Stanford MEDICINE
School of Medicine

Automated Intradural Tumor Segmentation and Sub-Type Classification in Spinal MRI Scans

Golnaz Moallem, Ph.D.
Postdoc Research Fellow, PIMed Lab
Department of Radiology, Stanford School of Medicine

January 2024

Outlines

- **Introduction**
  - What are intradural spinal tumors?
- **Data**
- **Methods**
  - Baseline framework
  - Proposed framework
- **Results**
- **Challenges and Next Steps**

Introduction: What are Intradural Spinal Tumors?

Spinal Tumors

- Large heterogenous group of abnormal mass of tissue affecting the spinal cord
- Developed within or near the spinal cord
  - **Intradural**: growth within the dura of the spinal cord
  - Extradural: mass within the spinal column
- Malignant or Benign
- Ramifications: pain, neurological damage, loss of mobility, etc.

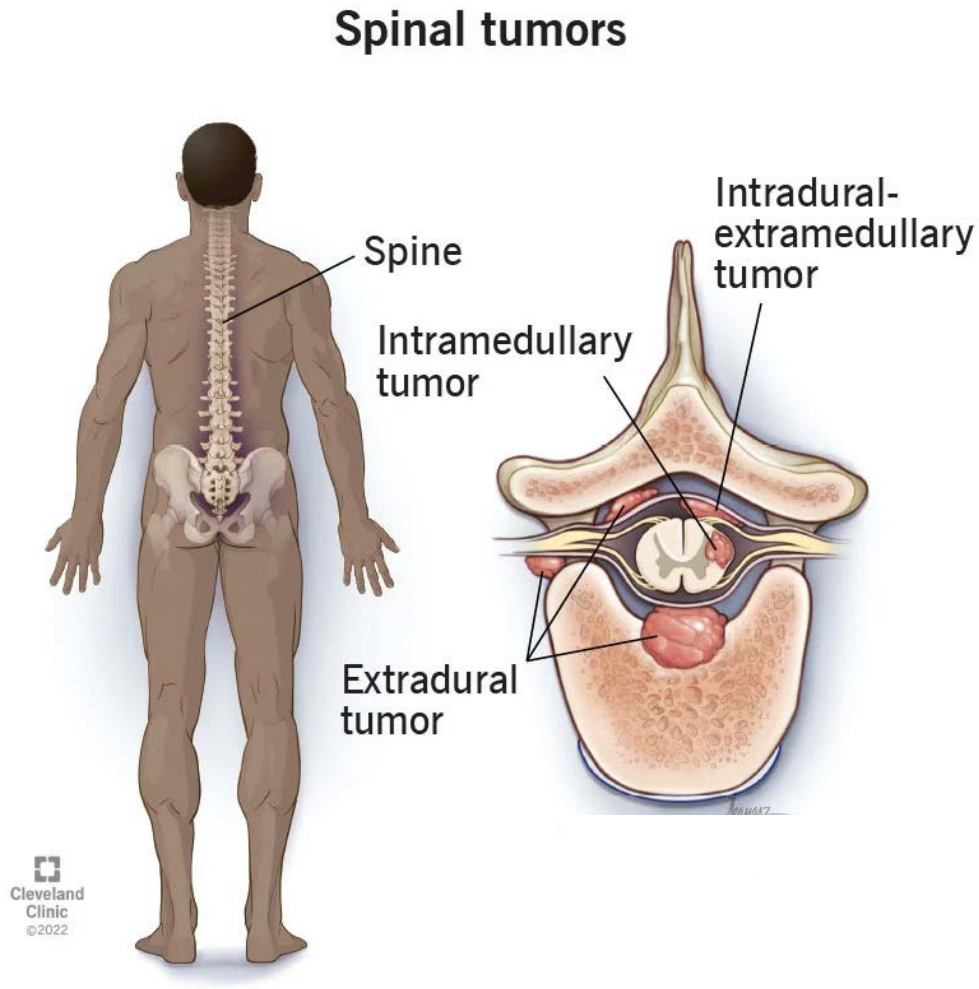
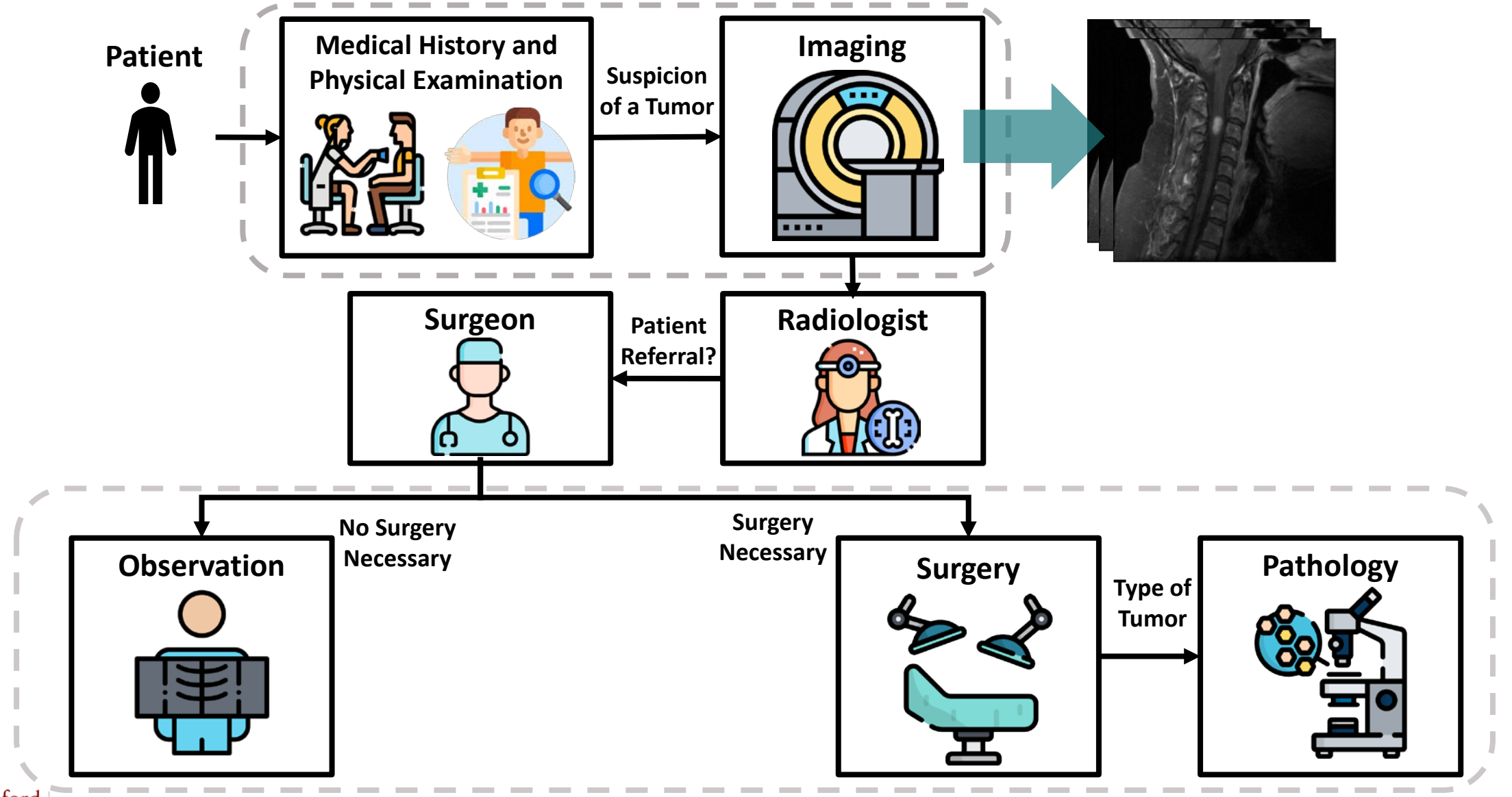


