanh@upstate.edu; Timothy E. Richardson - richatim@upstate.edu; Michael A. Galgano - galganom@upstate.edu

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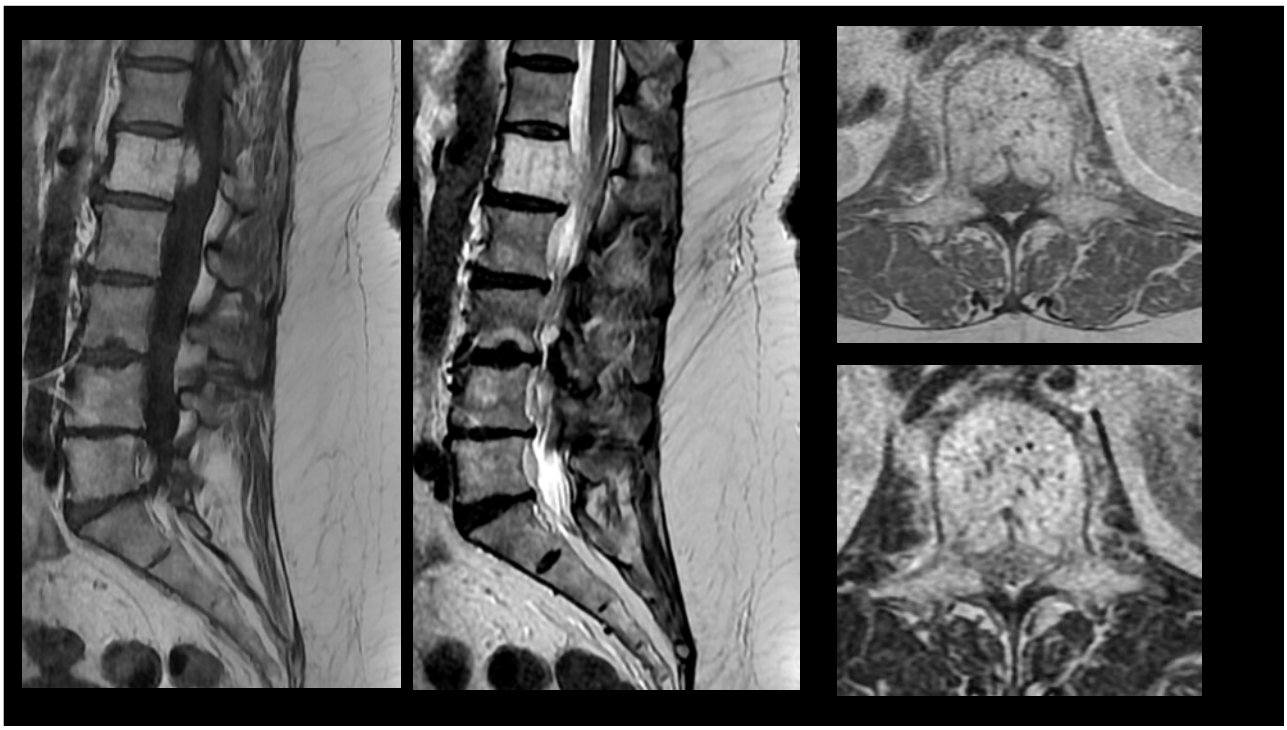

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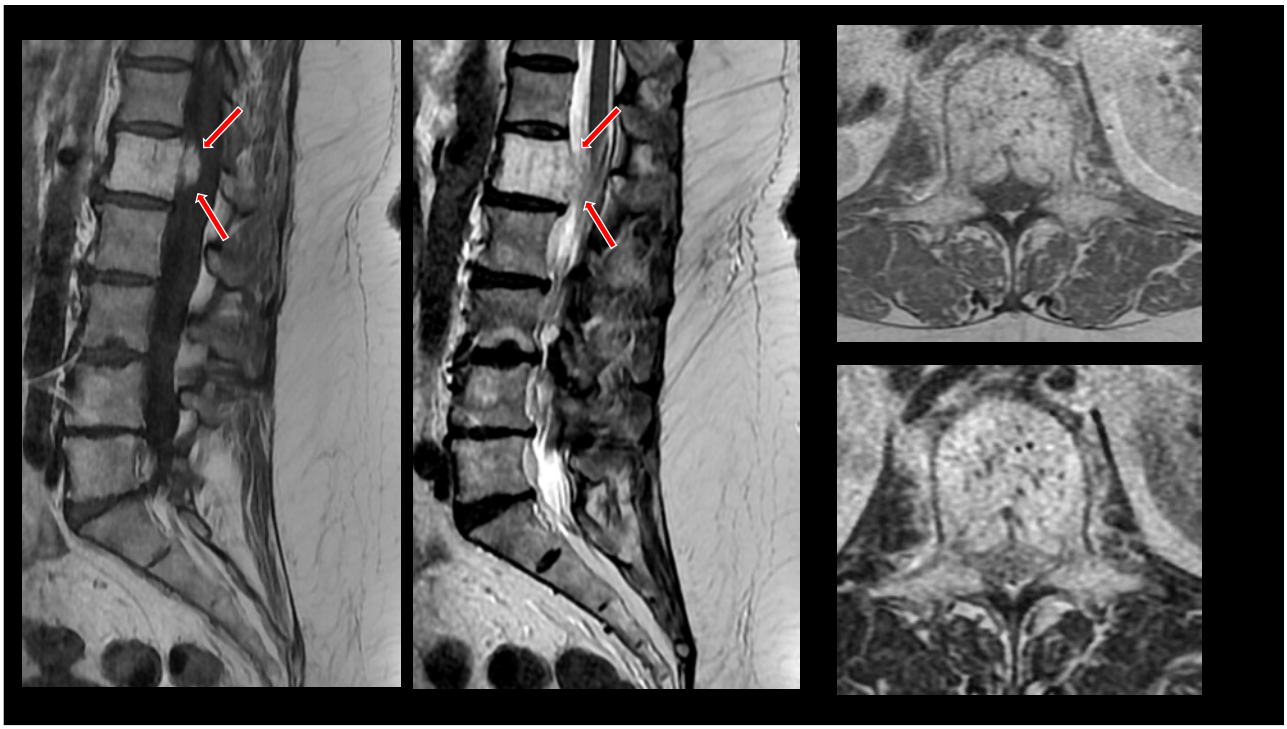

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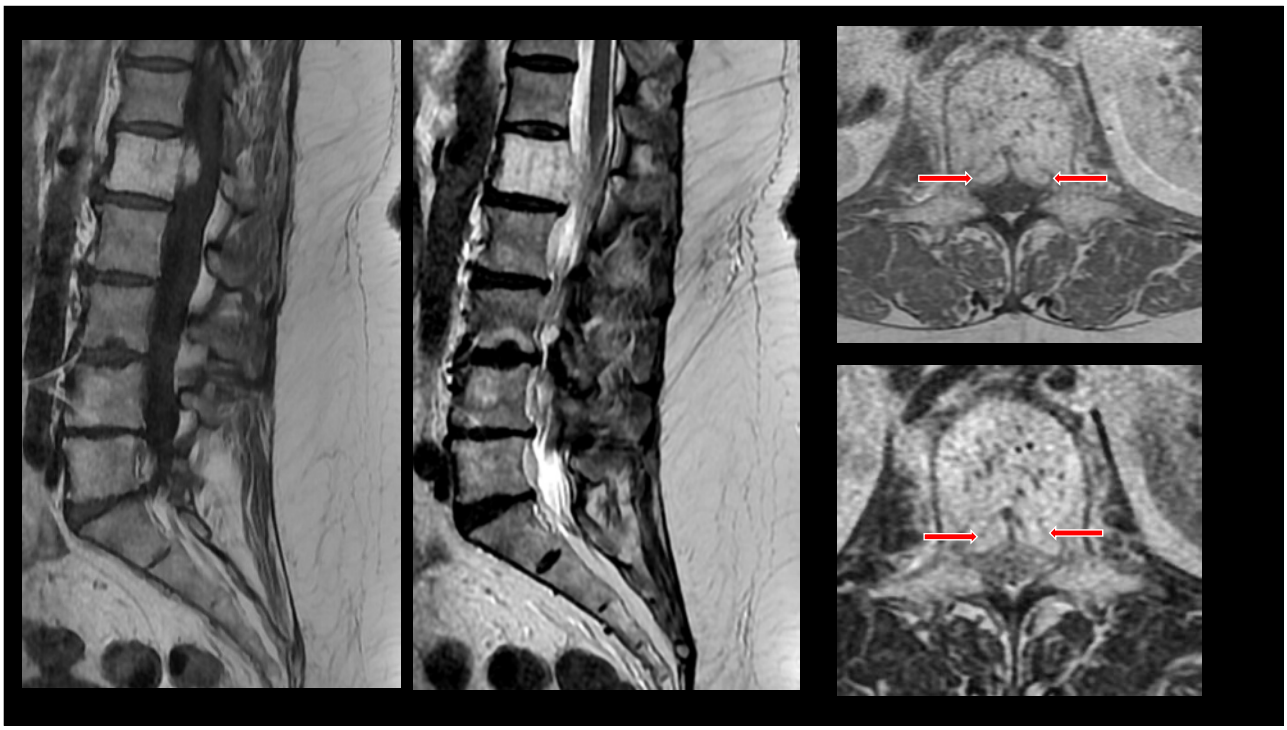

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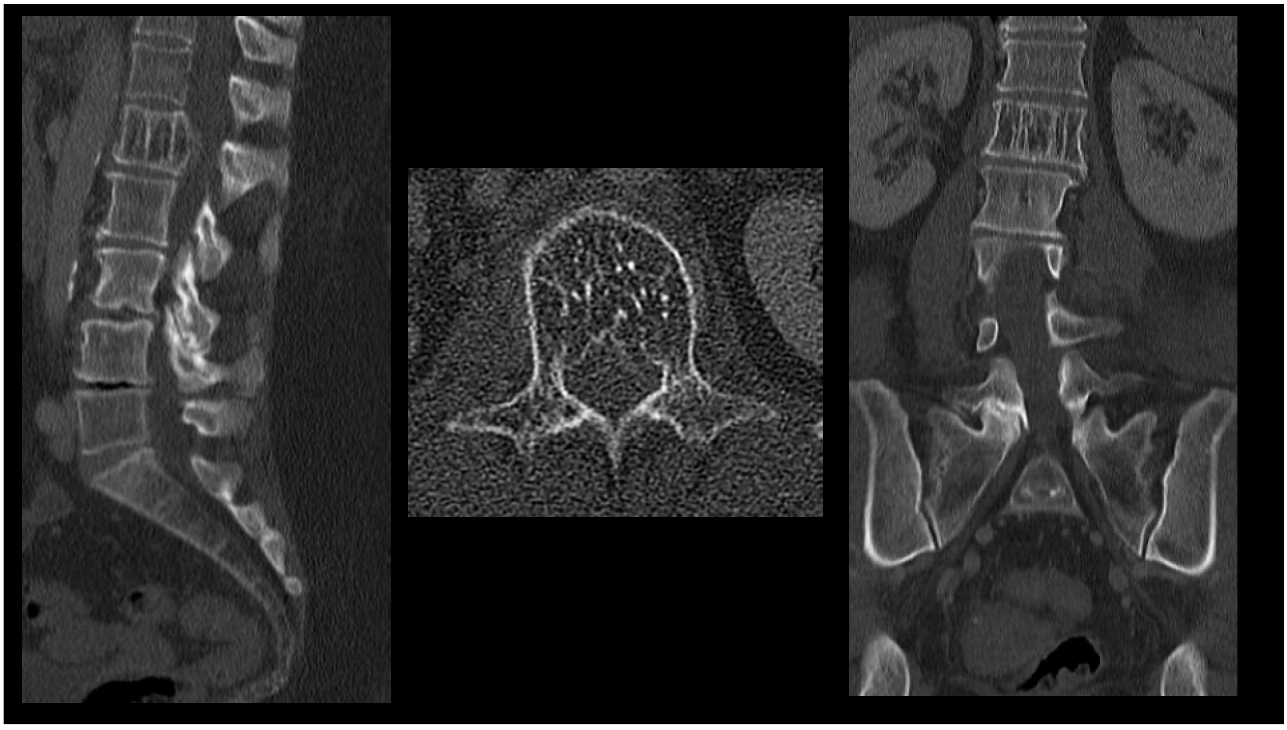

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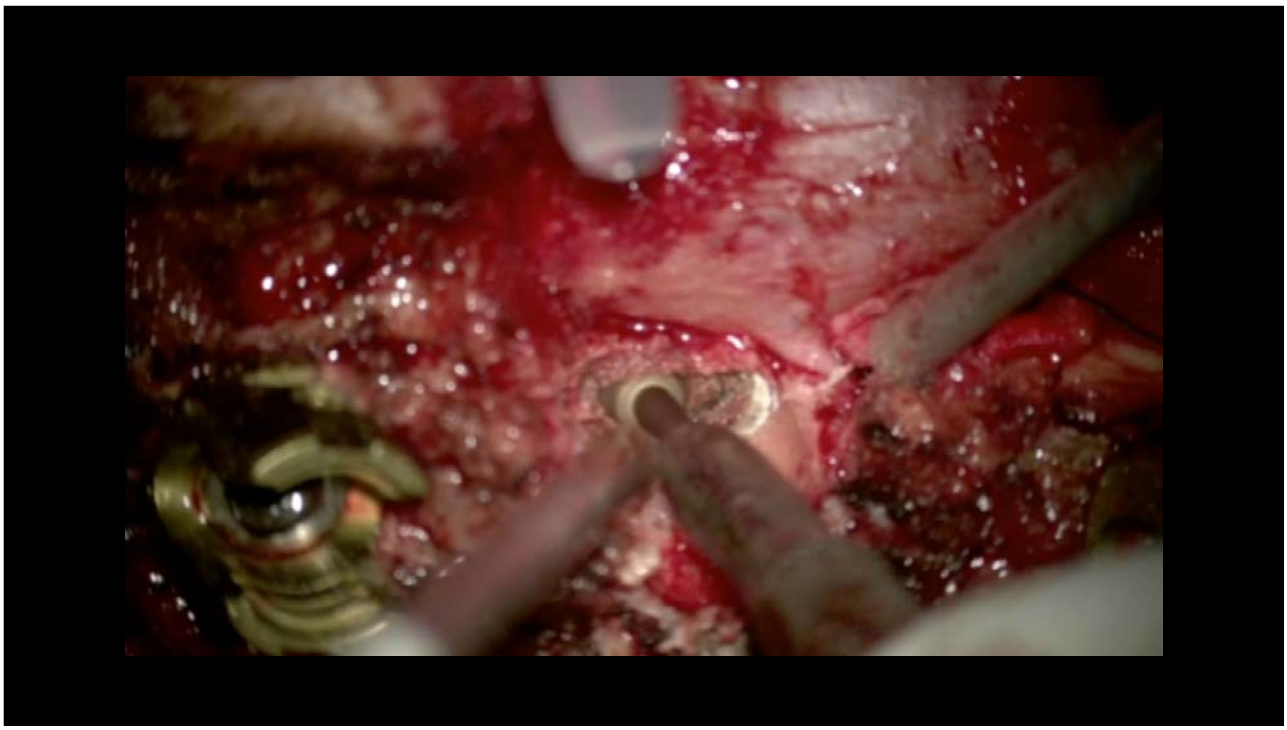

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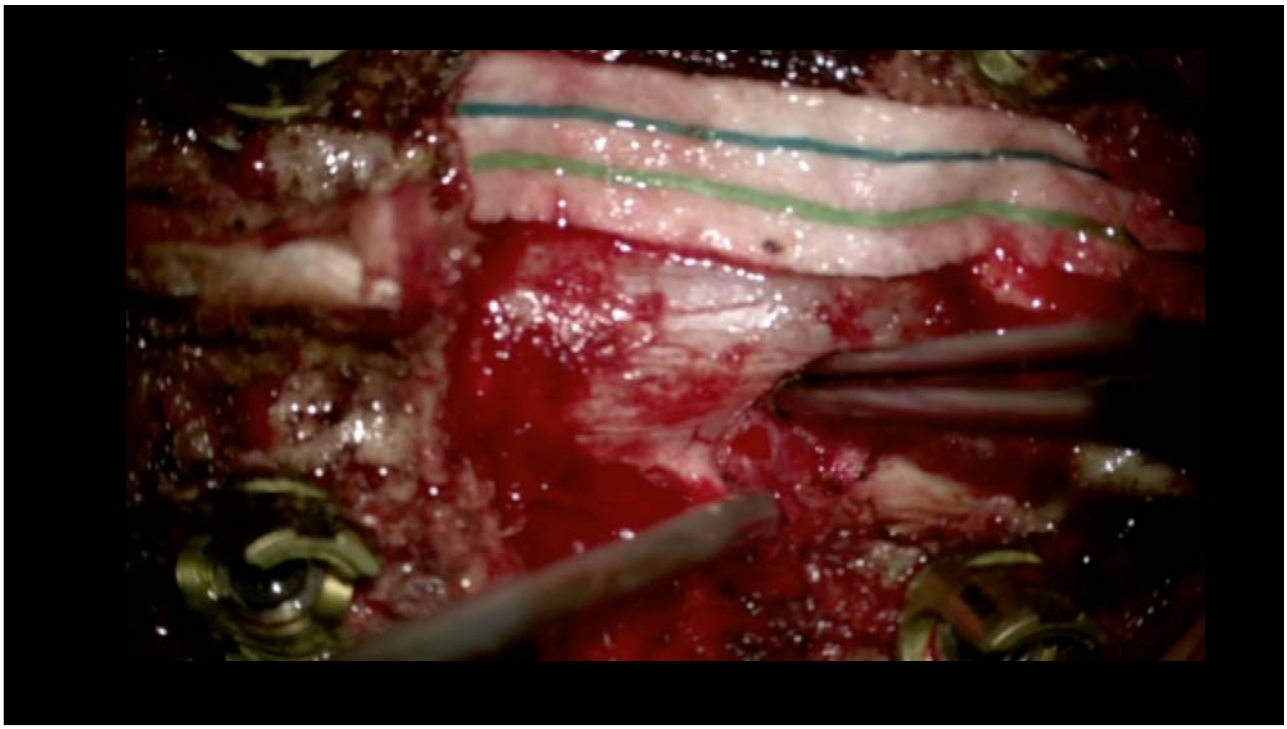

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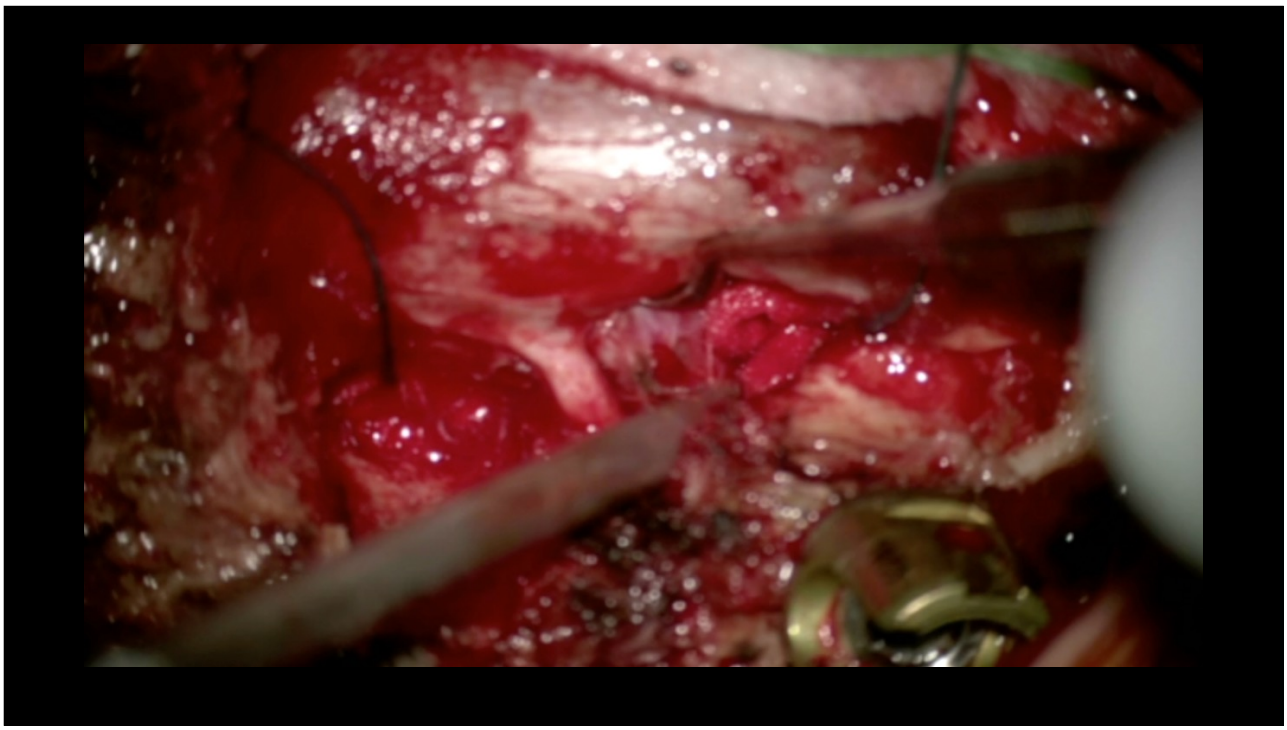

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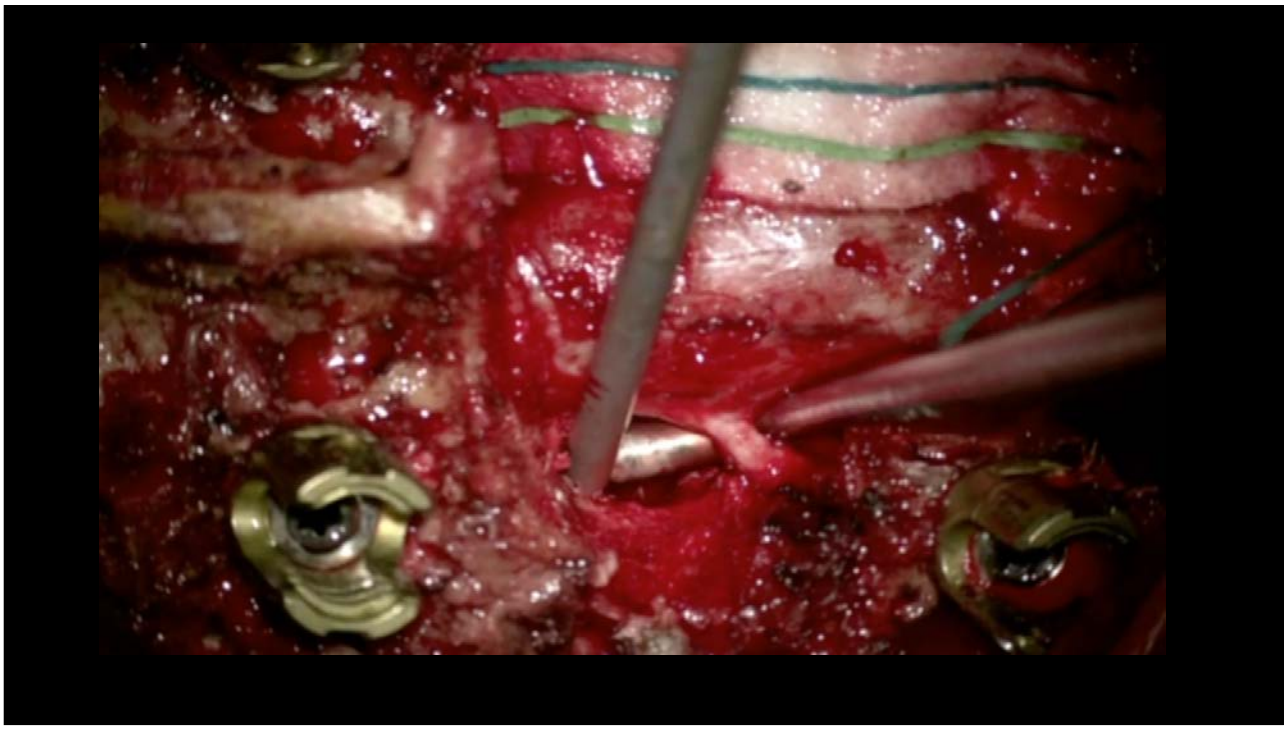

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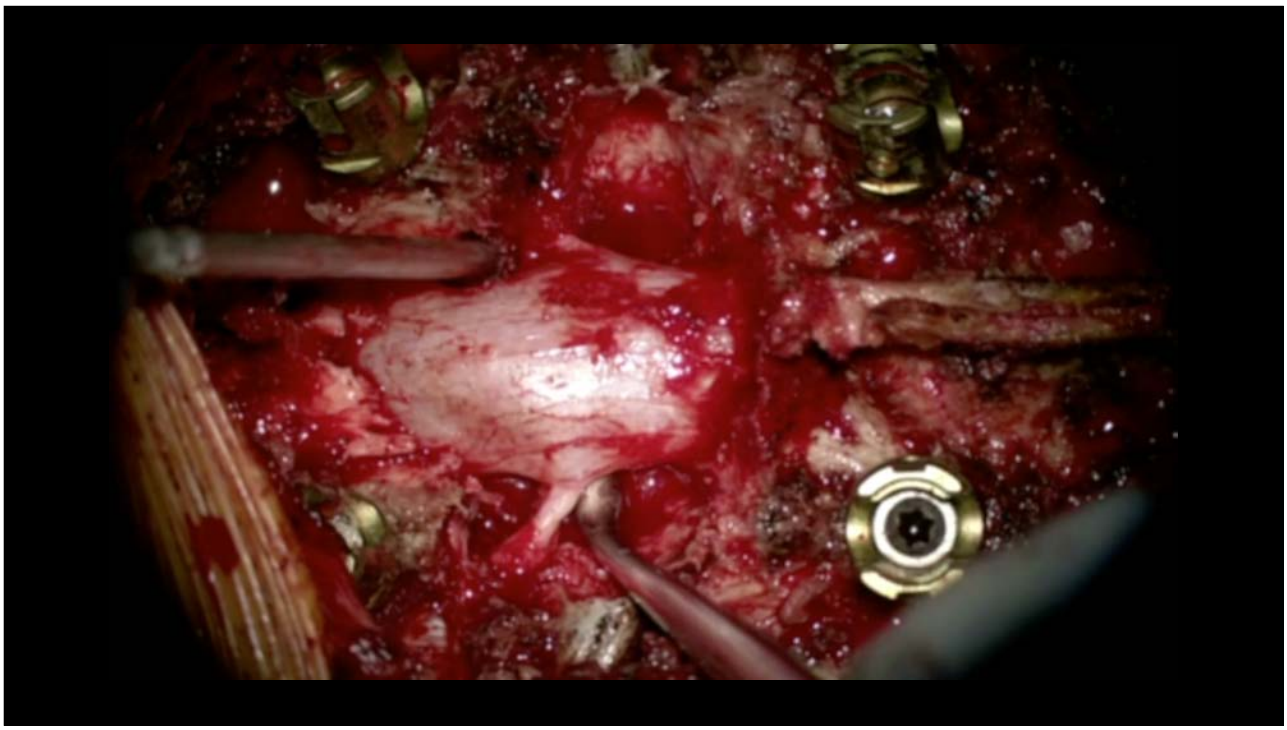

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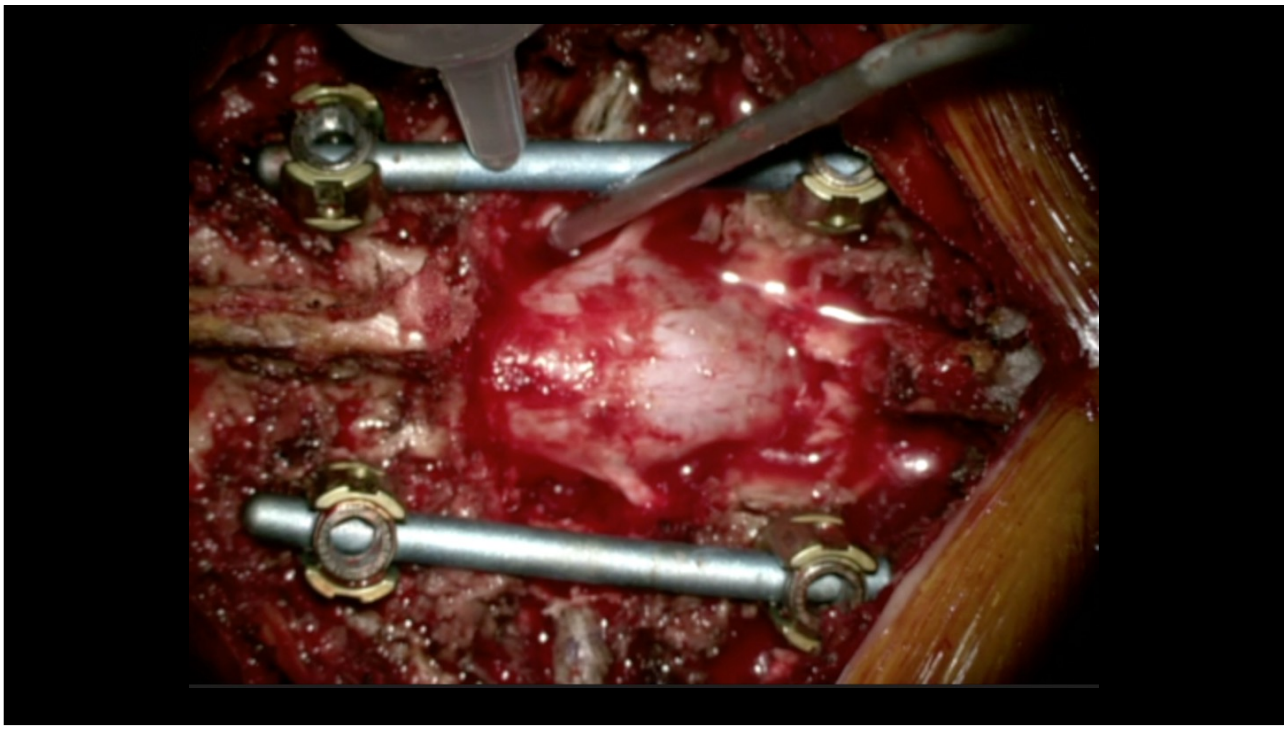

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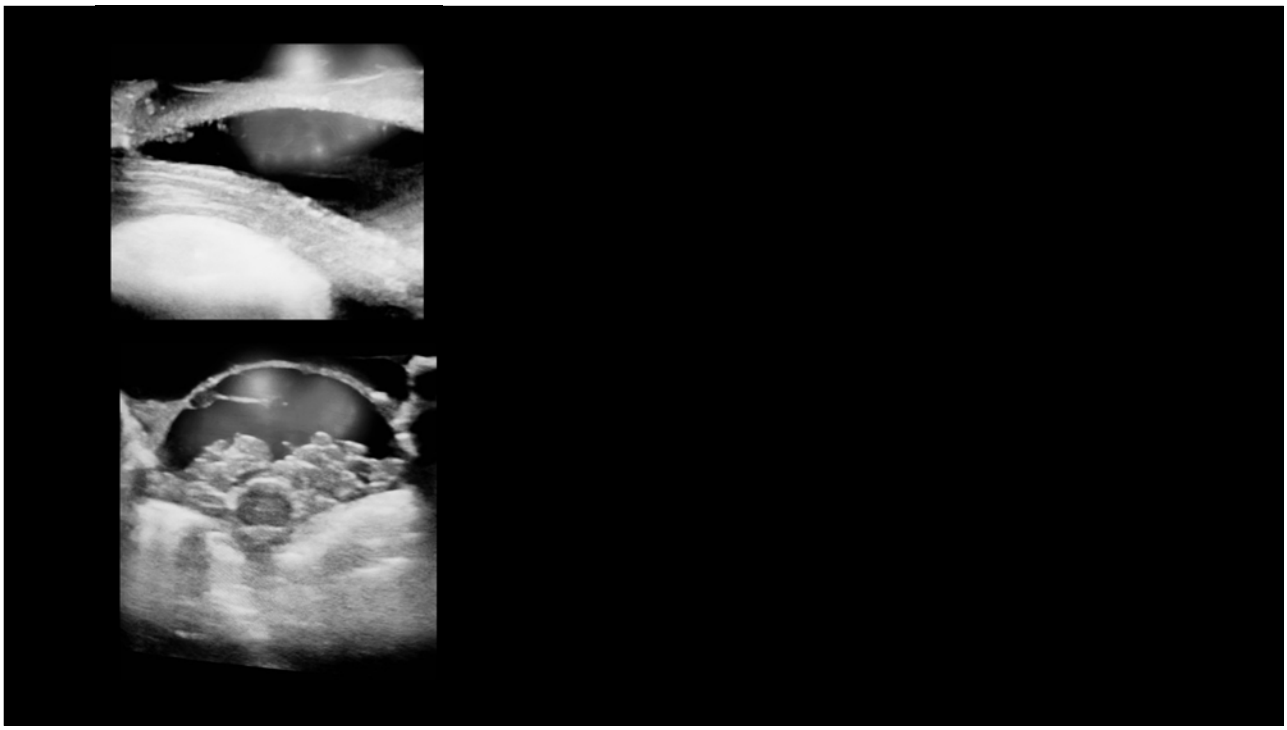

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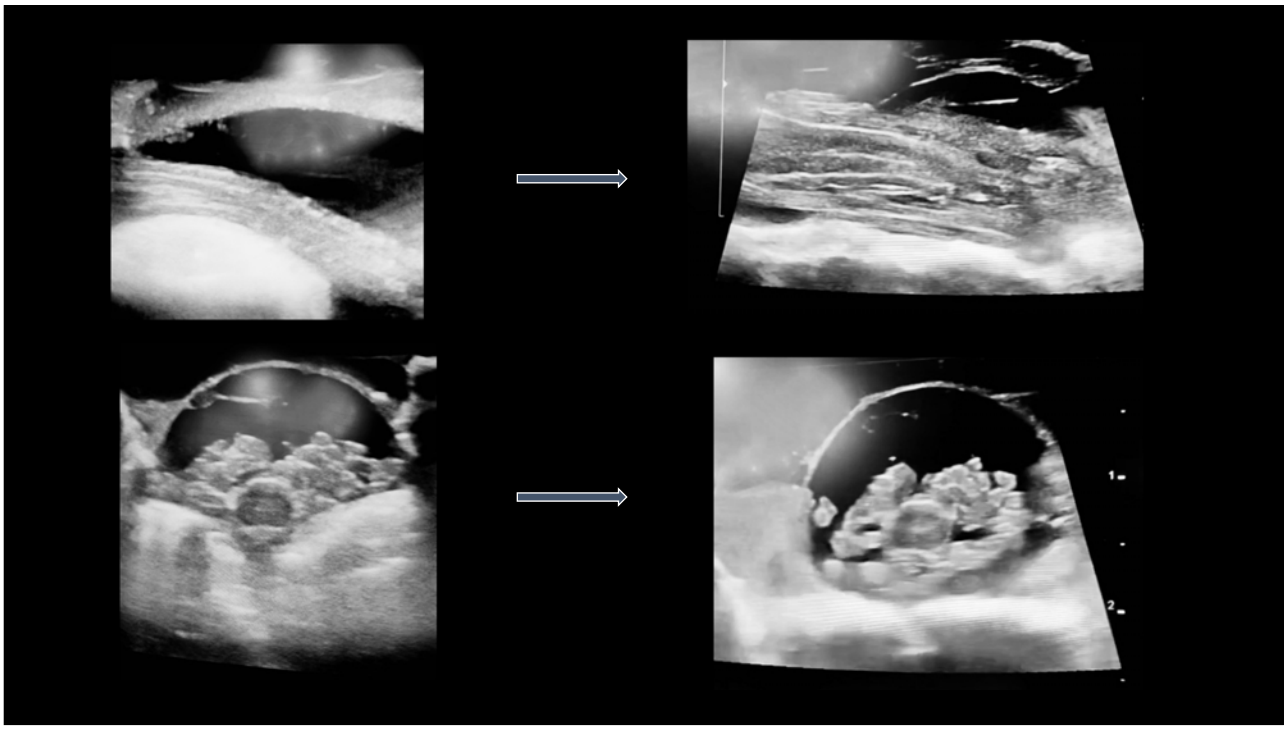

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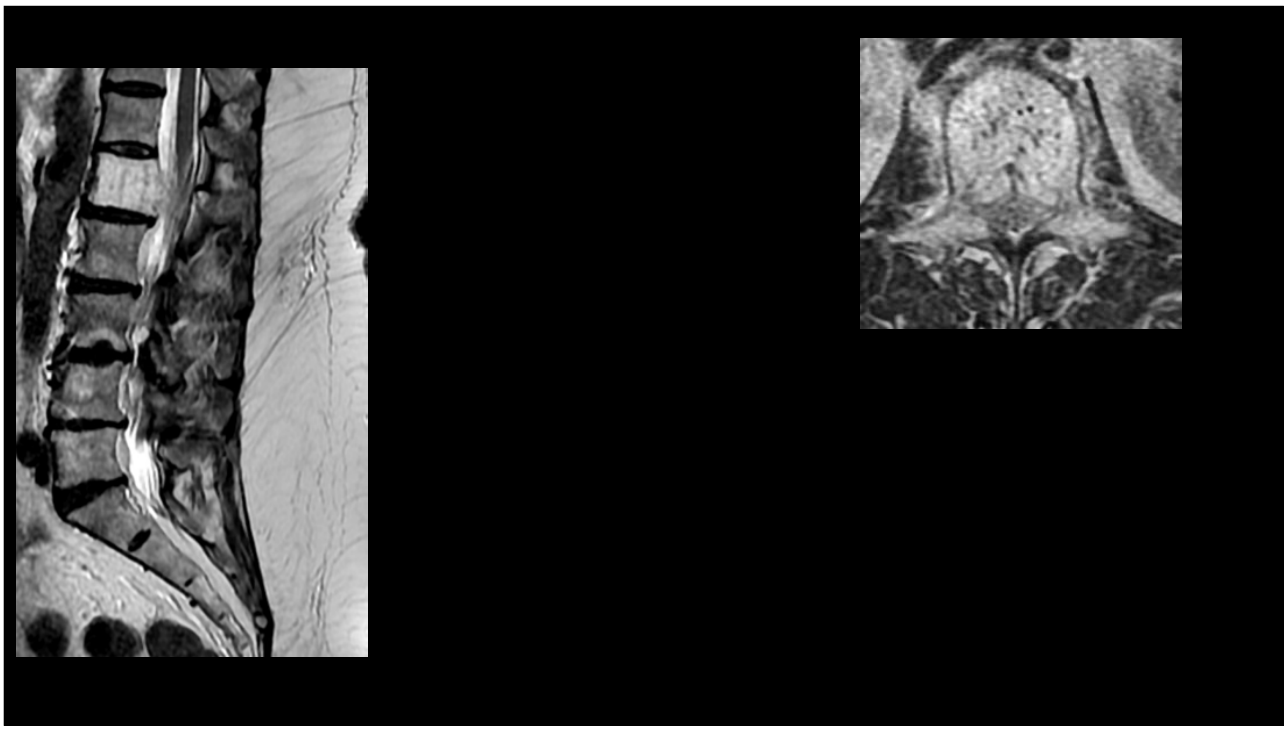

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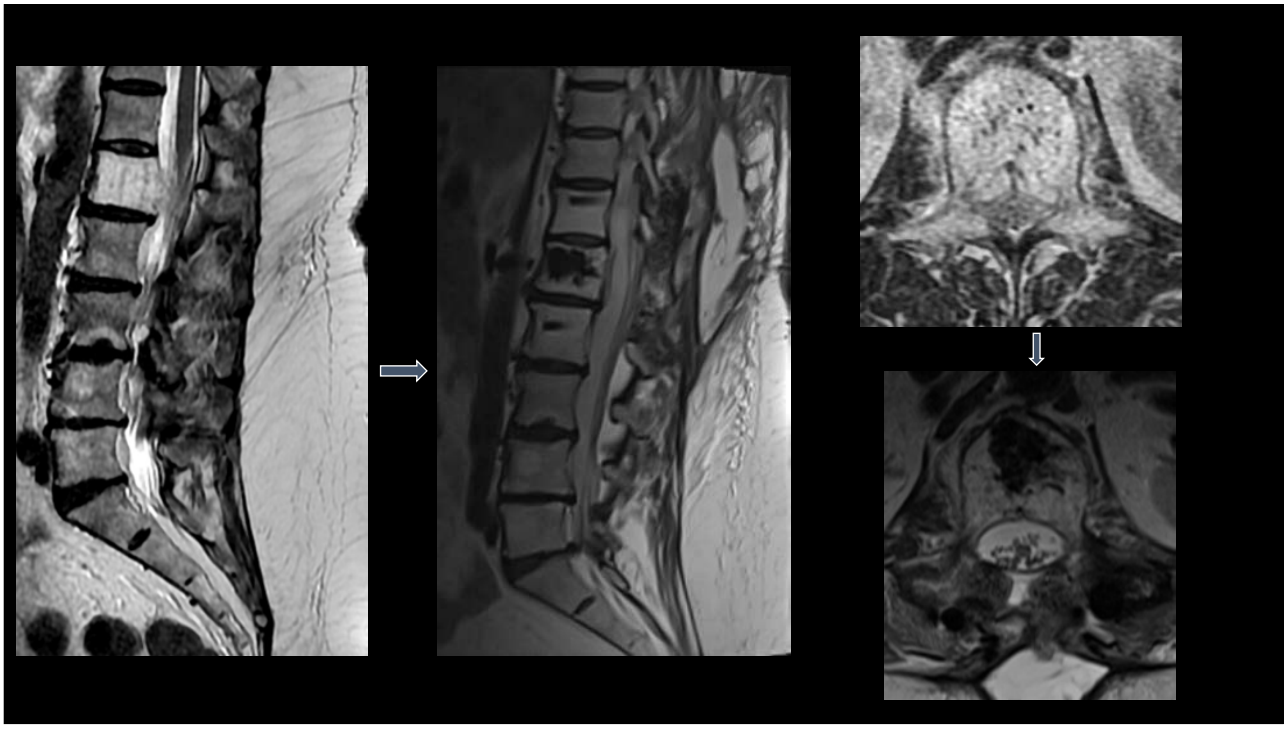

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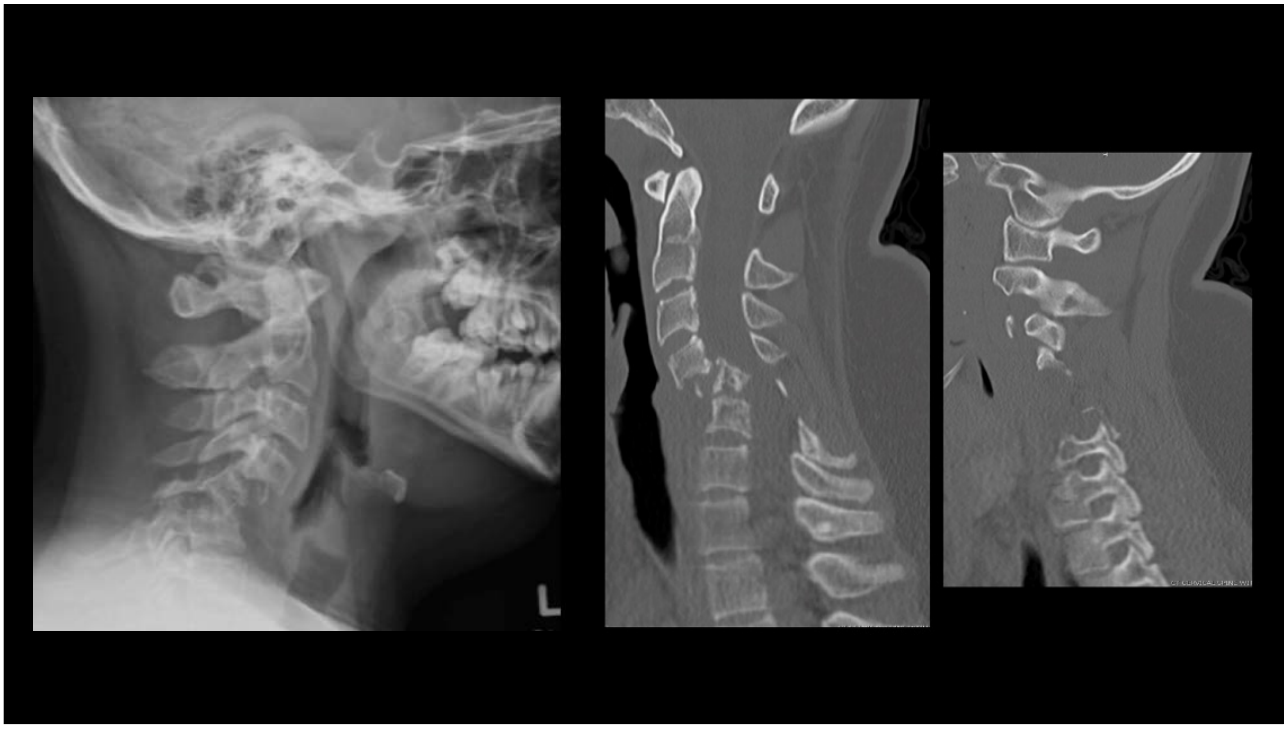

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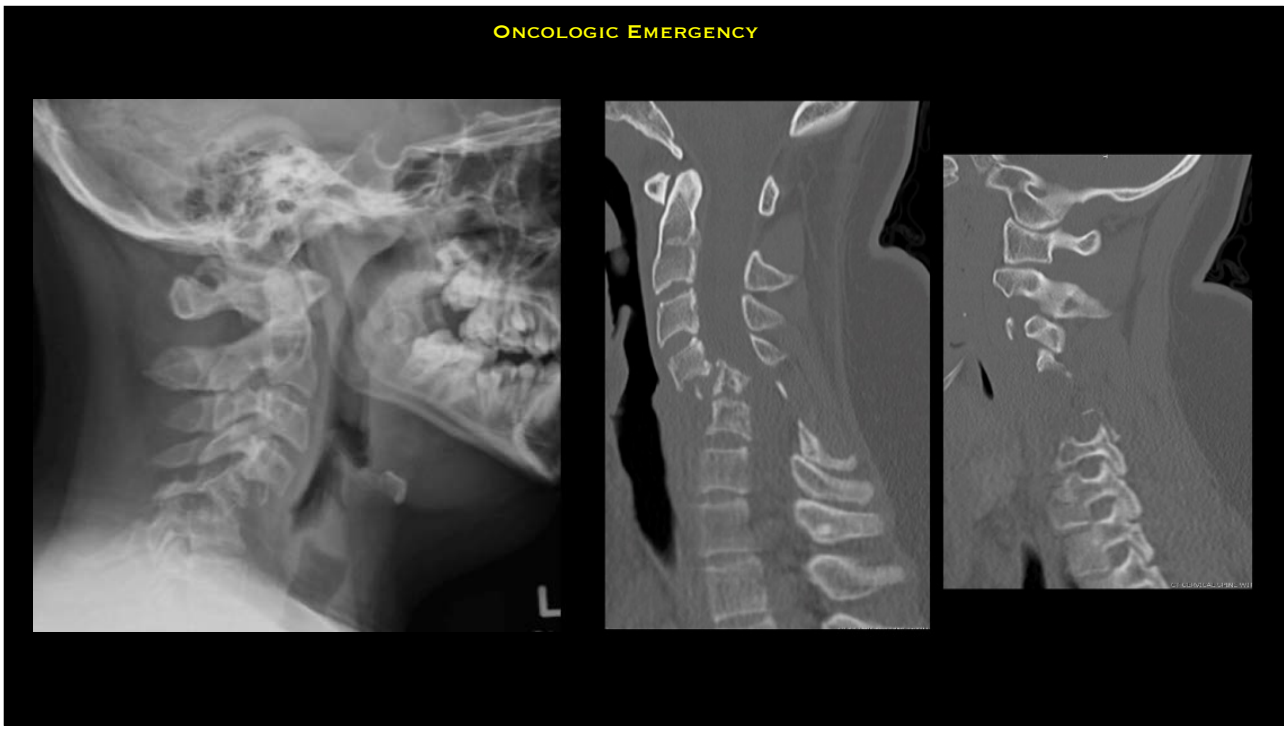
ONCOLOGIC EMERGENCY
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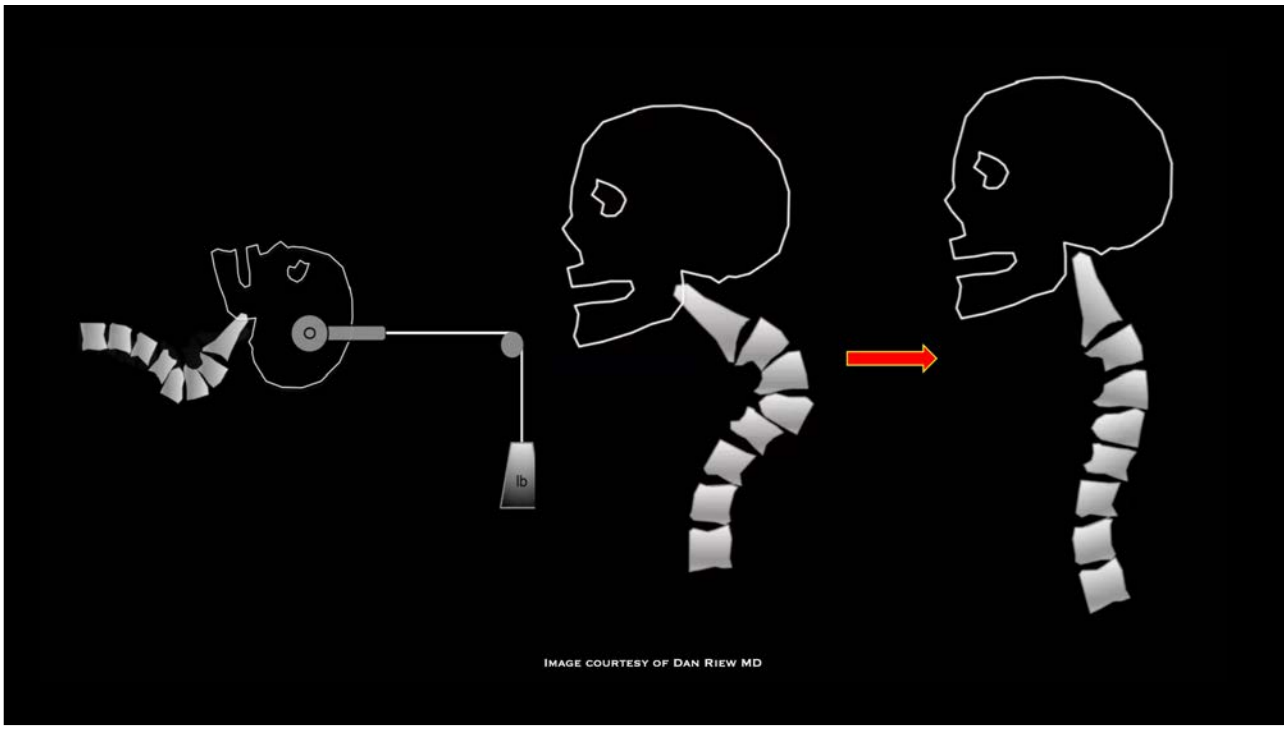
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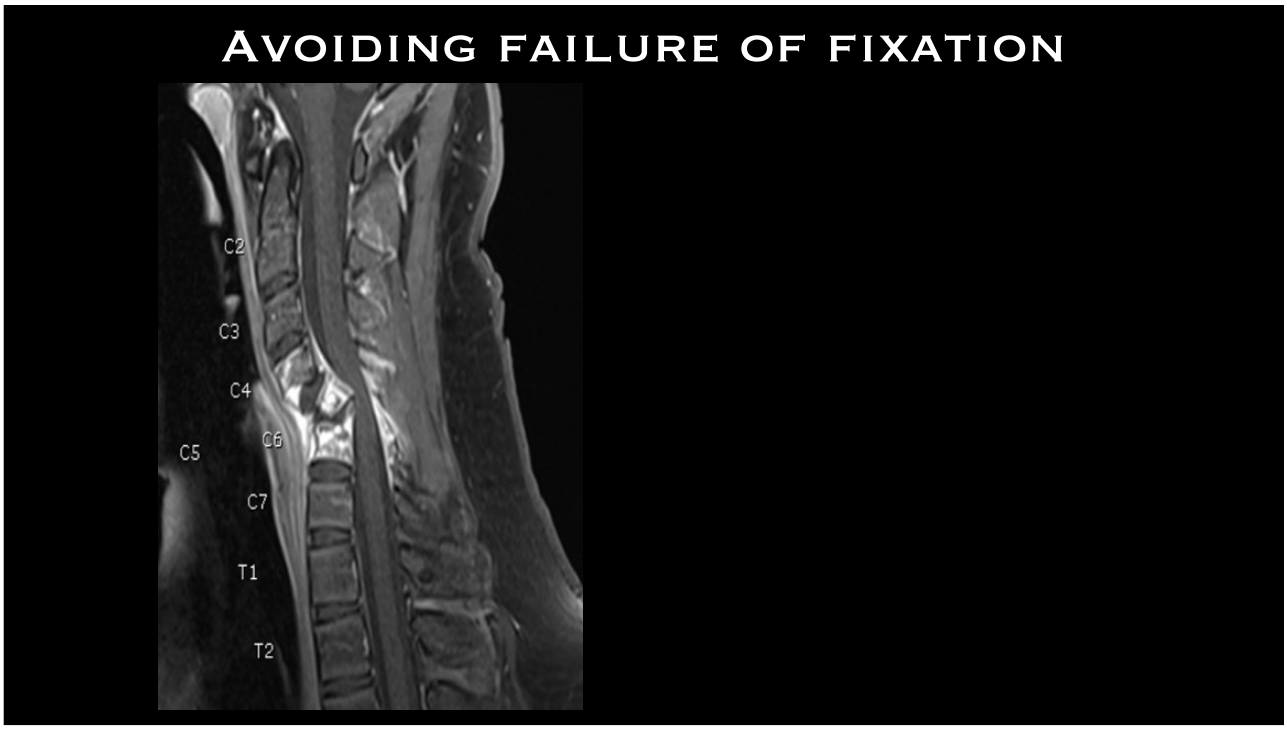
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AVOIDING FAILURE OF FIXATION
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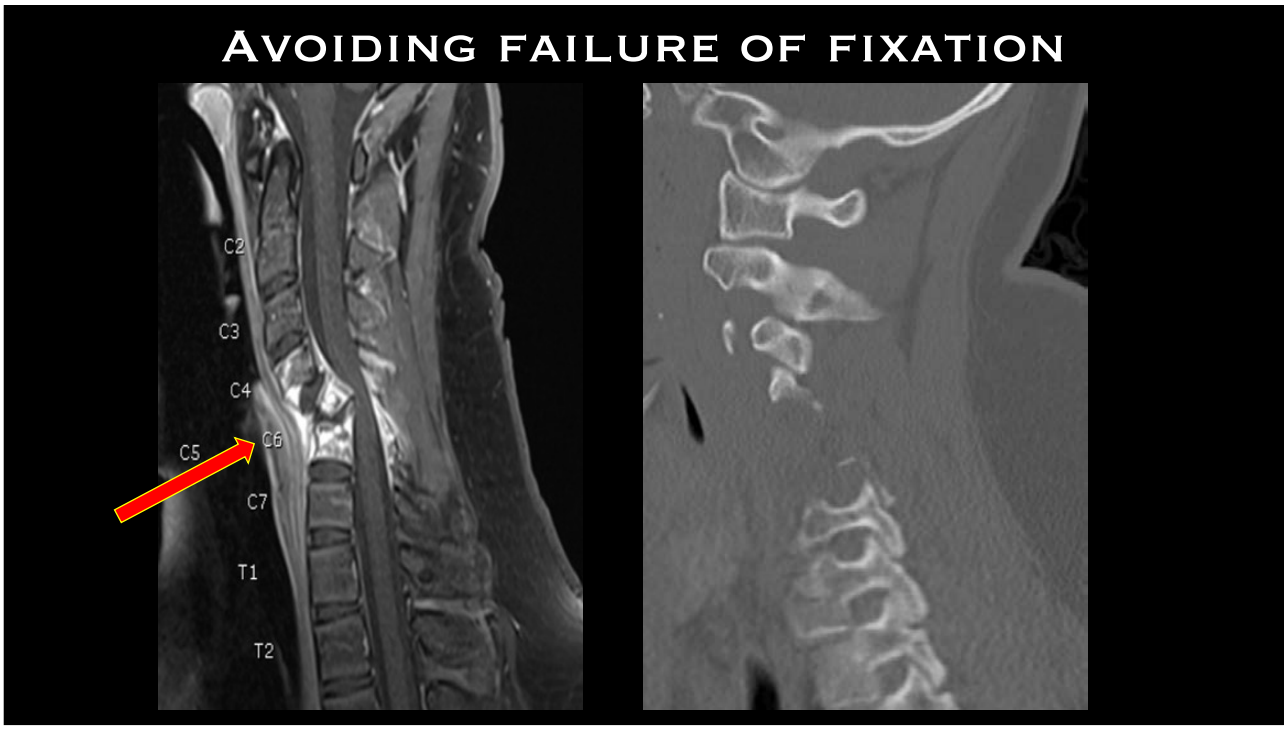
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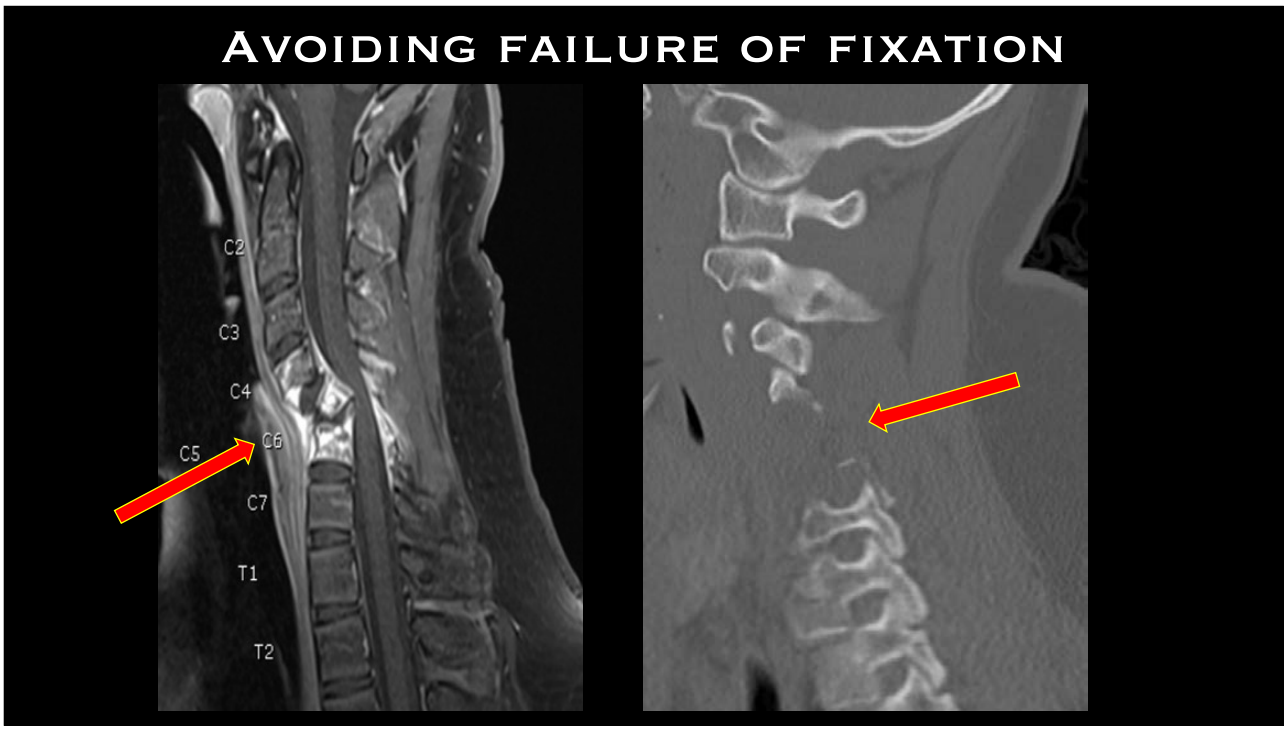
AVOIDING FAILURE OF FIXATION
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T2