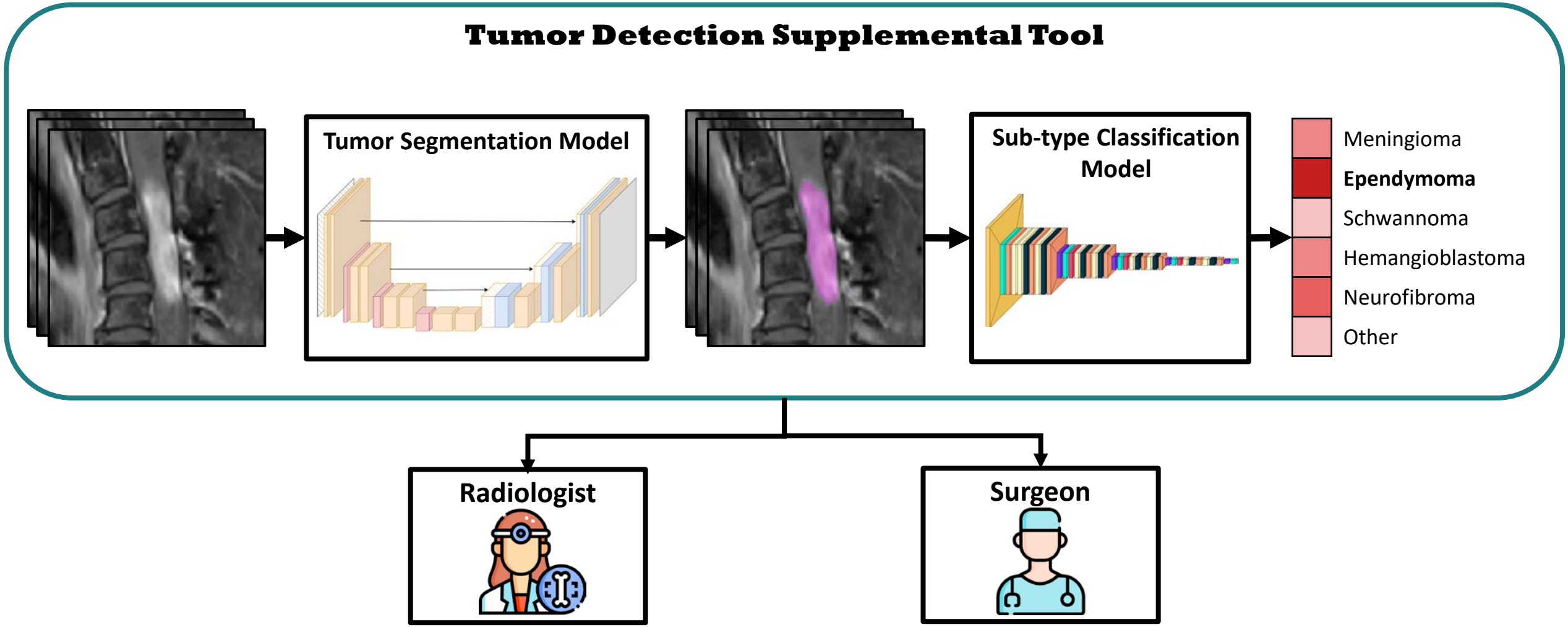
Photo from: my.clevelandclinic.org

Intradural Spinal Tumor Treatment Workflow



Photos from: www.flaticon.com

Intradural Spinal Tumor Detection Framework



Photos from:
- www.flaticon.com
- https://towardsdatascience.com/u-net-explained-understanding-its-image-segmentation-architecture-56e4842e313a