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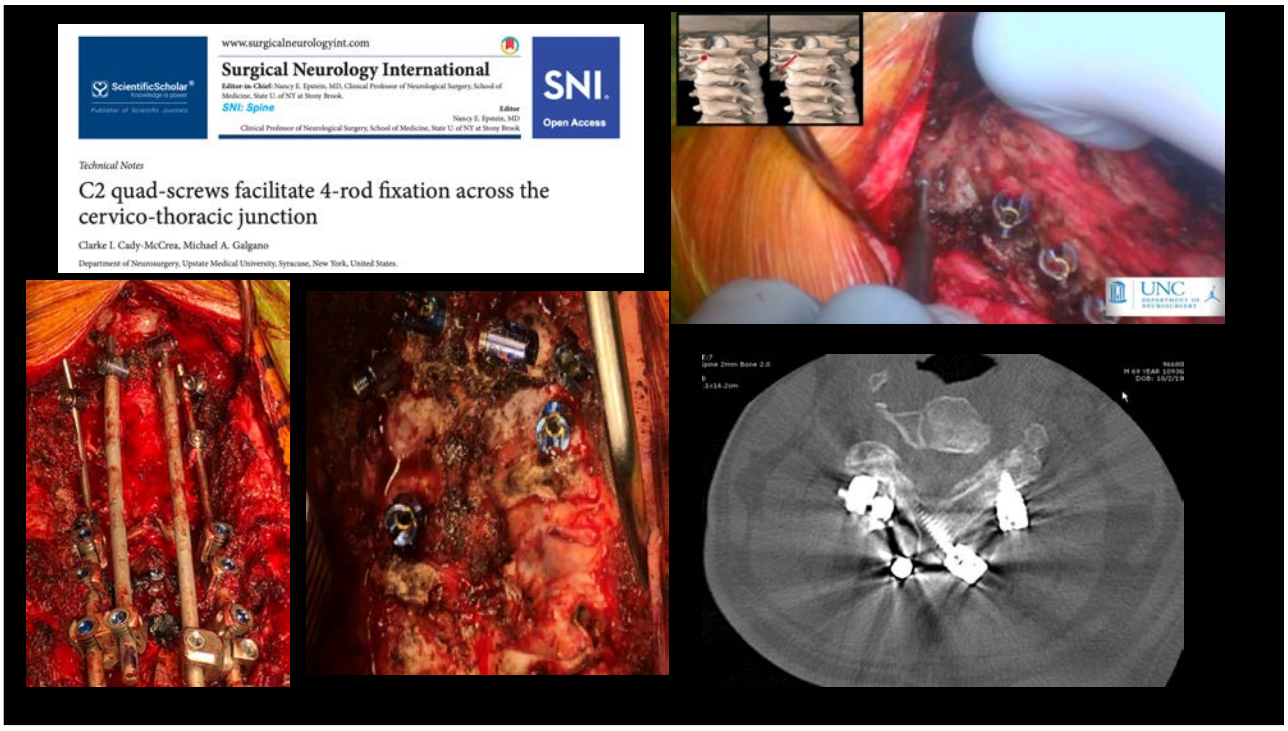
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Technical Notes
C2 quad-screws facilitate 4-rod fixation across the cervico-thoracic junction
Clarke I. Cady-McCrea, Michael A. Galgano
Department of Neurosurgery, Upstate Medical University, Syracuse, New York, United States.
UNC

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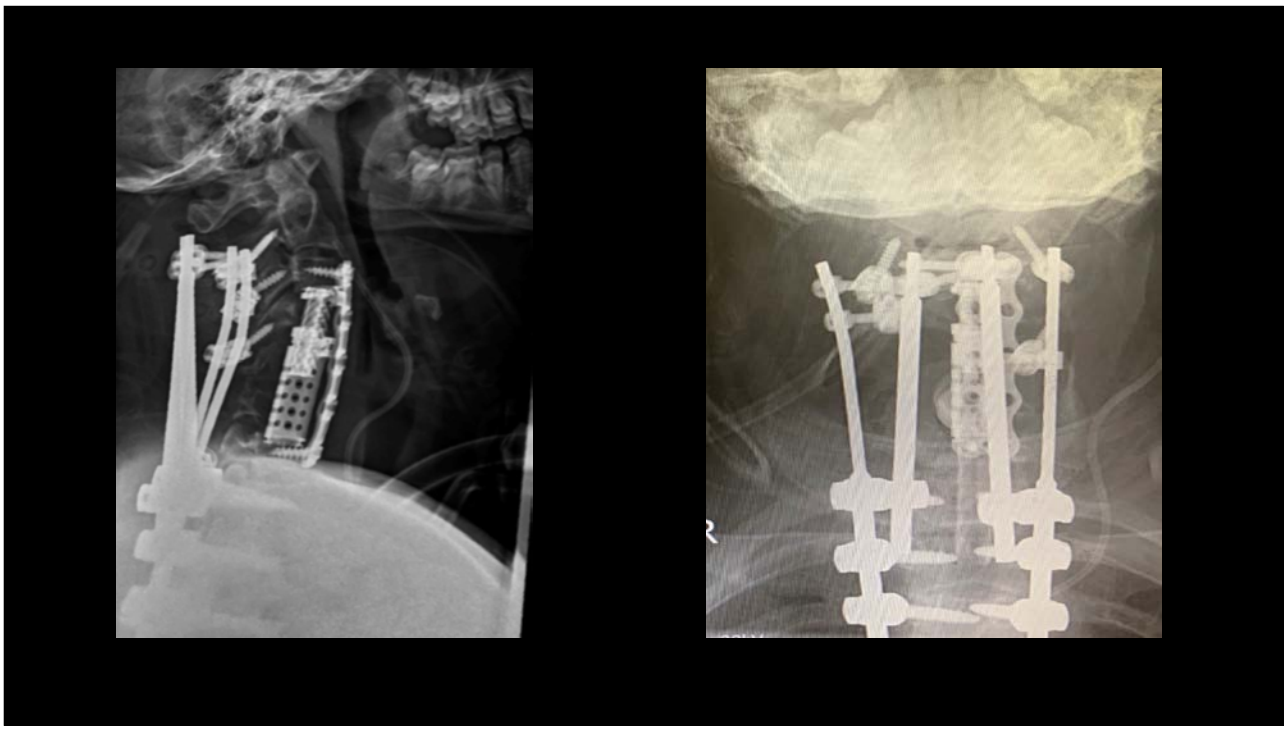

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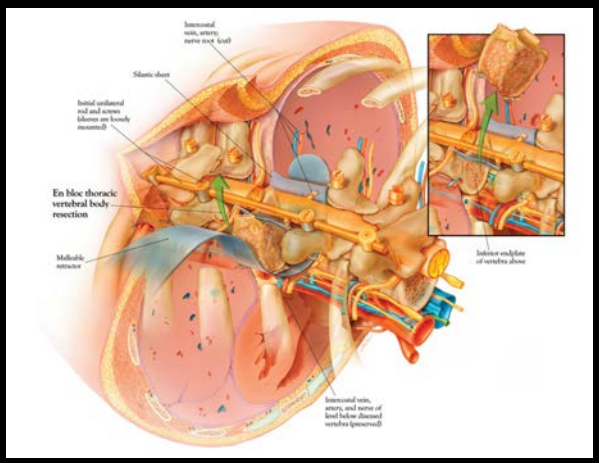
Primary Vertebral Column Tumors

- Osteochondroma
- Aneurysmal Bone Cyst (ABC)
- Hemangioma
- Osteoid osteoma
- Osteoblastoma
- Chondromyxoid fibroma
- *Giant Cell Tumor*
- Osteogenic sarcoma
- Ewing's sarcoma
- Plasmacytoma / Myeloma
- Chordoma
- Chrondrosarcoma



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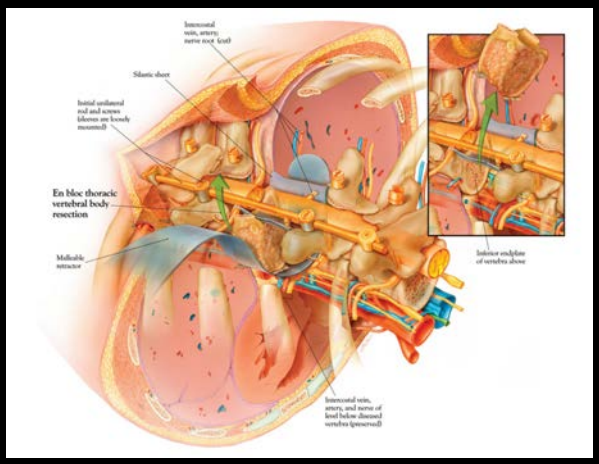
Primary Vertebral Column Tumors

- Osteochondroma
- Aneurysmal Bone Cyst (ABC)
- Hemangioma
- Osteoid osteoma
- Osteoblastoma
- Chondromyxoid fibroma
- *Giant Cell Tumor*
- Osteogenic sarcoma
- Ewing's sarcoma
- Plasmacytoma / Myeloma
- Chordoma
- Chrondrosarcoma

Metastatic Potential



313

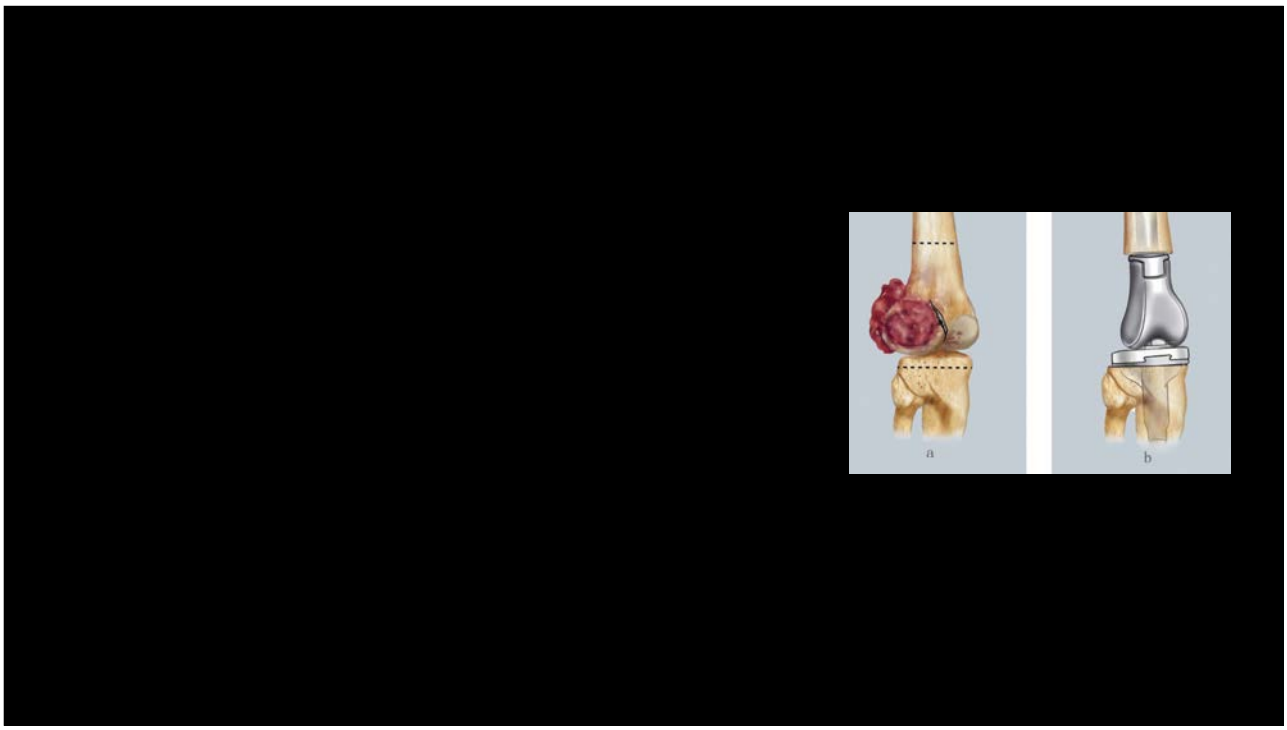
What is the ideal treatment to induce an oncological cure or prolonged disease-free intervals in patients with malignant primary bone tumors (ie. sacral chordoma)?

Nobody has responded yet.

Hang tight! Responses are coming in.

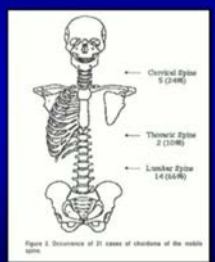
Start the presentation to see live content. For screen share software, share the entire screen. Get help at **pollev.com/app**

314



315

Method of Resection Correlates Strongly with Disease-Free Survival



Boriani et al, SPINE 21:1569-1577, 1996

Table 2. Treatment and Evolution of 21 Cases of Chordoma of the Spine

Treatment	No. of Cases	Progression: Local	Progression: Recurrence	No. of Deaths
RTR ± palliative surgery	9	8	(0-26 mo)	7 (1-135 mo; avg 57)
Intralesional excision	2	2	(18-41 mo)	1 (72 mo)
Intralesional excision + RTR	6	4	(7-119 mo; avg 60 mo)	7 (15-129 mo)
Marginal resection	2	0	(48-108 mo)	
Marginal resection + RTR	2	0	(39-112 mo)	

RTR = conventional radiation therapy (dose, 30-60 Gy); avg = average.

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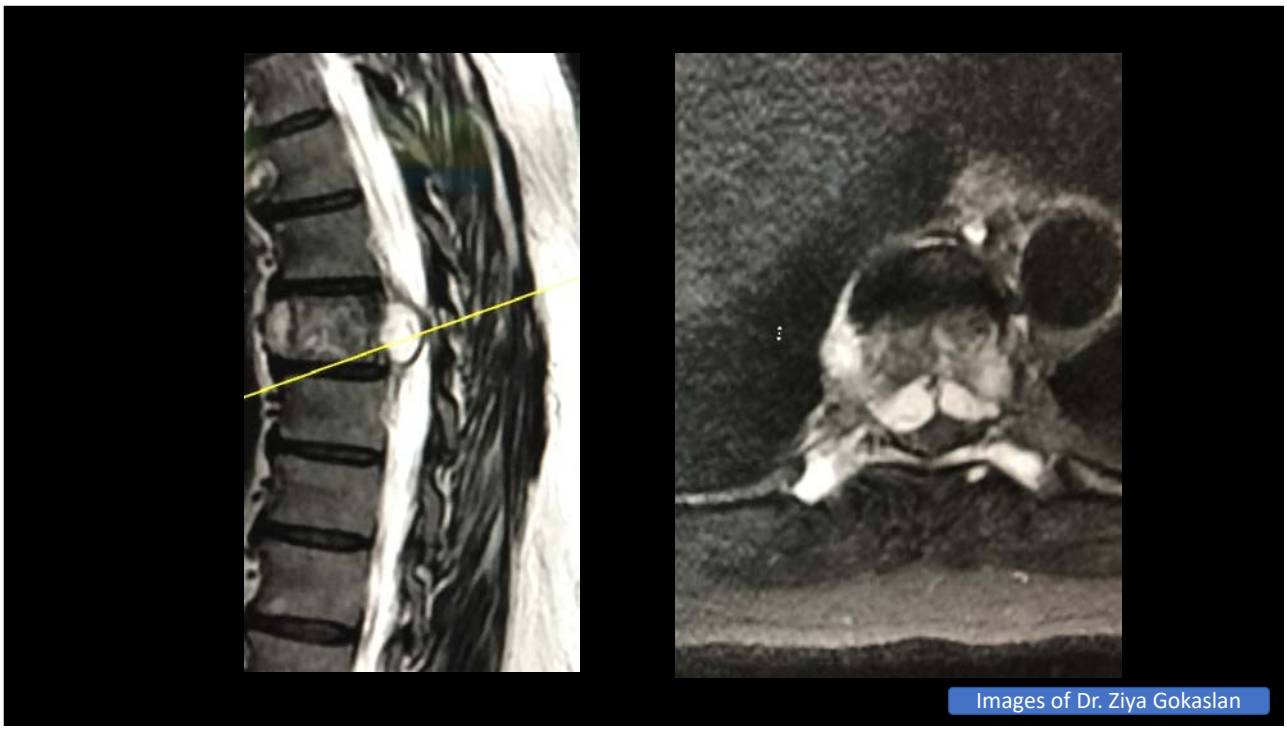

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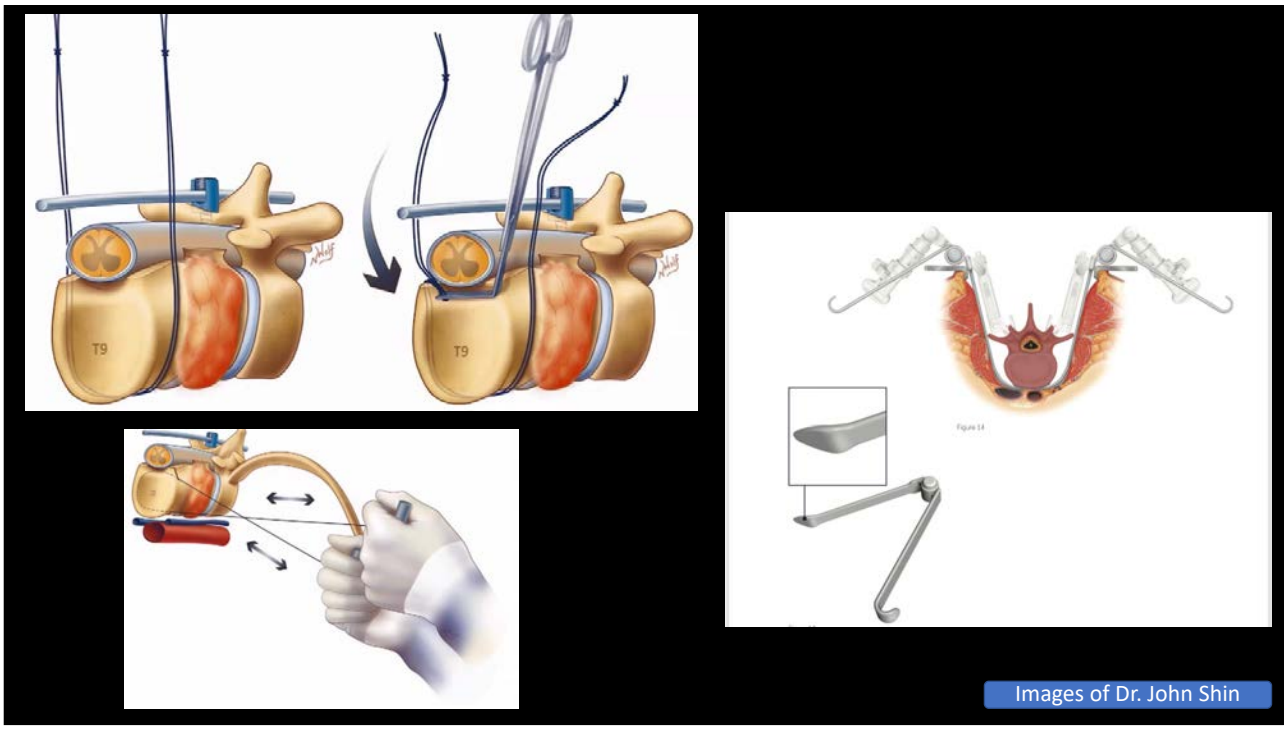

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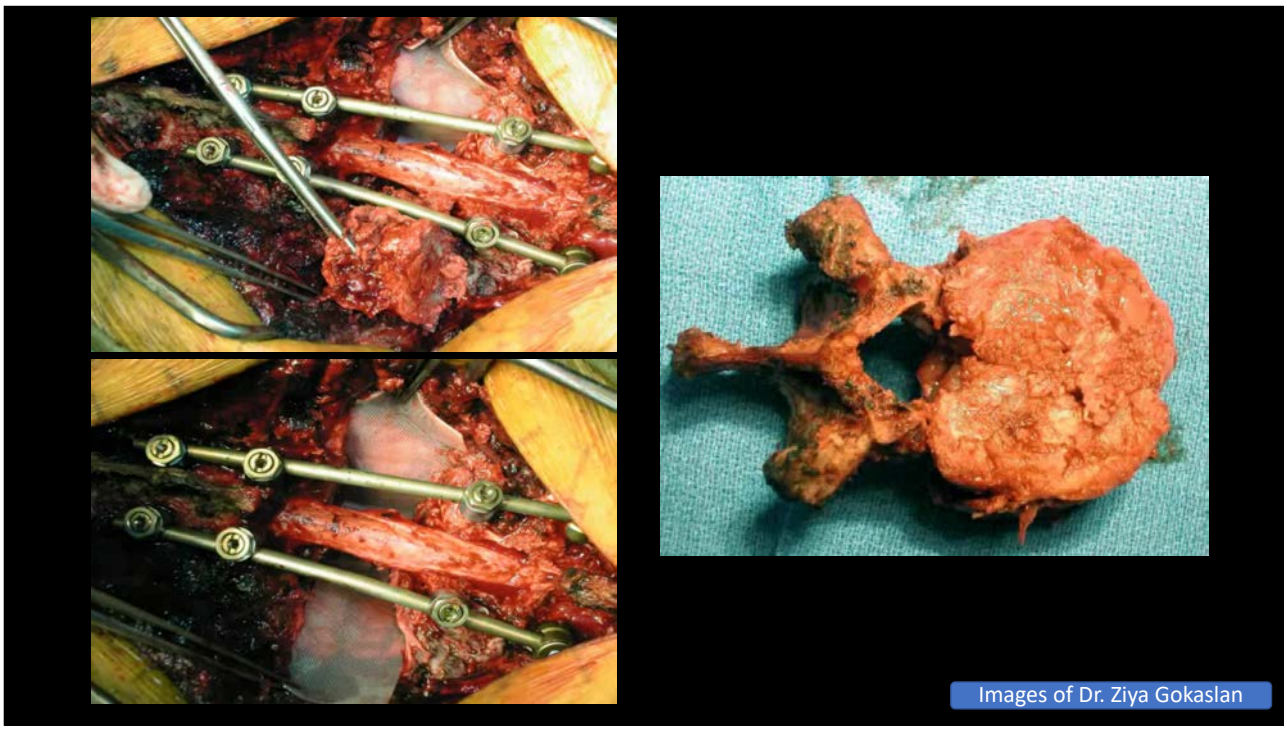
Images of Dr. Ziya Gokaslan

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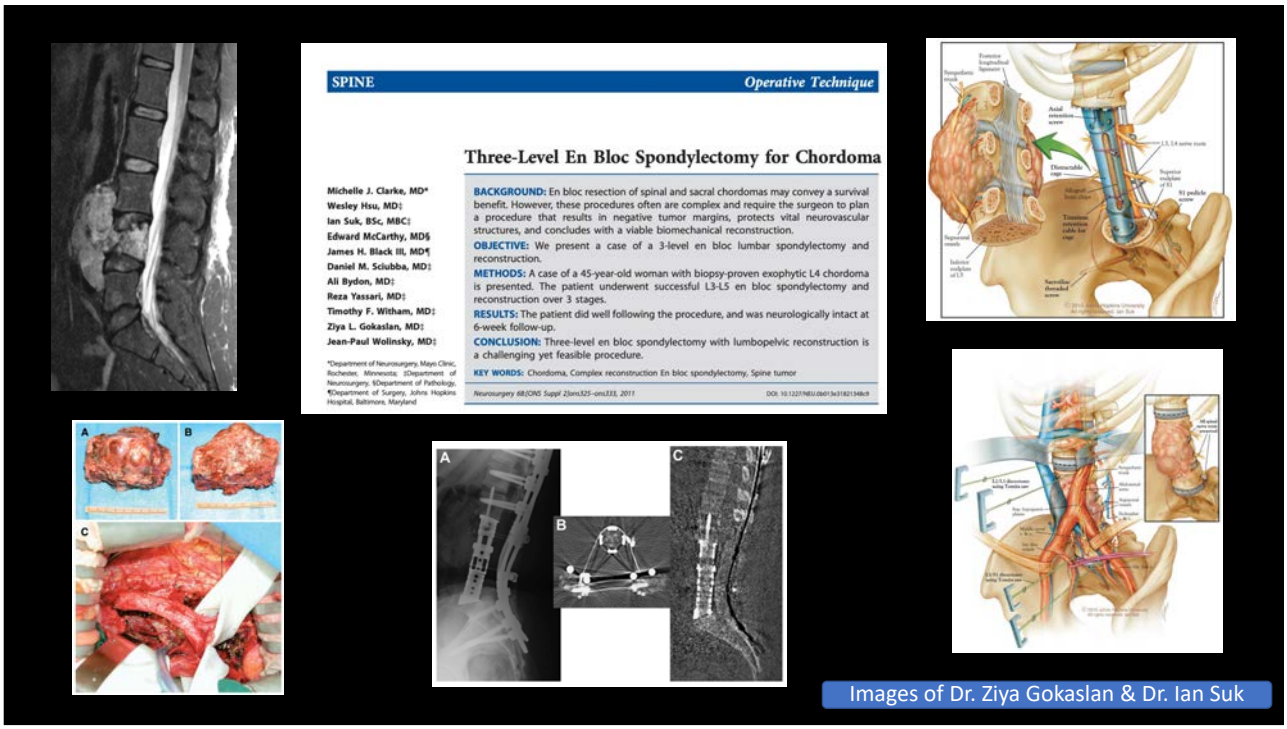
SPINE
Operative Technique
Three-Level En Bloc Spondylectomy for Chordoma
Michelle J. Clarke, MD*
Wesley Hsu, MD‡
Ian Suk, BSc, MBC‡
Edward McCarthy, MD§
James H. Black III, MD¶
Daniel M. Sciubba, MD‡
Ali Bydon, MD‡
Reza Yassari, MD‡
Timothy F. Witham, MD‡
Ziya L. Gokaslan, MD‡
Jean-Paul Wolinsky, MD‡
BACKGROUND: En bloc resection of spinal and sacral chordomas may convey a survival benefit. However, these procedures often are complex and require the surgeon to plan a procedure that results in negative tumor margins, protects vital neurovascular structures, and concludes with a viable biomechanical reconstruction.
OBJECTIVE: We present a case of a 3-level en bloc lumbar spondylectomy and reconstruction.
METHODS: A case of a 45-year-old woman with biopsy-proven exophytic L4 chordoma is presented. The patient underwent successful L3-L5 en bloc spondylectomy and reconstruction over 3 stages.
RESULTS: The patient did well following the procedure, and was neurologically intact at 6-week follow-up.
CONCLUSION: Three-level en bloc spondylectomy with lumbopelvic reconstruction is a challenging yet feasible procedure.
KEY WORDS: Chordoma, Complex reconstruction En bloc spondylectomy, Spine tumor
Images of Dr. Ziya Gokaslan & Dr. Ian Suk

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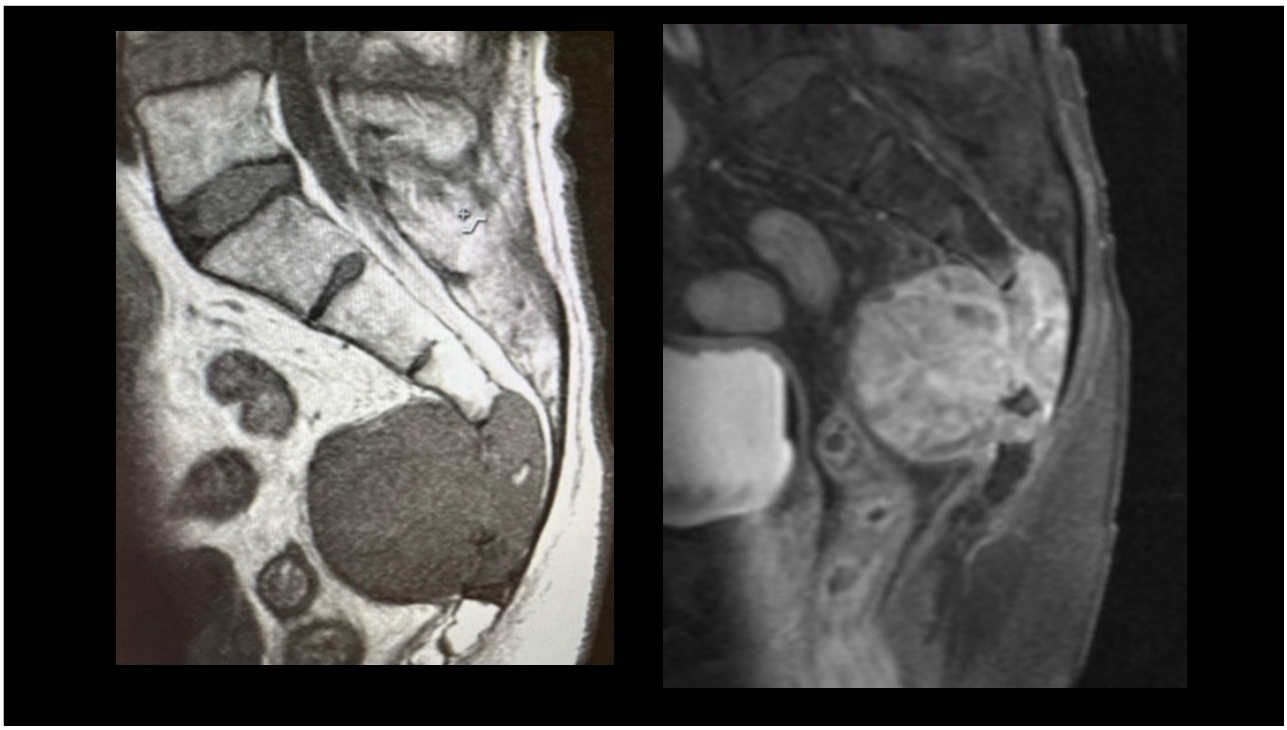

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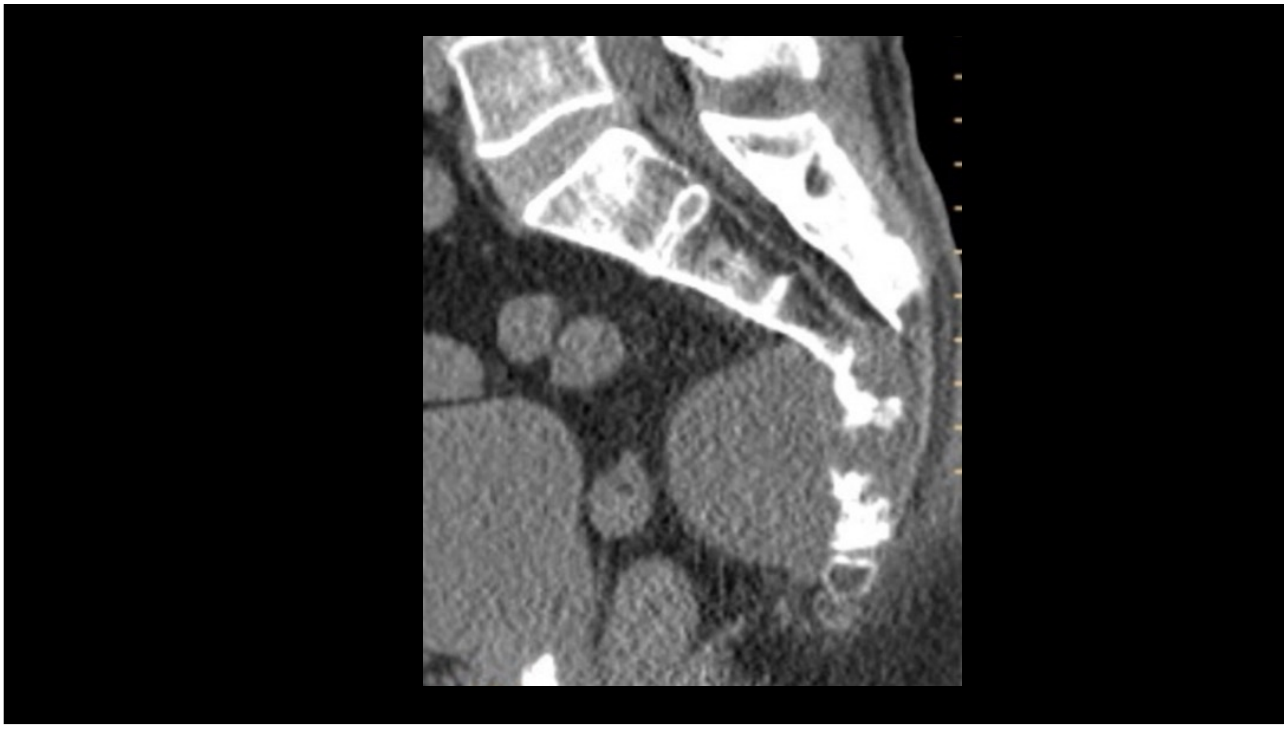

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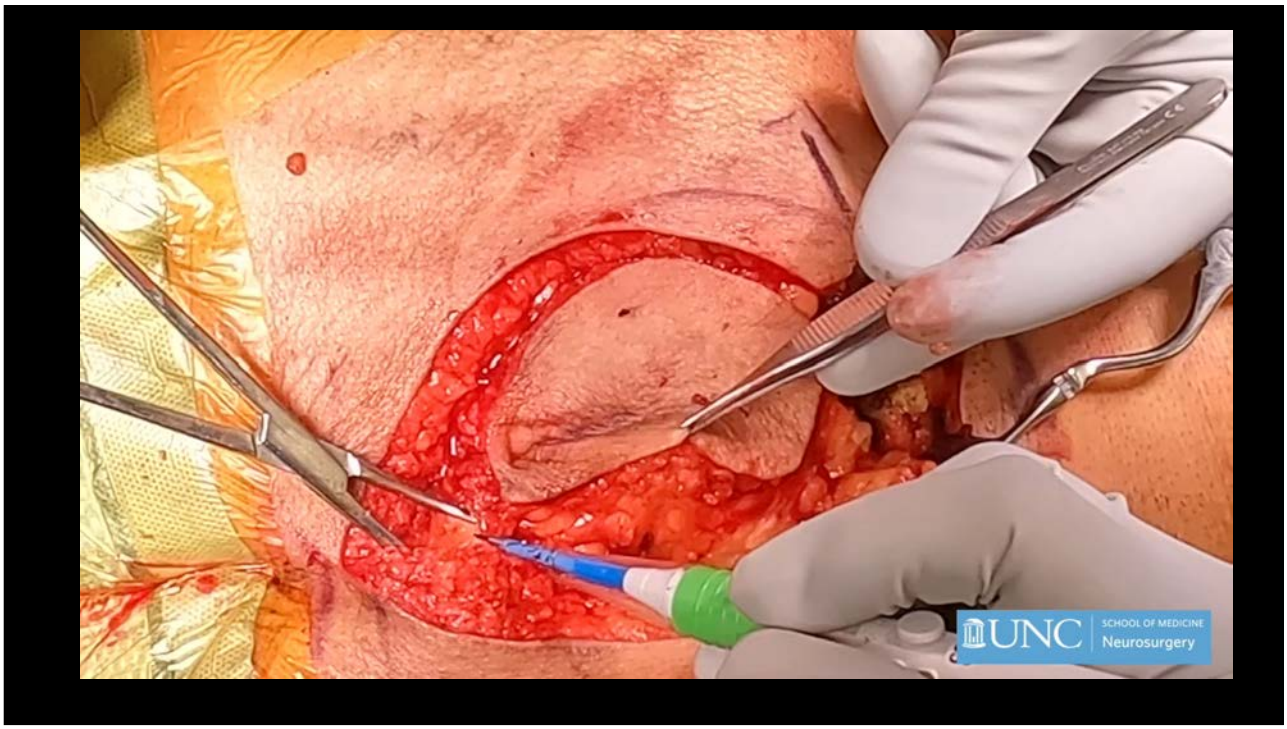

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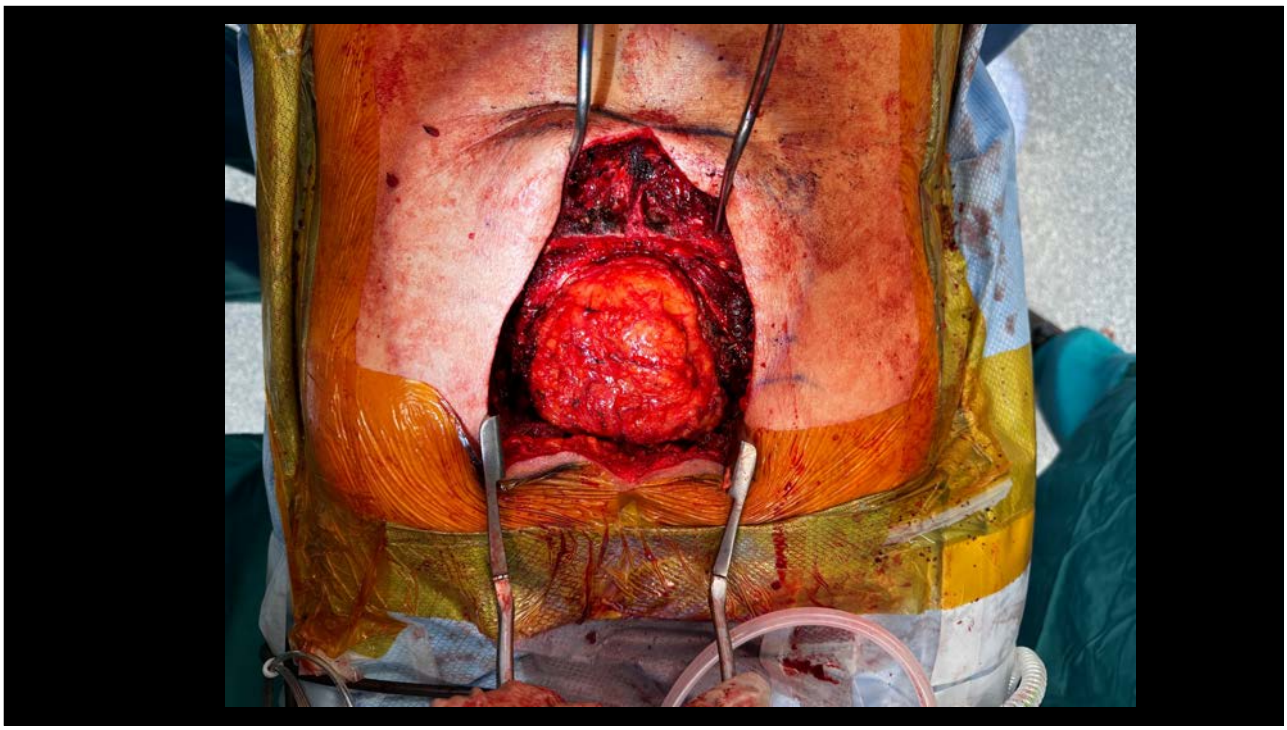

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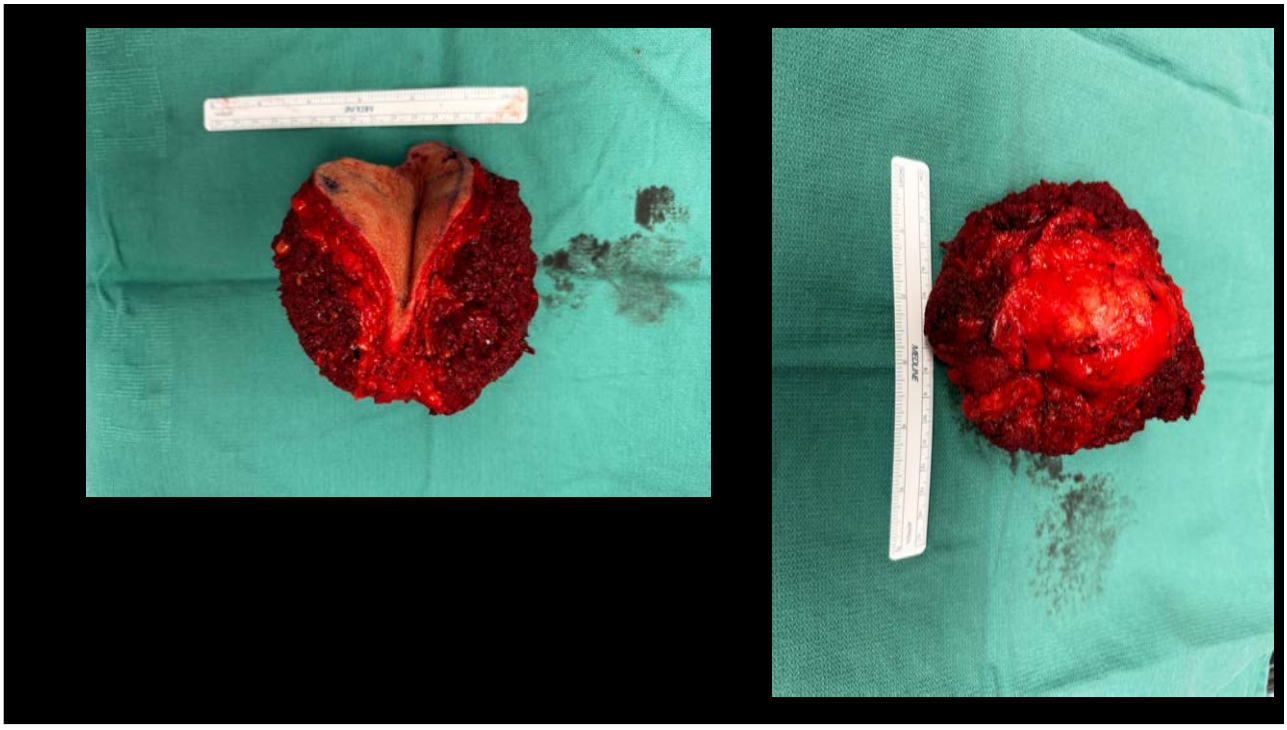

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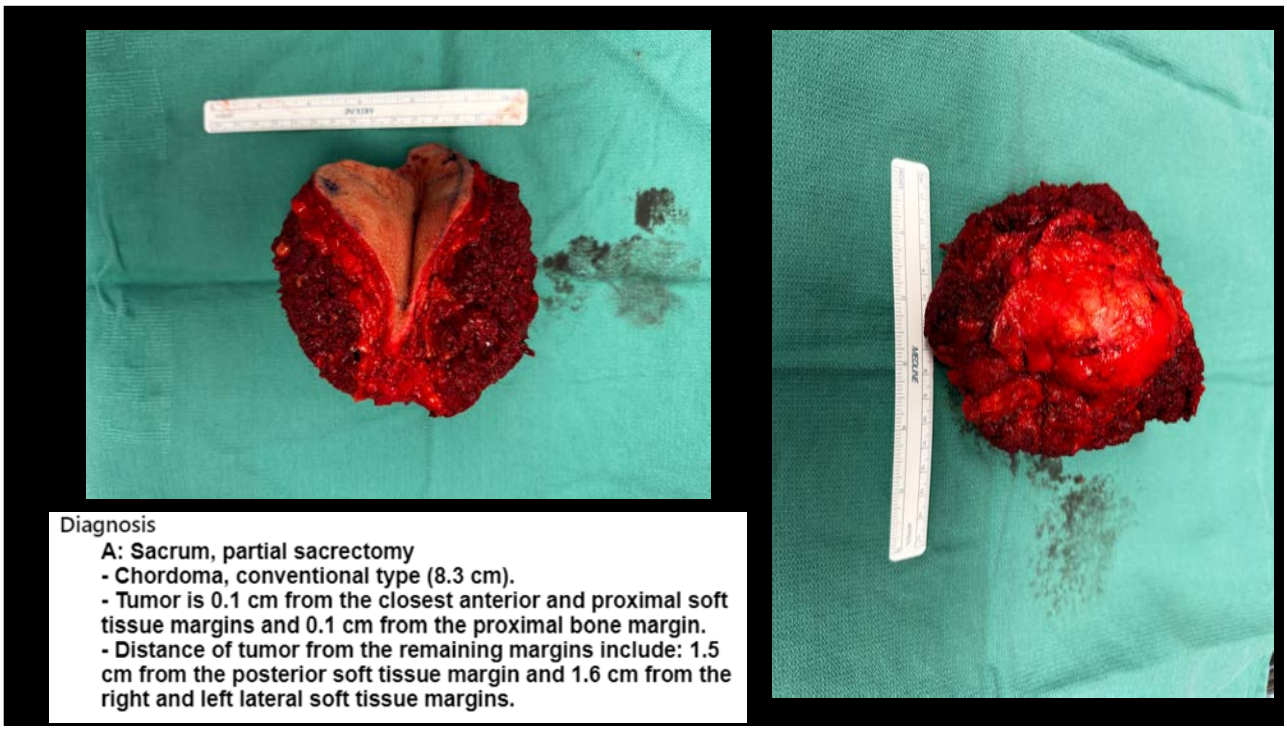
Diagnosis
A: Sacrum, partial sacrectomy
- Chordoma, conventional type (8.3 cm).
- Tumor is 0.1 cm from the closest anterior and proximal soft tissue margins and 0.1 cm from the proximal bone margin.
- Distance of tumor from the remaining margins include: 1.5 cm from the posterior soft tissue margin and 1.6 cm from the right and left lateral soft tissue margins.