Data

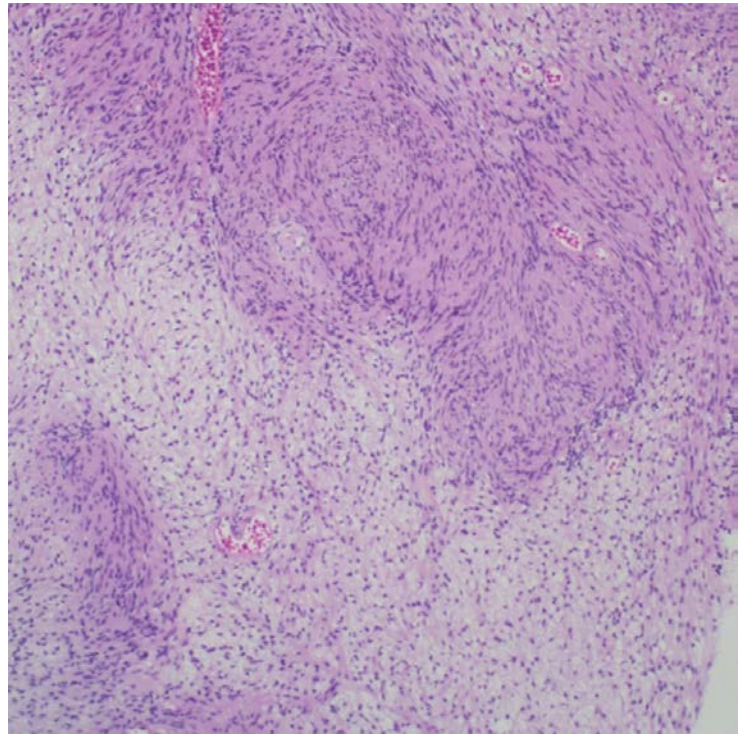
Data

- **84 intradural spinal tumor cases** from the Stanford University hospital database
  - Surgical cases; pathology images available
  - T1-weighted, T2-weighted, and post-contrast T1-weighted MRI scans
  - The pathology slides are used to determine the tumor sub-types

Sagittal View

Axial View

Pathology Slide



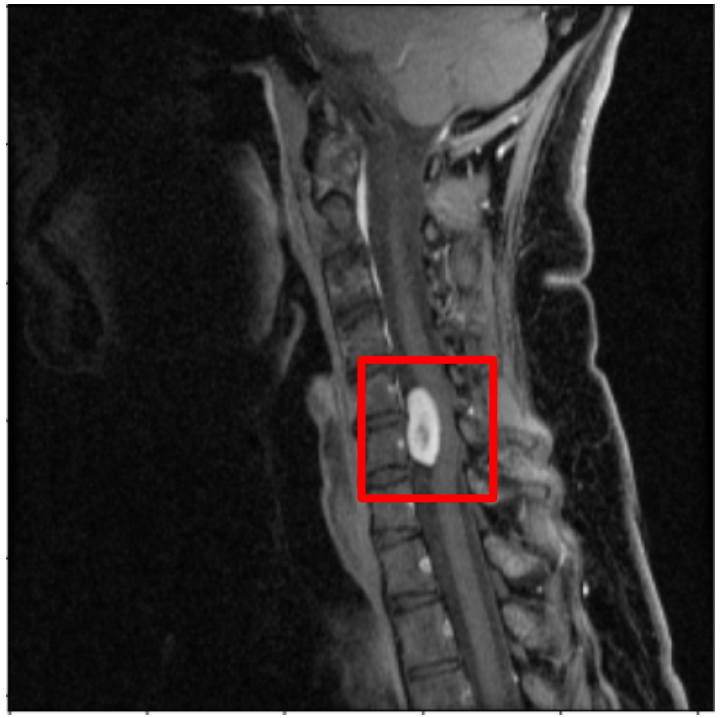
Stanford MEDICINE | School of Medicine

Pathology slide from: https://pubs.rsna.org/doi/full/10.1148/rg.2019180200

Data

- **Variation in the field of view; different spinal section**
  - Cervical: 29 cases
  - Thoracic: 31 cases
  - Lumbar: 24 cases