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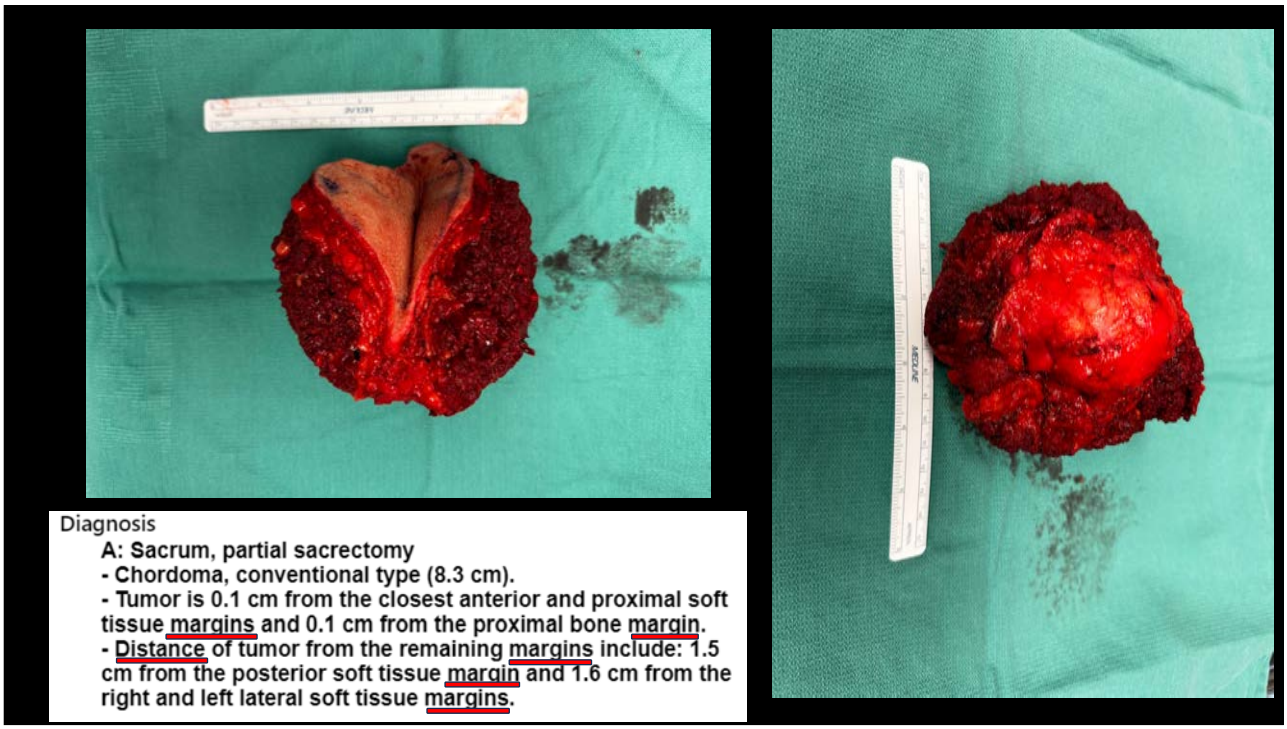
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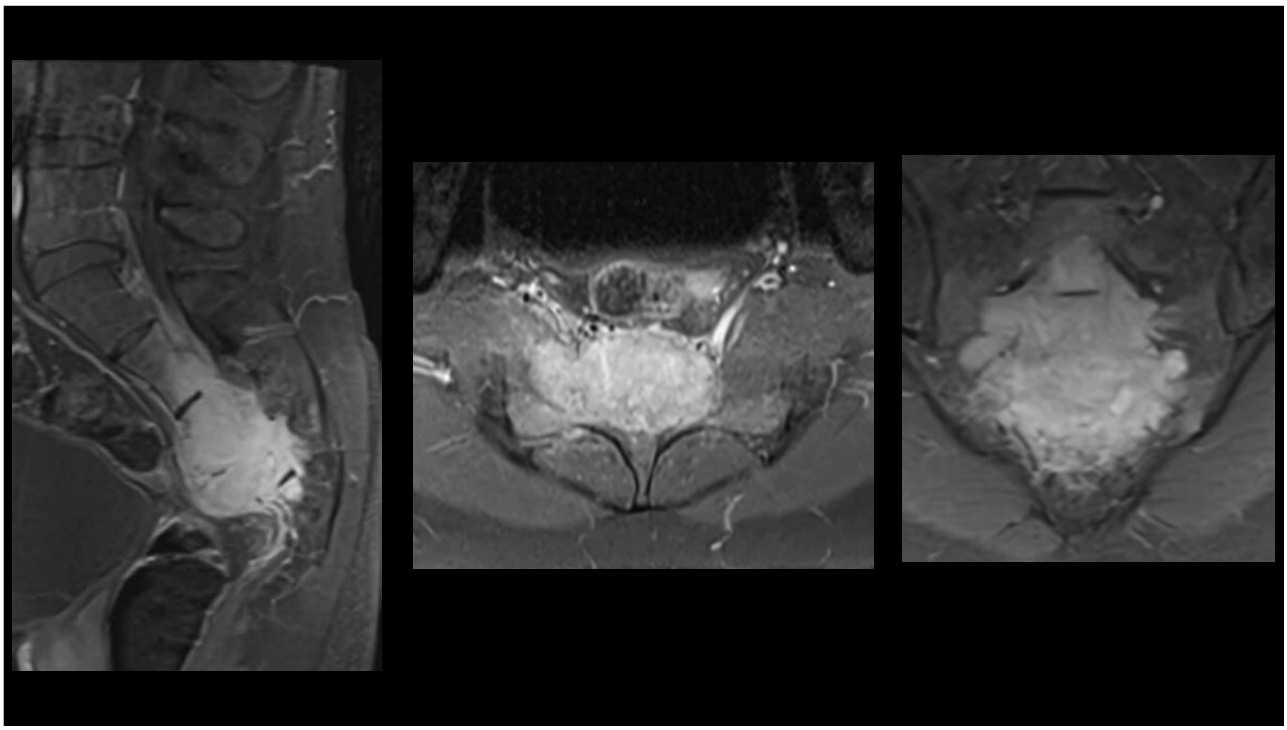

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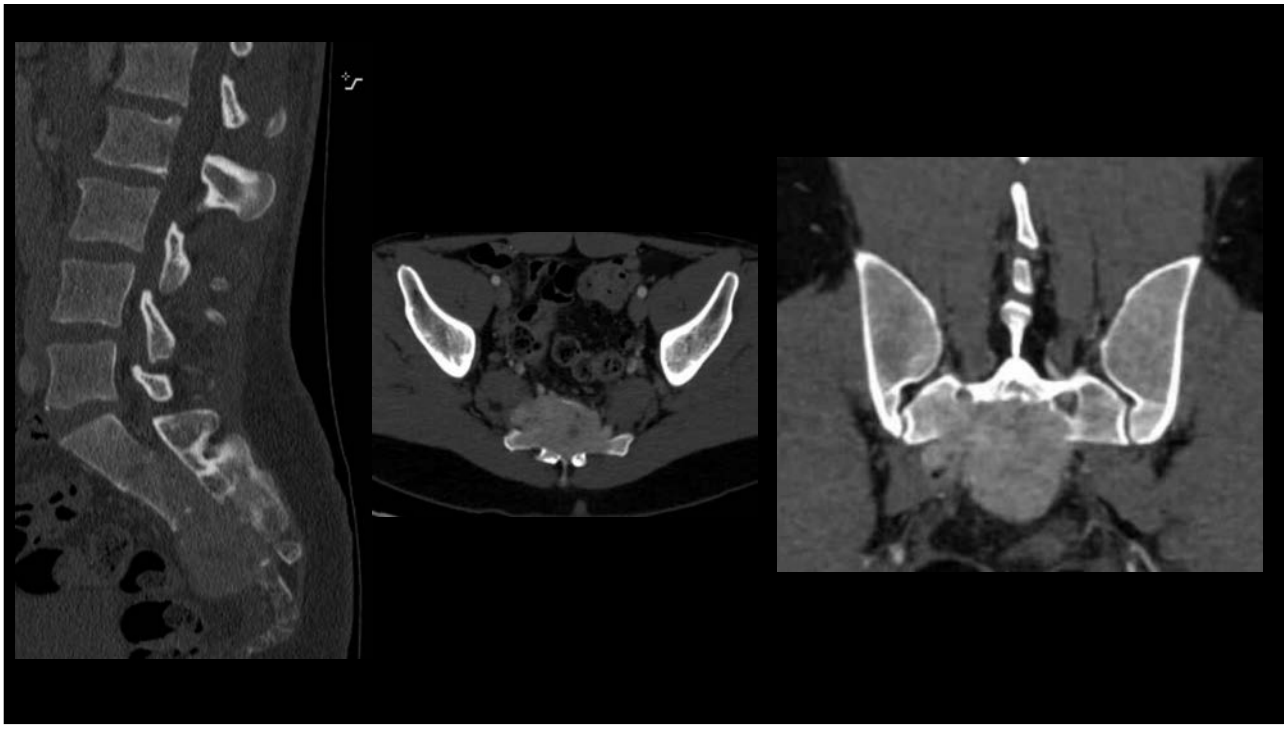

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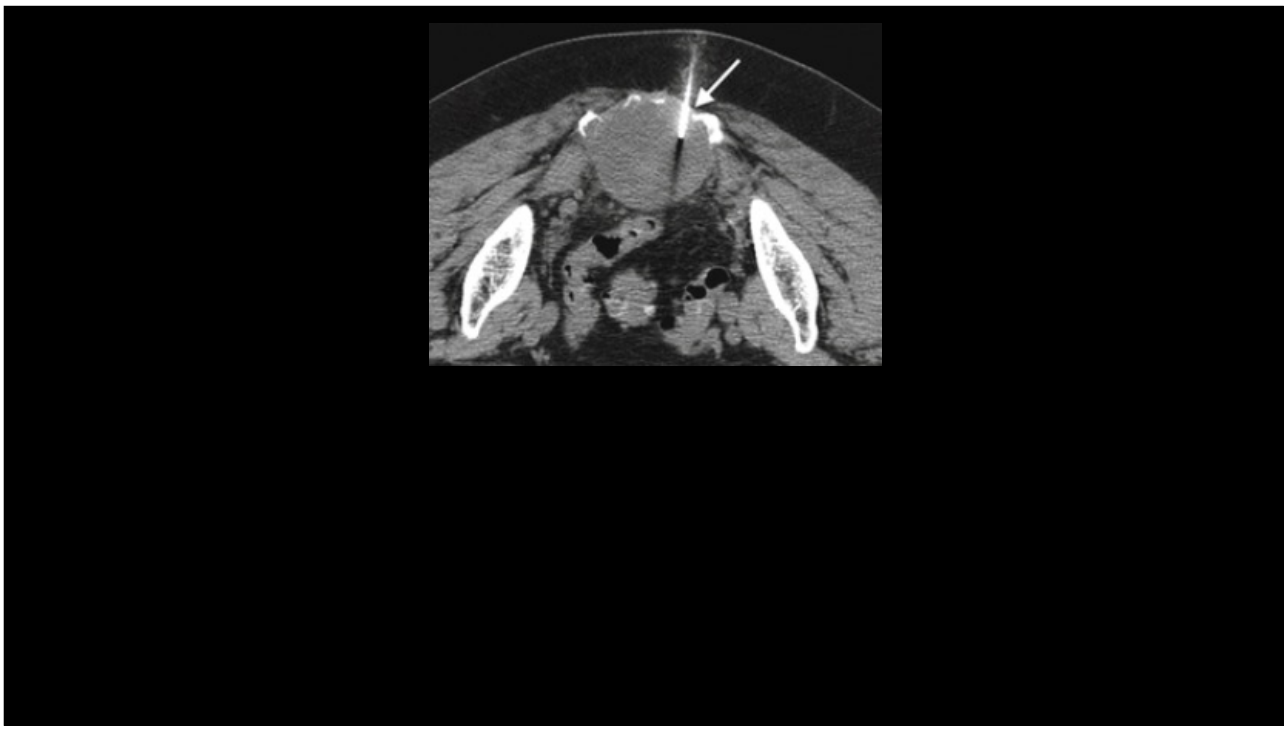

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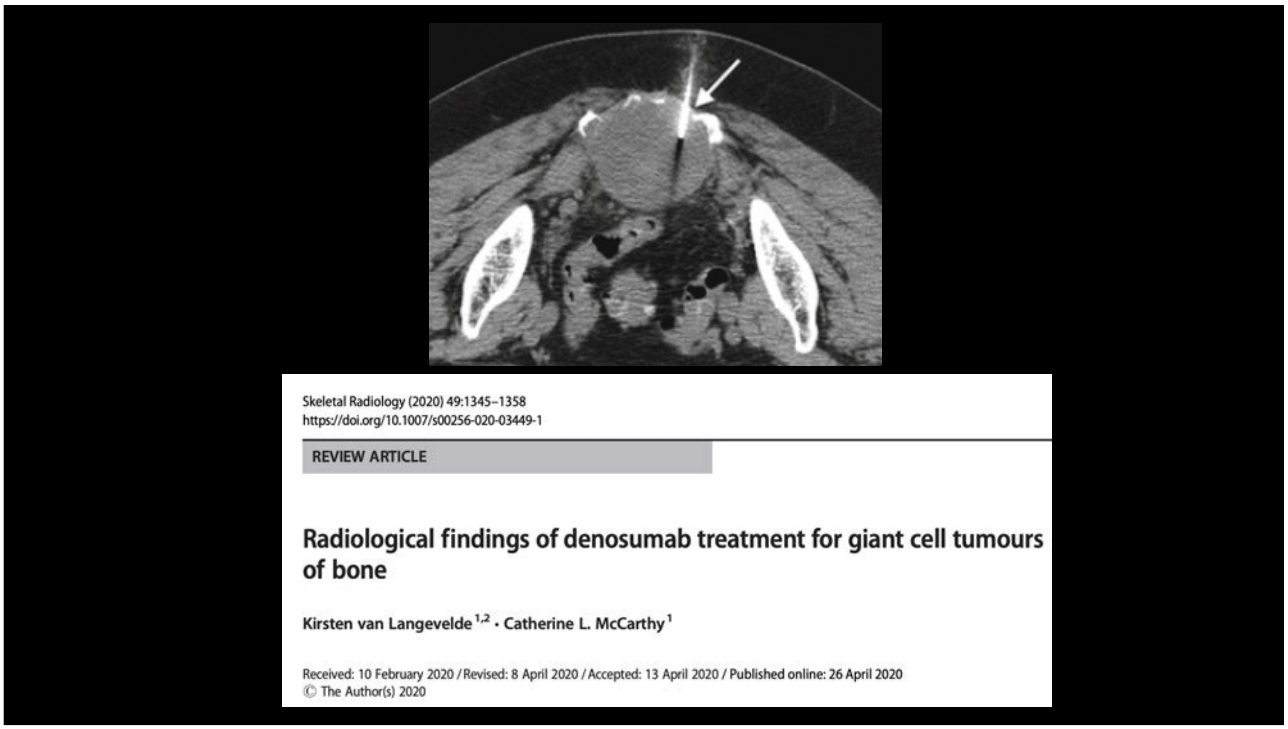

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https://doi.org/10.1007/s00256-020-03449-1

REVIEW ARTICLE

Radiological findings of denosumab treatment for giant cell tumours of bone

Kirsten van Langevelde[1,2] · Catherine L. McCarthy[1]

Received: 10 February 2020 / Revised: 8 April 2020 / Accepted: 13 April 2020 / Published online: 26 April 2020

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Denosumab Treatment

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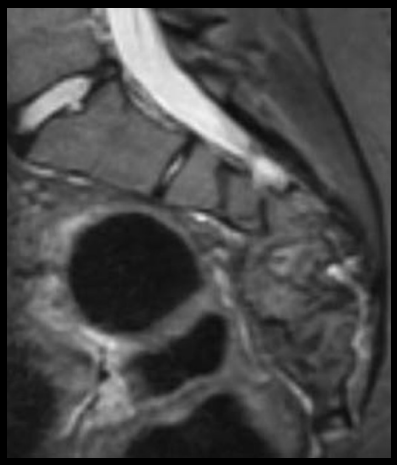
Denosumab Treatment



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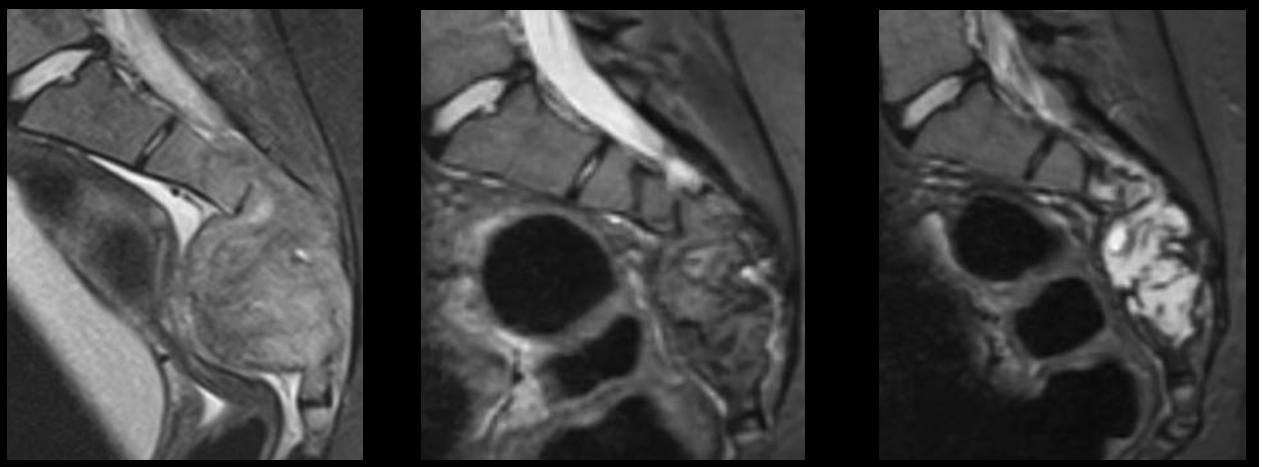
Denosumab Treatment



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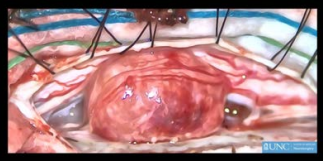
Intradural Spinal Tumors

Intradural Extramedullary

- Meningioma
- Schwannoma
- Neurofibroma
- Dermoid / Epidermoid



Intradural Intramedullary

- Ependymoma
- Pilocytic Astrocytoma
- Hemangioblastoma
- Cavernoma

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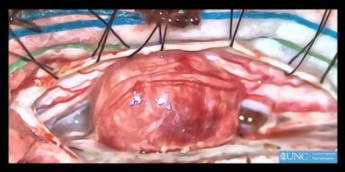
Intradural Extramedullary

- Meningioma
- Schwannoma
- Neurofibroma
- Dermoid / Epidermoid



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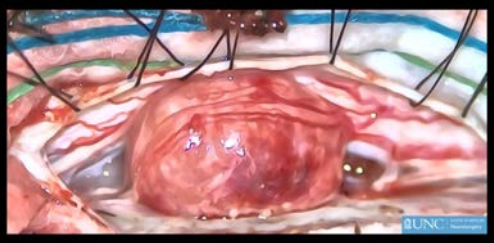
Intradural Extramedullary

- Meningioma
- Schwannoma
- Neurofibroma
- Dermoid / Epidermoid

338

Intradural Extramedullary

- Meningioma
- Schwannoma
- Neurofibroma
- Dermoid / Epidermoid



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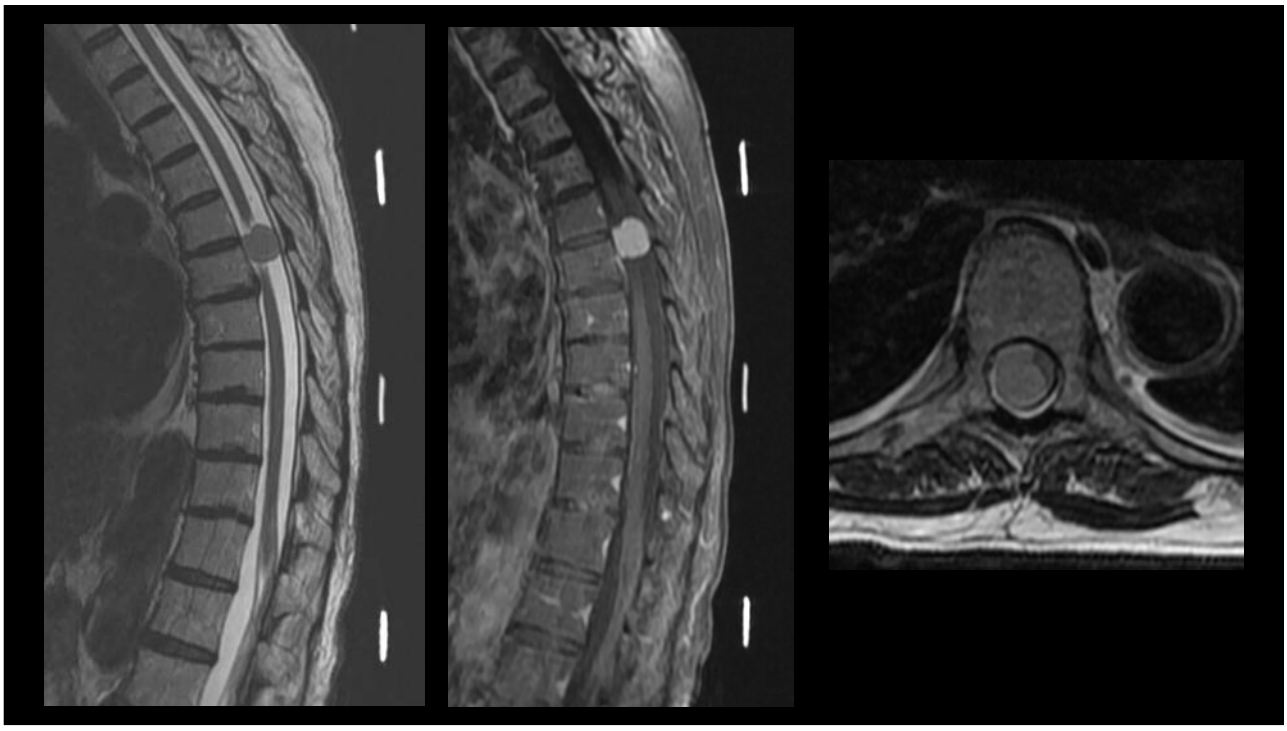

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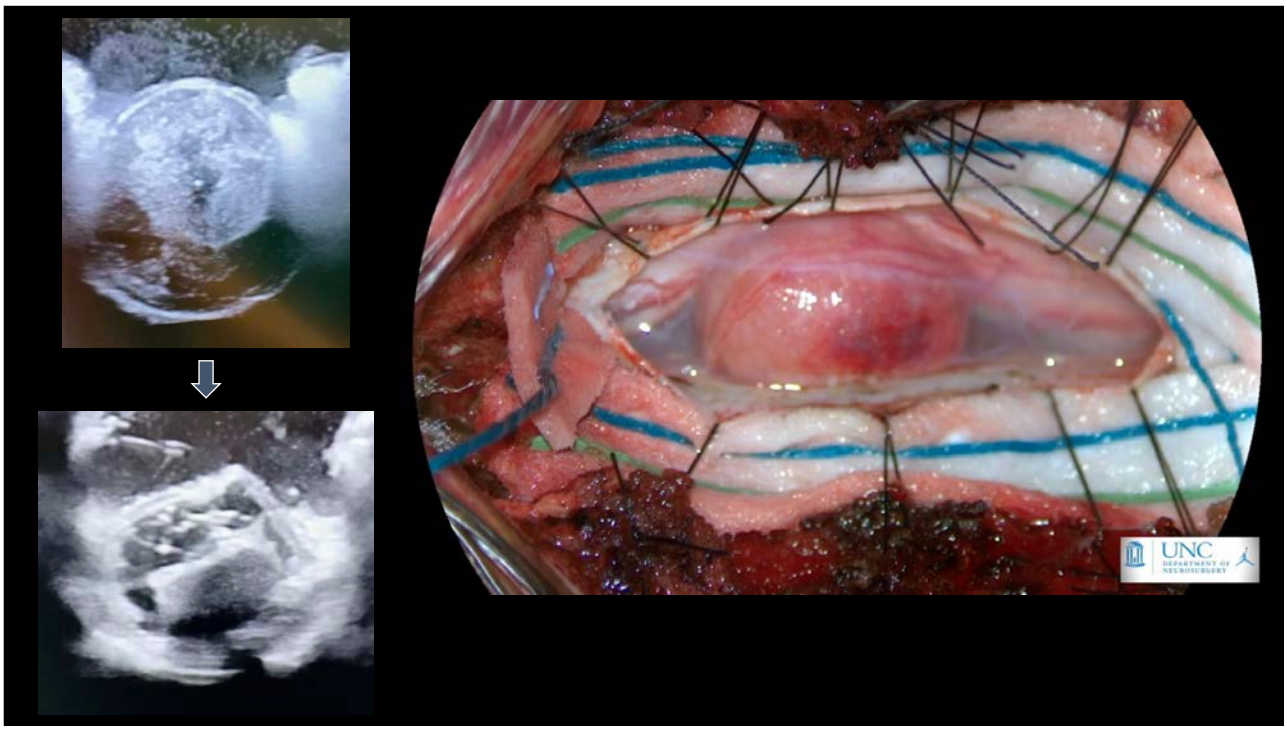

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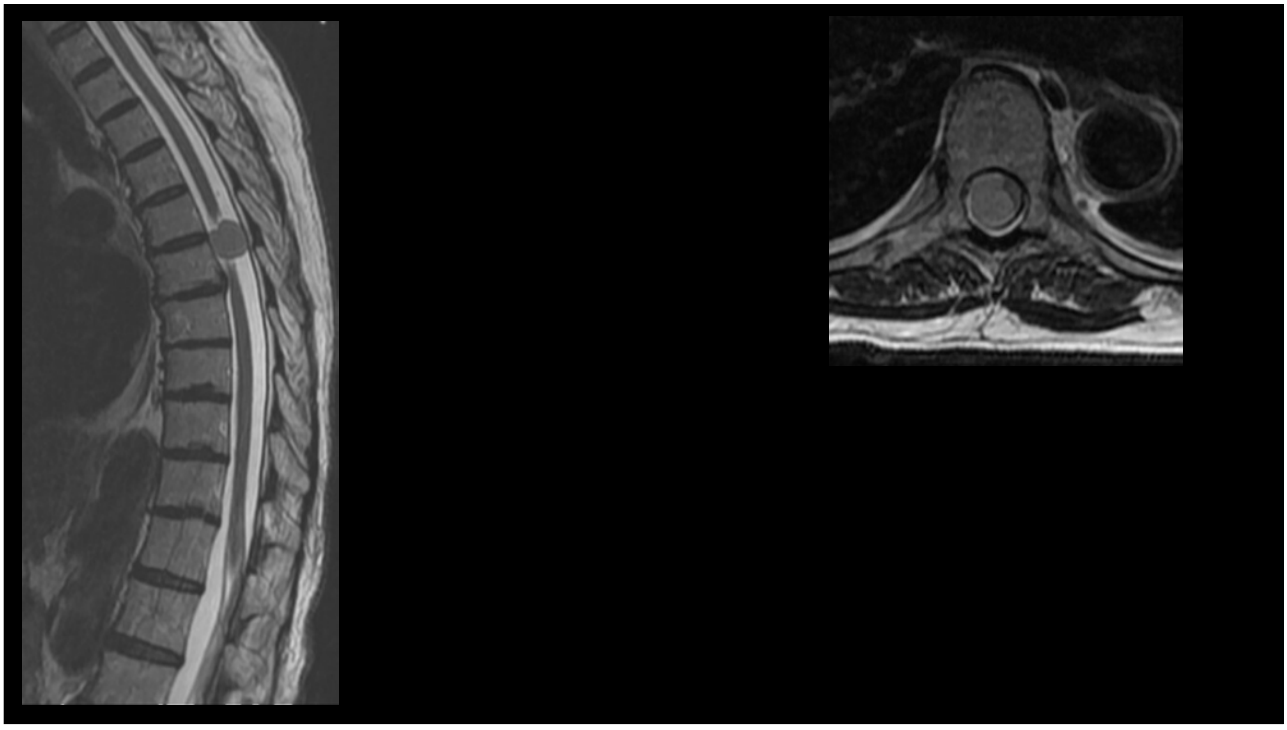

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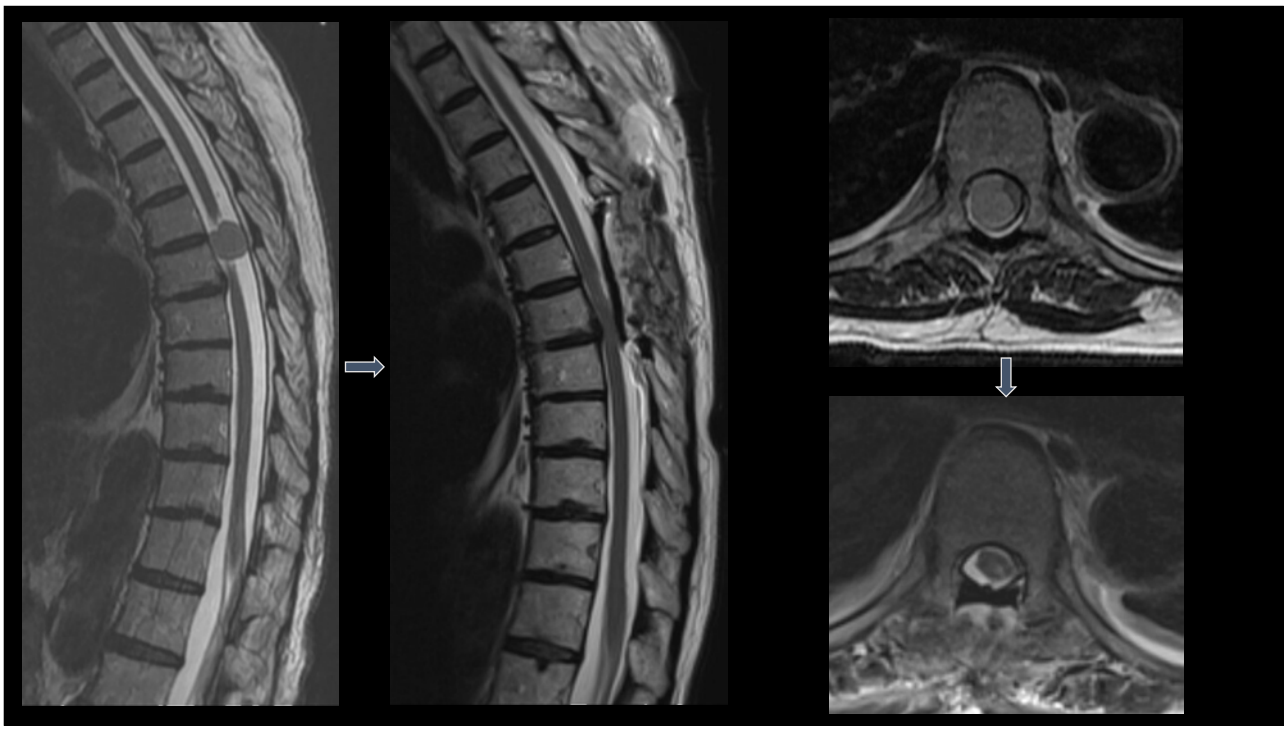

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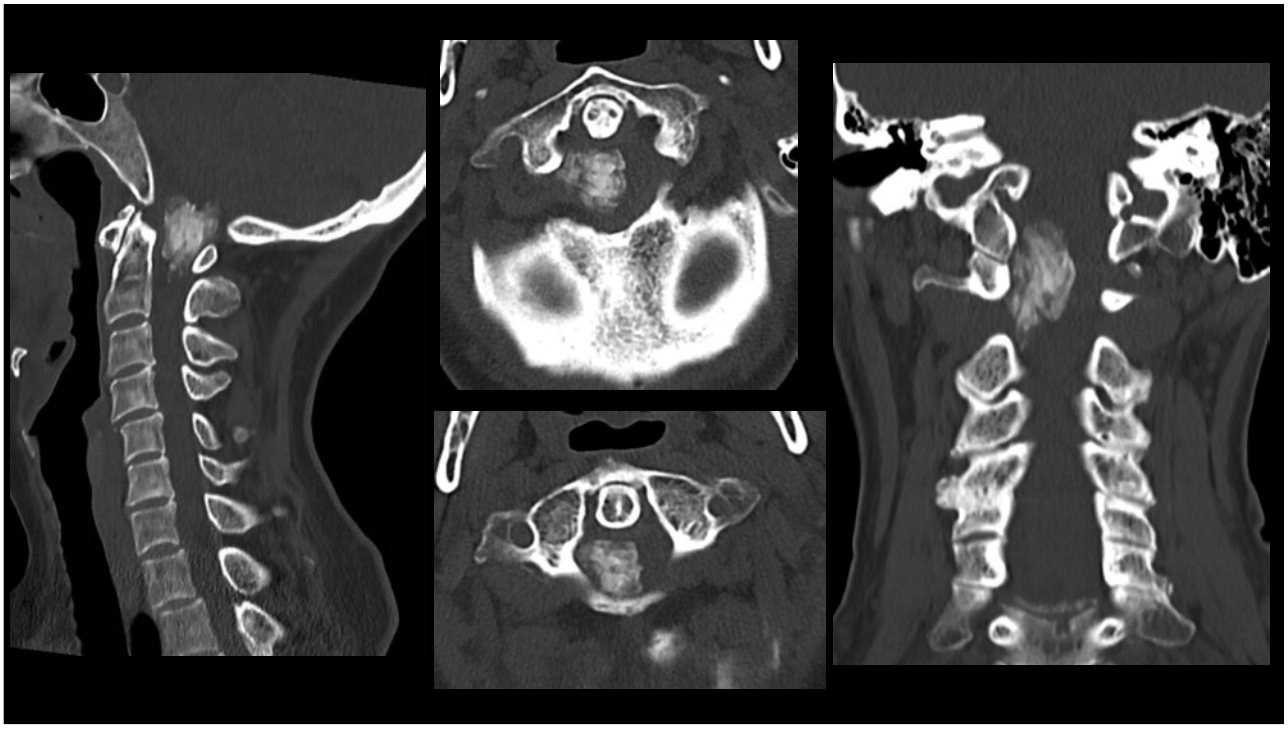

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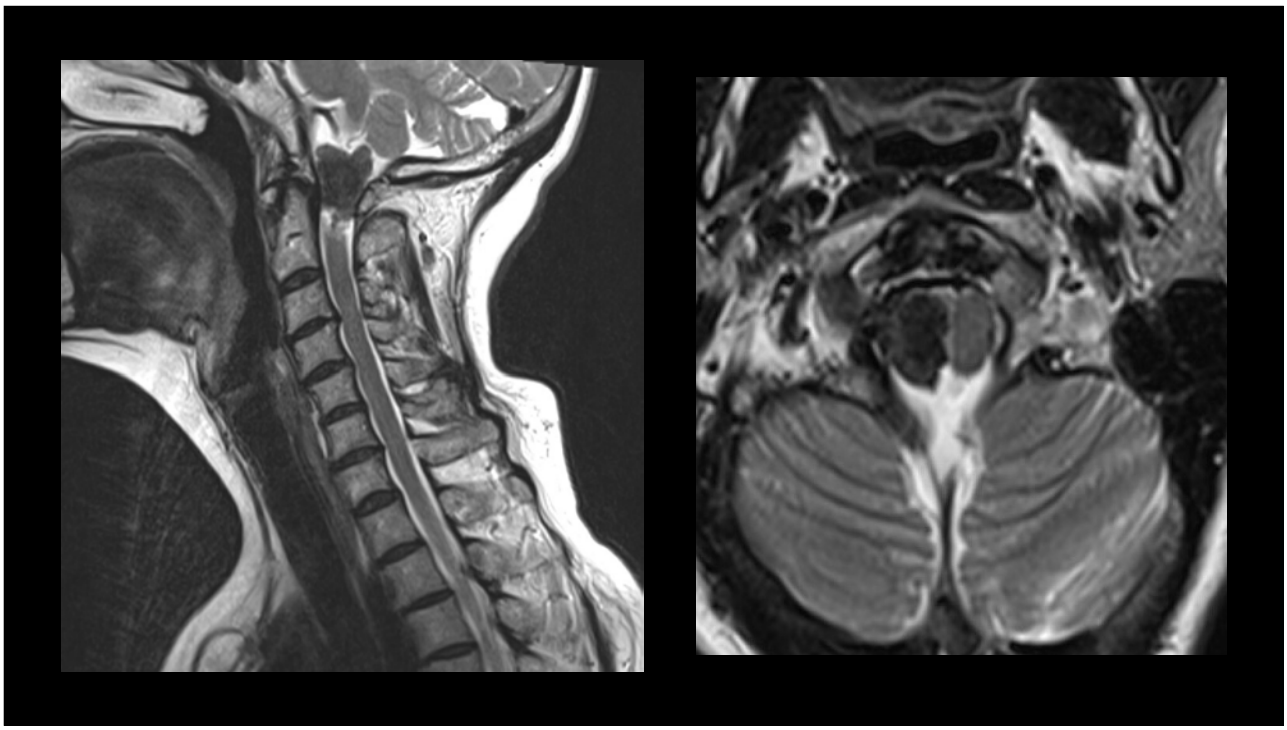

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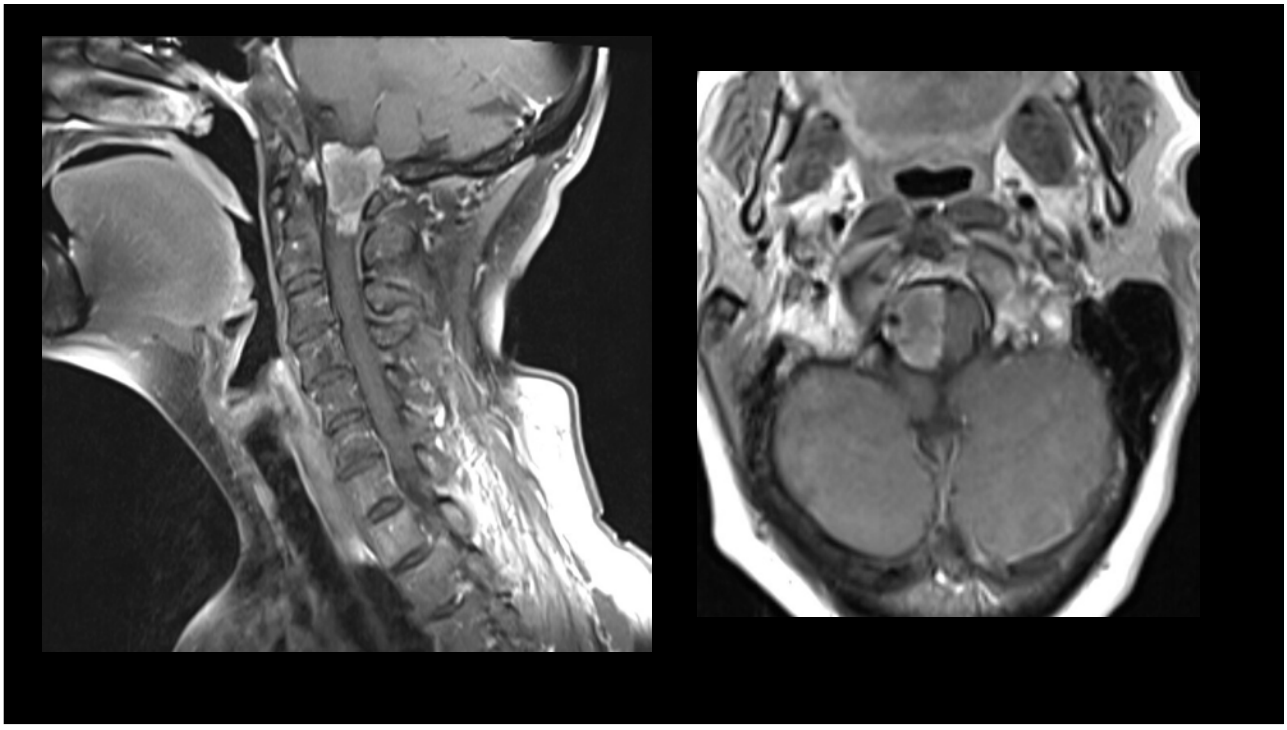

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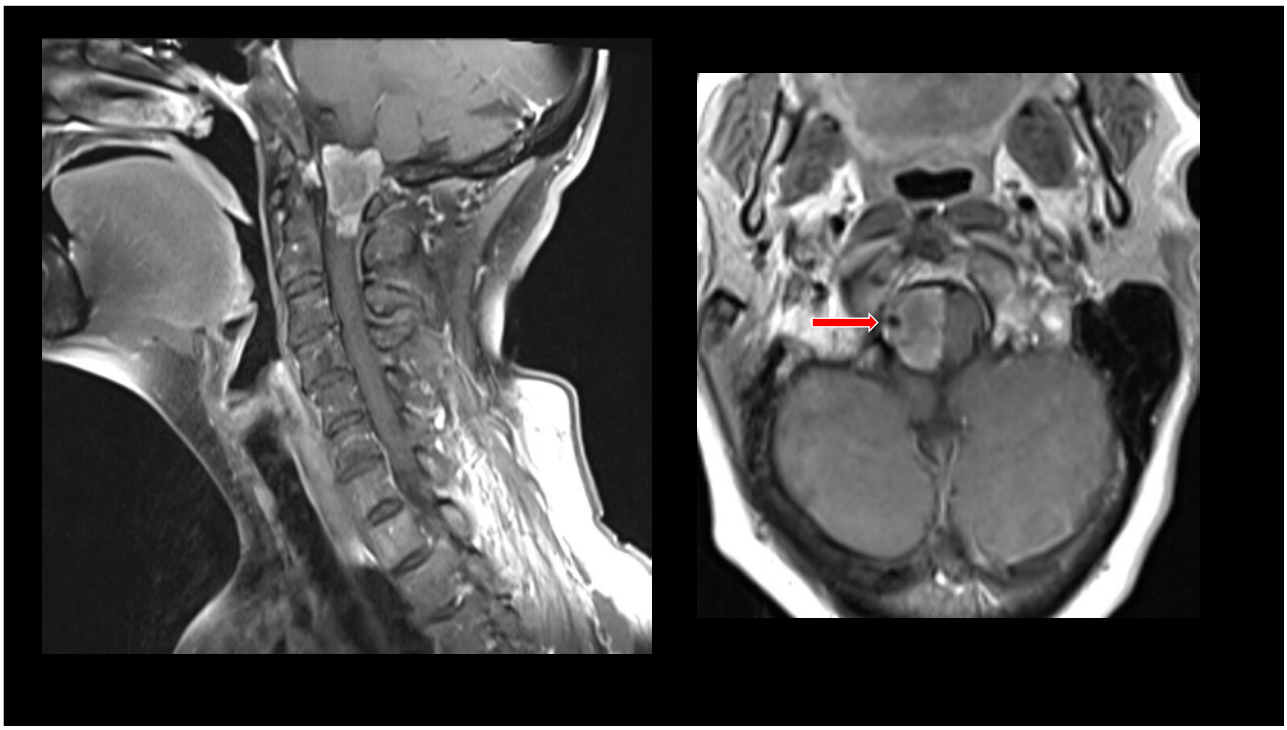

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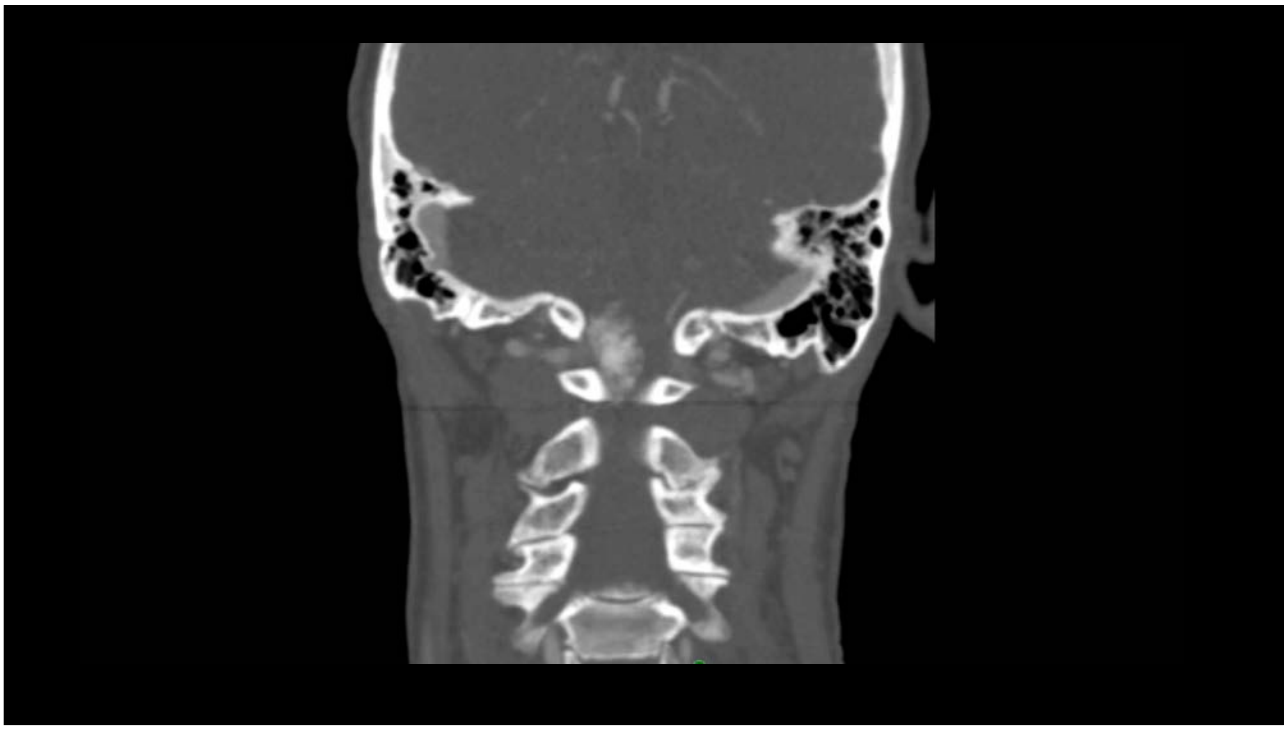

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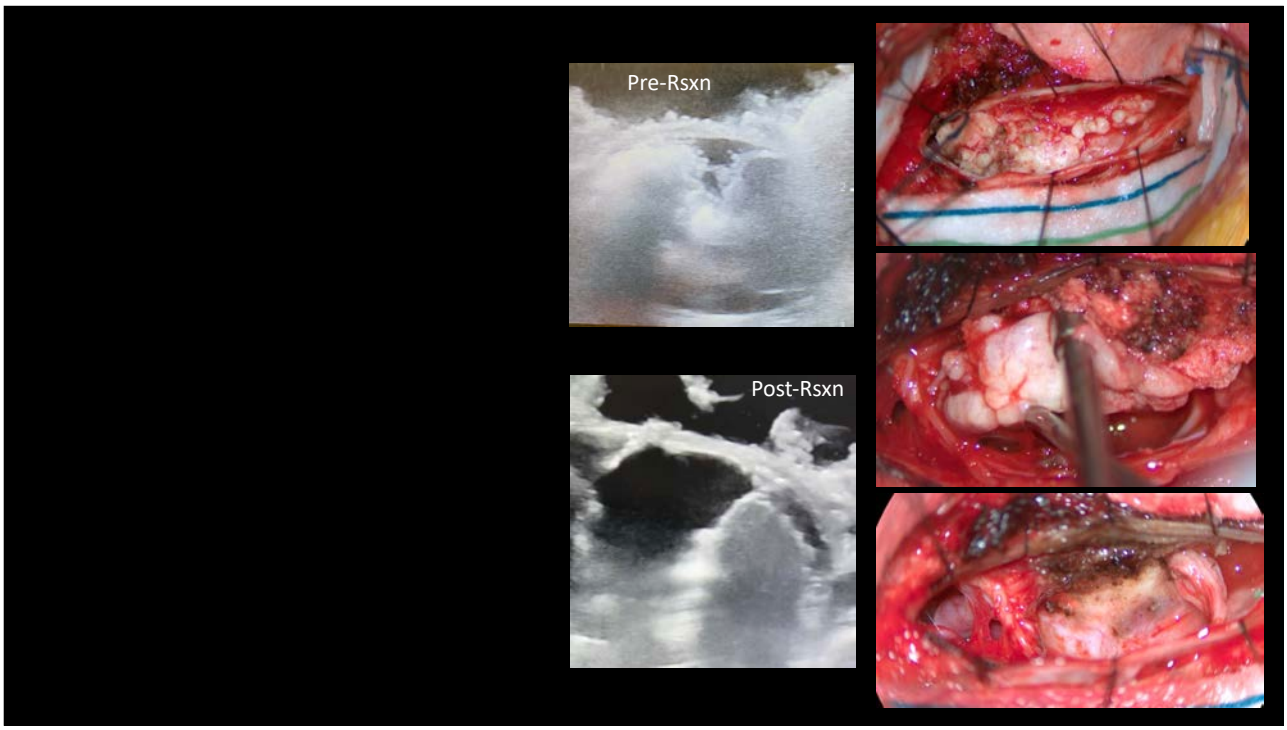

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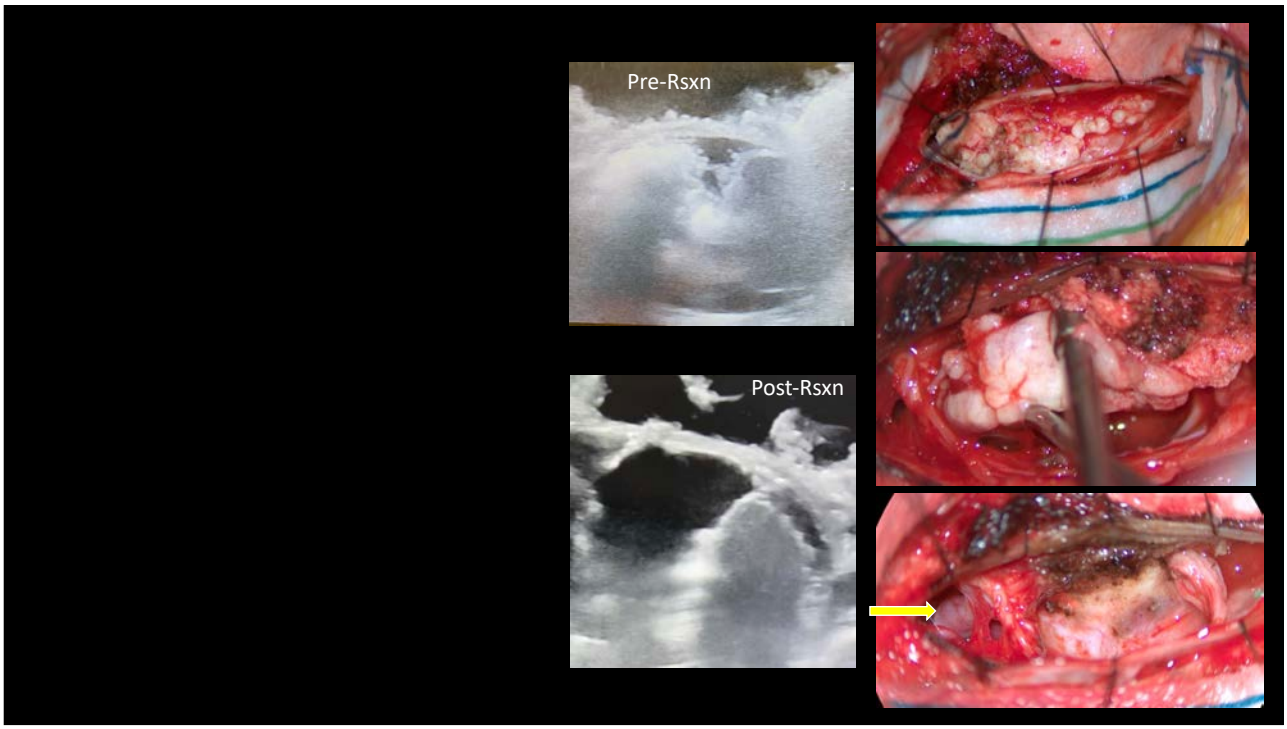

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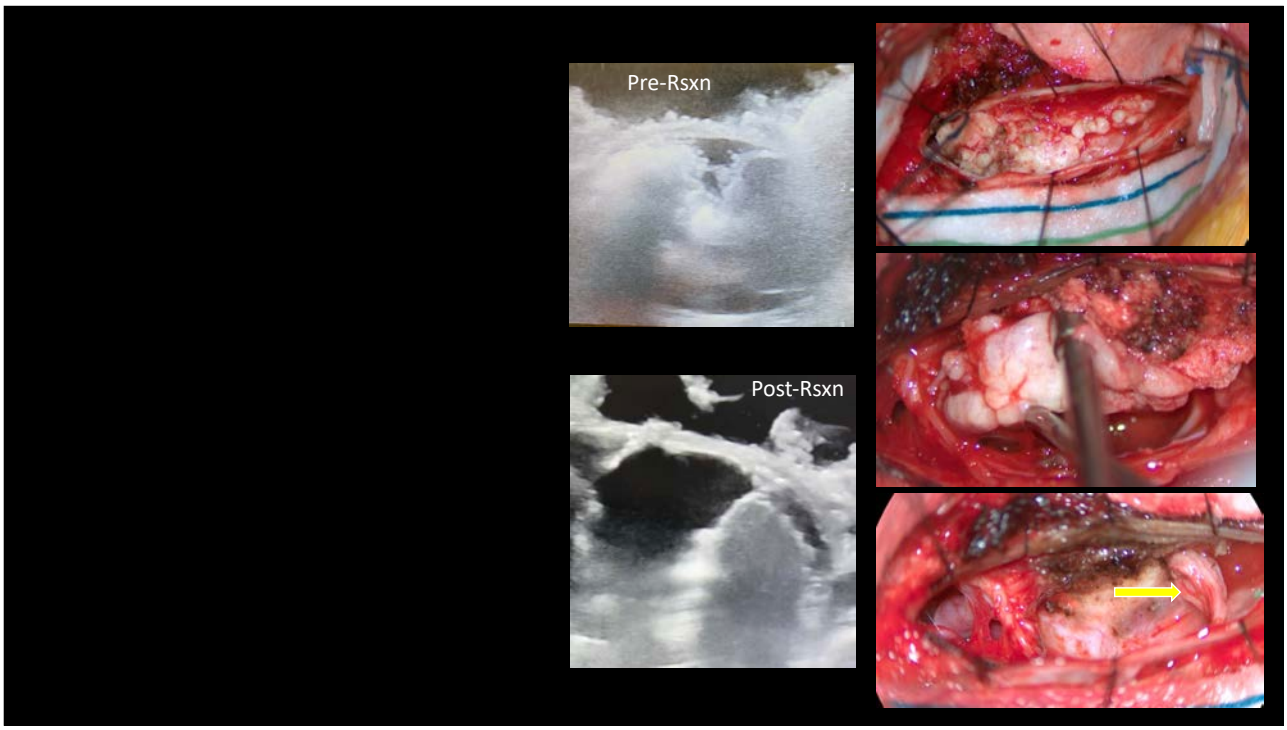

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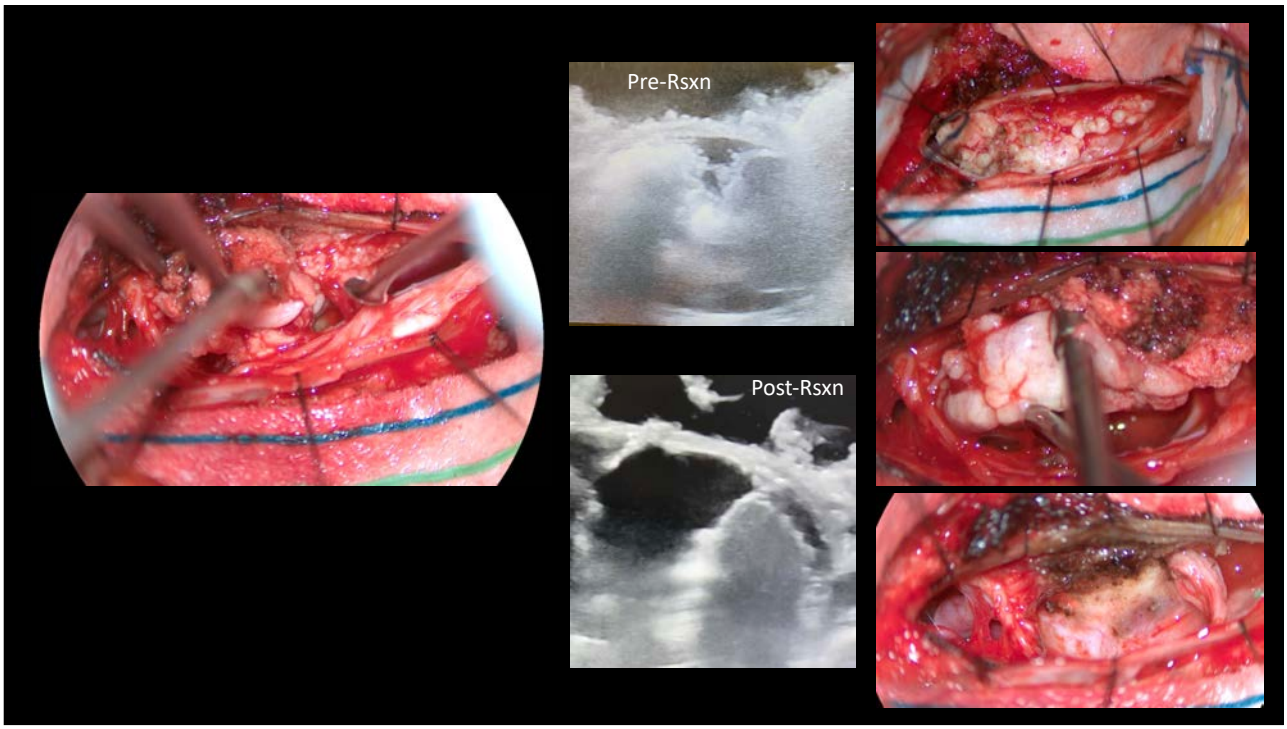

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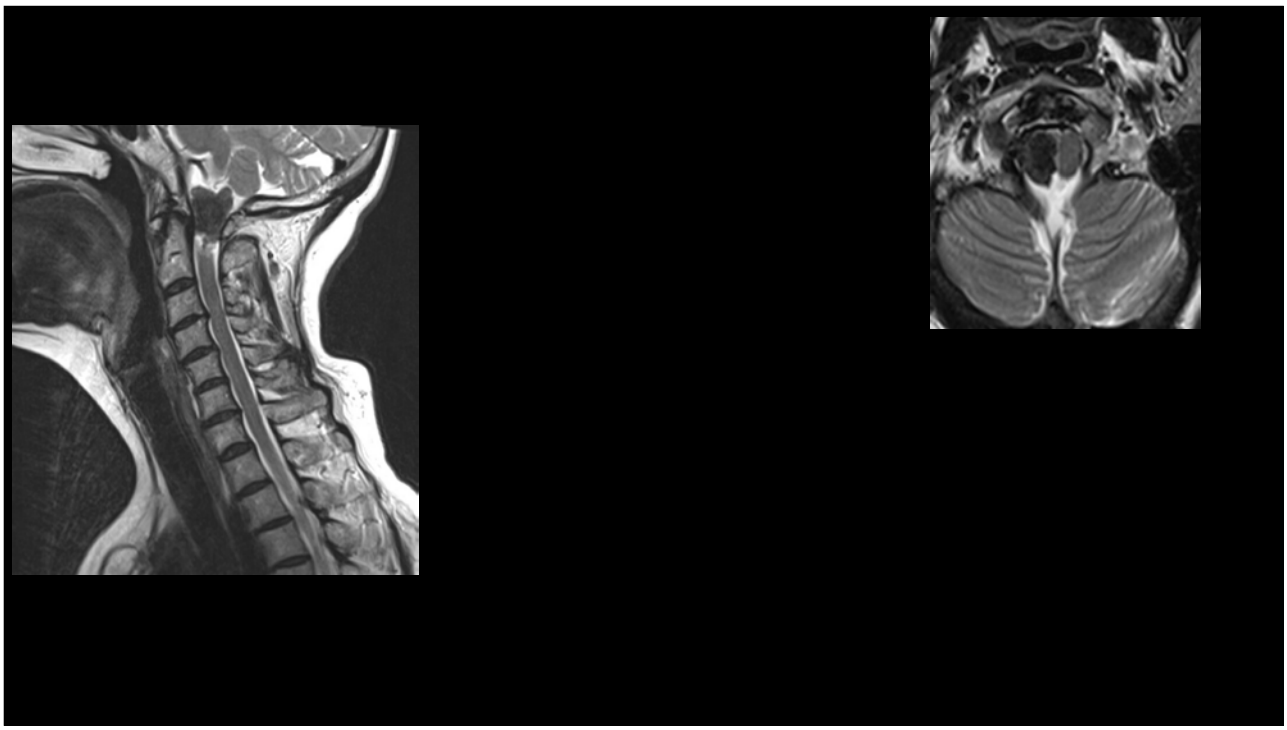

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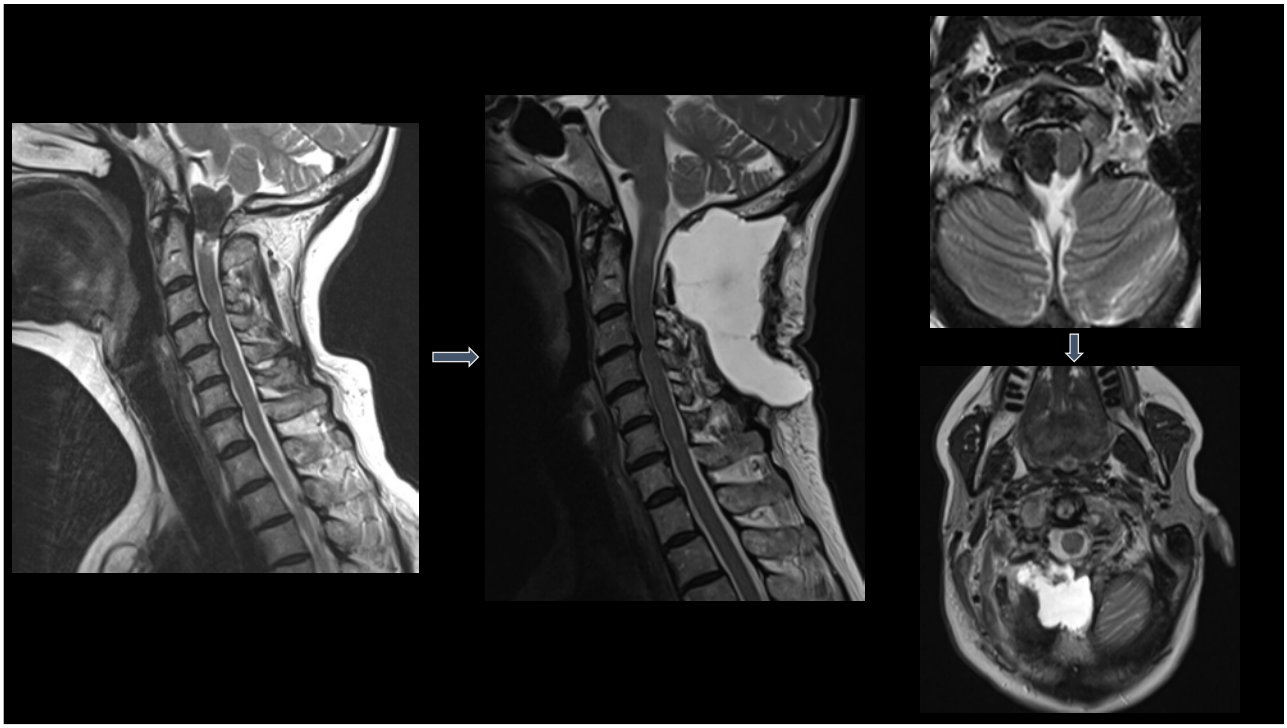

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Intradural Extramedullary

- Meningioma
- Schwannoma
- Neurofibroma
- Dermoid / Epidermoid

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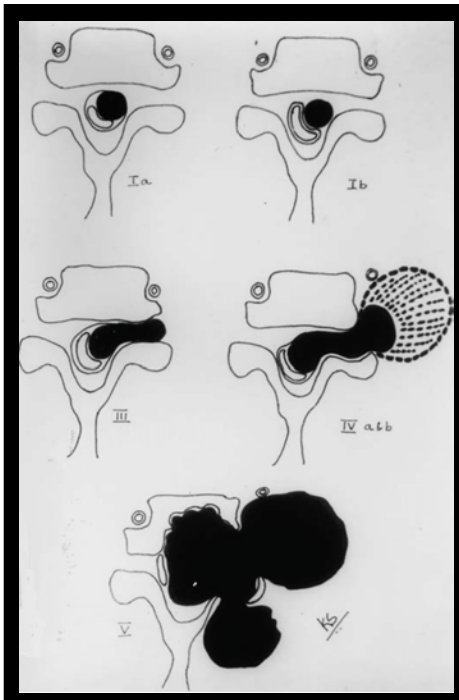

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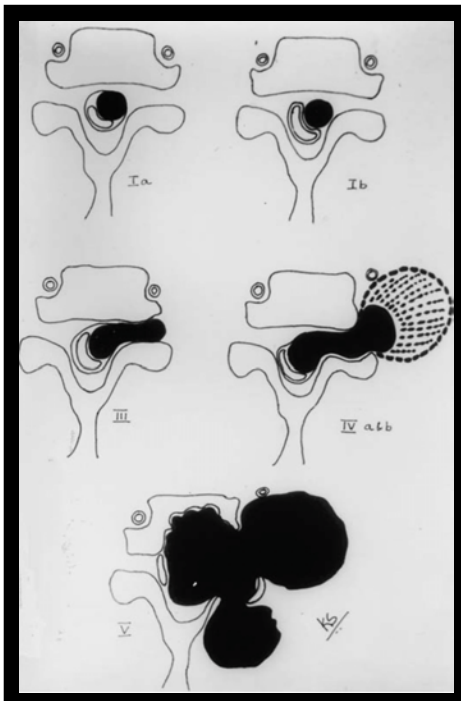

TABLE 1

Classification of benign nerve sheath tumors

	Classification
Type I	intraspinal tumor, < 2 vertebral segments in length; a: intradural; b: extradural.
Type II	intraspinal tumor > 2 vertebral segments in length (giant tumor)
Type III	intraspinal tumor w/ extension into nerve root foramen
Type IV	intraspinal tumor w/ extraspinal extension (dumbbell tumors); a: extraspinal component < 2.5 cm; b: extraspinal component > 2.5 cm (giant tumor)
Type V	tumor w/ erosion into the VBs (giant invasive tumor), lat & posterior extentions into myofascial planes

Togral, Guray, et al. "Incidentally diagnosed giant invasive sacral schwannoma: Its clinical features and surgical management without stability." Neurosciences Journal July 2014, 19 (3) 224-228. https://nsj.org.sa/content/19/3/224/tab-figures-data

357

Schwannomas

- Pure Extradural
- Pure Intradural
- Hybrid (ie. Dumbbell)

358

Schwannomas

- Pure Extradural
- Pure Intradural
- Hybrid (ie. Dumbbell)

359

Schwannomas

- Pure Extradural
- Pure Intradural
- Hybrid (ie. Dumbbell)

360

Schwannomas

- Pure Extradural
- Pure Intradural
- Hybrid (ie. Dumbbell)

361

Pure Extradural

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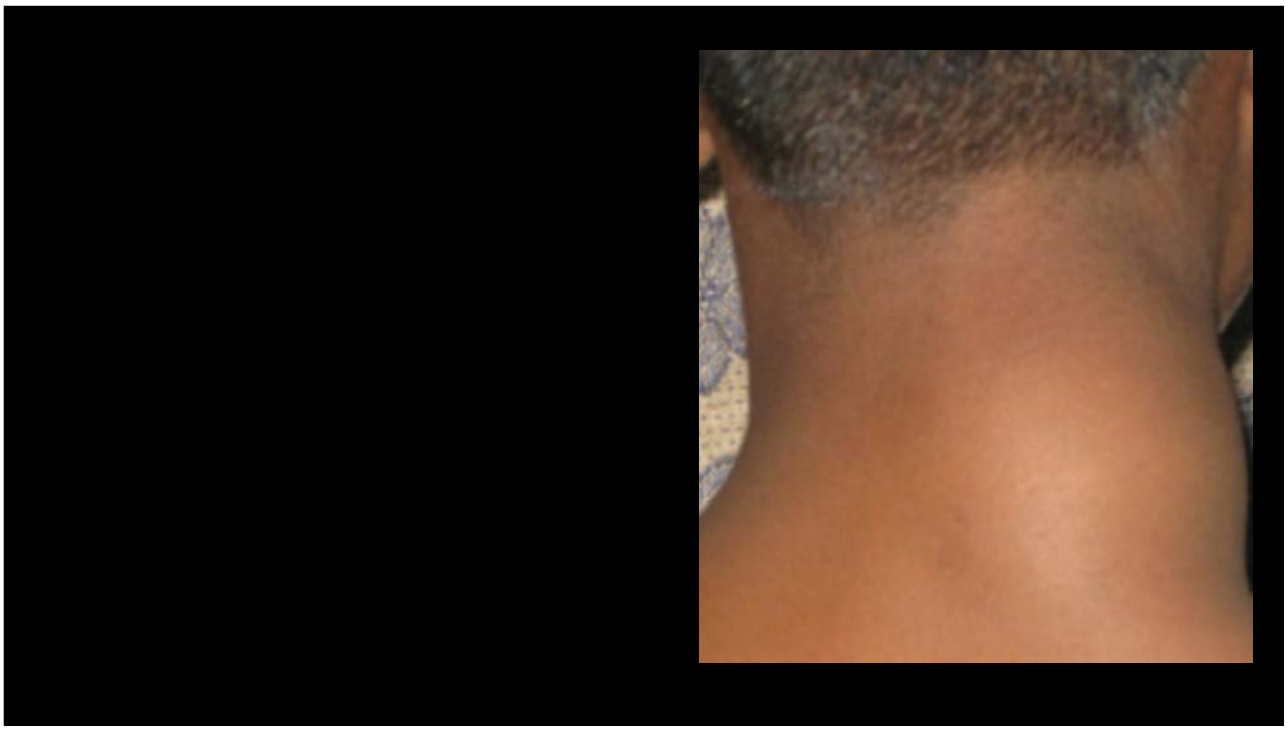

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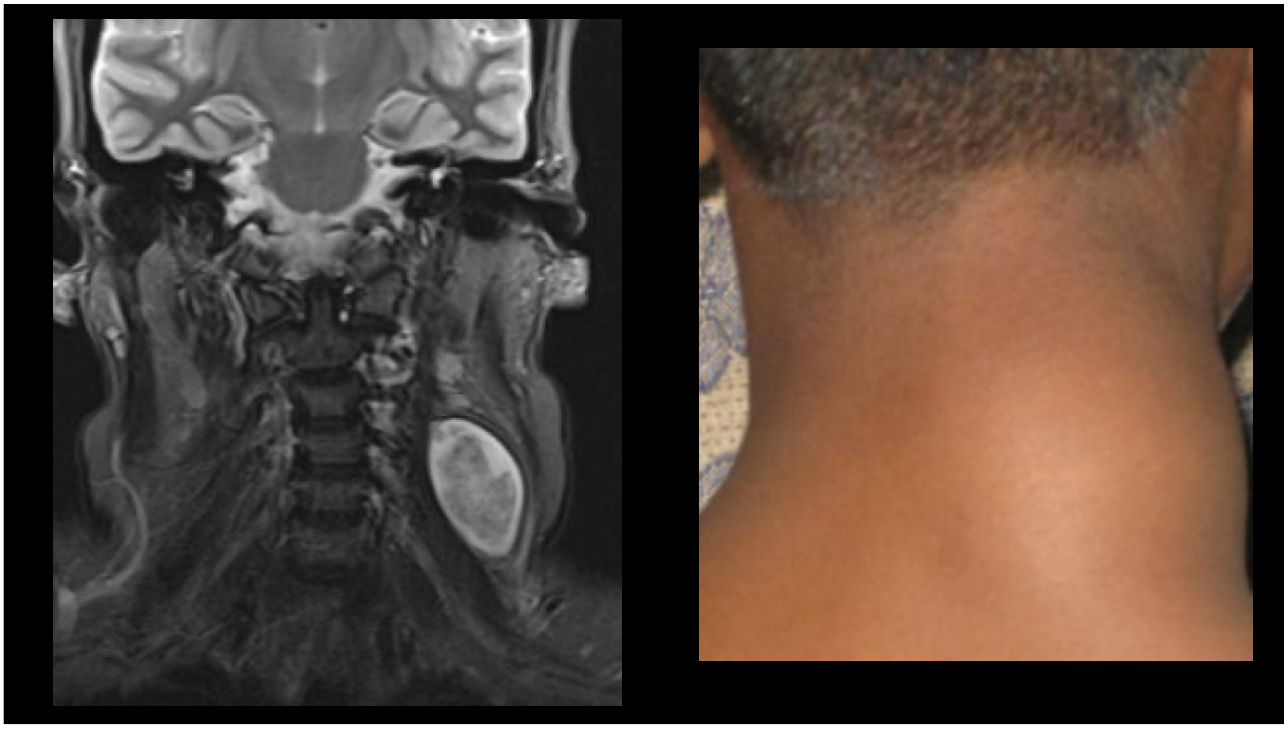

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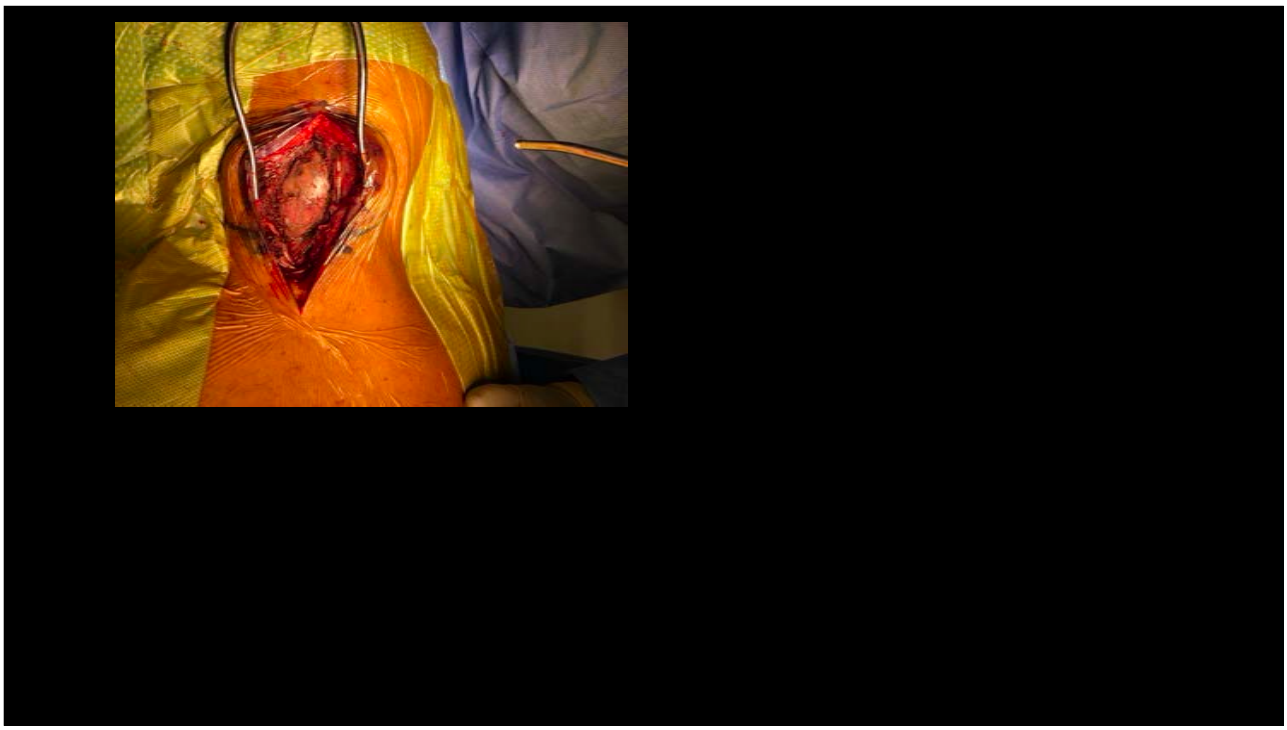

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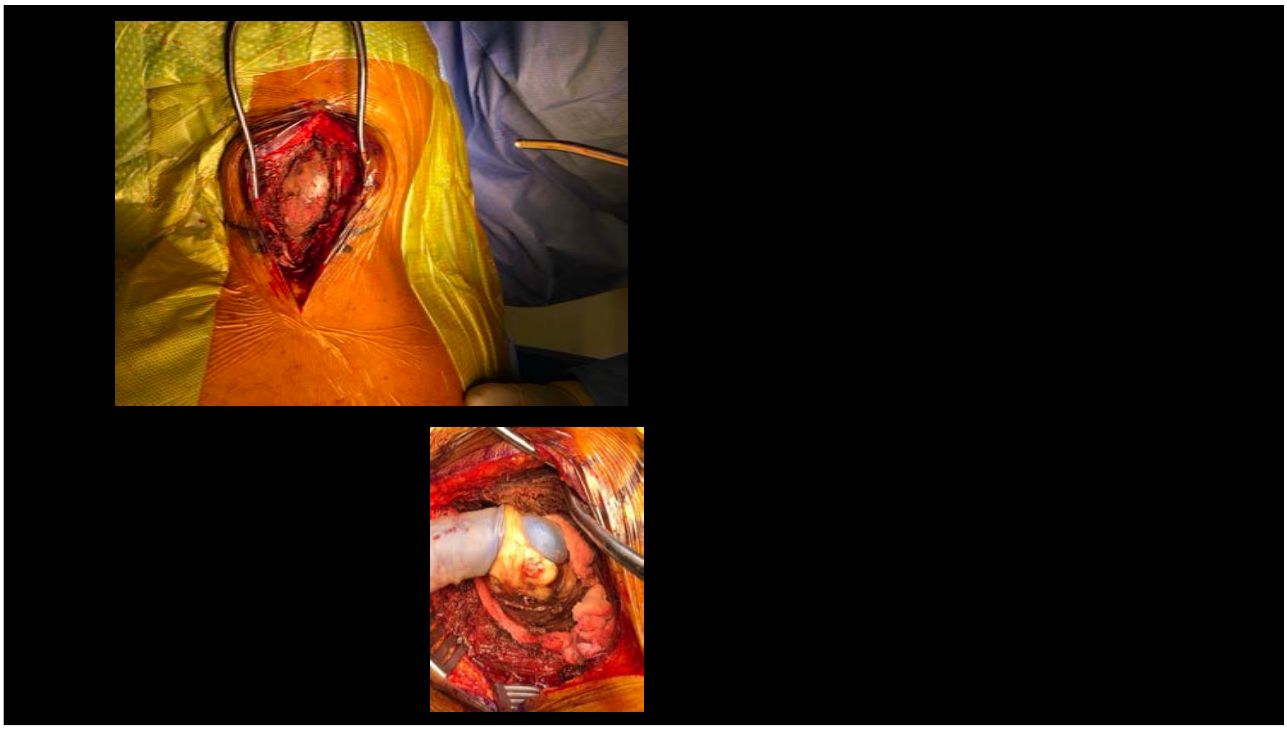

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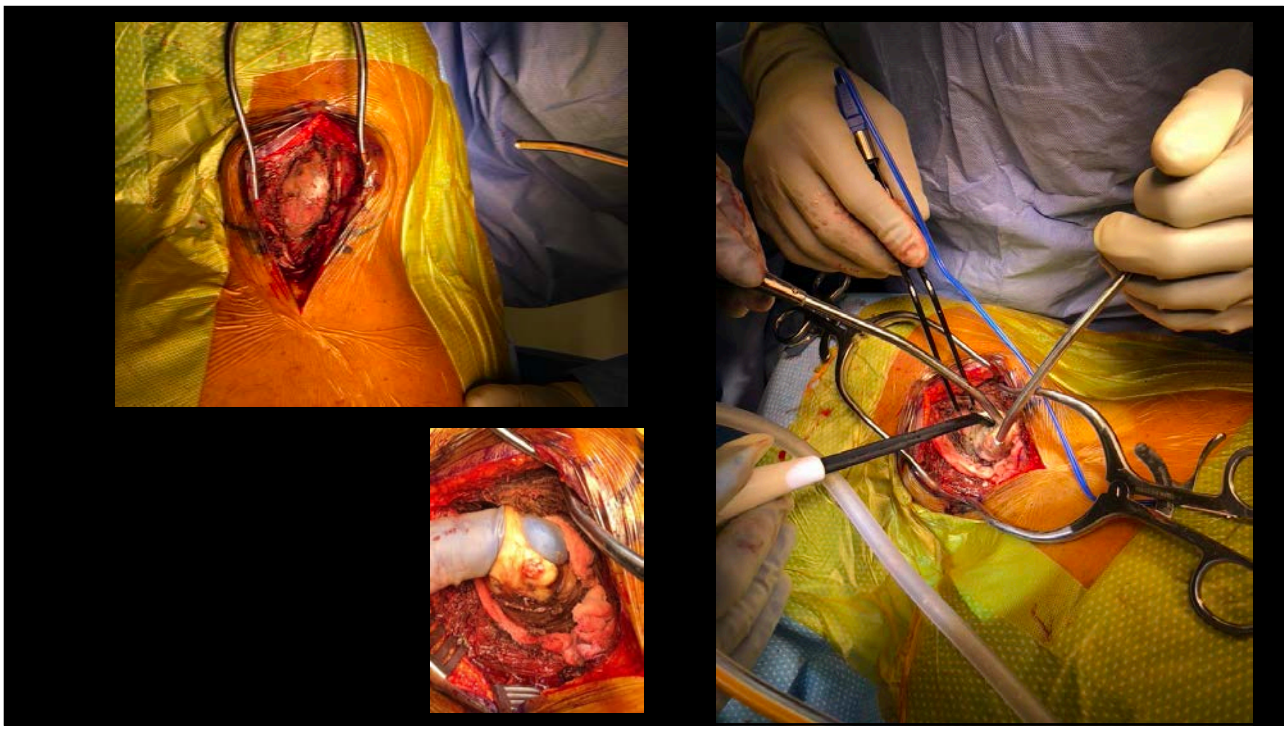

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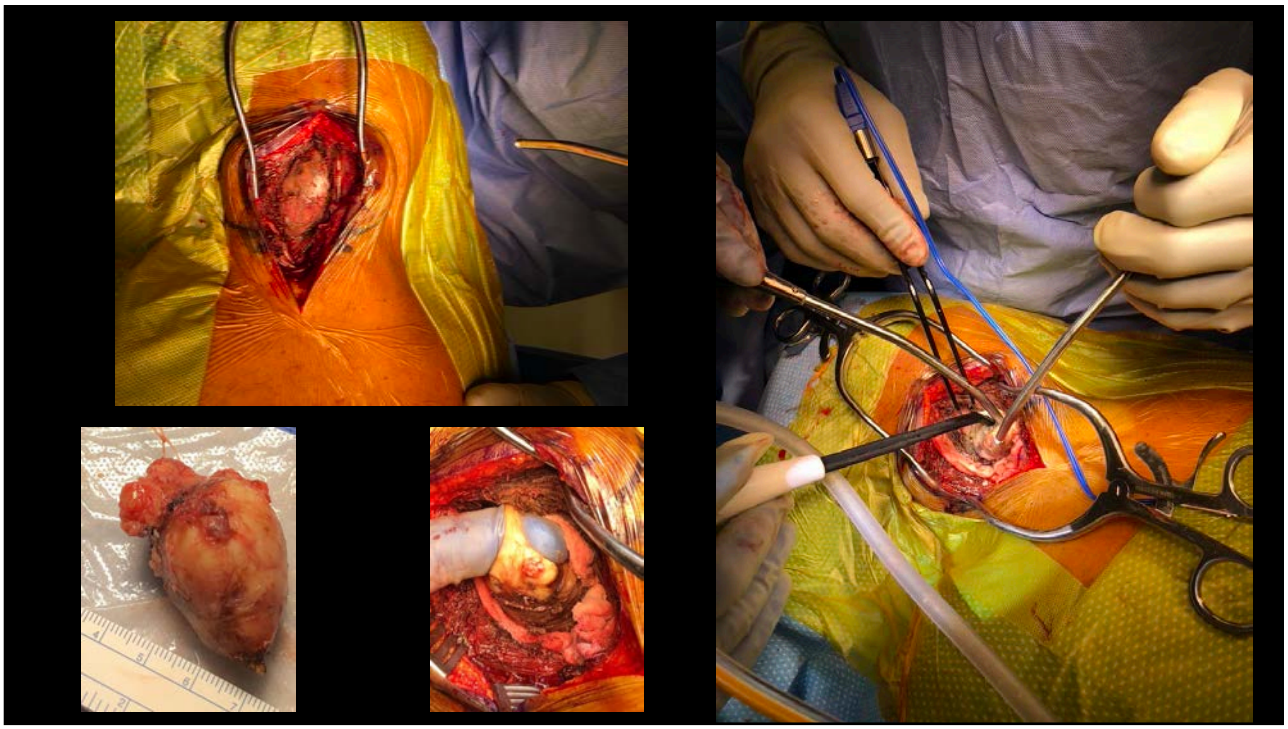

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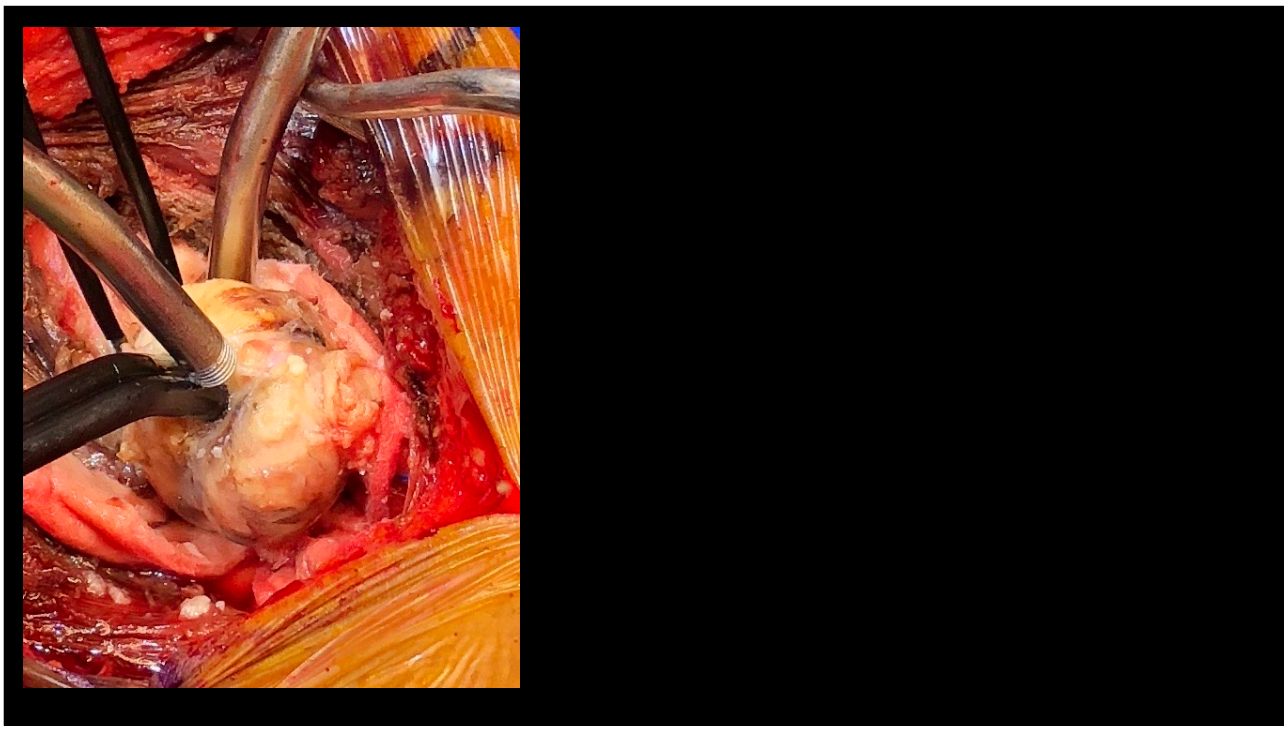

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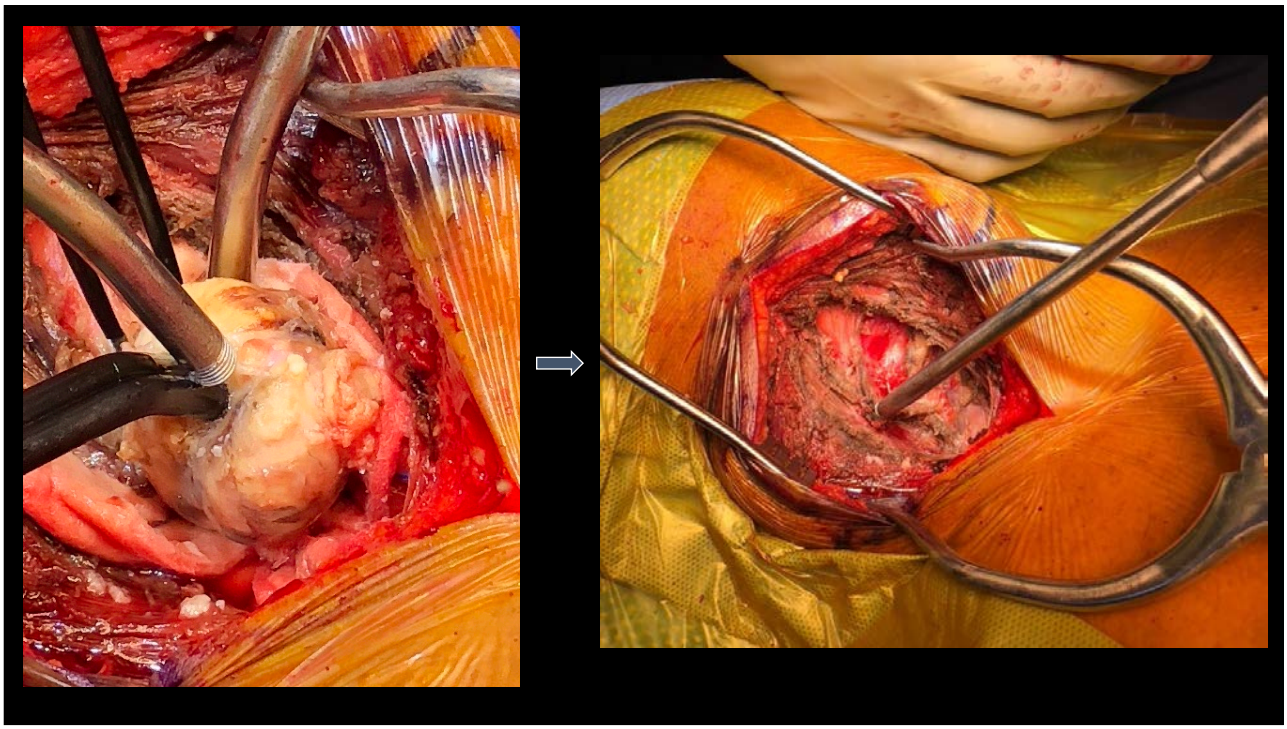

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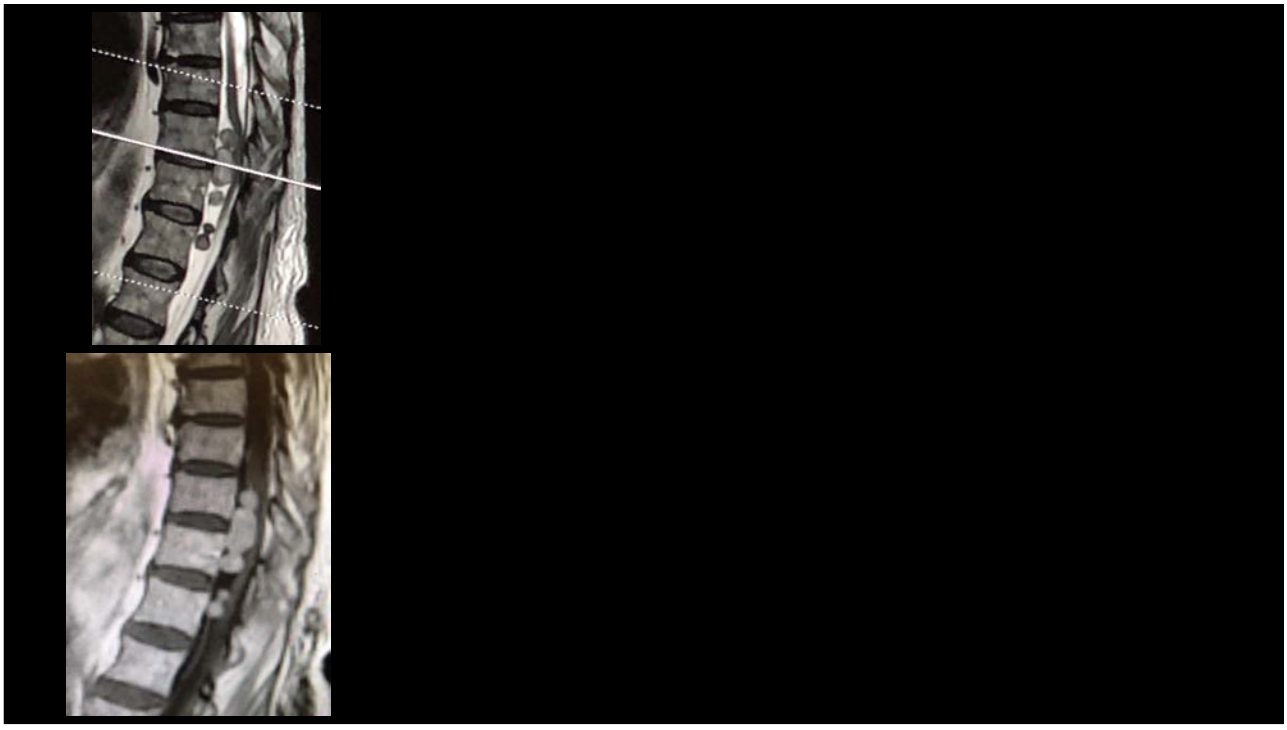

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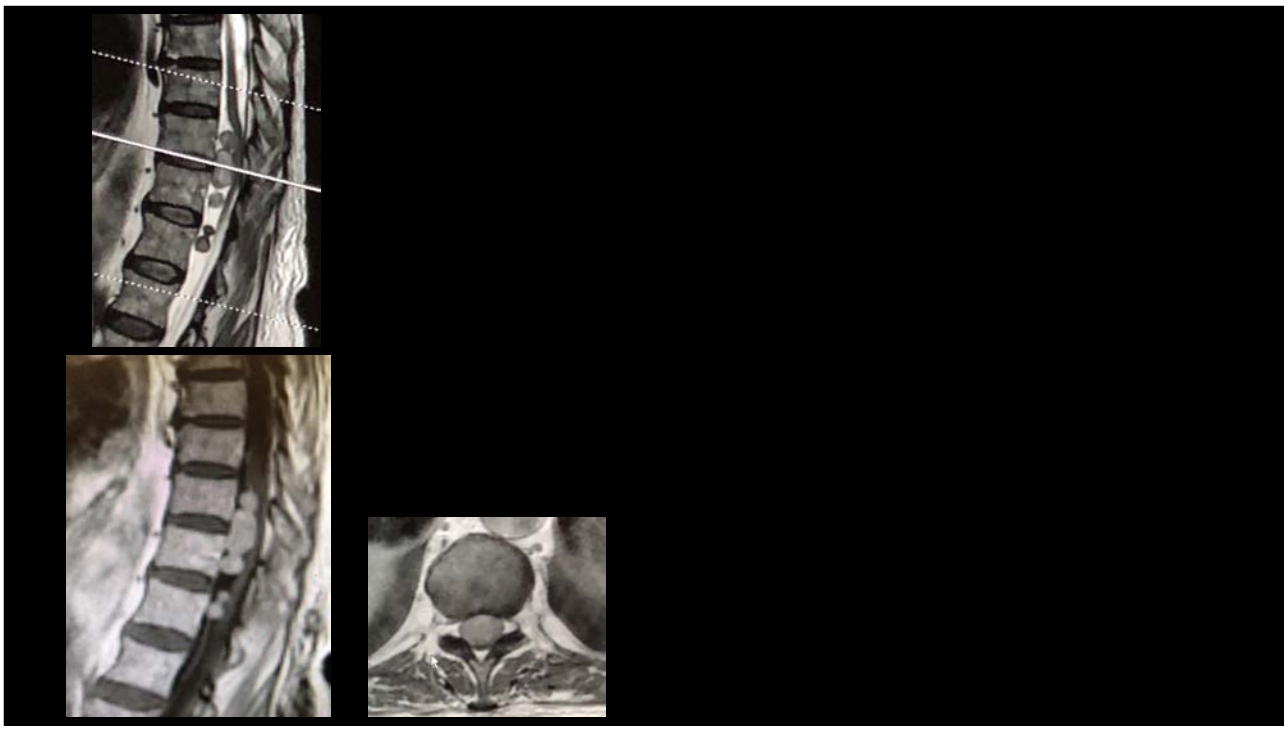

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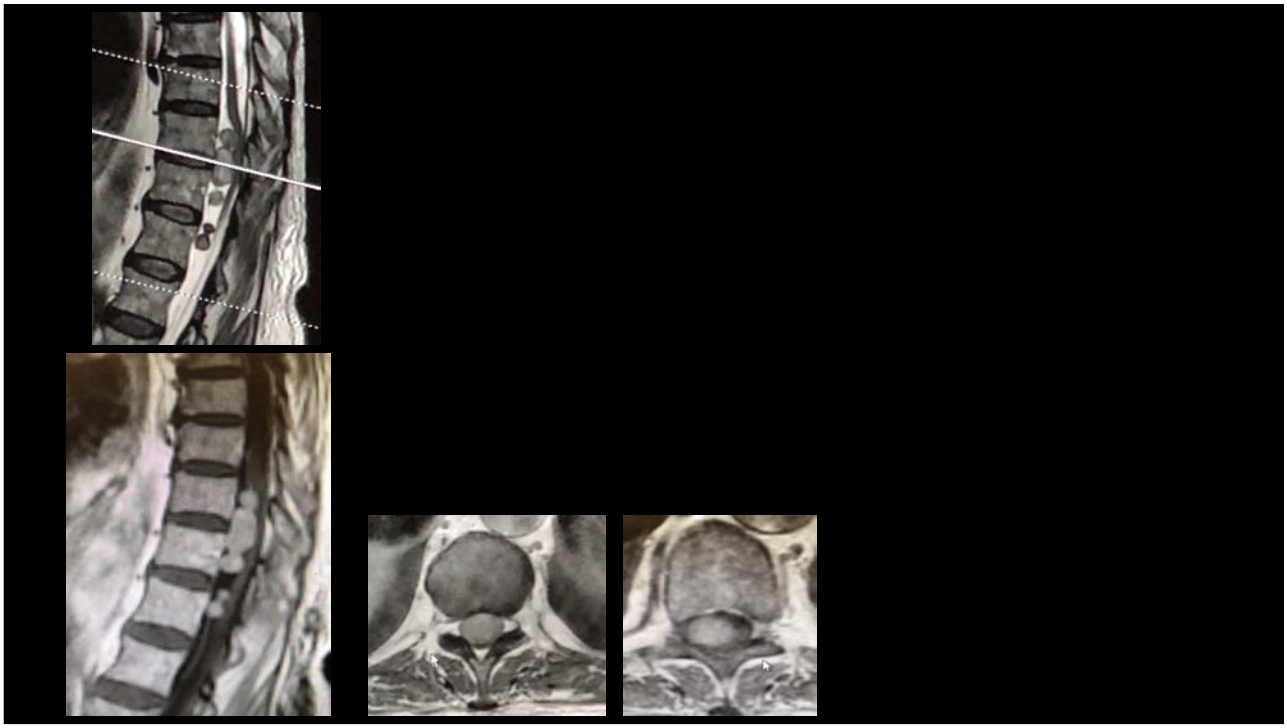

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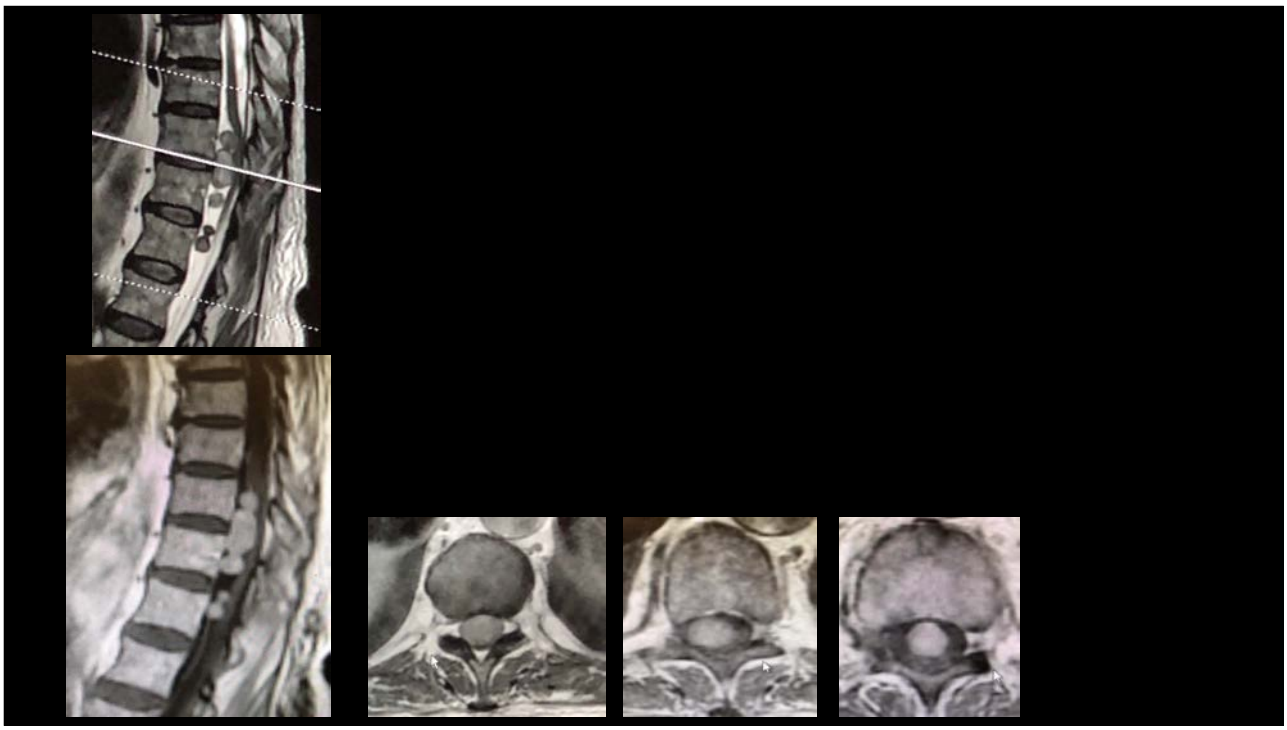

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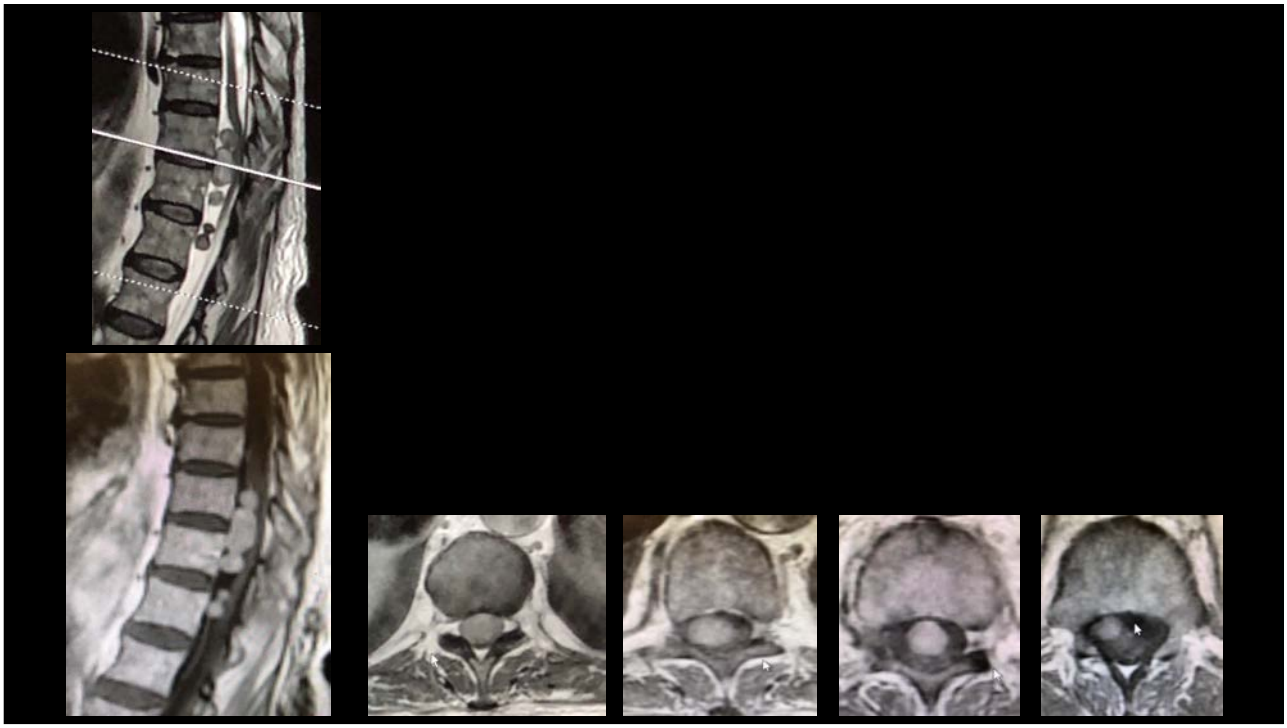