Cervical case



Post-Contrast T1 scan

Thoracic case

Post-Contrast T1 scan

Lumbar case

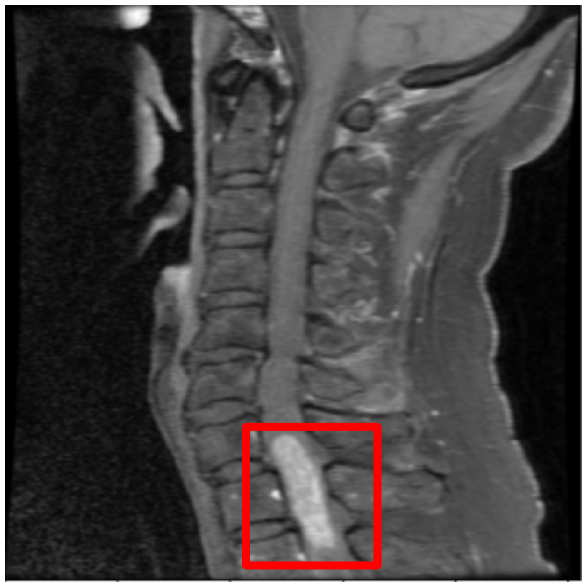
Post-Contrast T1 scan

Stanford MEDICINE | School of Medicine

Data

- **Variation in the appearance of the tumor; different tumor sub-types**
  - Ependymoma: 21 cases
  - Meningioma: 23 cases
  - Schwannoma: 26 cases
  - Others (Hemangioblastoma, Neurofibroma, etc.): 16 cases

Ependymoma



Post-Contrast T1 scan

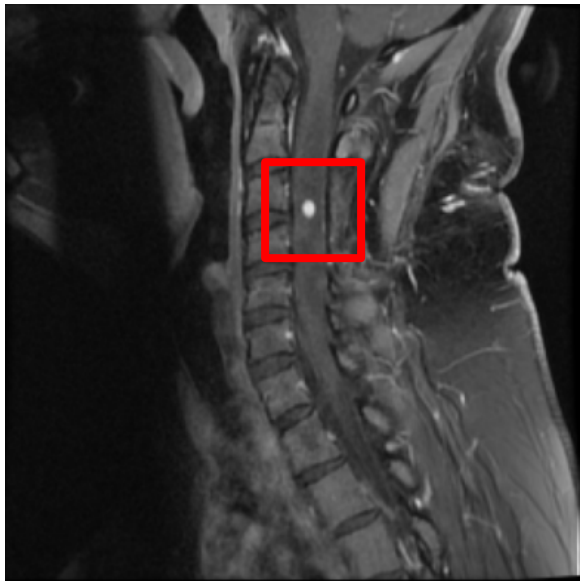
Meningioma

Post-Contrast T1 scan

Schwannoma

Post-Contrast T1 scan

Others



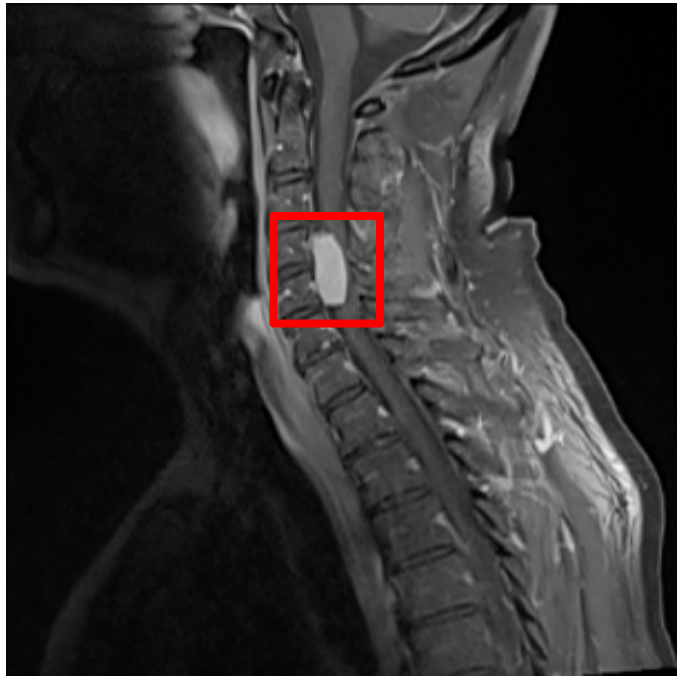
Post-Contrast T1 scan

Data

- **Variation in the volume intensity distributions; different manufacturers**
  - GE MEDICAL SYSTEMS: 68 cases
  - SIEMENS: 10 cases
  - Others (TOSHIBA, PHILIPS , HITACHI): 6 cases