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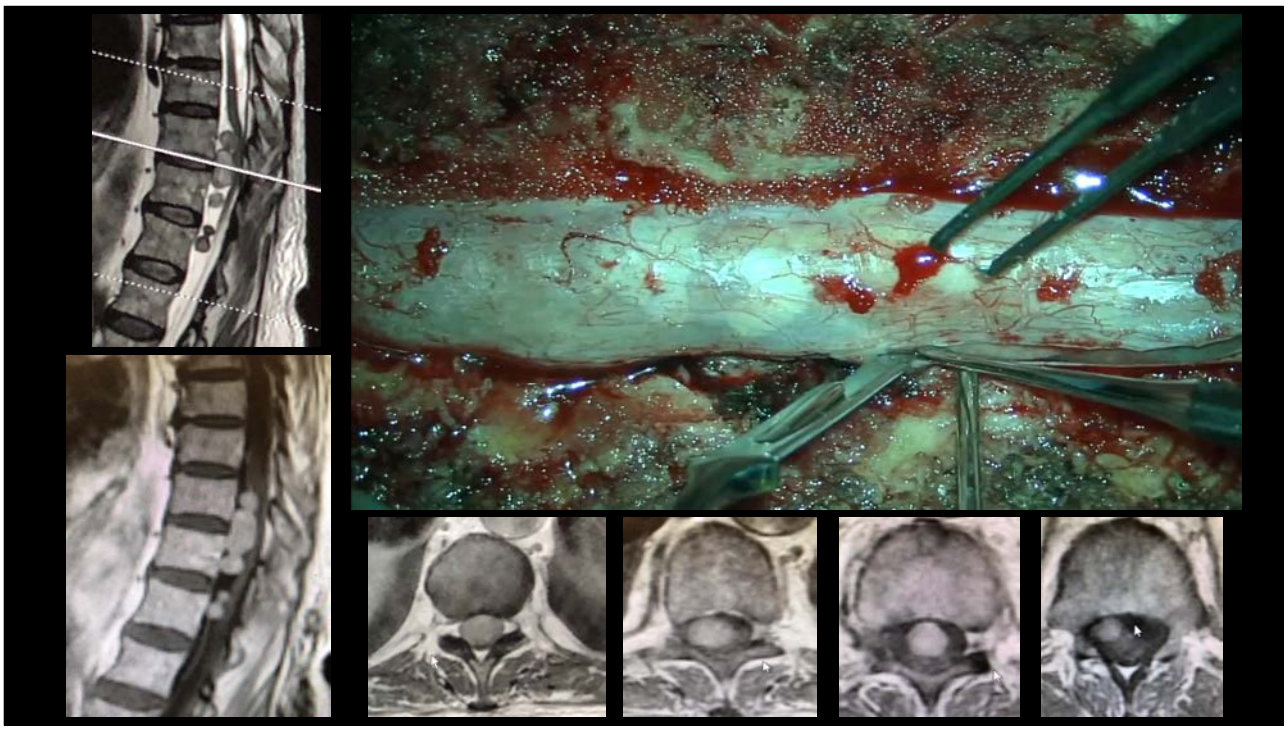

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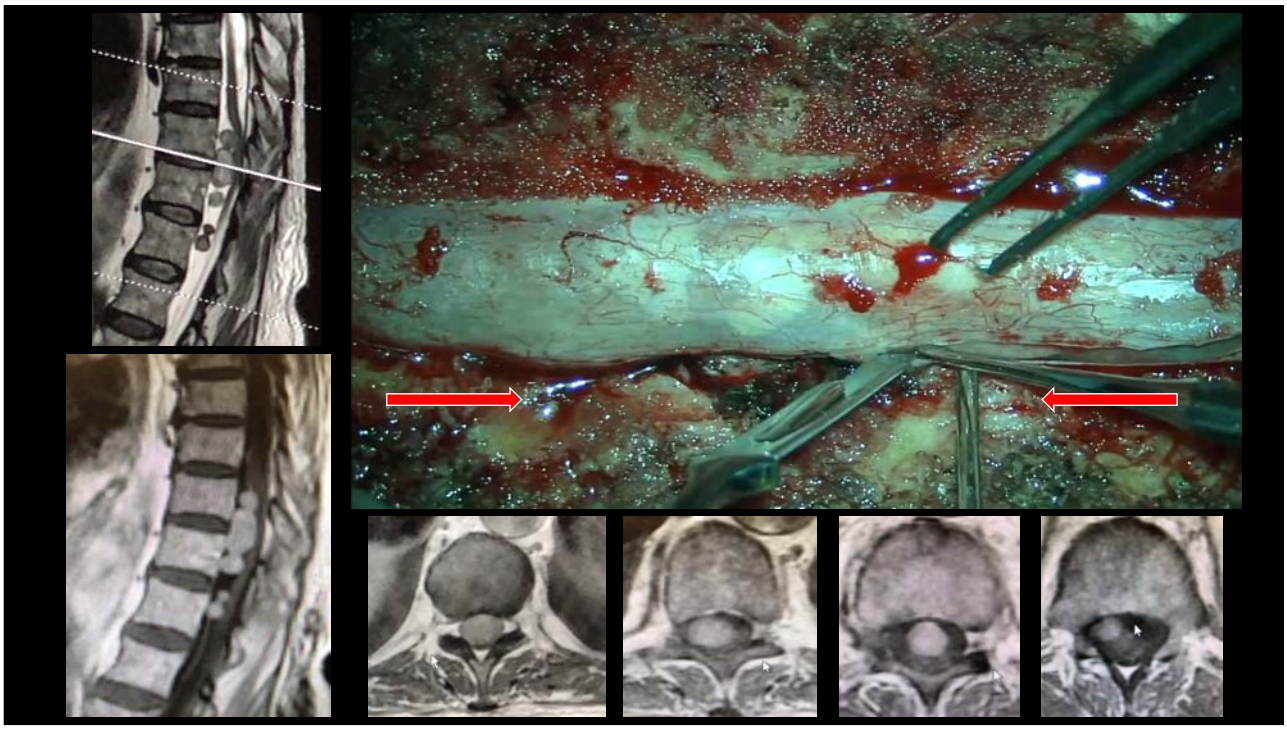

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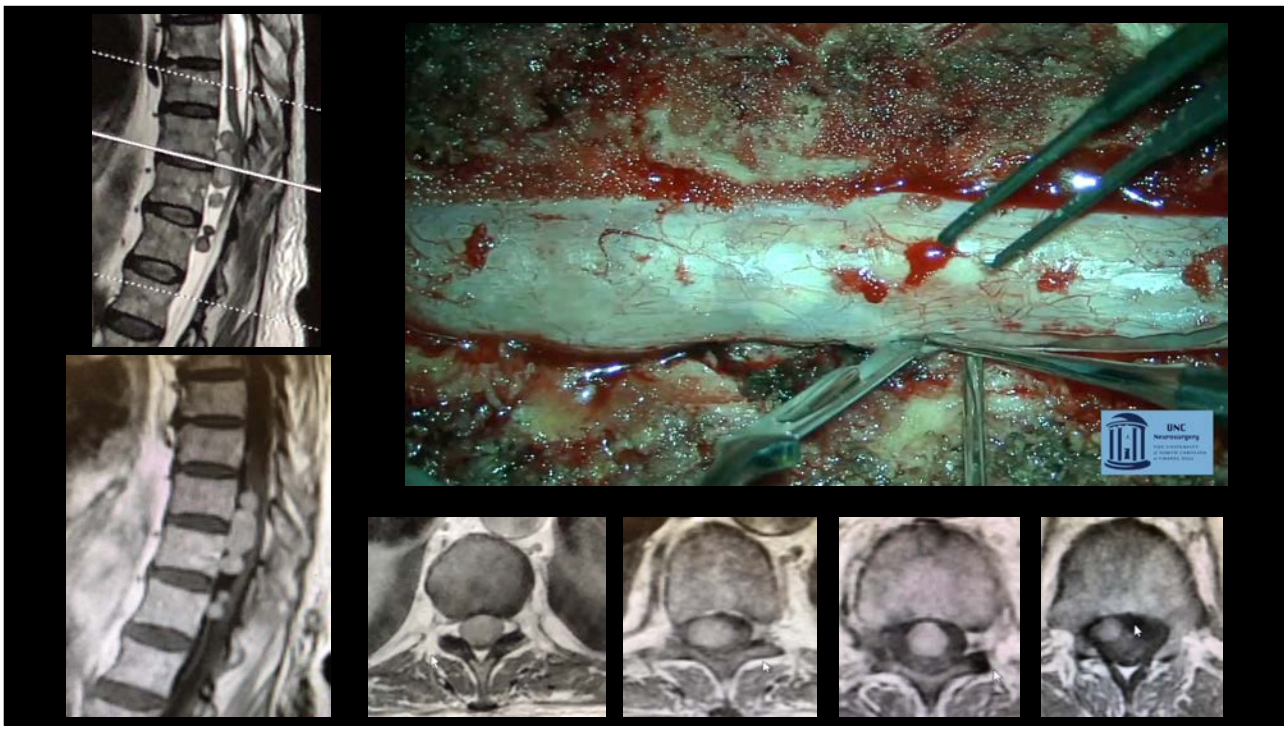

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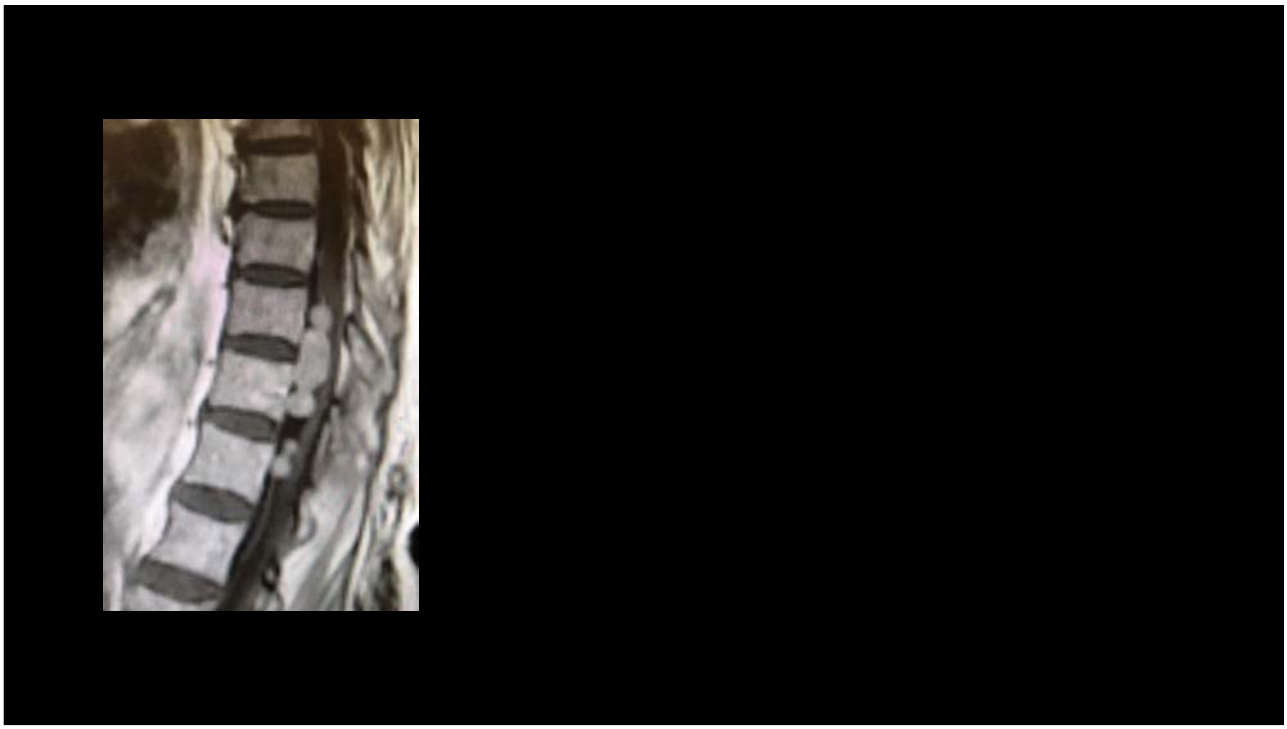

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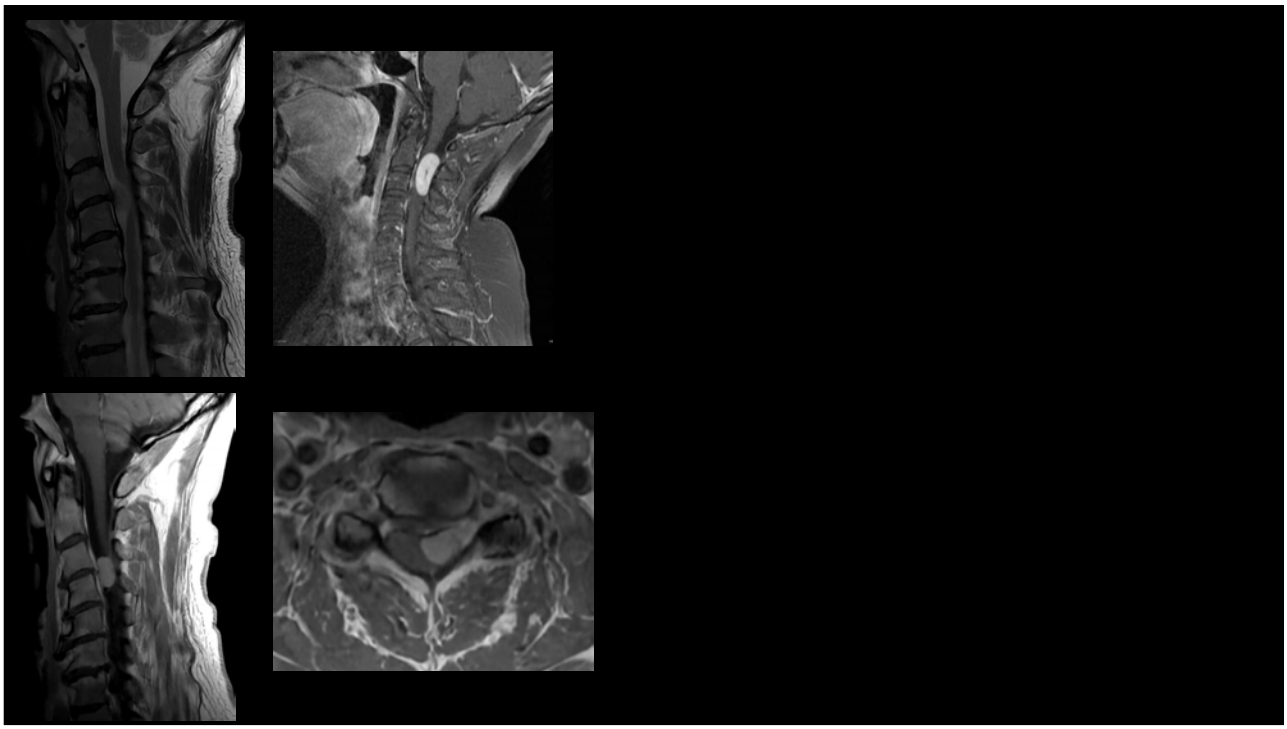

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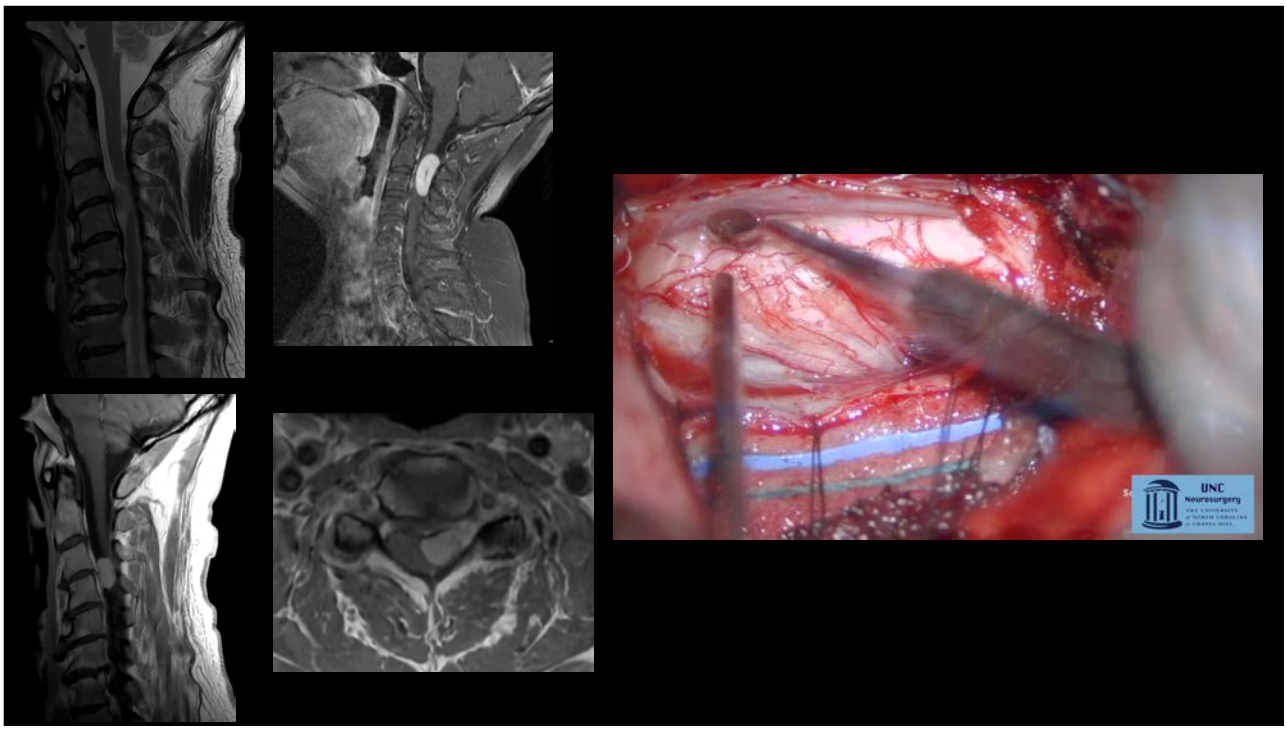

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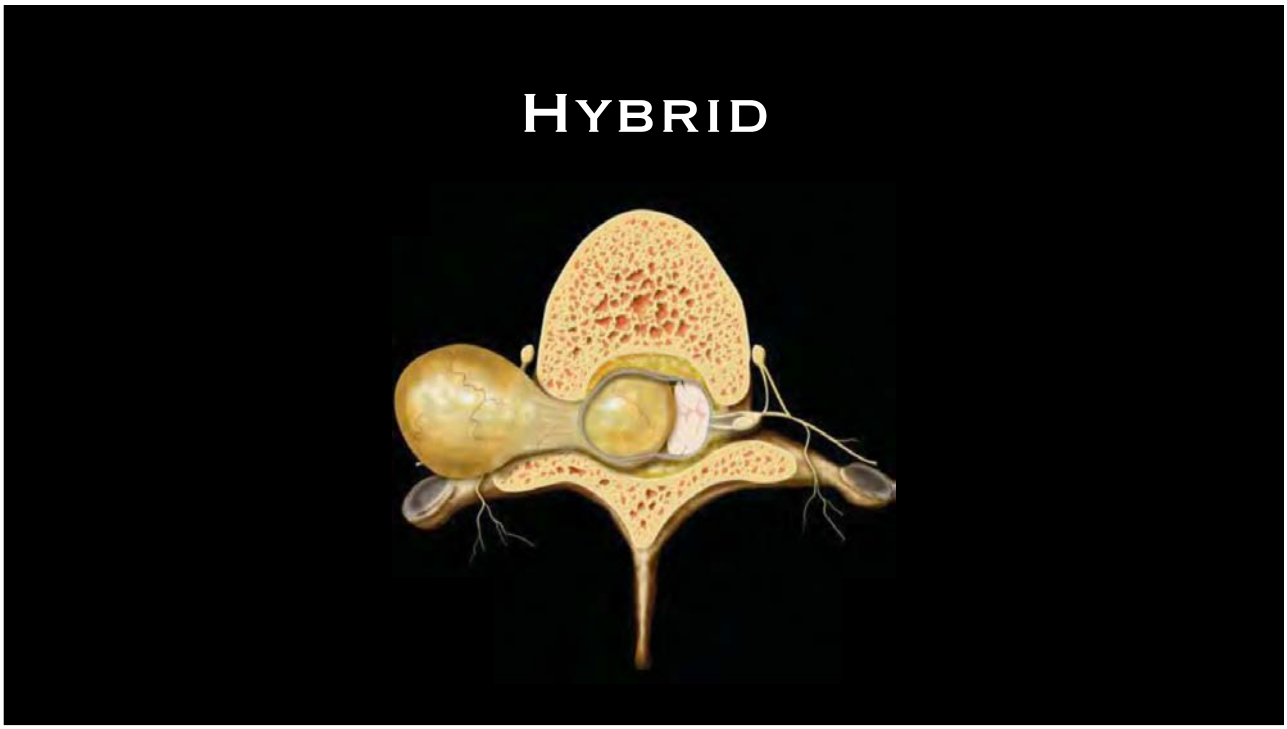

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Video Abstract

Surgical technique: Posterior retropleural thoracotomy for resection of a T10 dumbbell schwannoma

Disep I. Ojukwu[1], Brandon M. Wilkinson[2], Timothy Dawson, II[1], Michael A. Galgano[2,3]

[1]St. George's University, School of Medicine, Great River, [2]Department of Neurosurgery, SUNY Upstate Medical University, Syracuse, [3]Department of Neurosurgery, University of North Carolina, Chapel Hill, New York, United States.

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Open Access Technical Report

Novel Single-Staged Posterior Retropleural Approach with Thoracoscopic Guidance for Resection of a Thoracic Dumbbell Schwannoma

Jared Sweeney [1], Stephanie Zyck [1], Mark Crye [2], Michael Galgano [1]

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Abstract

Dumbbell spinal cord tumors are infrequent pathologic entities. The optimal approach to safe surgical resection is ill-defined and must often be individualized. This is assisted with multiple tumor classification systems. Here, we describe a novel technique used to safely and successfully resect a large thoracic dumbbell schwannoma originating from the left T3 spinal nerve root with extension into the posterior mediastinum adjacent to the parietal pleura and thoracic aorta. A review of the literature was performed to study described surgical approaches to primary spinal dumbbell tumors. The decision-making process and preoperative imaging for operative planning are included. A detailed description of the procedure follows with intraoperative images. Gross total resection with no neurologic sequelae was achieved. Previously described operative techniques for resection of primary spinal dumbbell tumors with advantages and limitations of each are then reviewed. Gross total resection was safely achieved utilizing a single-staged posterior retropleural approach with anterior thoracoscopic guidance. The tumor was removed en bloc through a large posterior window. The prone position was utilized for the entire case with no intraoperative repositioning required. No intraoperative or immediate postoperative complications occurred. We report a novel approach to resecting a large primary spinal dumbbell tumor. A single-stage retropleural approach with anterior thoracoscopic guidance facilitated safe and successful gross total resection. Maintenance of the prone position throughout surgery allowed for reduced operative time, excellent anterior, and posterior visualization and no added patient morbidity. Repositioning to the lateral decubitus position may not be required in select cases.

Categories: Cardiac/Thoracic/Vascular Surgery, Neurosurgery
Keywords: spine, neoplasms, neurosurgery, spine neurosurgery, tumor resection

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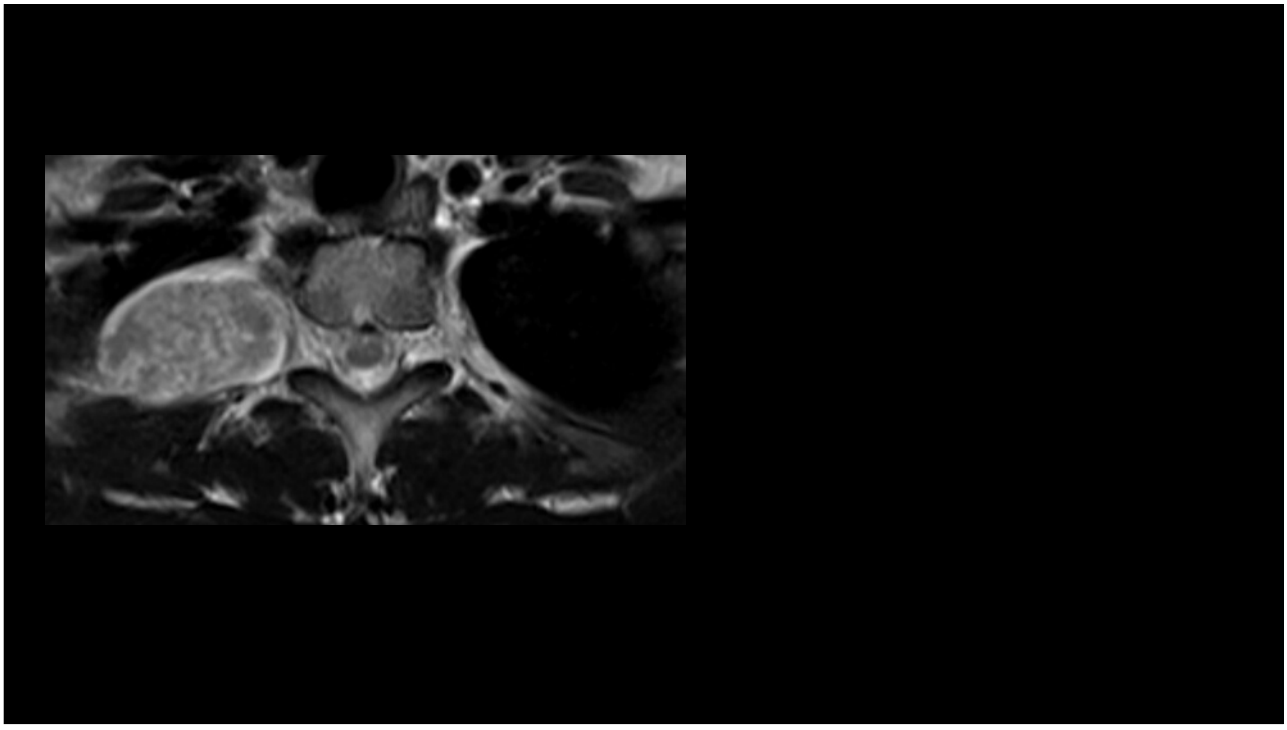

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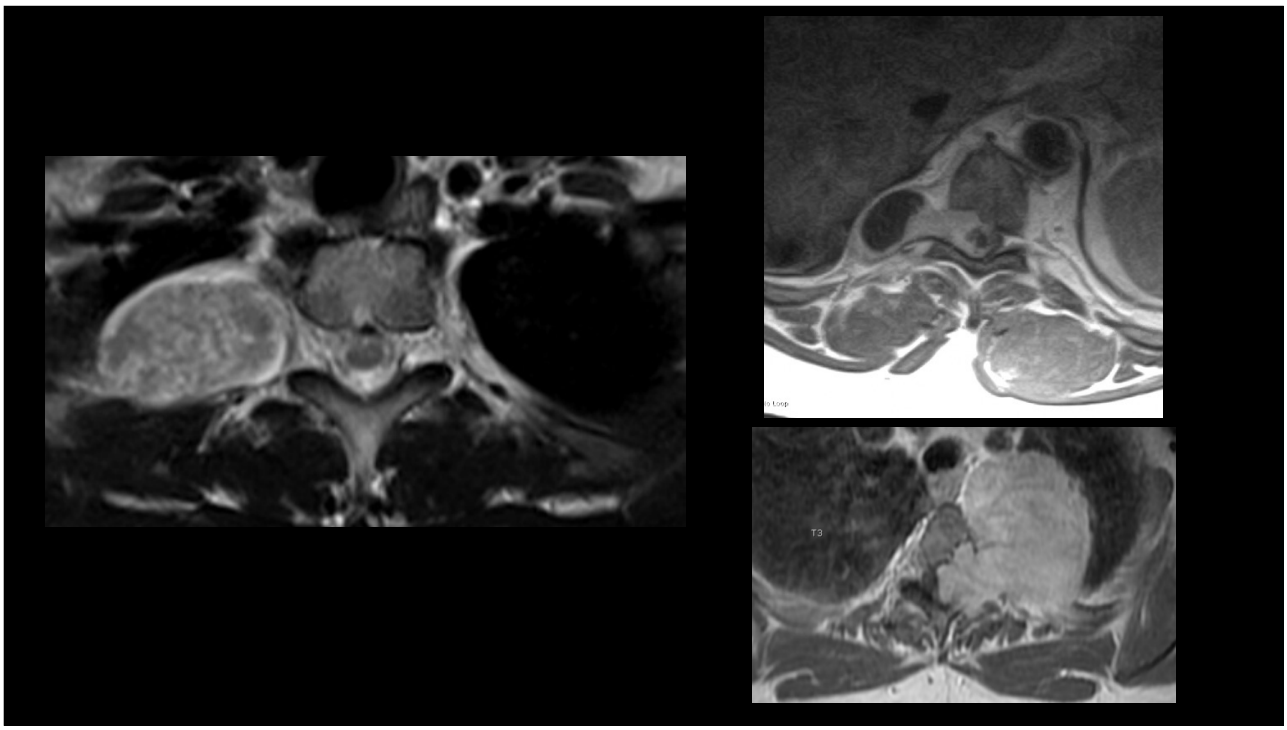

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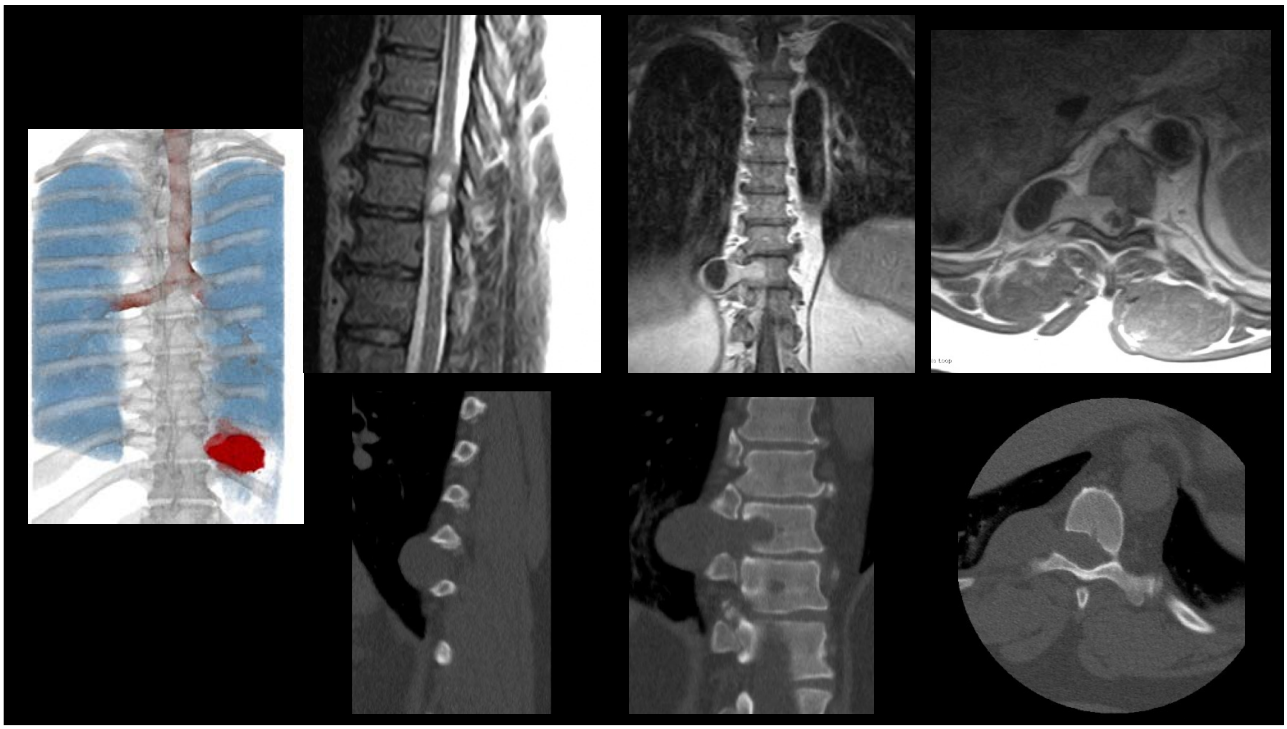

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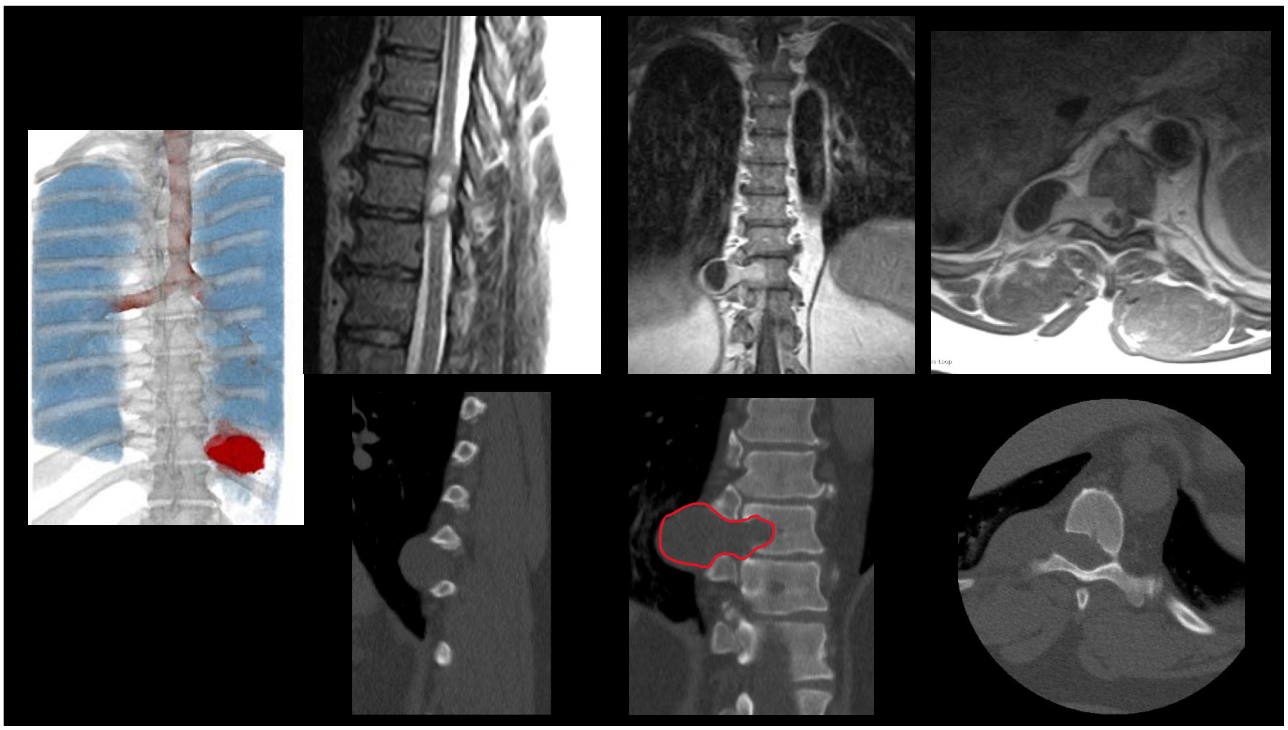

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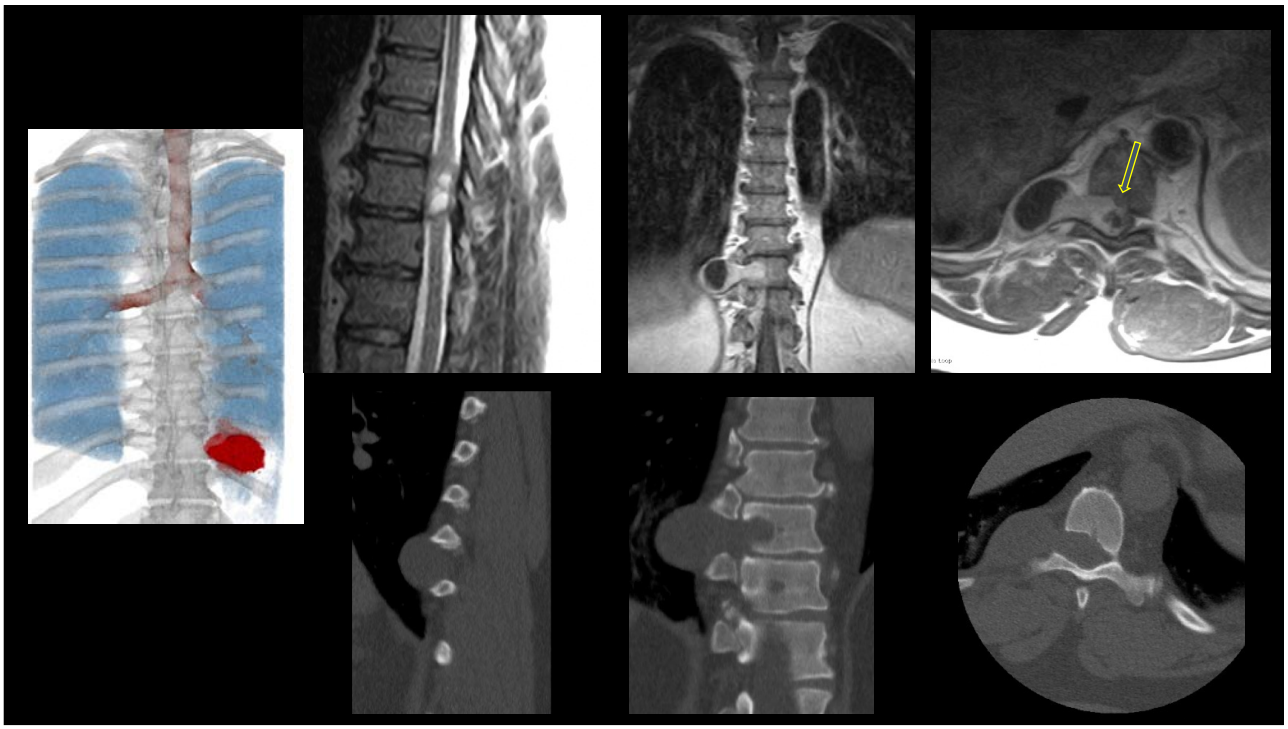

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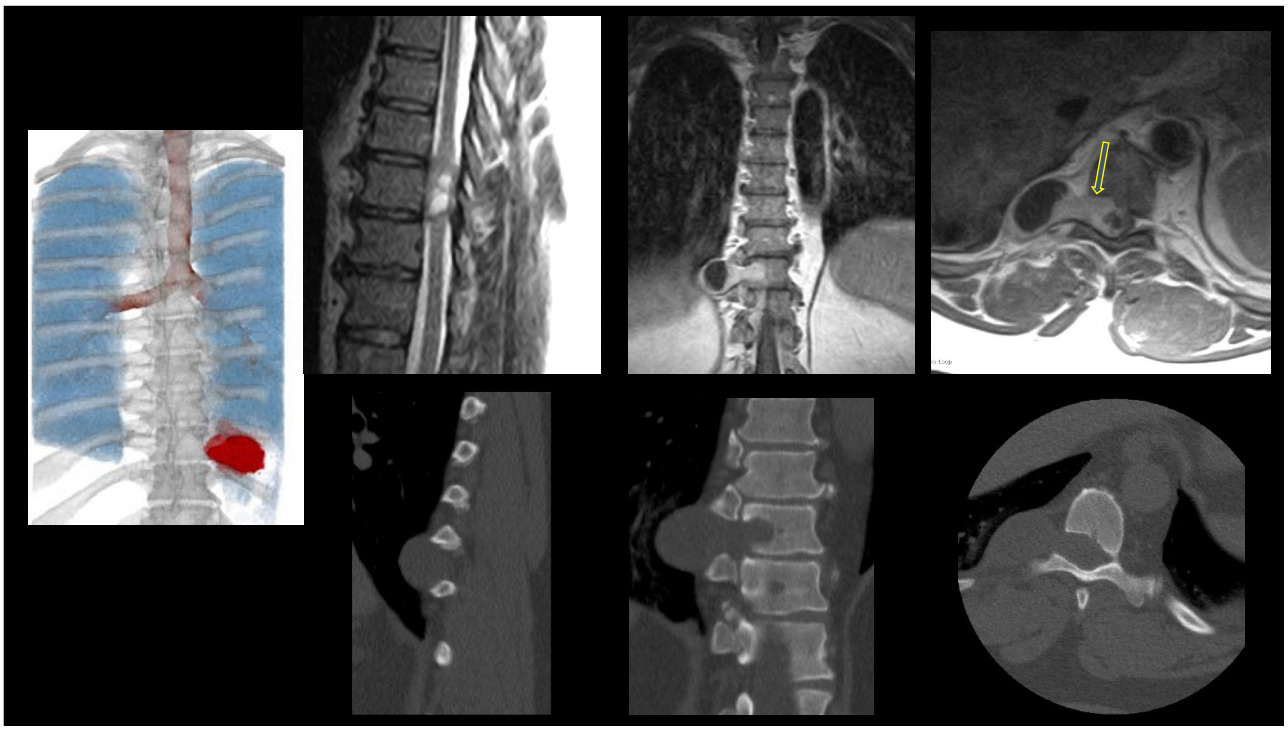

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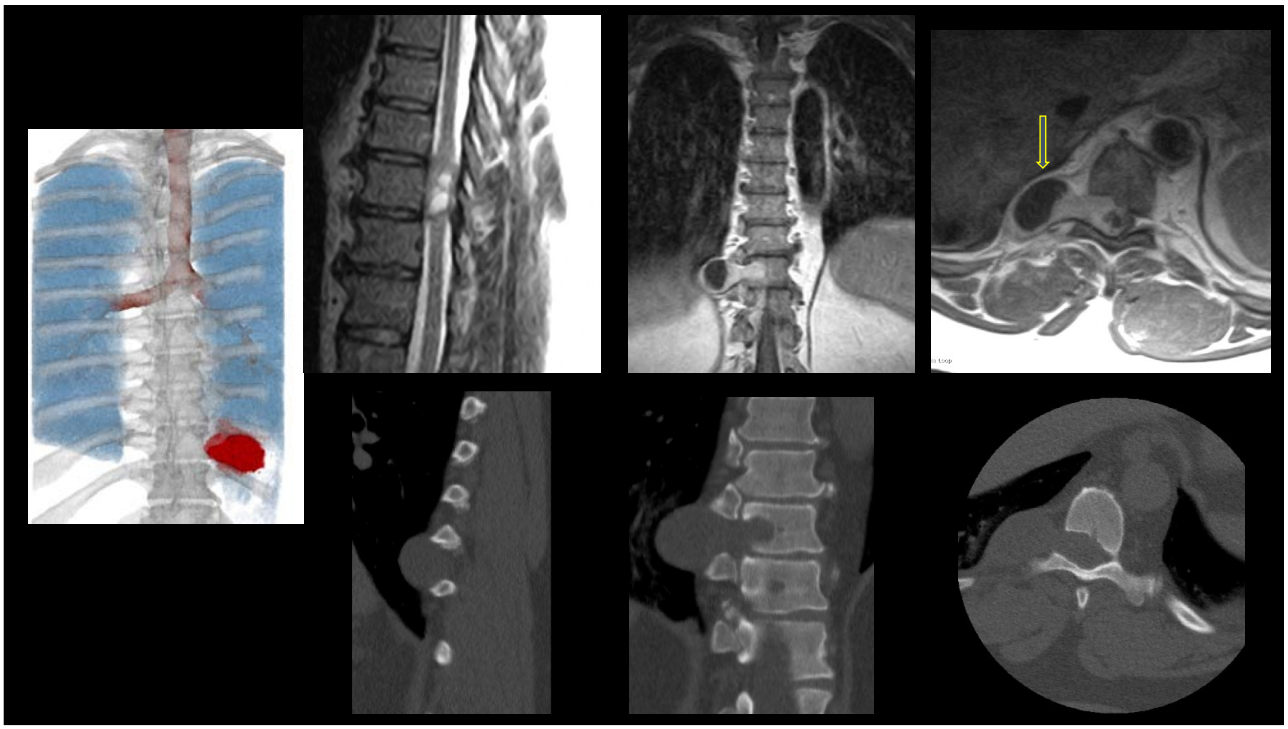

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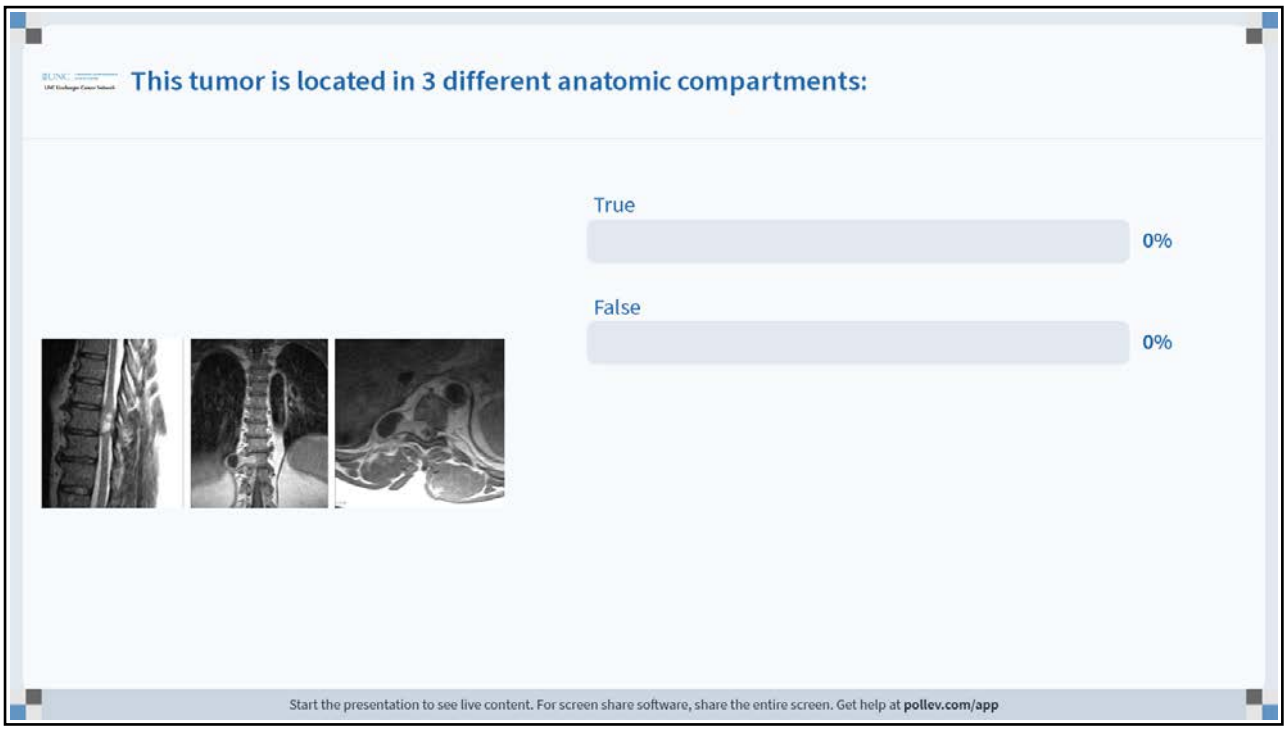
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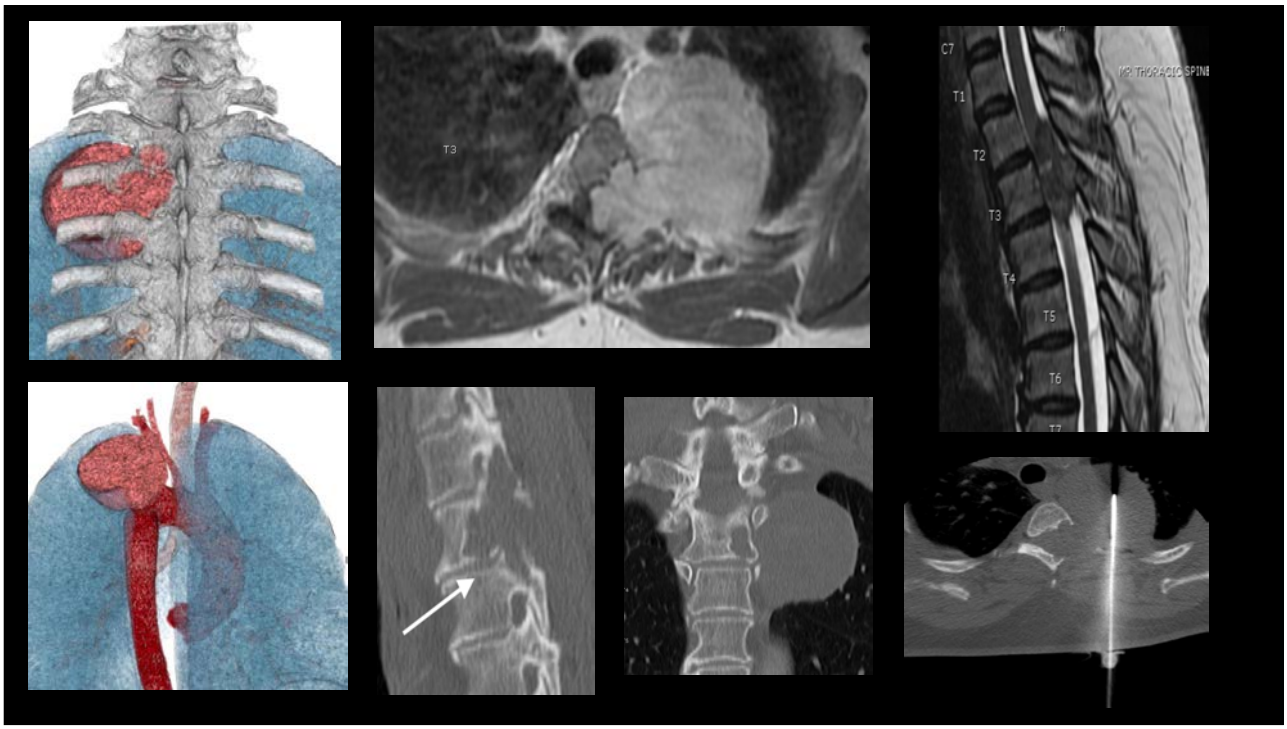
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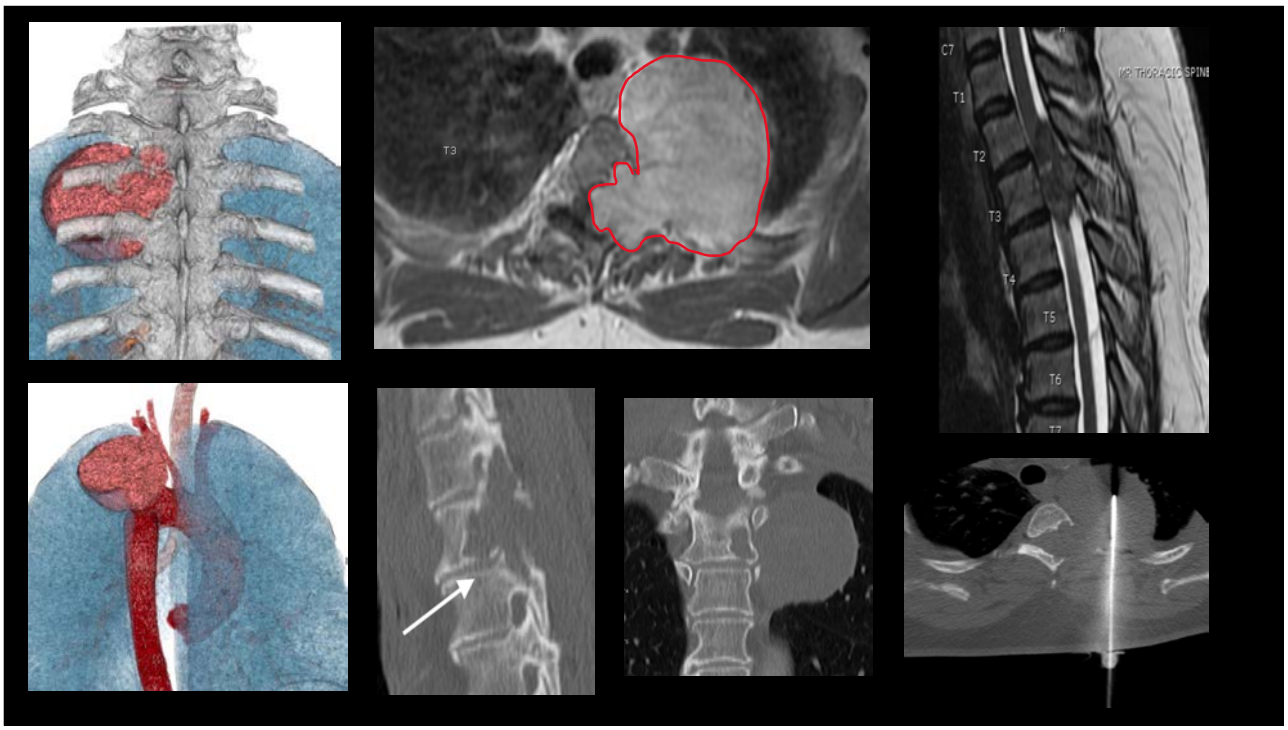

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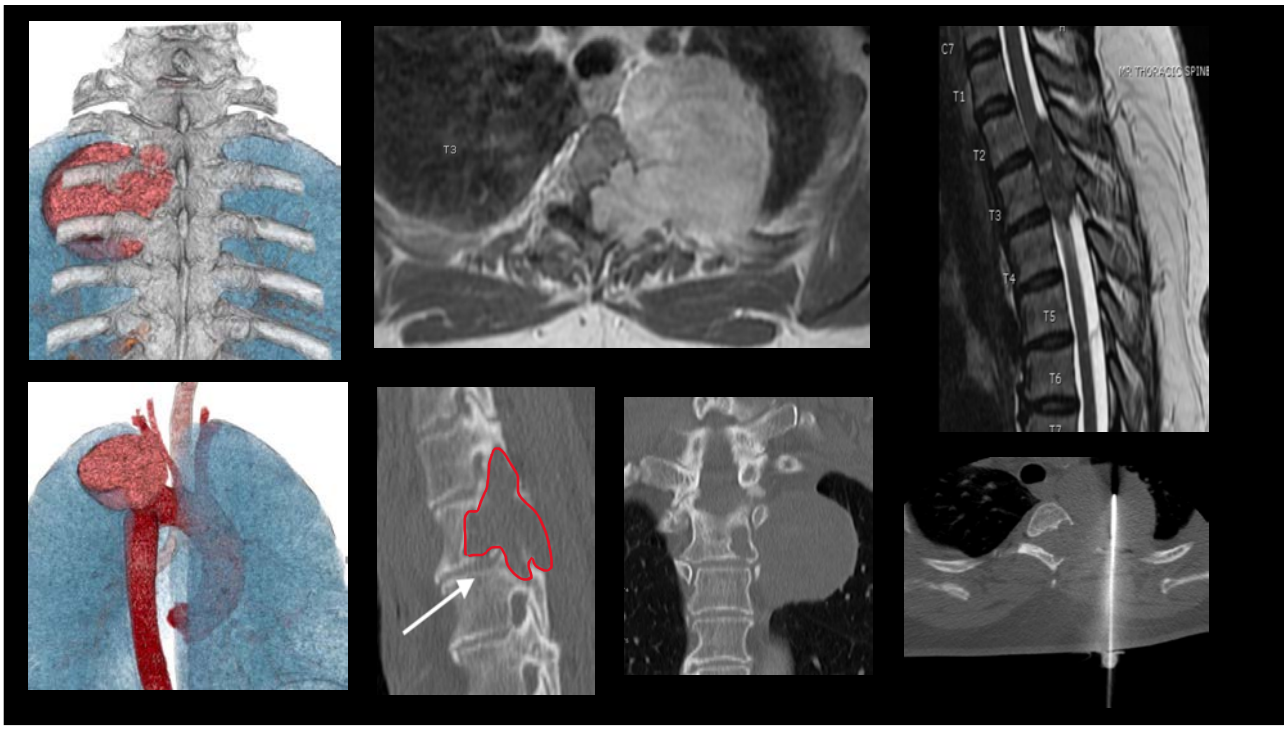

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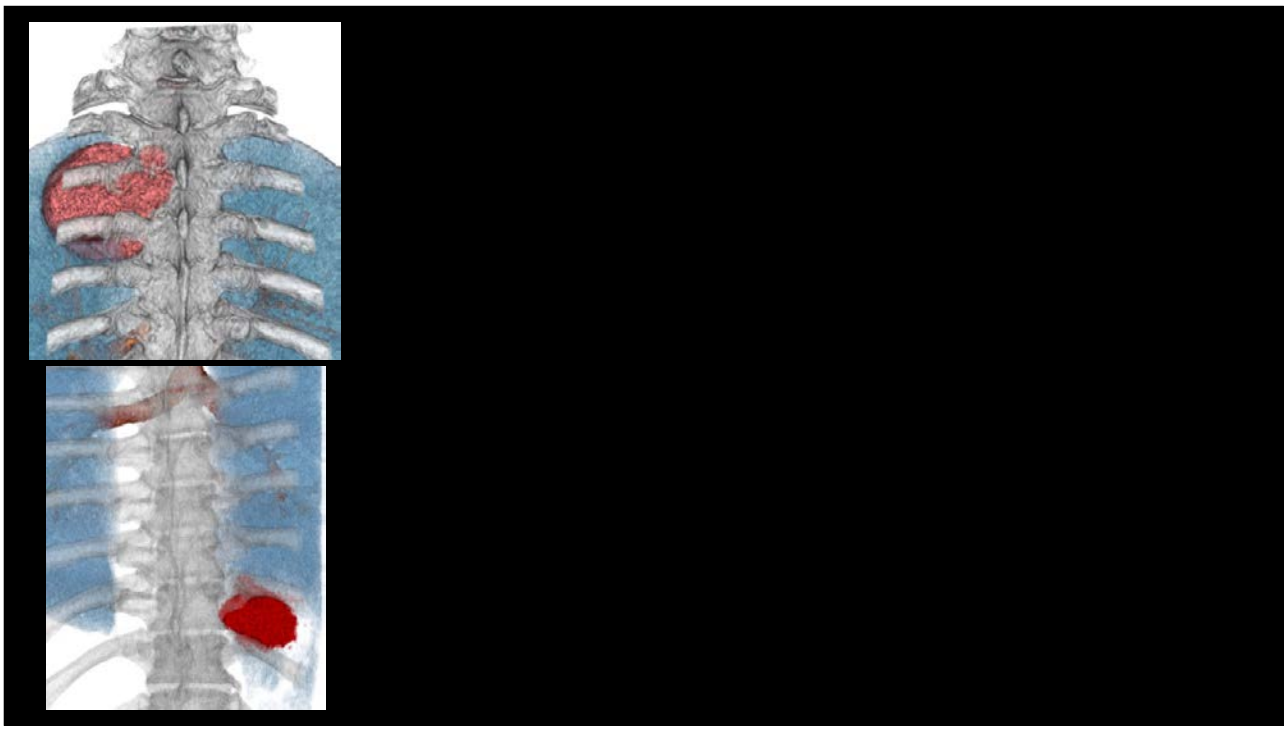

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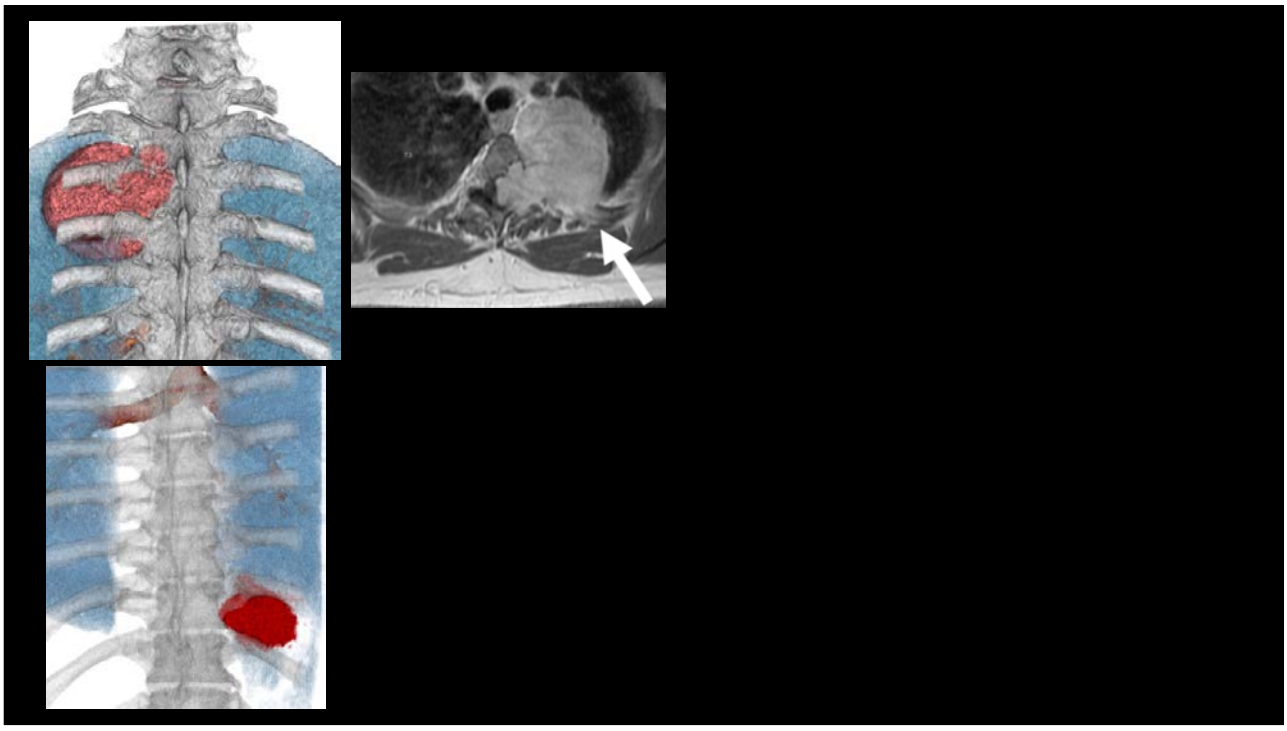

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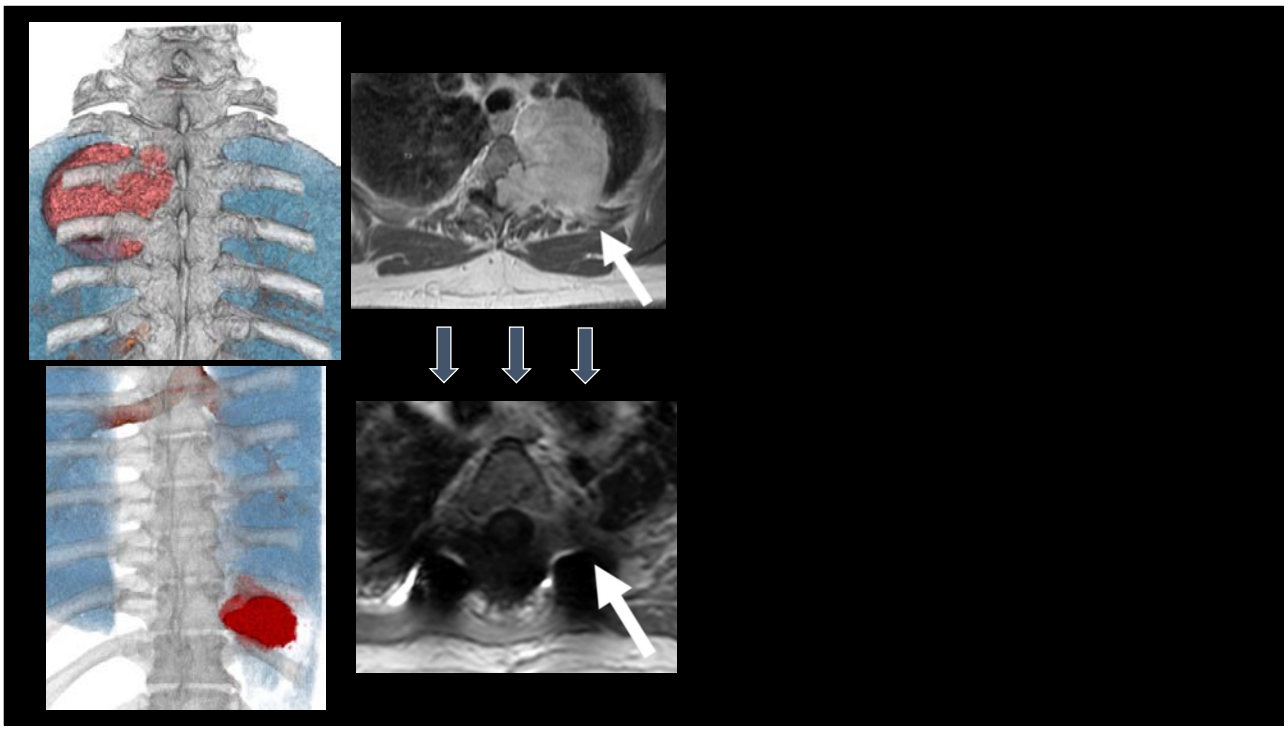

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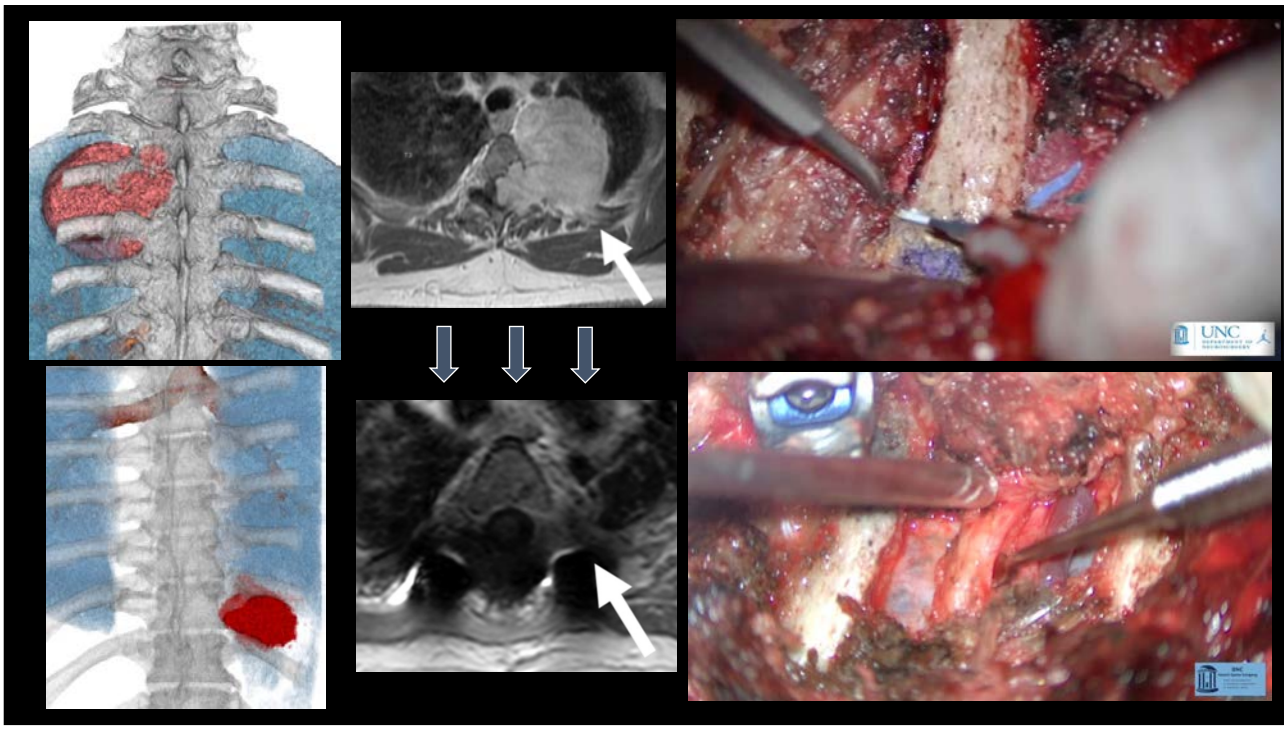

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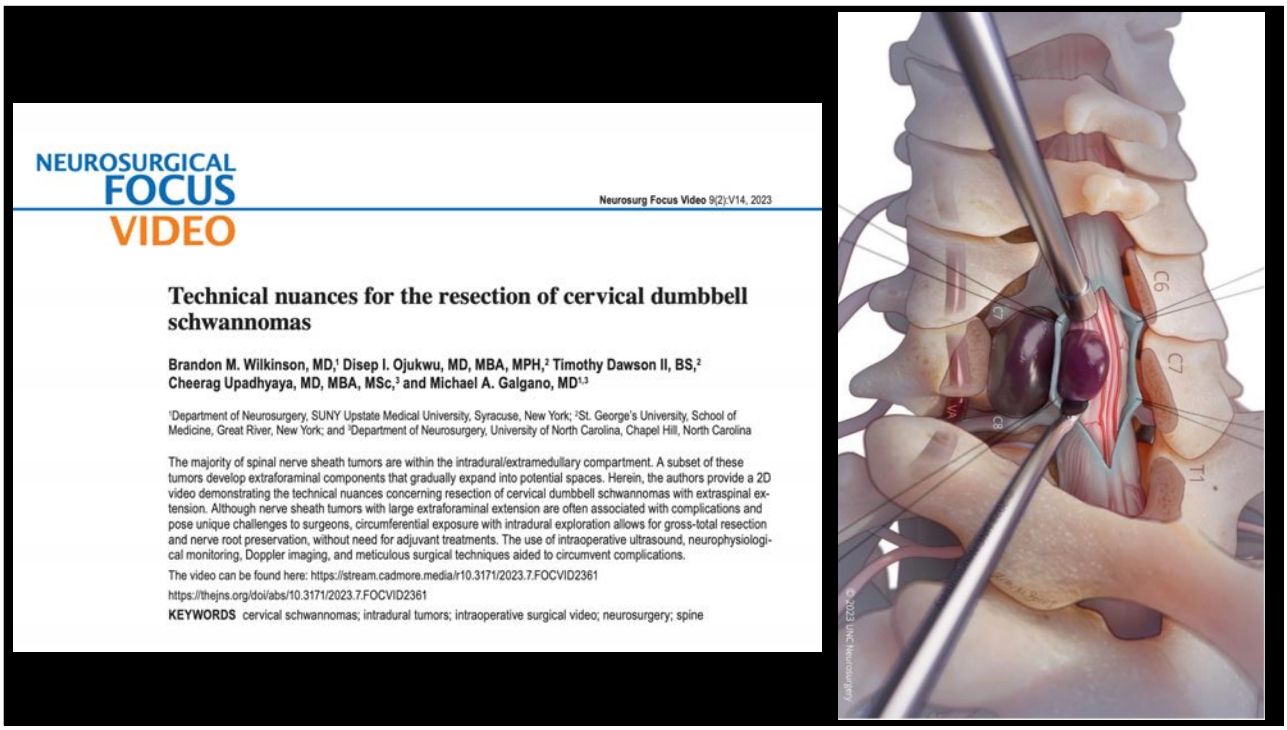
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Technical nuances for the resection of cervical dumbbell schwannomas
Brandon M. Wilkinson, MD,[1] Disep I. Ojukwu, MD, MBA, MPH,[2] Timothy Dawson II, BS,[2] Cheerag Upadhyaya, MD, MBA, MSc,[3] and Michael A. Galgano, MD[1,3]
[1]Department of Neurosurgery, SUNY Upstate Medical University, Syracuse, New York; [2]St. George's University, School of Medicine, Great River, New York; and [3]Department of Neurosurgery, University of North Carolina, Chapel Hill, North Carolina
The majority of spinal nerve sheath tumors are within the intradural/extramedullary compartment. A subset of these tumors develop extraforaminal components that gradually expand into potential spaces. Herein, the authors provide a 2D video demonstrating the technical nuances concerning resection of cervical dumbbell schwannomas with extraspinal extension. Although nerve sheath tumors with large extraforaminal extension are often associated with complications and pose unique challenges to surgeons, circumferential exposure with intradural exploration allows for gross-total resection and nerve root preservation, without need for adjuvant treatments. The use of intraoperative ultrasound, neurophysiological monitoring, Doppler imaging, and meticulous surgical techniques aided to circumvent complications.
The video can be found here: https://stream.cadmore.media/r10.3171/2023.7.FOCVID2361
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KEYWORDS cervical schwannomas; intradural tumors; intraoperative surgical video; neurosurgery; spine
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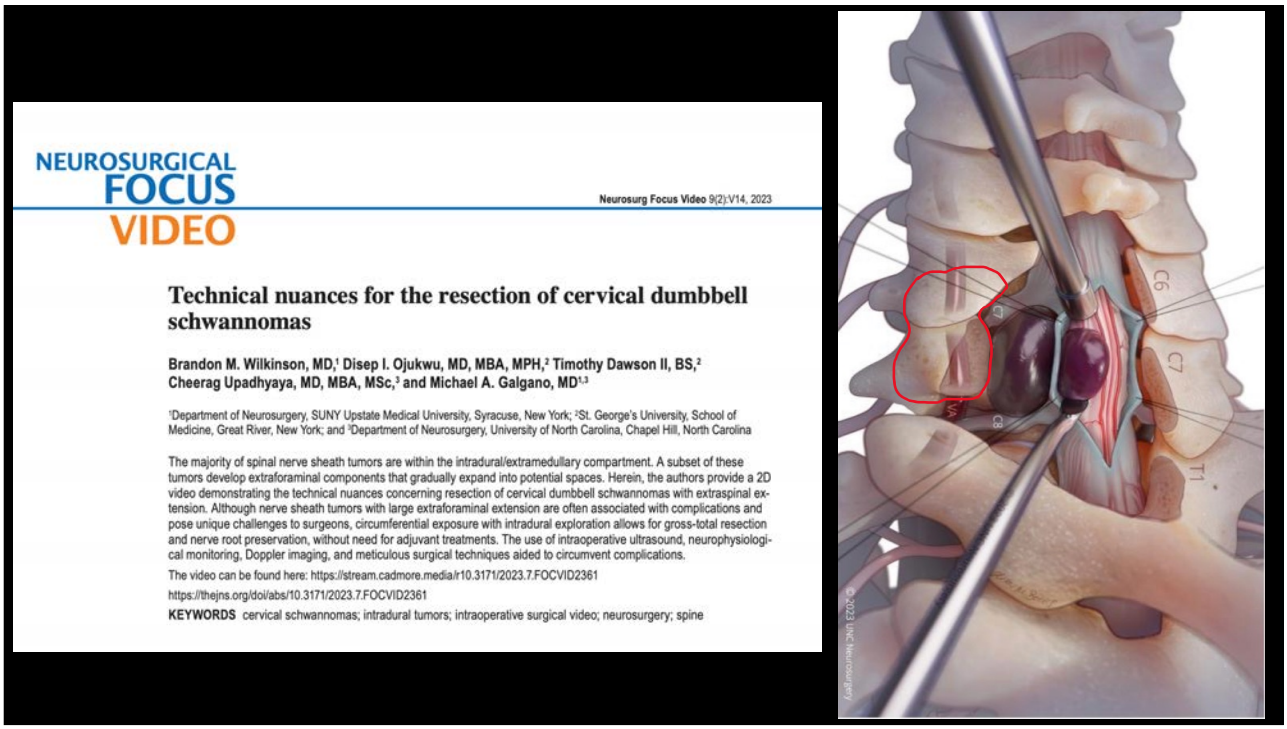
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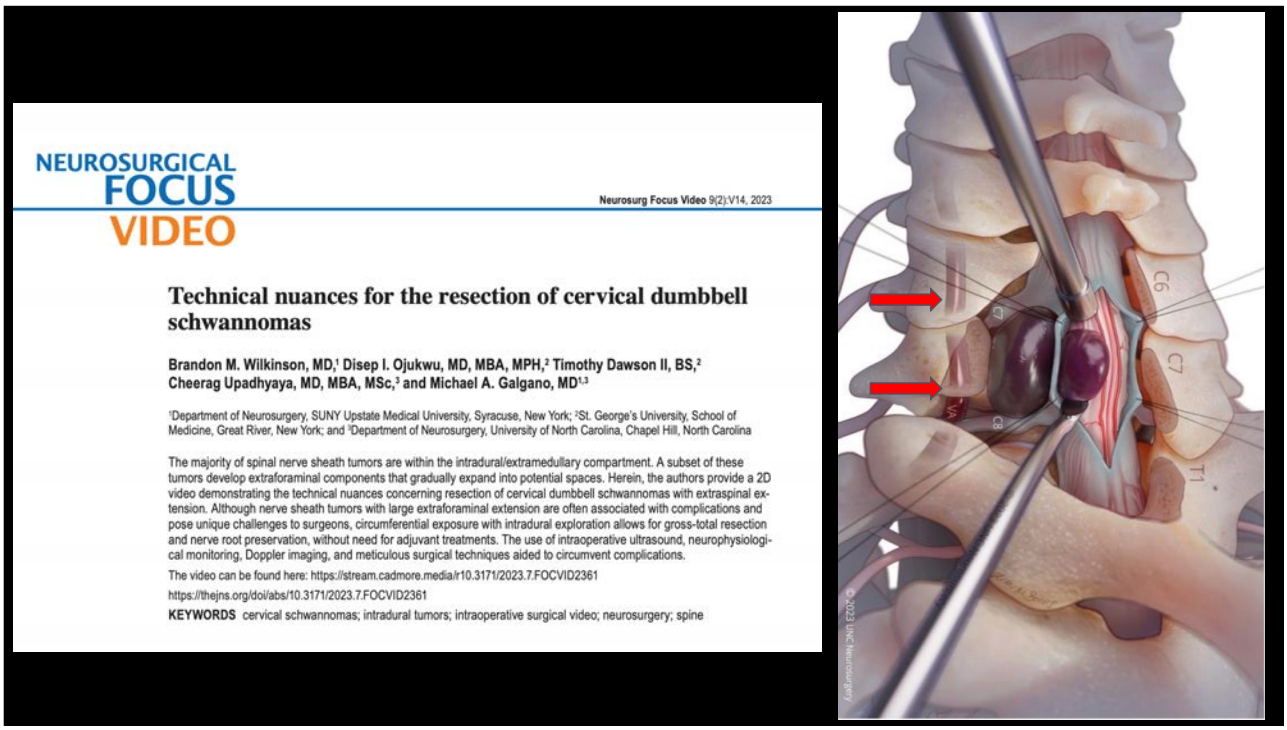
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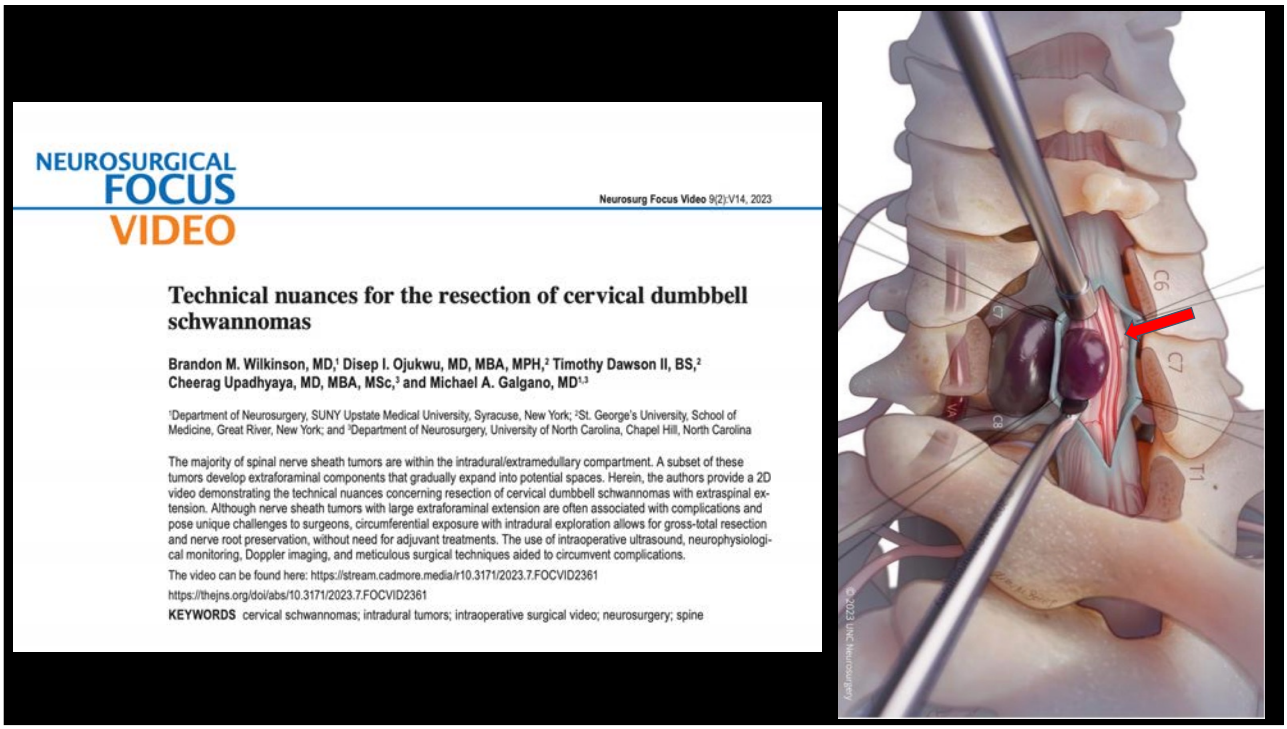
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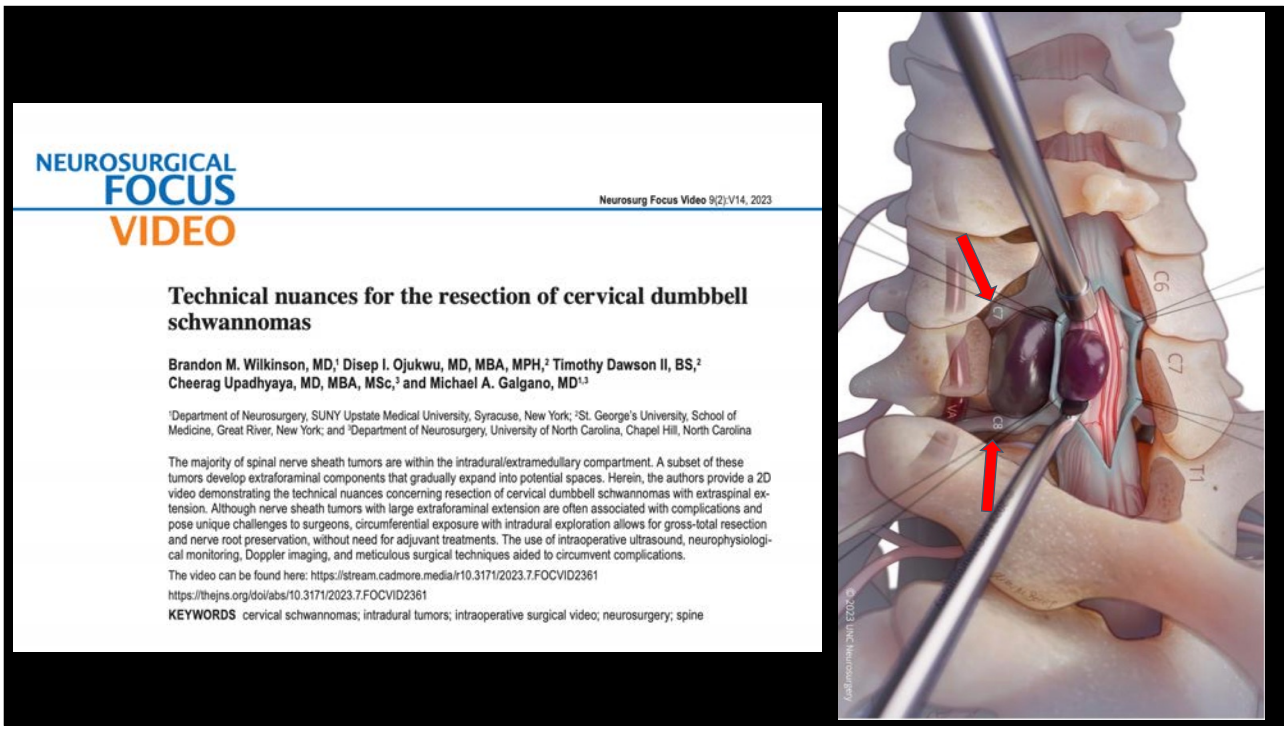
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CASE SERIES
A Case Series of Surgically Treated Spinal Dumbbell Tumors of Critical Parent Nerve Roots: To Cut or Not to Cut?
Vicki Marie Butenschoen, MD, MSc
Nikolaus Kögl, MD
Bernhard Meyer, MD
Claudius Thomé, MD
Maria Wostrack, MD
BACKGROUND: Dumbbell tumors present challenging cases, with either an incomplete tumor resection or a need to sacrifice nerve roots. Published literature suggests encouraging neurological outcomes after nerve root amputation.
OBJECTIVE: To determine the incidence of postoperative neurological deficits after amputating the parent nerve root.
METHODS: A retrospective consecutive analysis of all patients treated for dumbbell nerve sheet tumors with a reported amputation of the functional relevant parent nerve roots C5-Th1 and L3-S1.
RESULTS: Among 21 evaluated patients, minor postoperative neurological motor function deterioration occurred in 4 patients (19%). Most patients recovered to the preoperative level at the follow-up examination, and only one patient retained a new Medical Research Council (MRC) scale of 4/5 for deltoid weakness. The majority of tumors were resected at the lumbar level (nerve root L3: 28.6%, L5: 19%). Gross total resection was achieved in 90.5% of patients. Neuropathic pain was reported in one third of the patients during the long-term follow-up.
CONCLUSION: Amputating critical parent nerve roots during the dumbbell tumor resections seems to result in a low incidence of postoperative motor deficits and may offer an acceptable sacrifice in otherwise only incompletely resectable dumbbell tumors. The cross-innervation of neighboring nerve roots and its, probably, per-se-reduced functionality may be a possible mechanism for maintaining motor function.
KEY WORDS: Functional relevant nerve root, Schwannoma, Dumbbell tumor
Schwannomas are benign tumors and present the most common primary neoplasms of the spinal chord.
Standard treatment includes a gross total resection (GTR) in cases of nonsyndromic schwannoma while preserving neurological function.
Although most schwannomas grow intradural extramedullary, they can extend via intradural and extradural components then called dumbbell schwannomas, or "hourglass tumors."
ABBREVIATIONS: EMG, electromyography; GTR, gross total resection; KPS, Karnofsky Performance Scale; MRC, Medical Research Council; MRI, magnetic resonance imaging; WHO, World Health Organization grade
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VIDEO
Technical nuances for the resection of cervical dumbbell schwannomas
Brandon M. Wilkinson, MD, Disep I. Ojukwu, MD, MBA, MPH, Timothy Dawson II, BS, Cheerag Upadhyaya, MD, MBA, MSc, and Michael A. Galgano, MD

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CASE SERIES

A Case Series of Surgically Treated Spinal Dumbbell Tumors of Critical Parent Nerve Roots: To Cut or Not to Cut?

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BACKGROUND: Dumbbell tumors present challenging cases, with either an incomplete tumor resection or a need to sacrifice nerve roots. Published literature suggests encouraging neurological outcomes after nerve root amputation.
OBJECTIVE: To determine the incidence of postoperative neurological deficits after amputating the parent nerve root.
METHODS: A retrospective consecutive analysis of all patients treated for dumbbell nerve sheet tumors with a reported amputation of the functional relevant parent nerve roots C5-Th1 and L3-S1.
RESULTS: Among 21 evaluated patients, minor postoperative neurological motor function deterioration occurred in 4 patients (19%). Most patients recovered to the preoperative level at the follow-up examination, and only one patient retained a new Medical Research Council (MRC) scale of 4/5 for deltoid weakness. The majority of tumors were resected at the lumbar level (nerve root L3: 28.6%, L5: 19%). Gross total resection was achieved in 90.5% of patients. Neuropathic pain was reported in one third of the patients during the long-term follow-up.
CONCLUSION: Amputating critical parent nerve roots during the dumbbell tumor resections seems to result in a low incidence of postoperative motor deficits and may offer an acceptable sacrifice in otherwise only incompletely resectable dumbbell tumors. The cross-innervation of neighboring nerve roots and its, probably, per-se-reduced functionality may be a possible mechanism for maintaining motor function.

KEY WORDS: Functional relevant nerve root, Schwannoma, Dumbbell tumor

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Schwannomas are benign tumors and present the most common primary neoplasms of the spinal chord.[1,2] Standard treatment includes a gross total resection (GTR) in cases of nonsyndromic schwannoma while preserving neurological function.[3]

Although most schwannomas grow intradural extramedullary,[2] they can extend via intradural and extradural components then called dumbbell schwannomas, or "hourglass tumors."[4] Sridhar et al[5] characterizes spinal schwannoma according to their sizes and extensions in type I (intraspinal tumor) to V (giant invasive dumbbell schwannoma). Dumbbell tumors are classified as type IV tumors,[5] and tumors that reach the nerve root foramen but do not exit it are defined as type III tumors.

As most schwannoma are benign tumors, a complete tumor resection remains the gold standard of surgical treatment.[3,6–8] In some cases, the tumor is close to important neural structures (such as dumbbell tumors of relevant nerve roots) comprising the nerve roots of the brachial plexus for the upper limb (C5 to T1) and the nerve roots of the plexus lumbo-sacralis for the lower limb (L3 to S1).[9,10] Whether sacrificing the parent nerve root is necessary to achieve a GTR and to reduce the risk of tumor recurrence remains debatable, as does the risk of a postoperative permanent deficit.[2,9–12]

ABBREVIATIONS: EMG, electromyography; GTR, gross total resection; KPS, Karnofsky Performance Scale; MRC, Medical Research Council; MRI, magnetic resonance imaging; WHO°, World Health Organization grade

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NEUROSURGICAL FOCUS VIDEO

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The majority of spinal nerve sheath tumors are within the intradural/extramedullary compartment. A subset of these tumors develop extraforaminal components that gradually expand into potential spaces. Herein, the authors provide a 2D video demonstrating the technical nuances concerning resection of cervical dumbbell schwannomas with extraspinal extension. Although nerve sheath tumors with large extraforaminal extension are often associated with complications and pose unique challenges to surgeons, circumferential exposure with intradural exploration allows for gross-total resection and nerve root preservation, without need for adjuvant treatments. The use of intraoperative ultrasound, neurophysiological monitoring, Doppler imaging, and meticulous surgical techniques aided to circumvent complications.

The video can be found here: https://stream.cadmore.media/r10.3171/2023.7.FOCVID2361

https://thejns.org/doi/abs/10.3171/2023.7.FOCVID2361

KEYWORDS cervical schwannomas; intradural tumors; intraoperative surgical video; neurosurgery; spine

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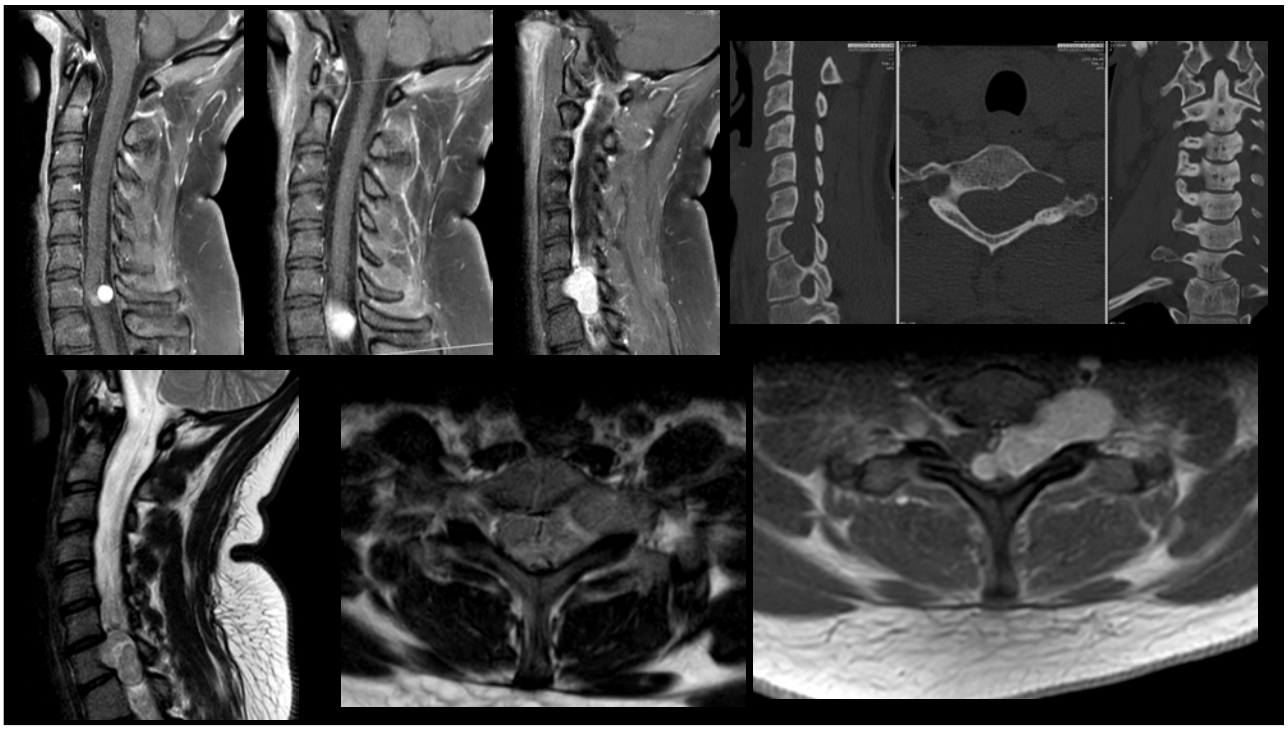

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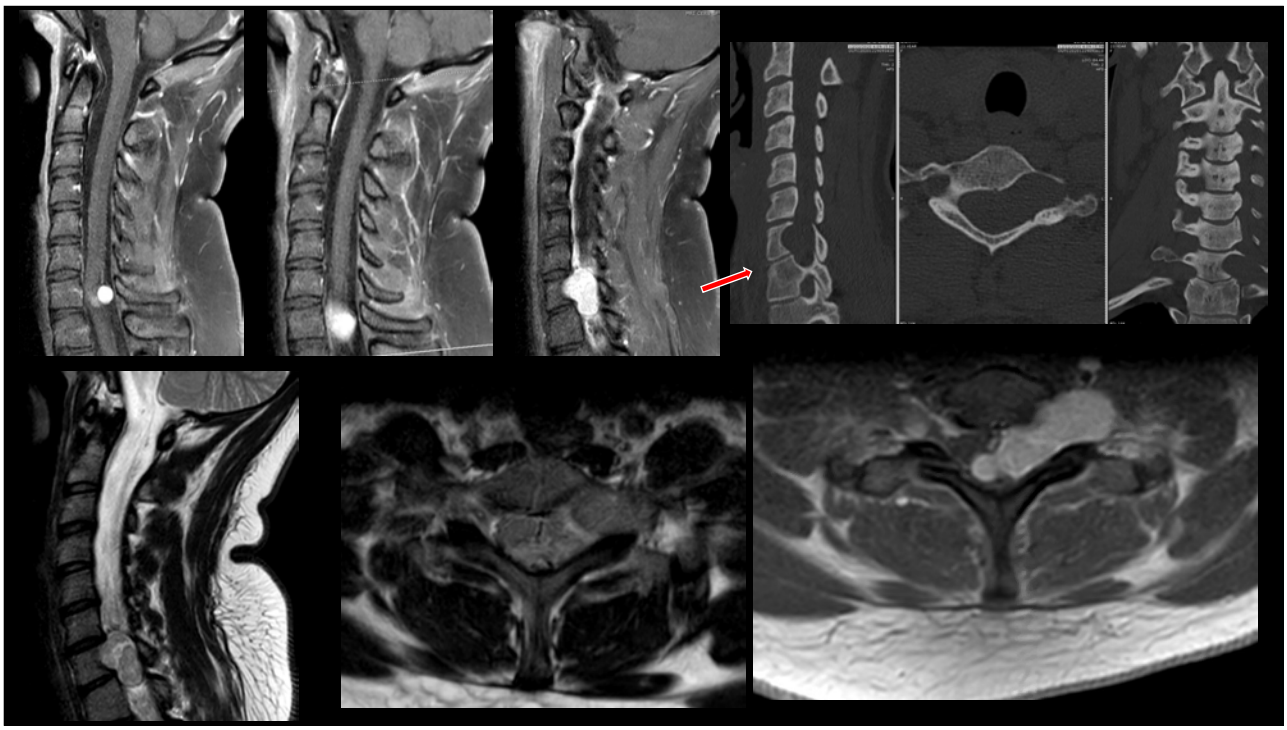

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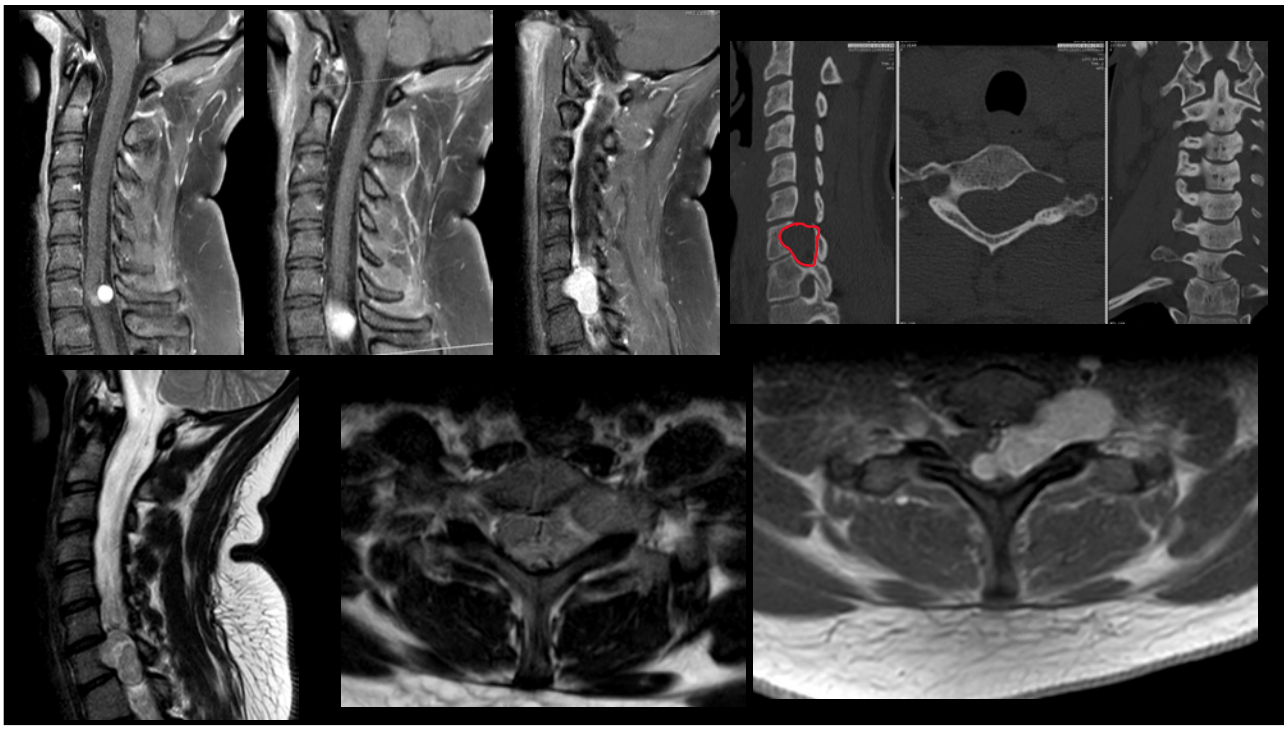

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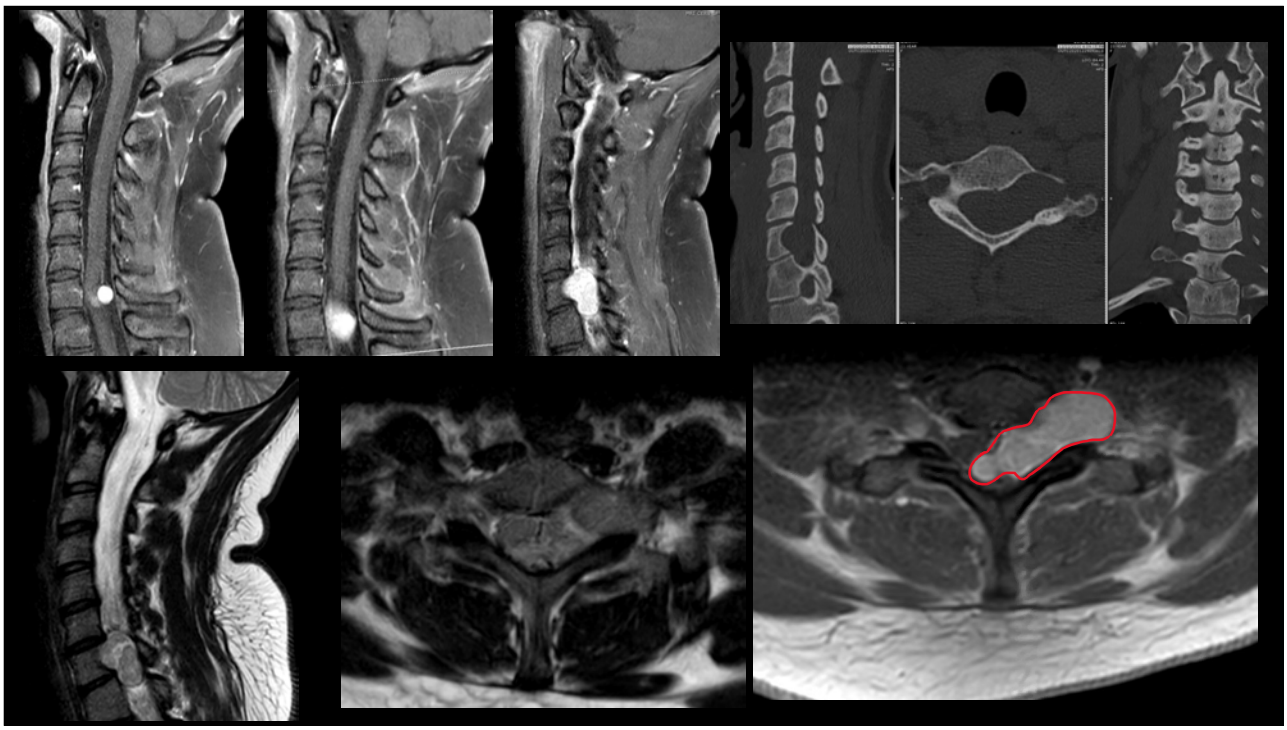

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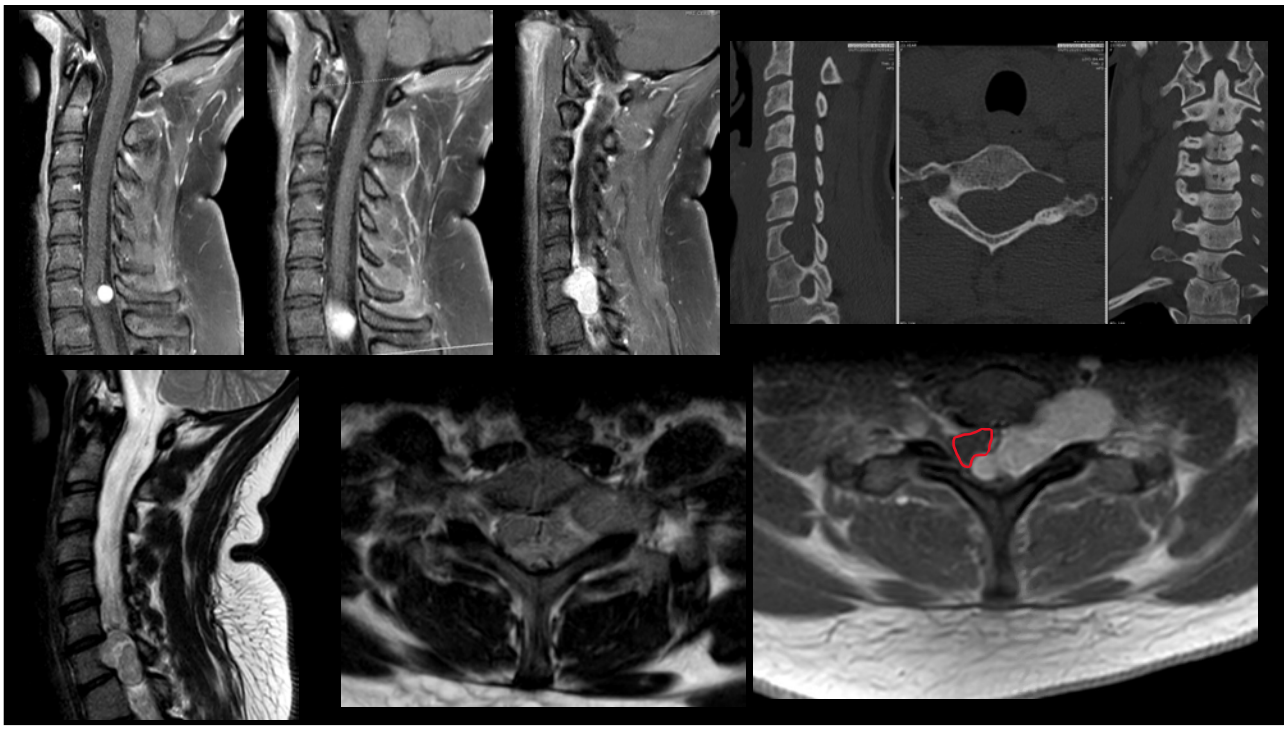

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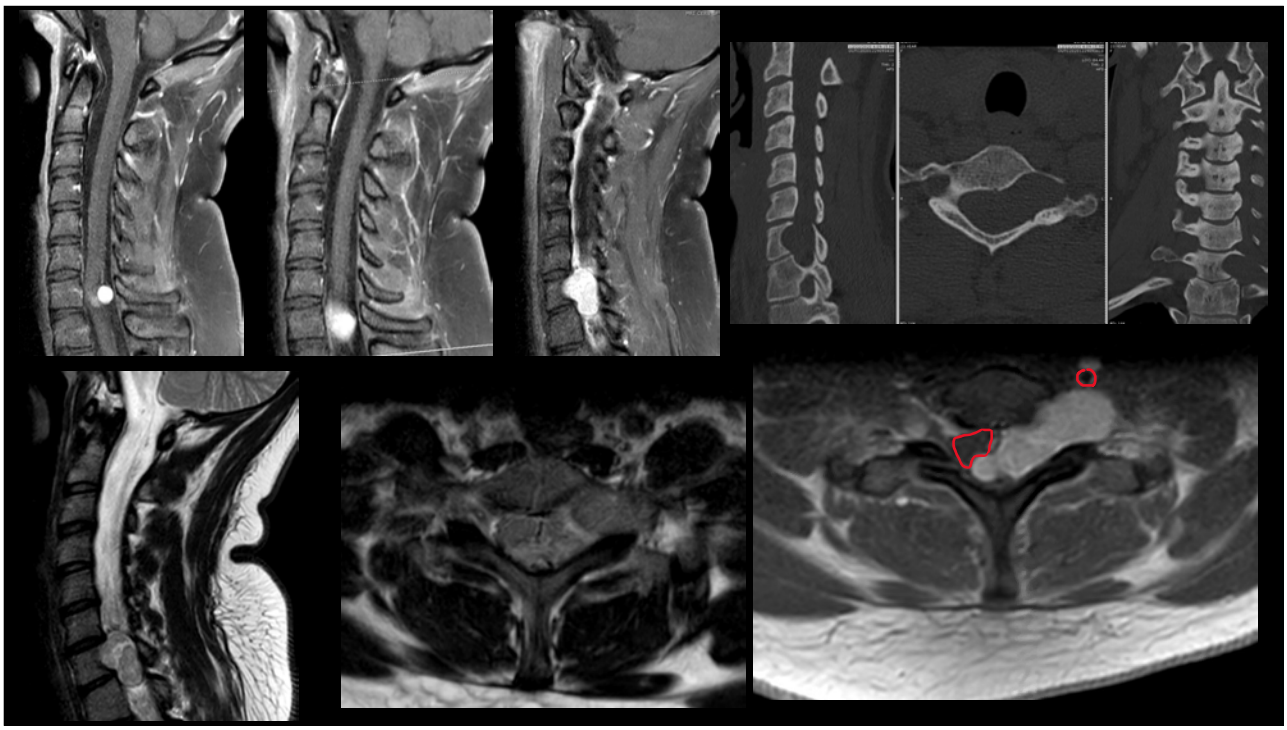

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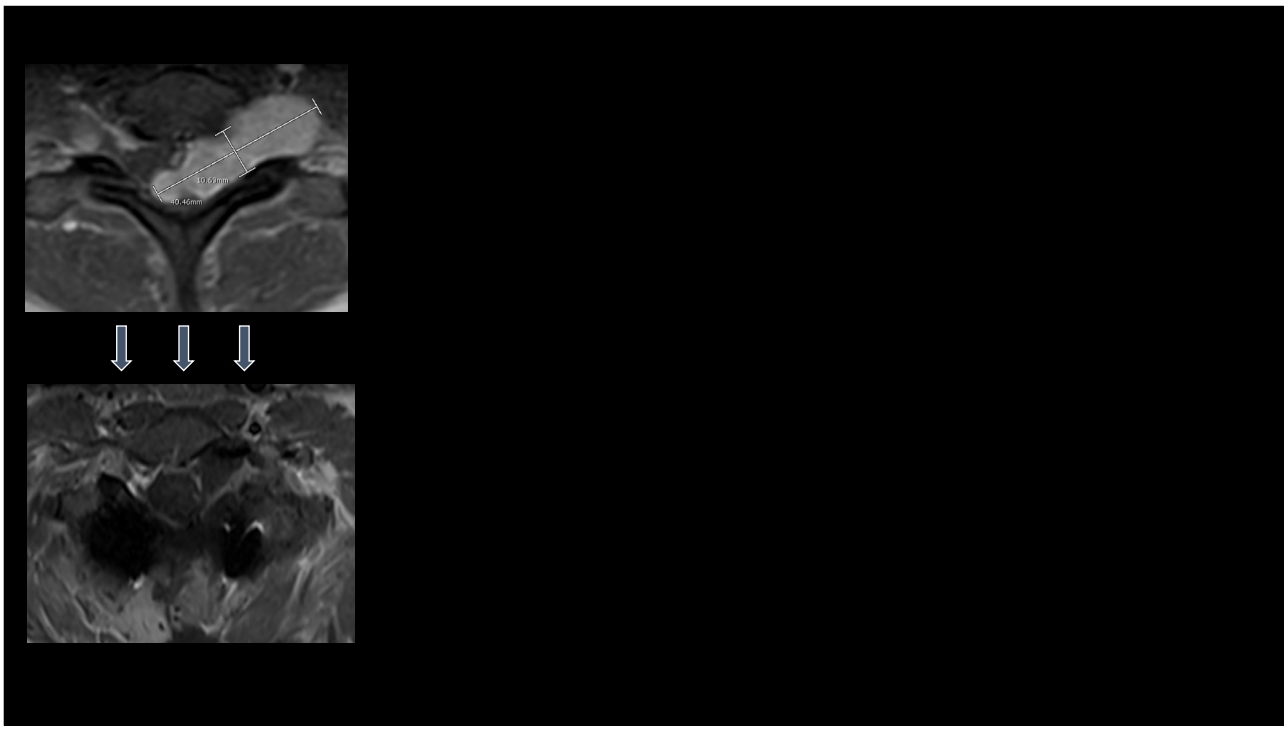

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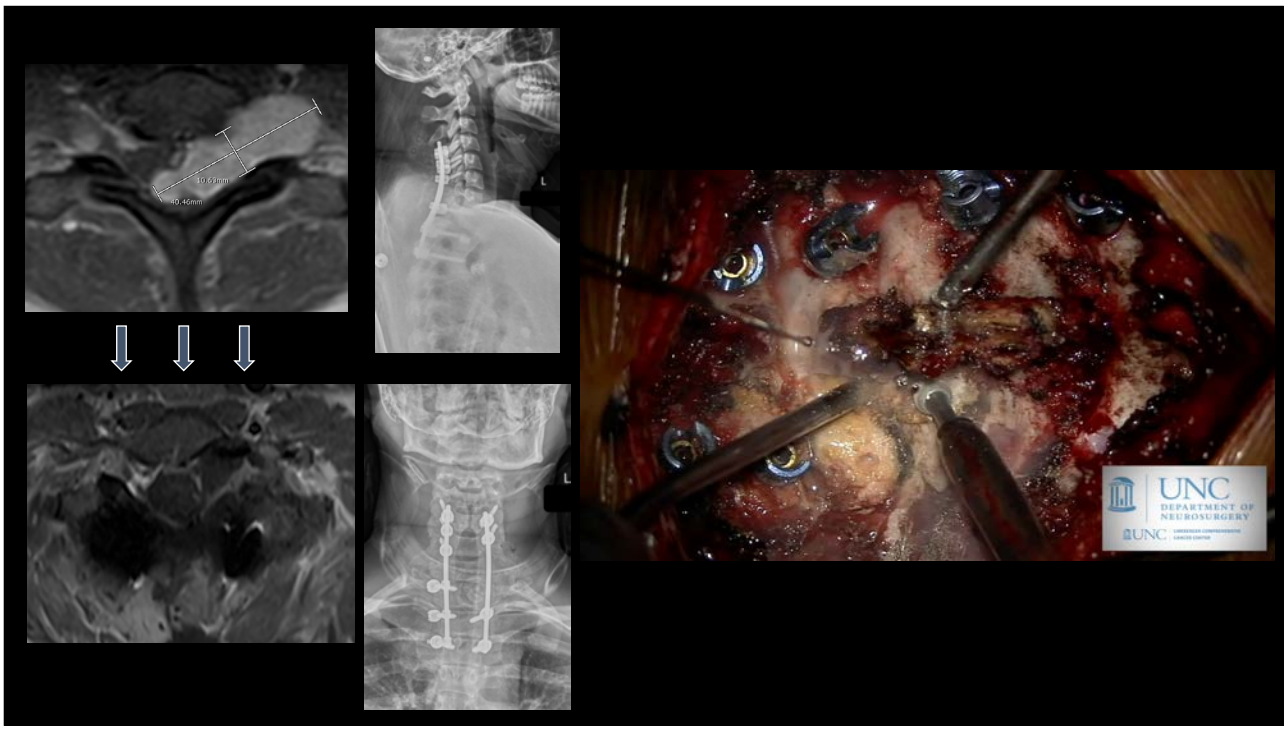

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PRESERVATION OF BIOMECHANICALLY RELEVANT STRUCTURES
WITHOUT
COMPROMISING THE EXTENT OF TUMOR RESECTION

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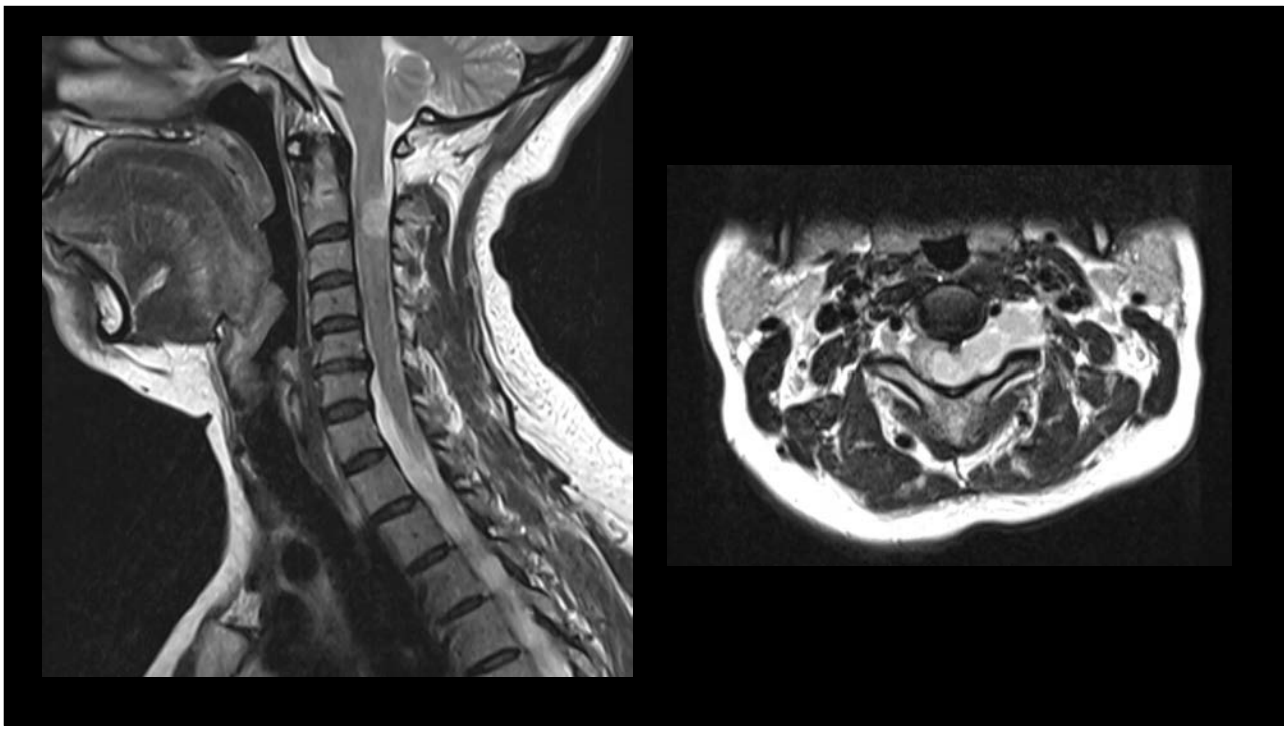

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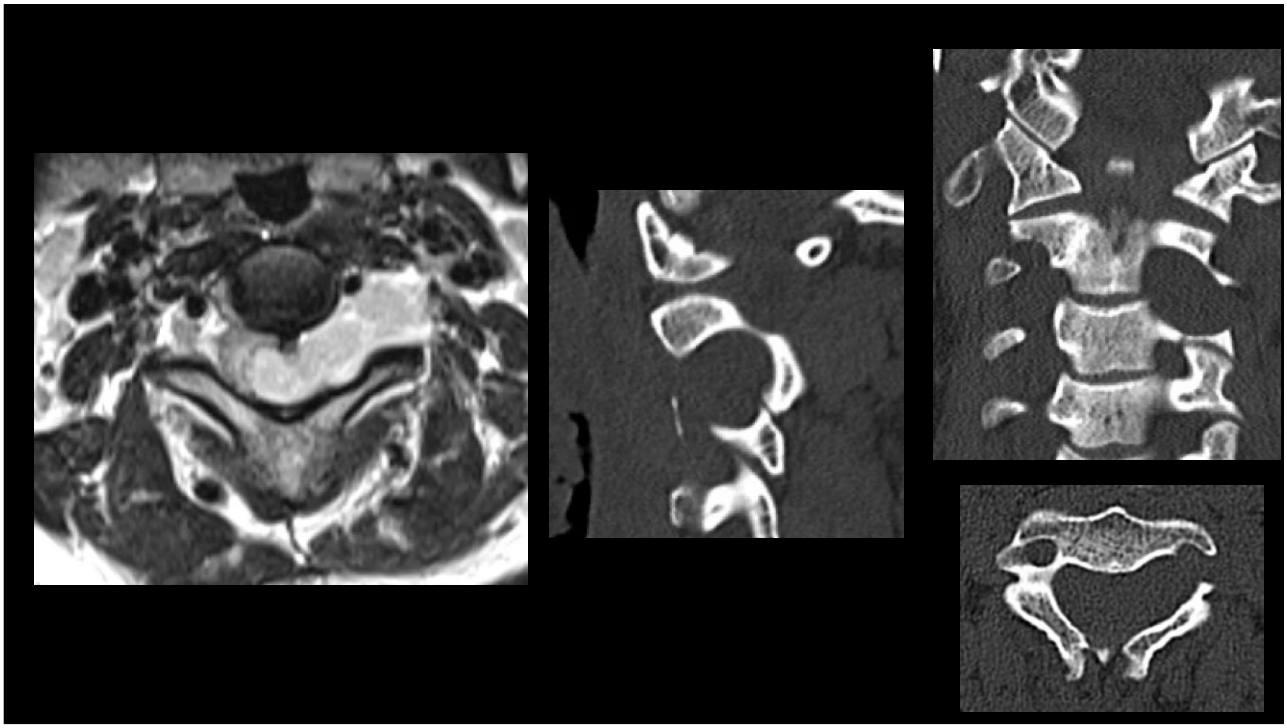

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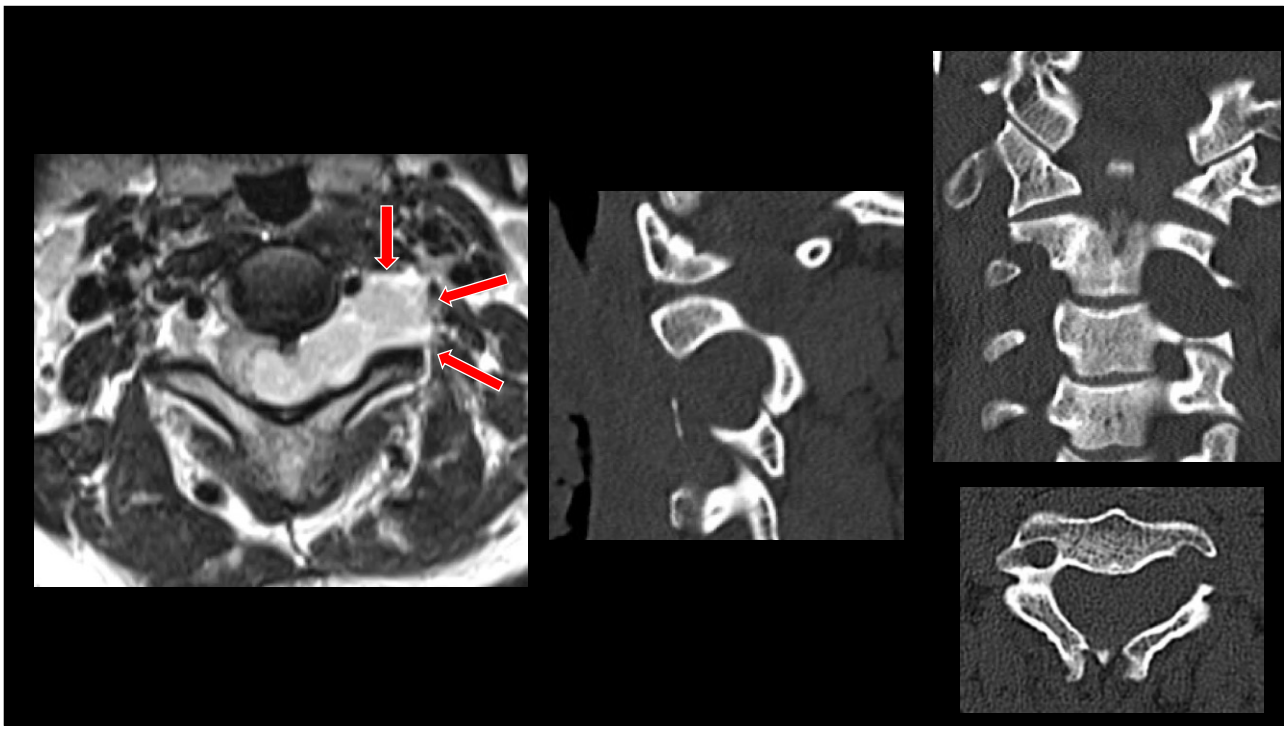

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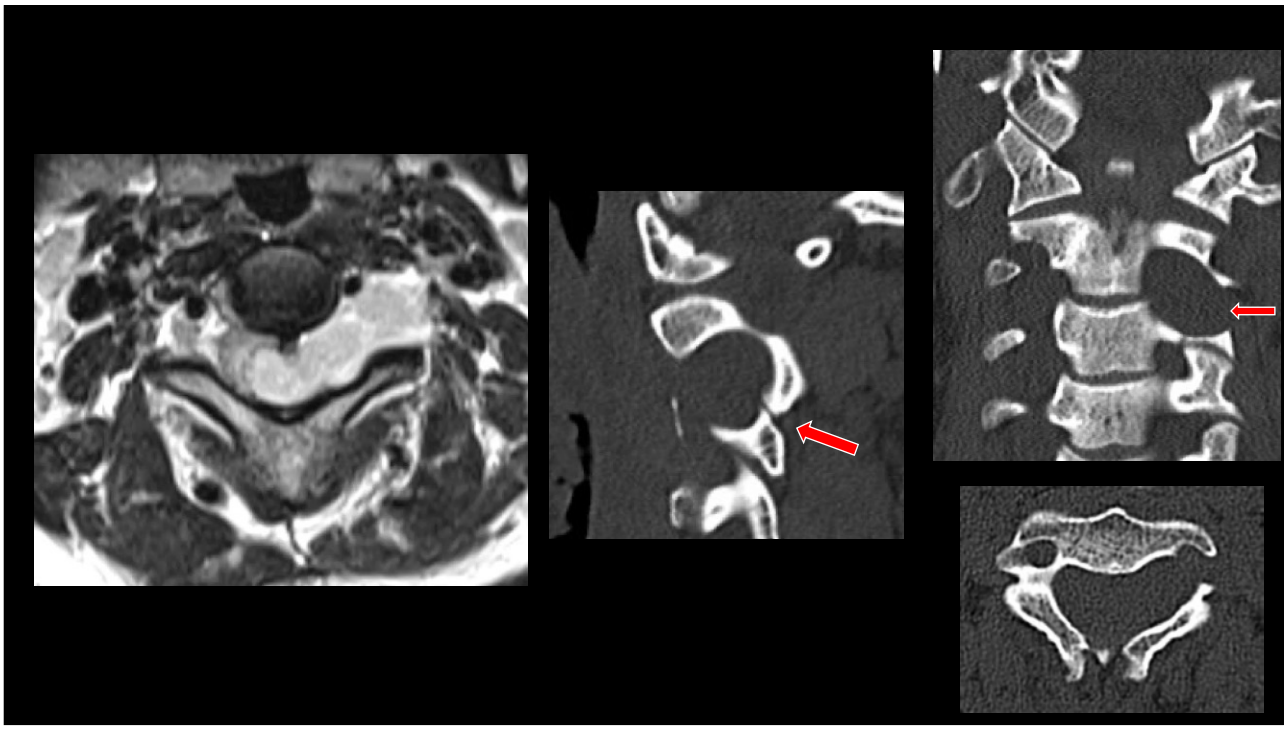

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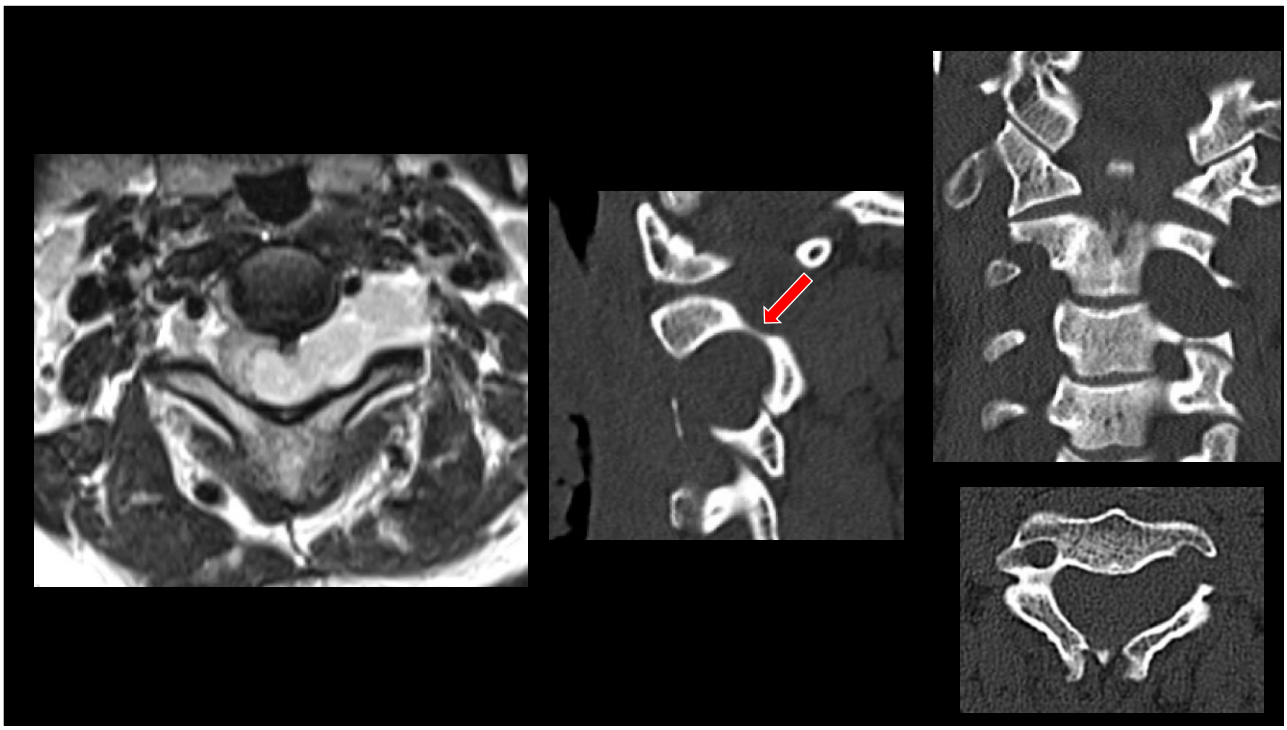

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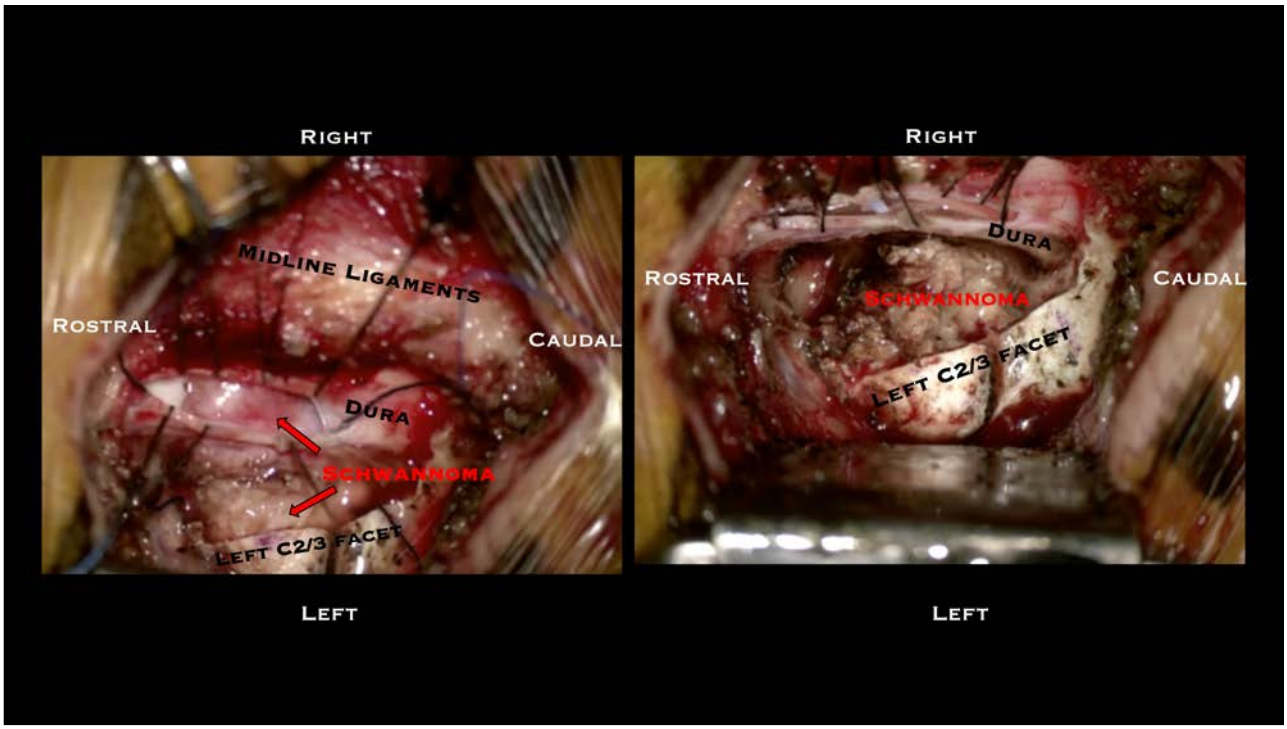
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LEFT C2/3 FACET
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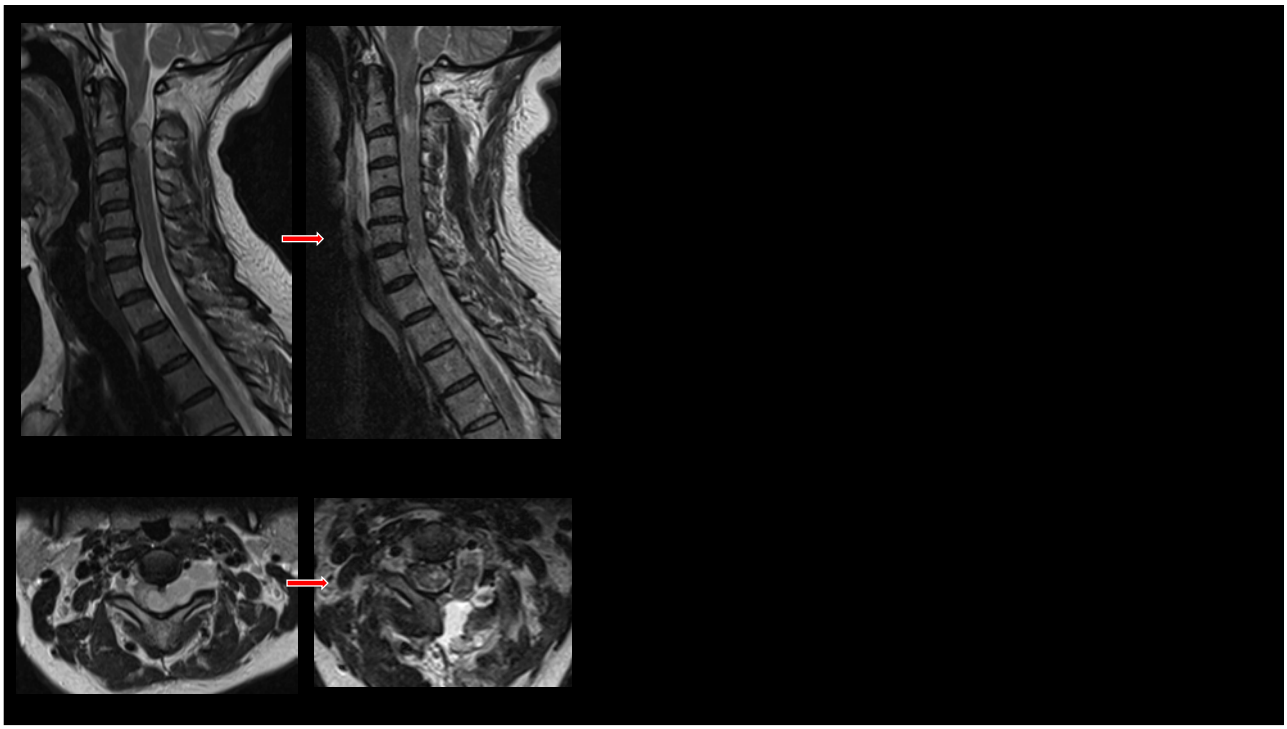

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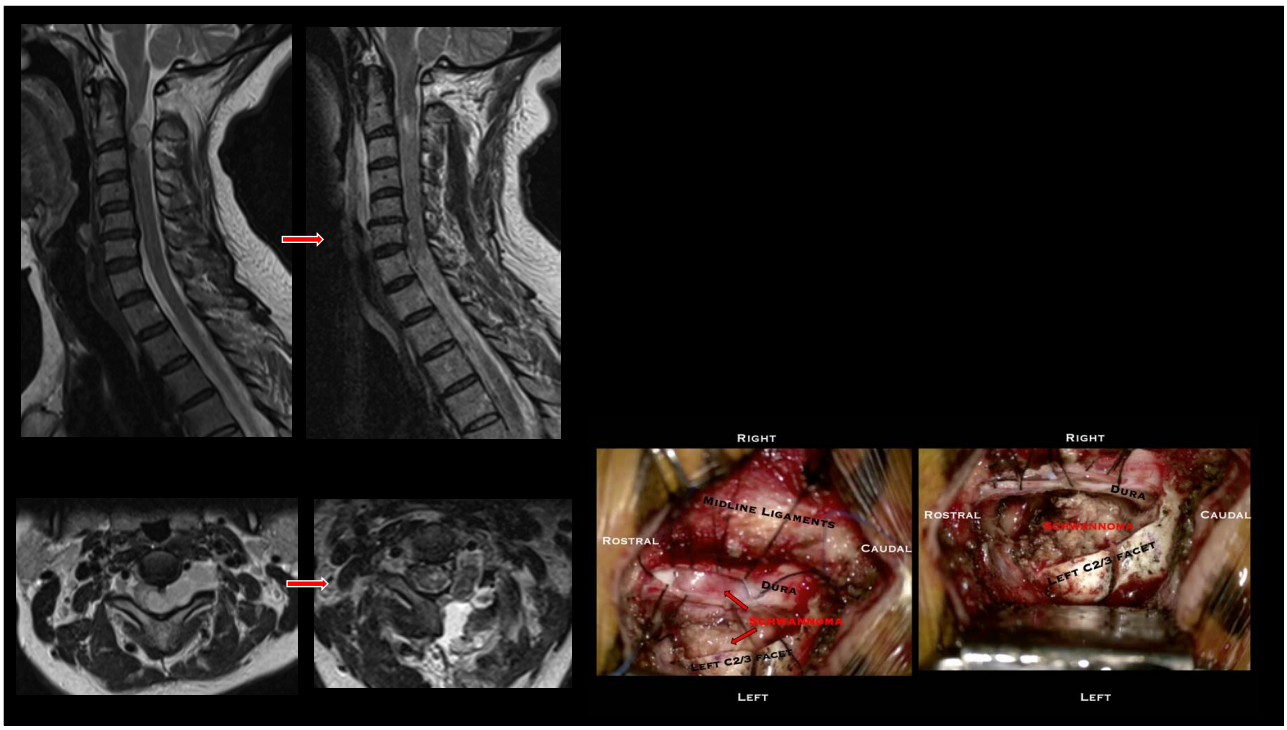
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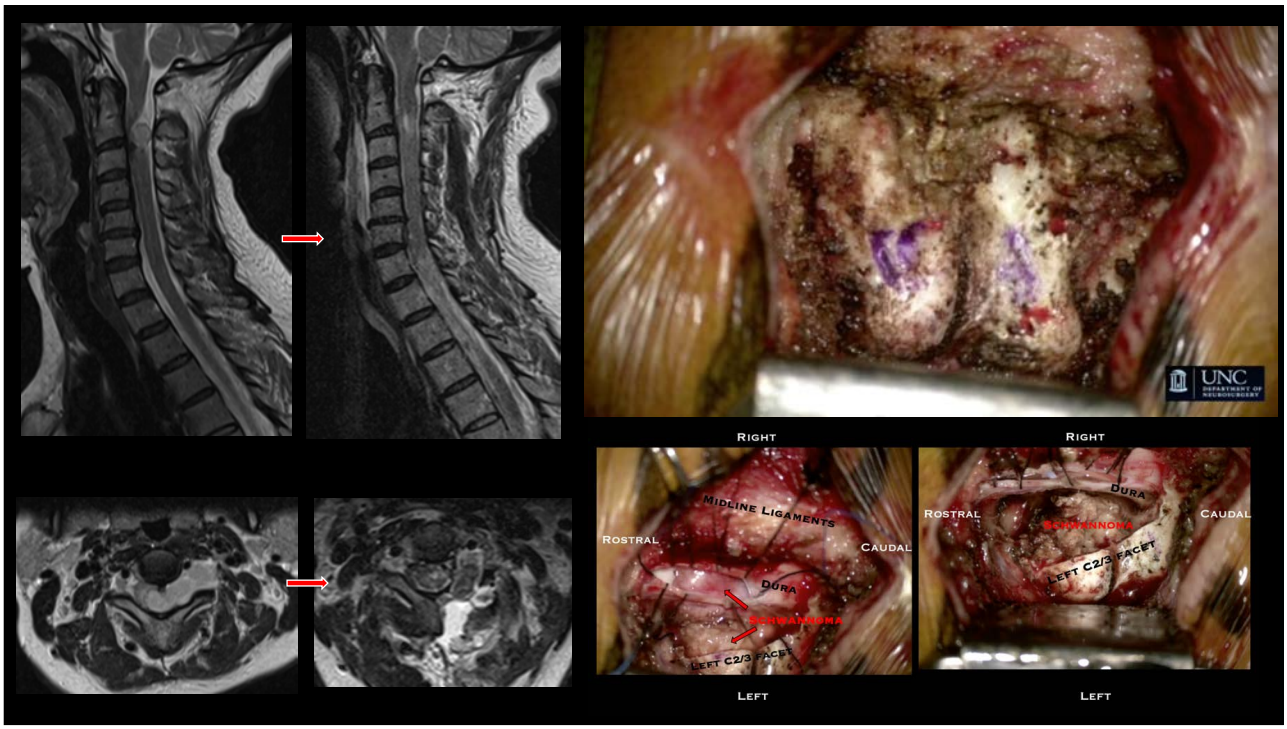
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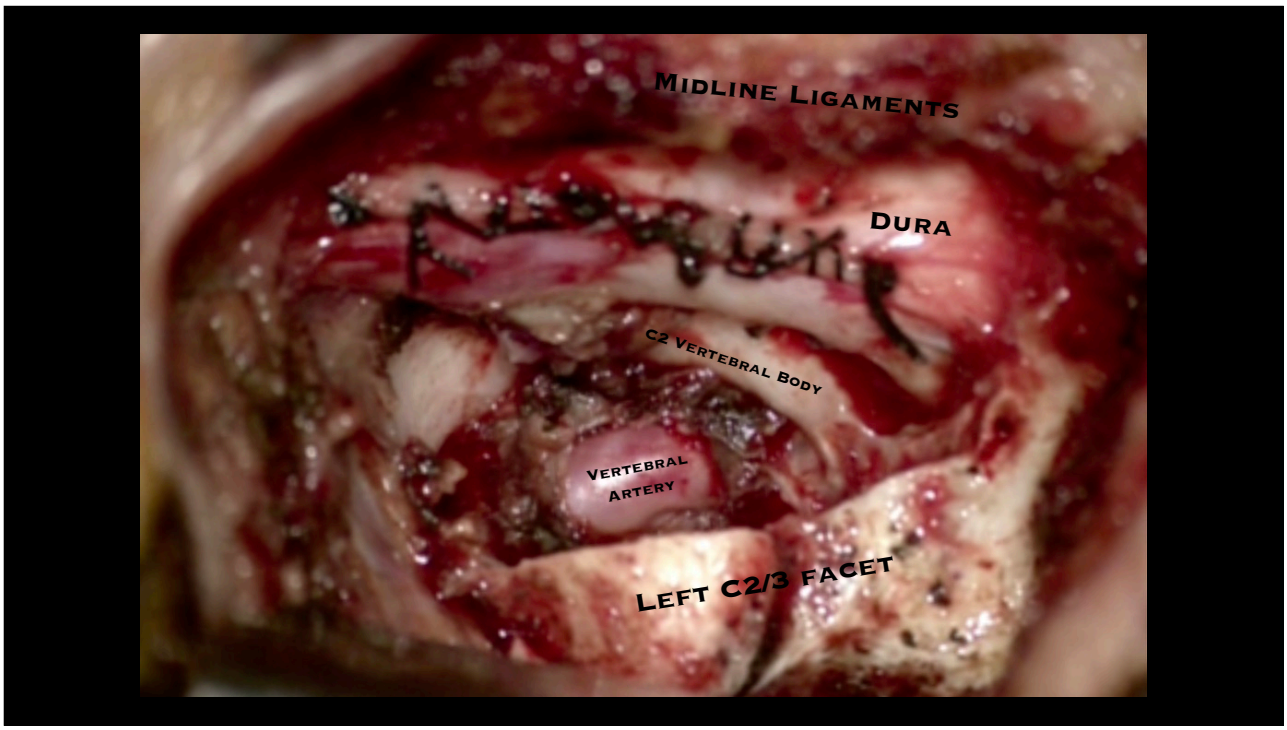
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Dura
C2 Vertebral Body
Vertebral Artery
Left C2/3 facet

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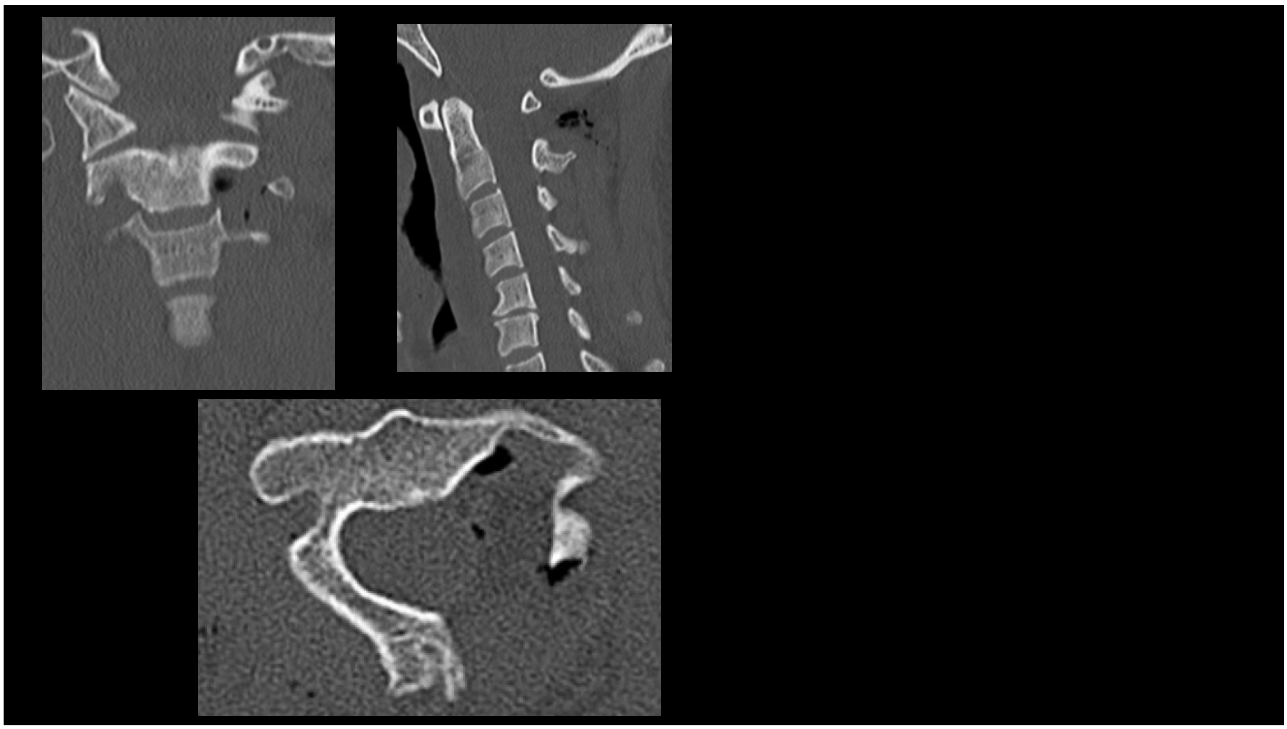

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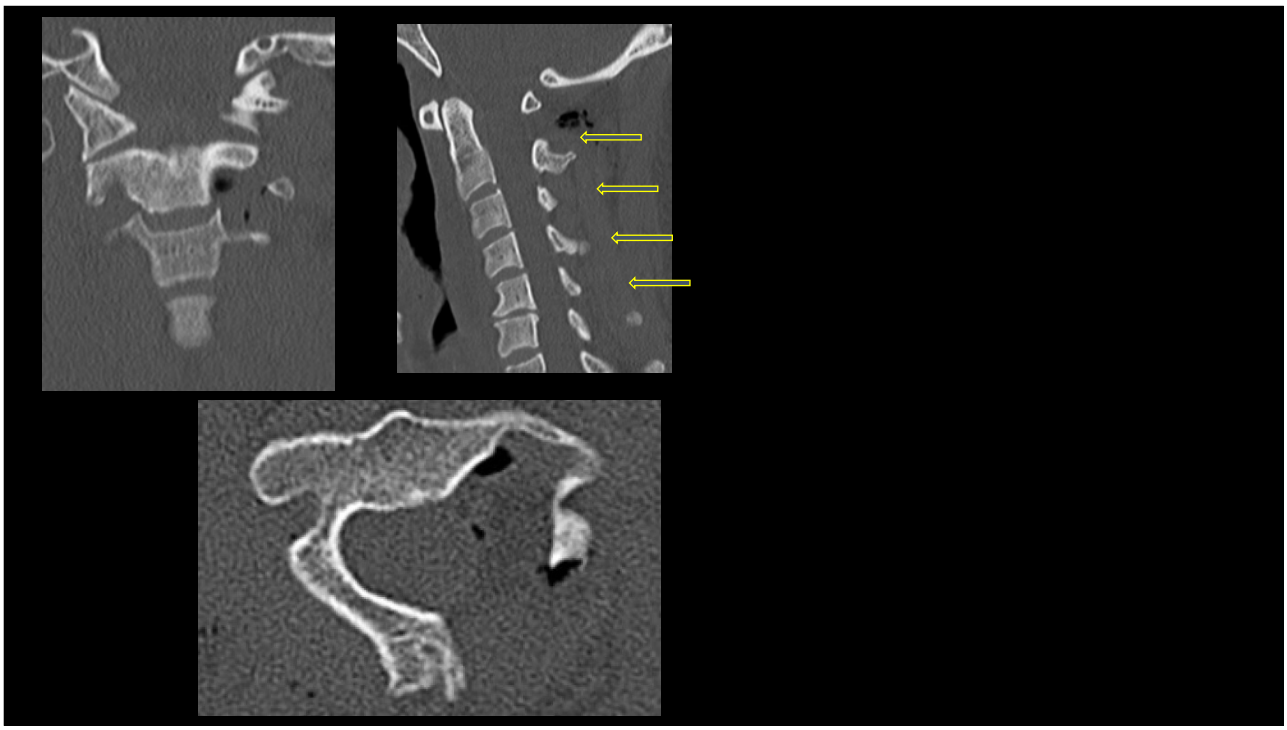

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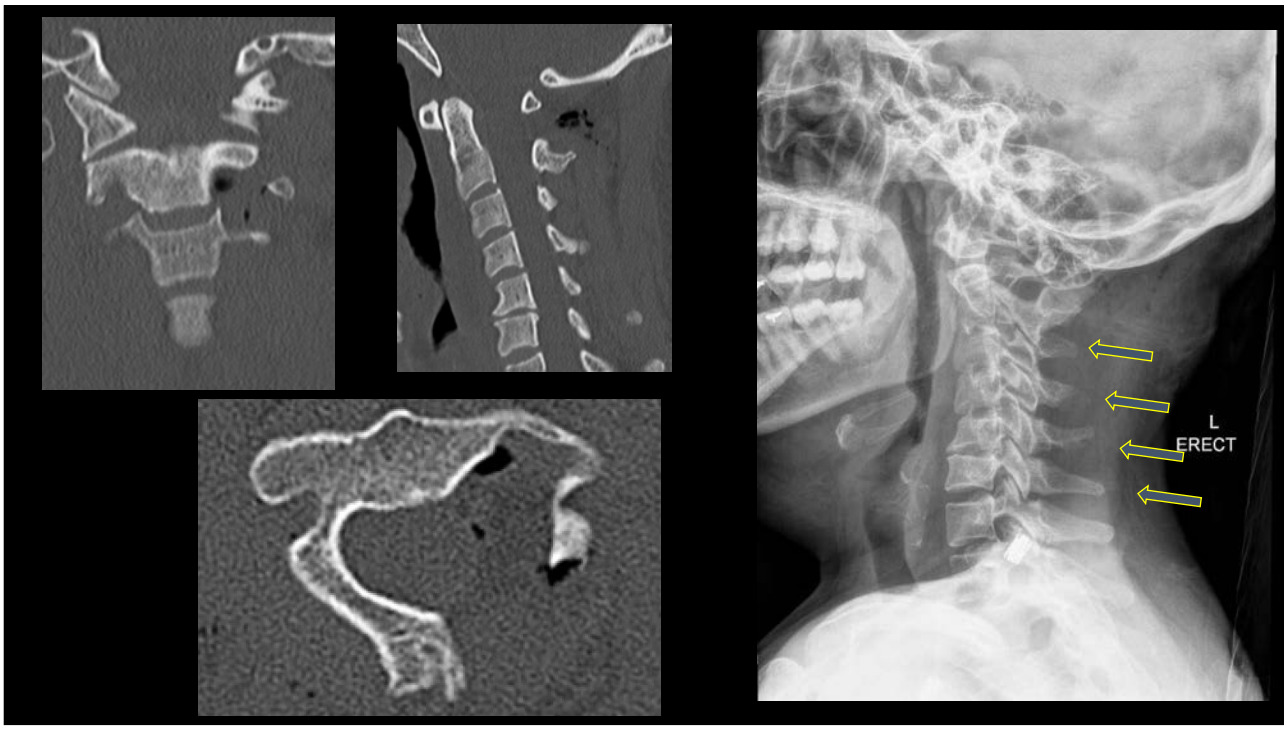

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Intradural Intramedullary

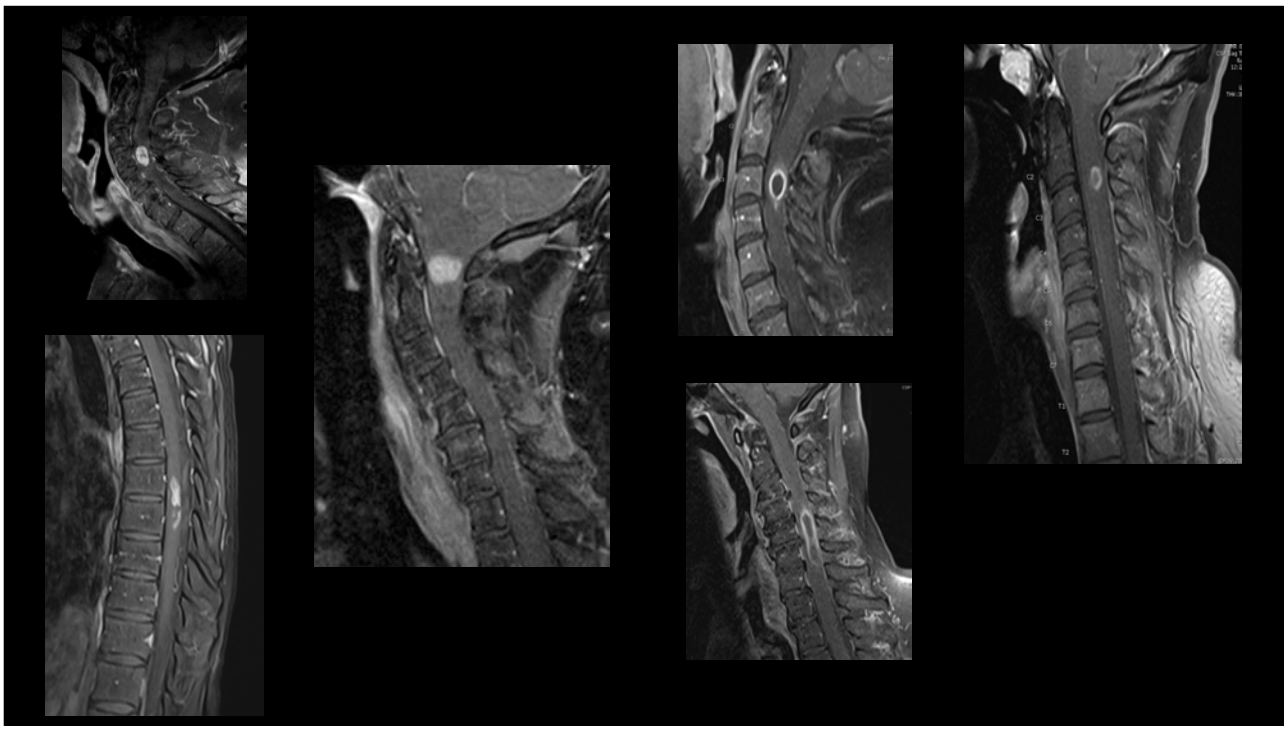
- Ependymoma
- Pilocytic Astrocytoma
- Hemangioblastoma
- Cavernoma

433

Intramedullary Tumors

Certainty of a
Neoplastic Process?

434



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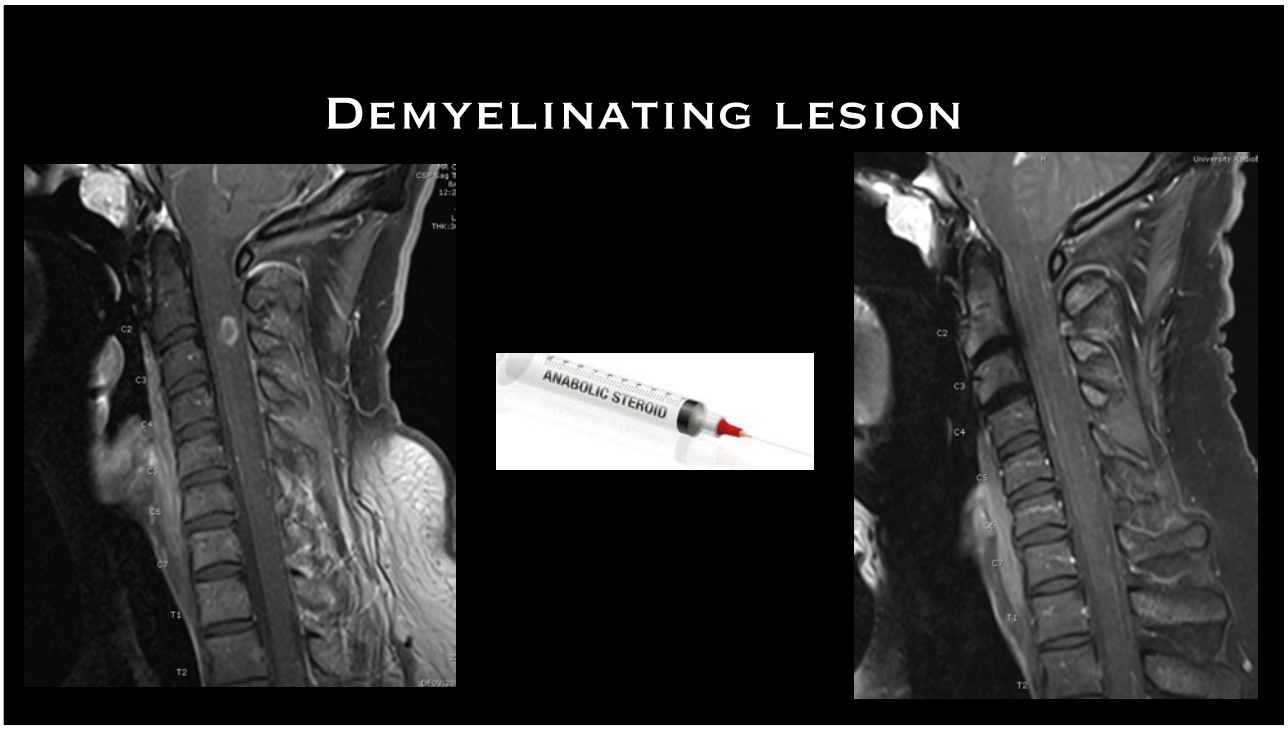

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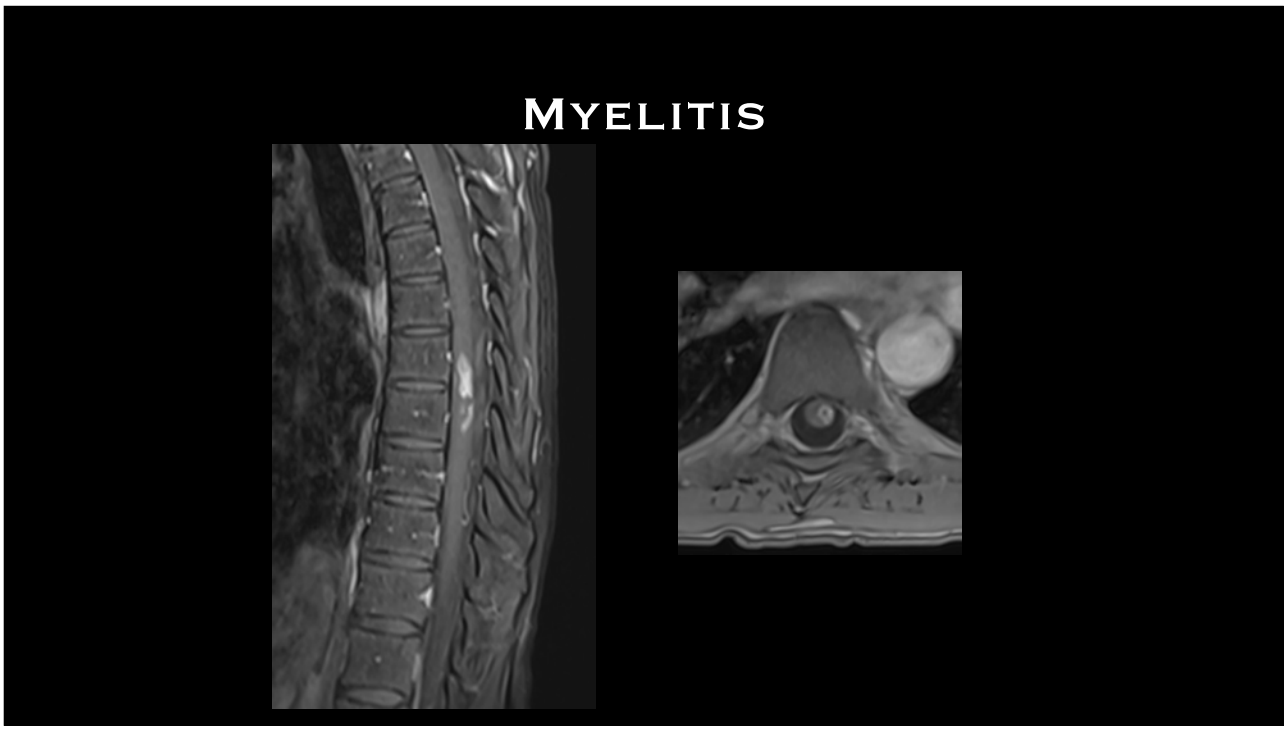

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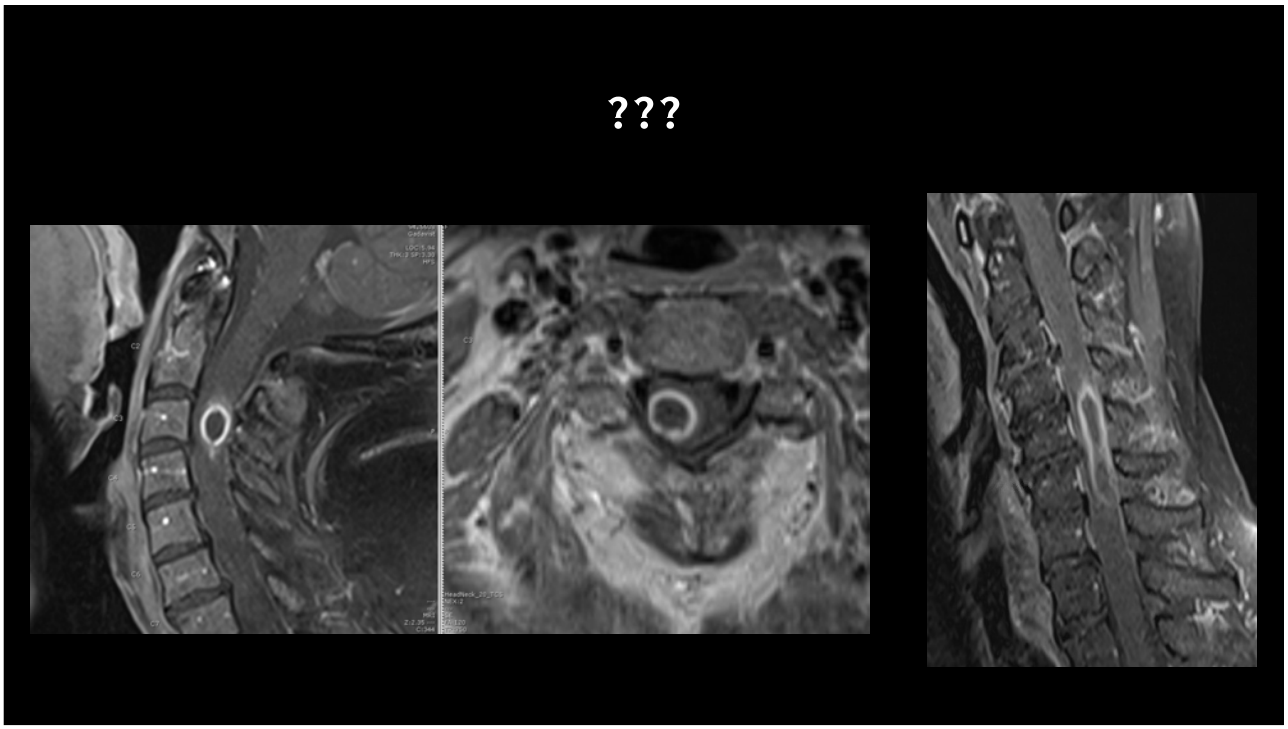

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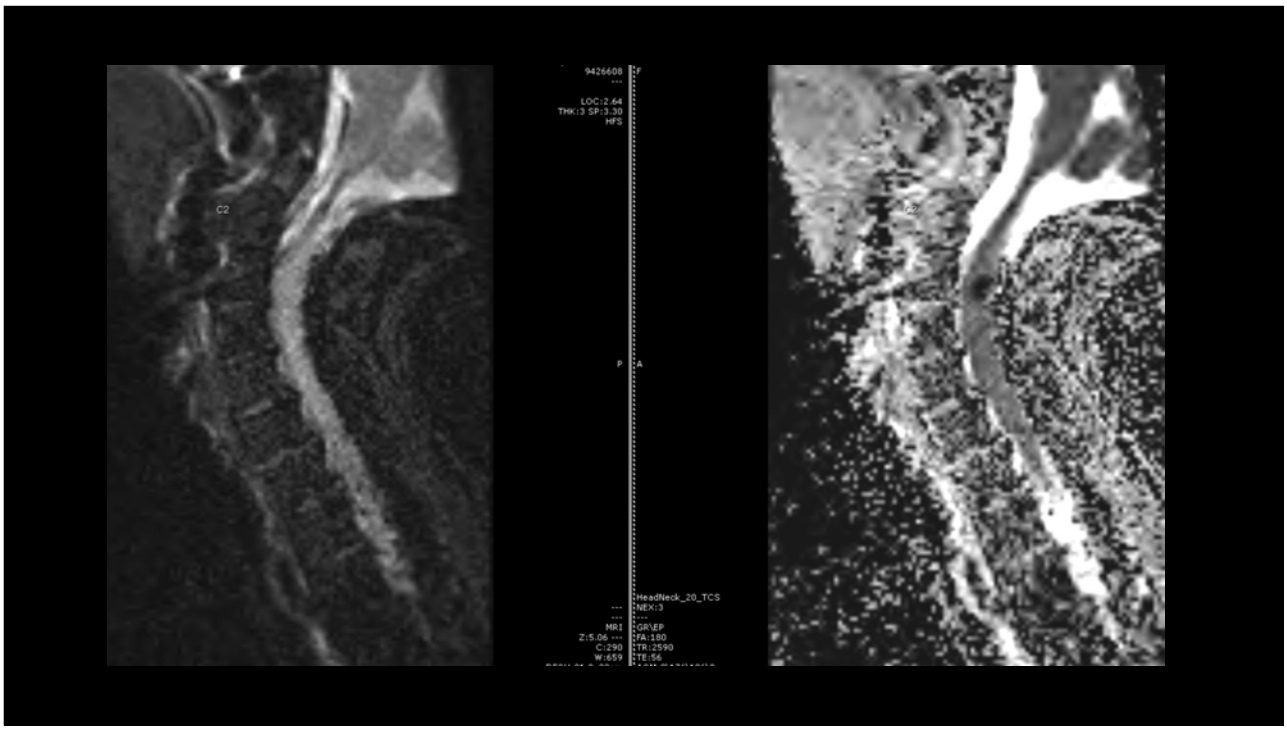
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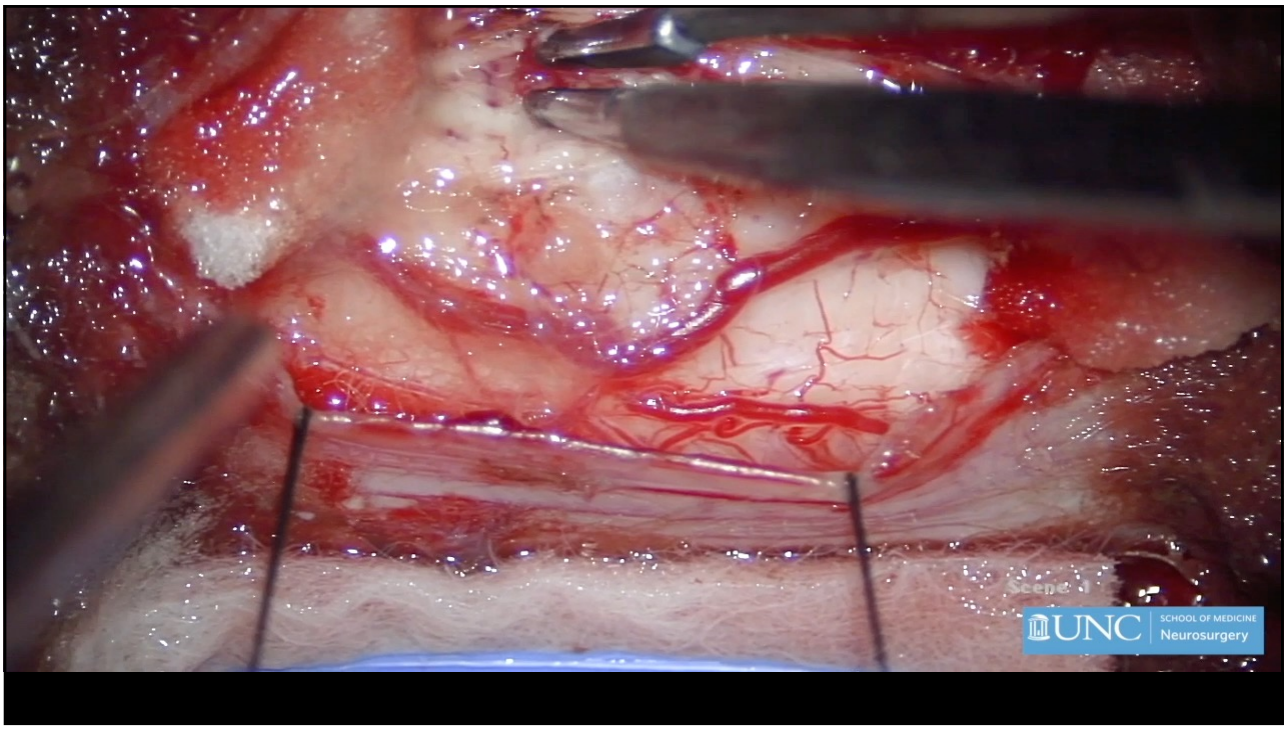
UNC
SCHOOL OF MEDICINE
Neurosurgery

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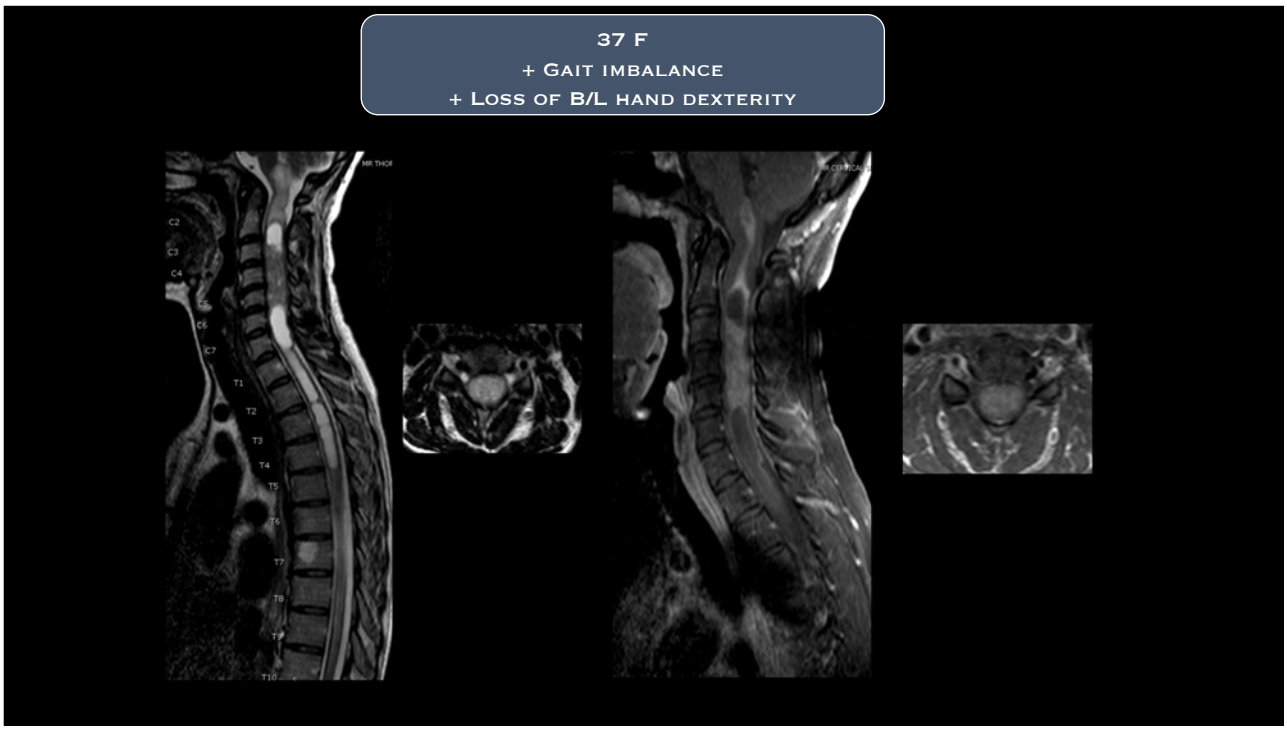

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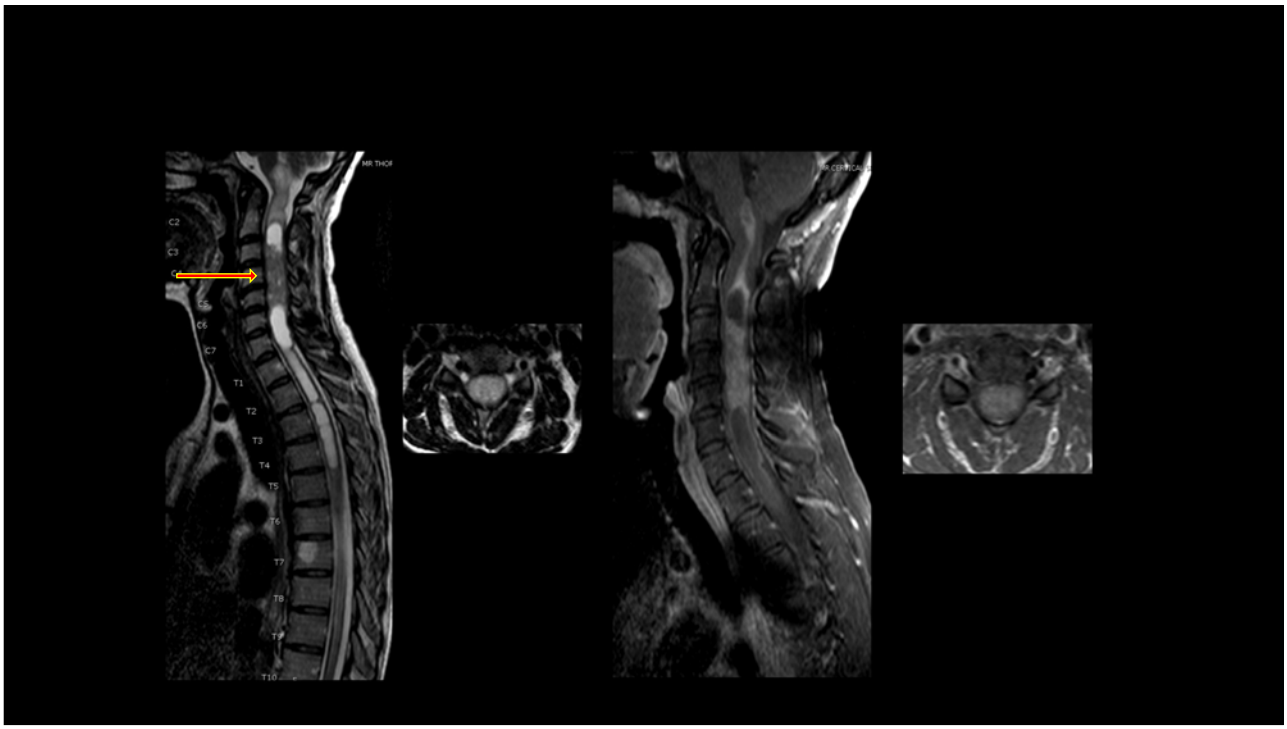

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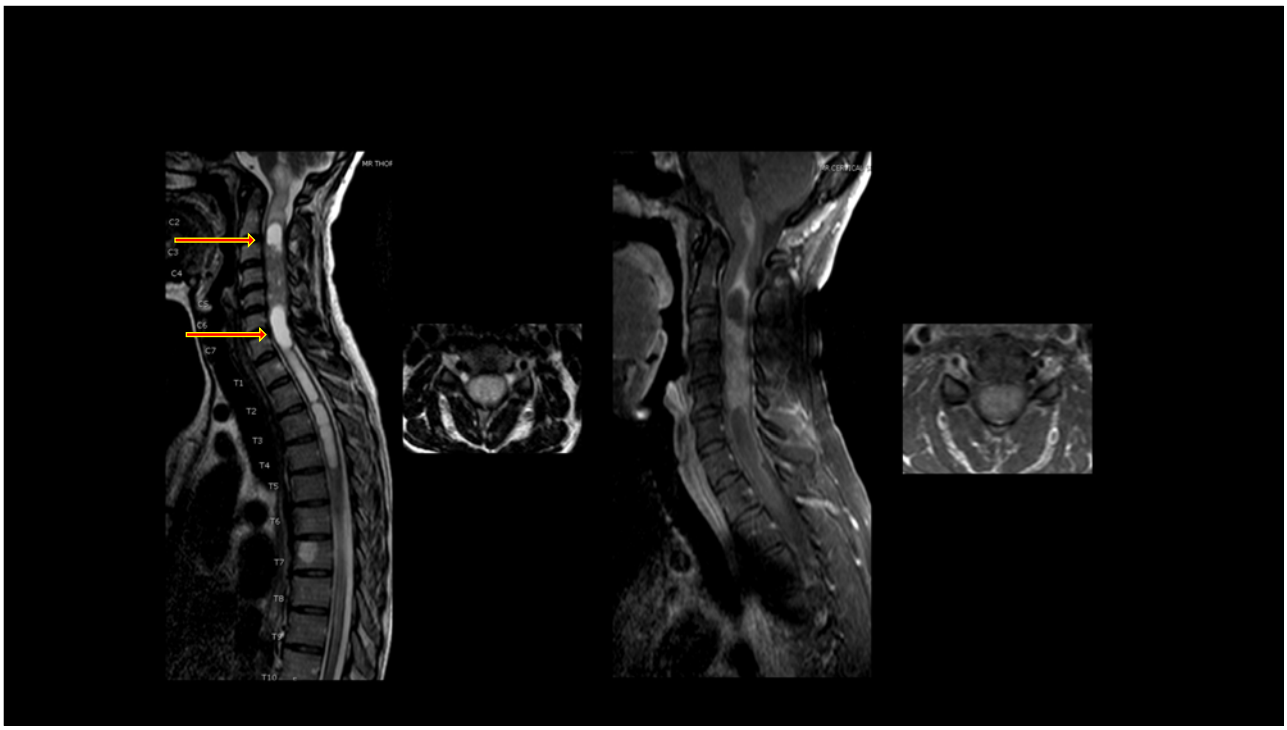
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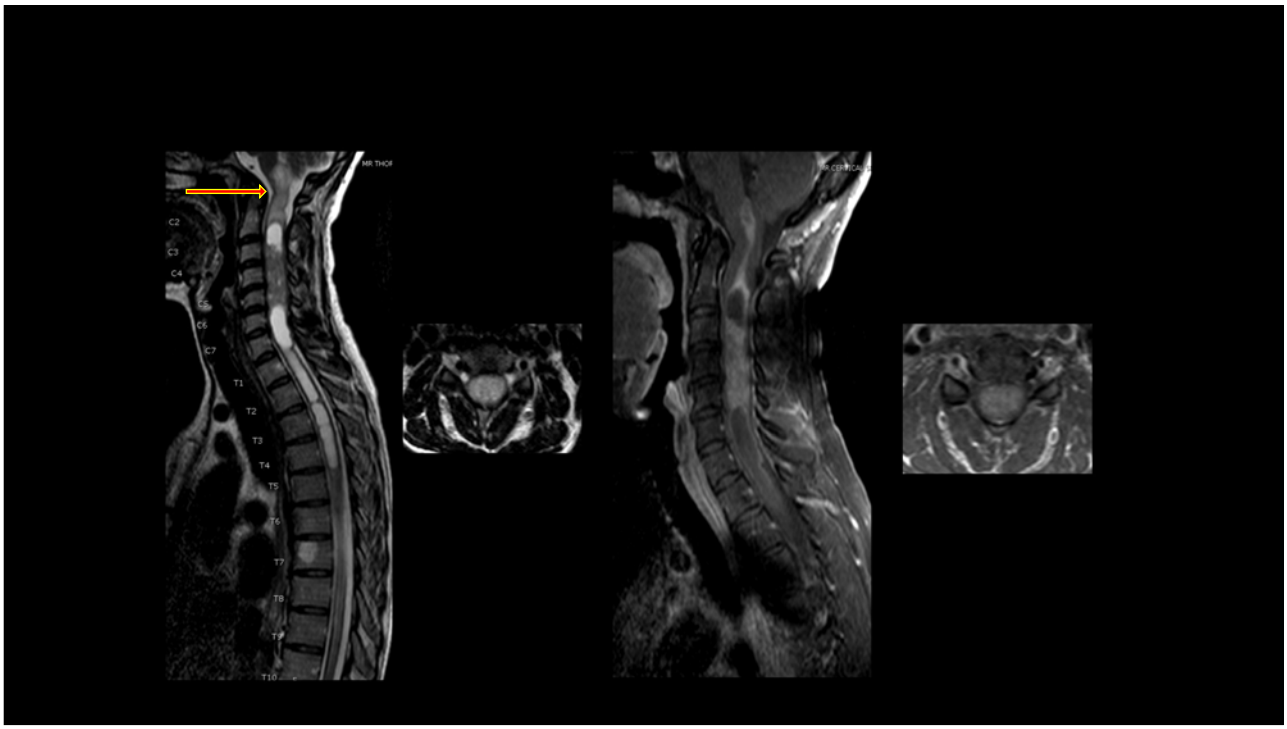
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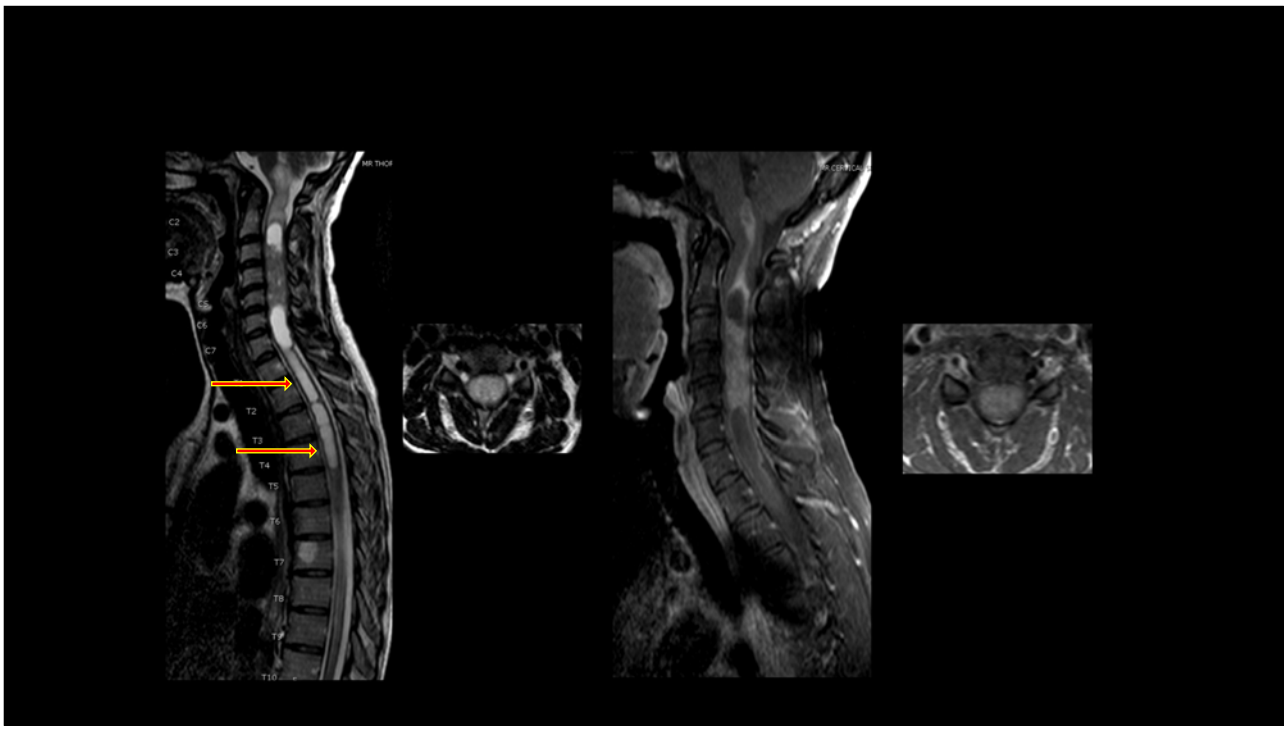

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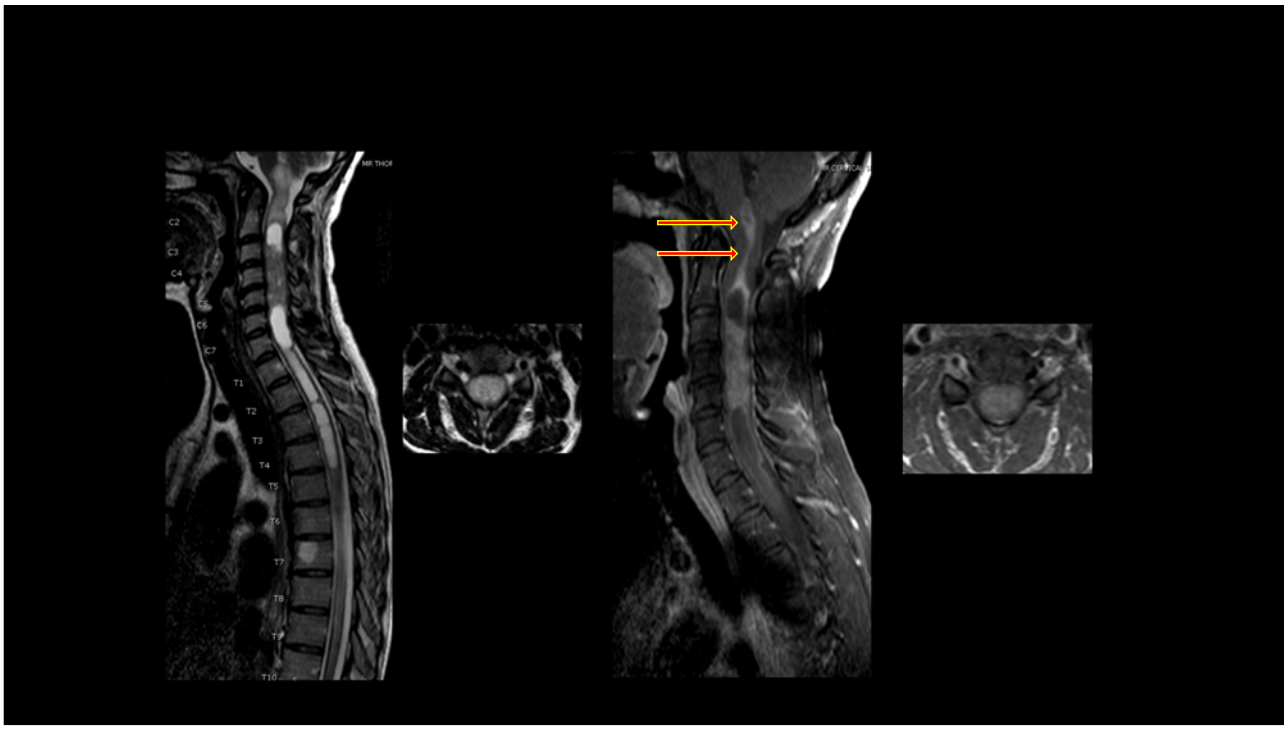

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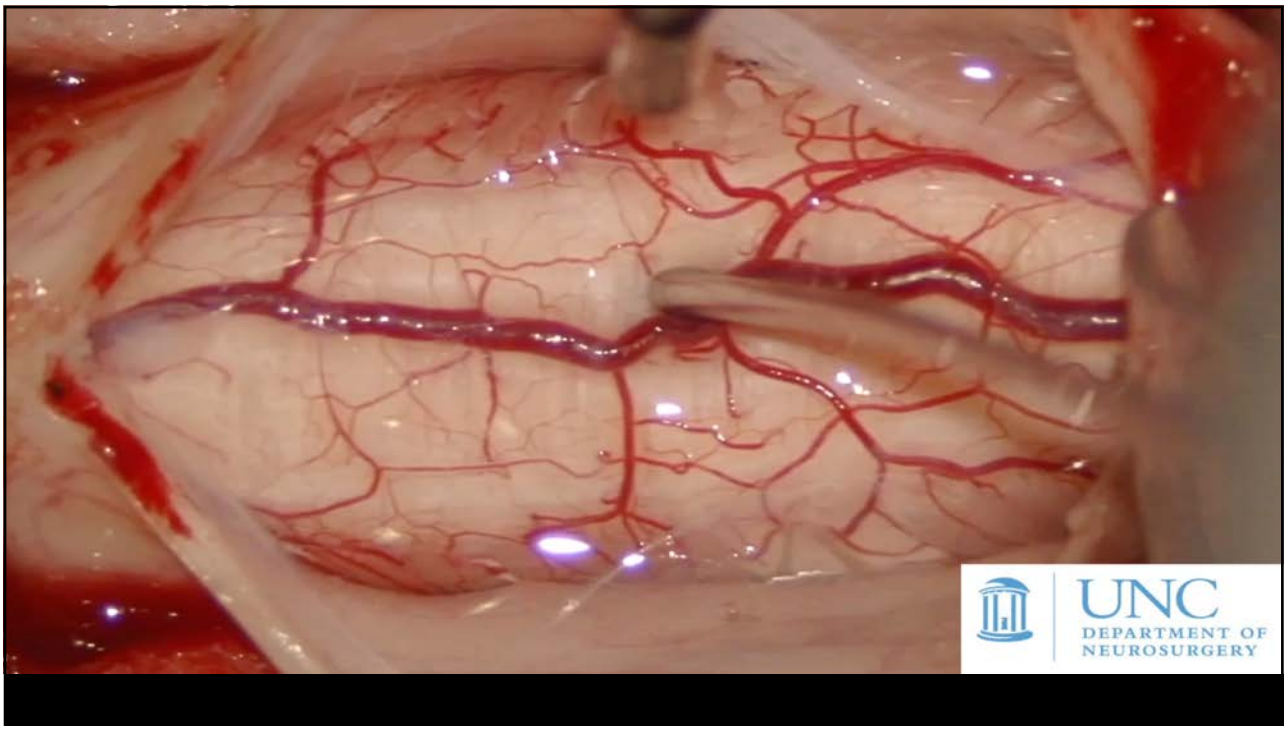

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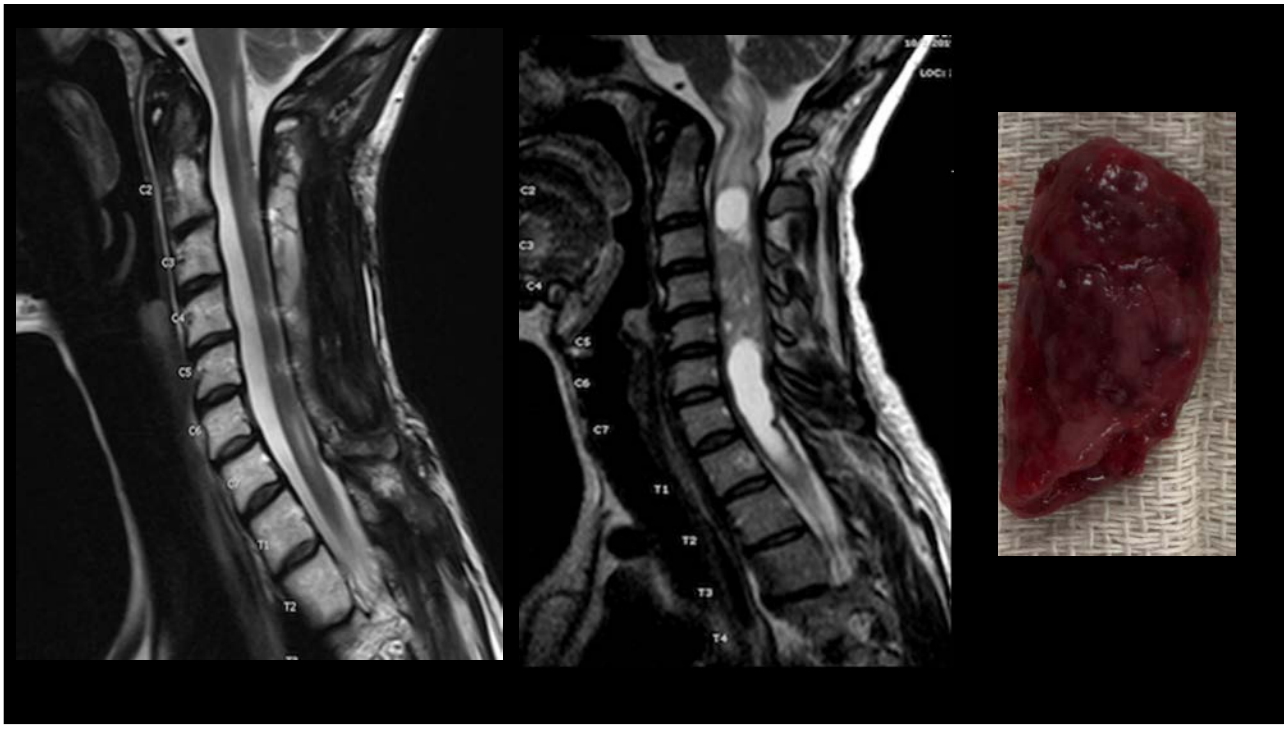

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Conclusion

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Conclusion

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Conclusion


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Conclusion



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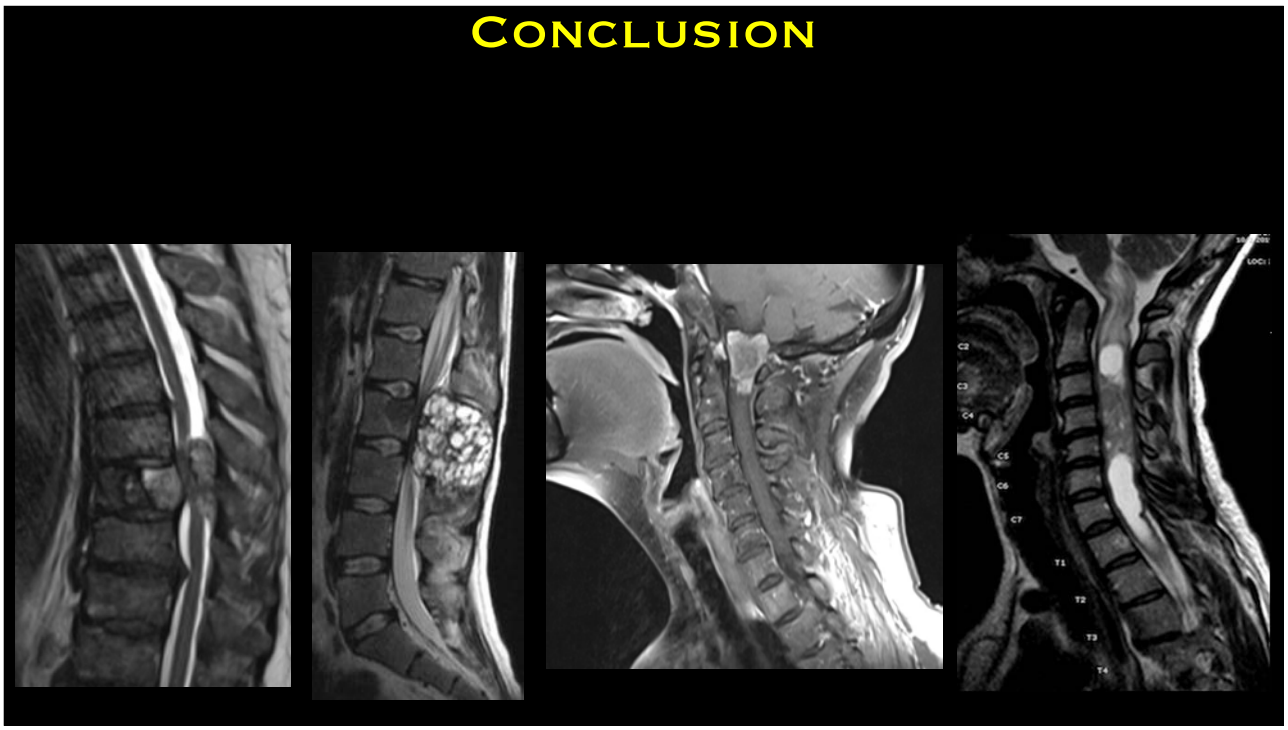

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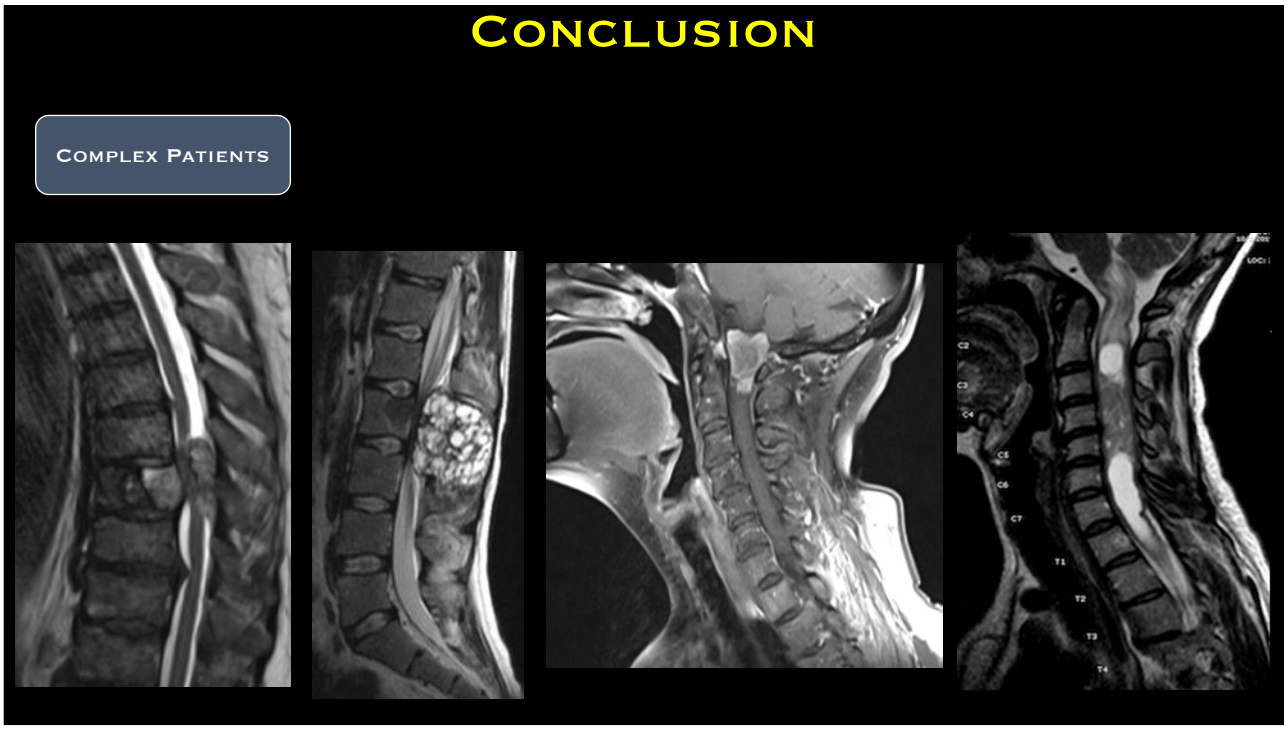

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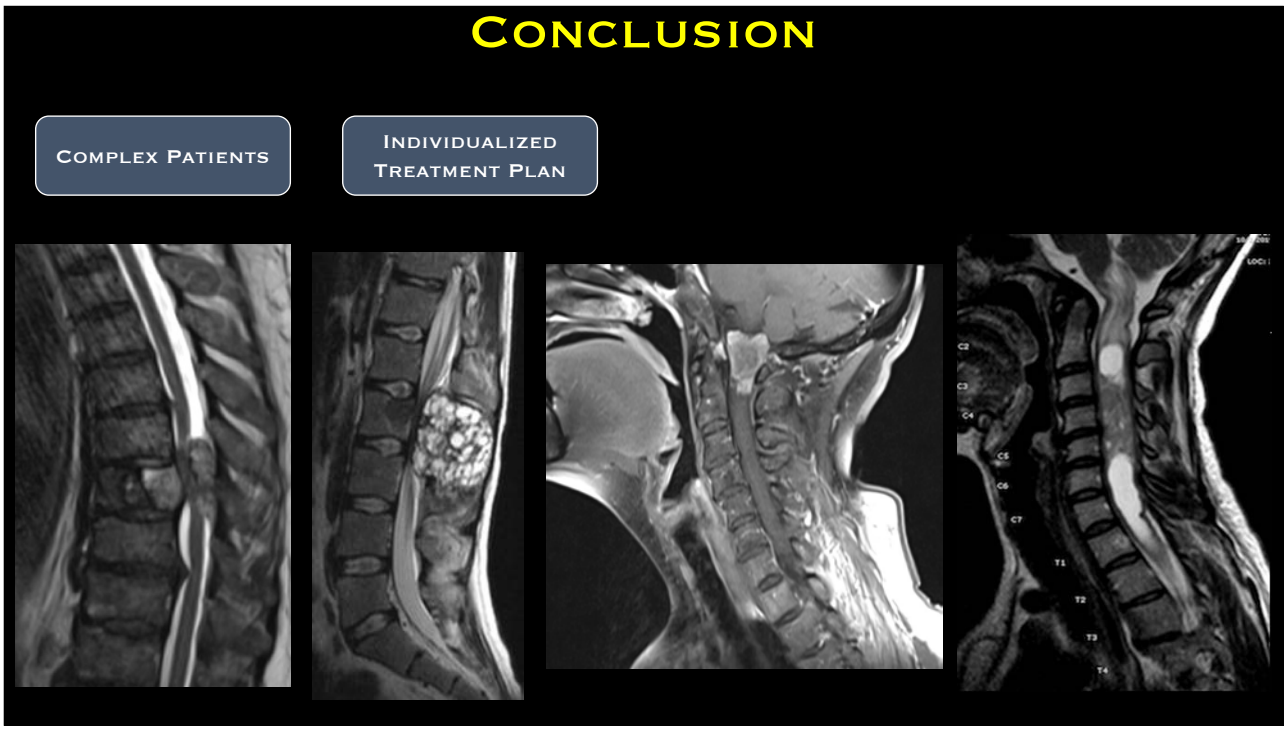
Conclusion
Complex Patients
Individualized Treatment Plan

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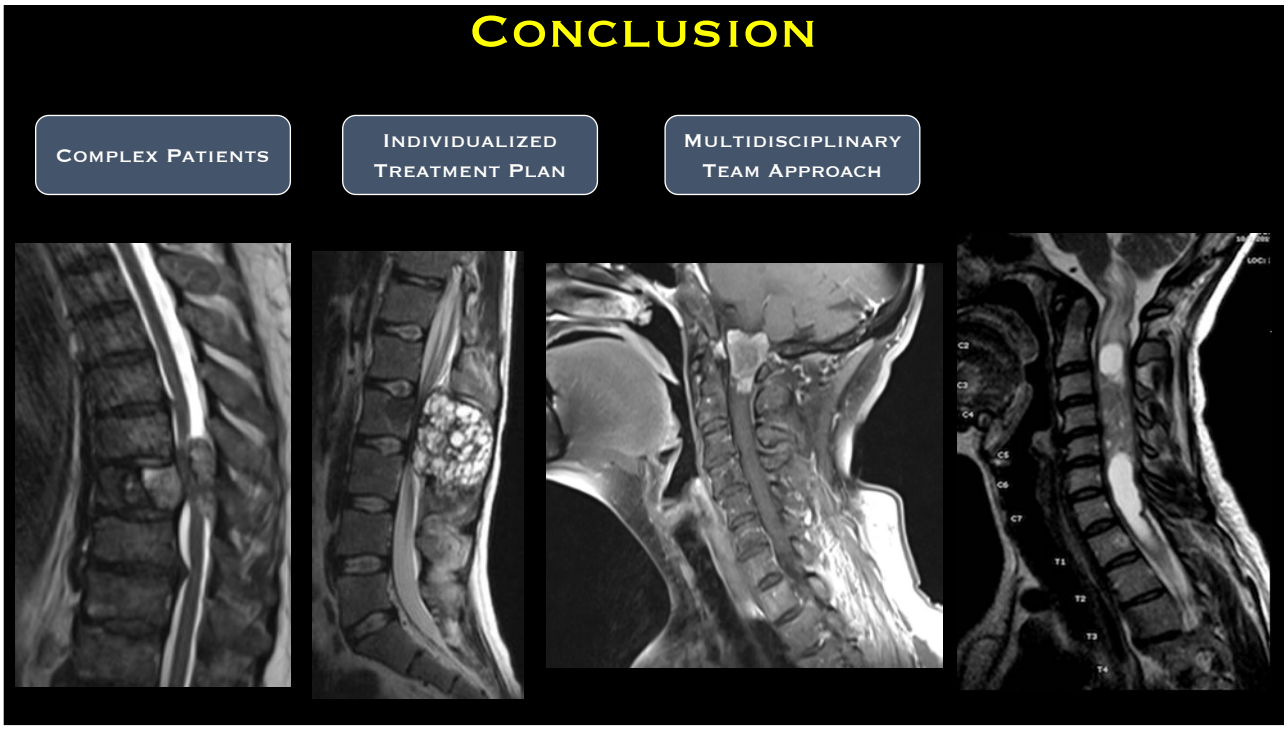
Conclusion
Complex Patients
Individualized Treatment Plan
Multidisciplinary Team Approach

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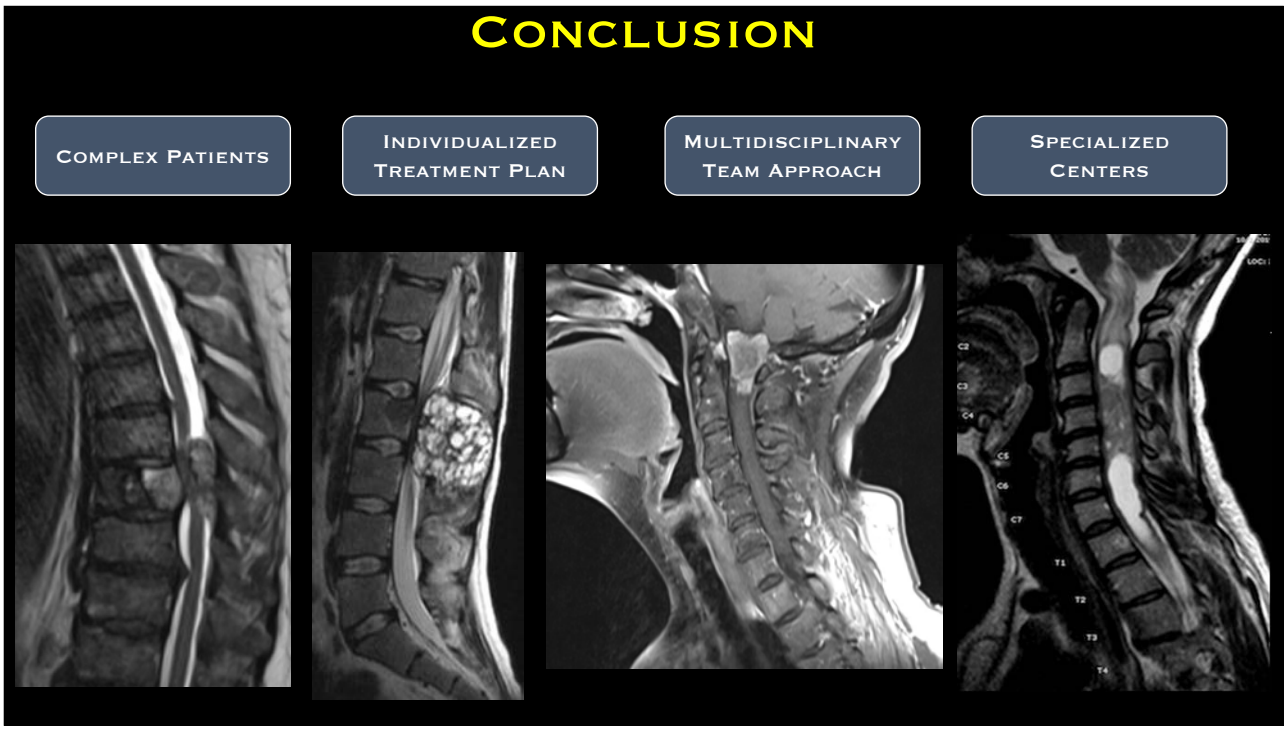
Conclusion
Complex Patients
Individualized Treatment Plan
Multidisciplinary Team Approach
Specialized Centers

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Citations

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