GE MEDICAL SYSTEMS

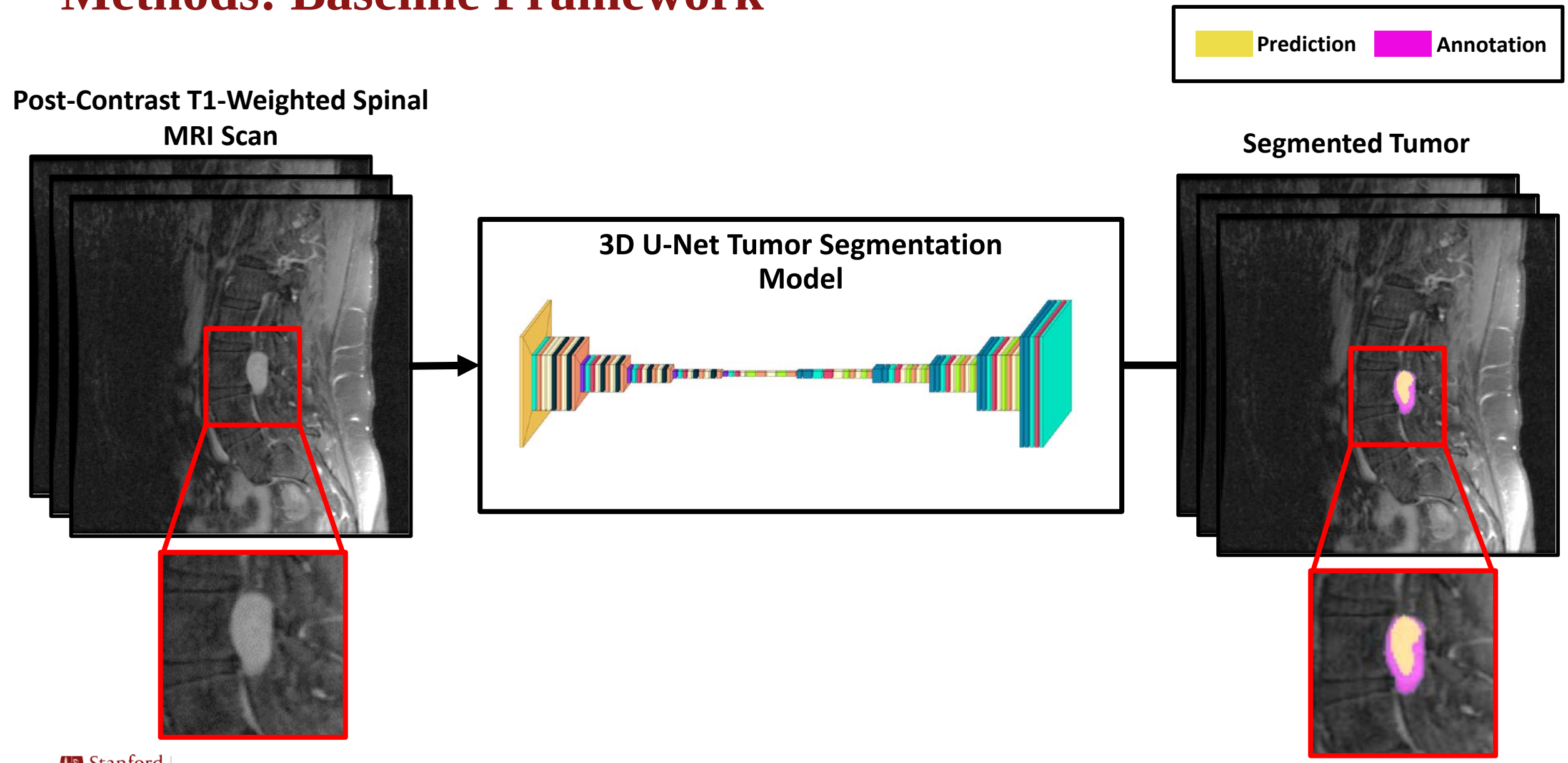
SIEMENS



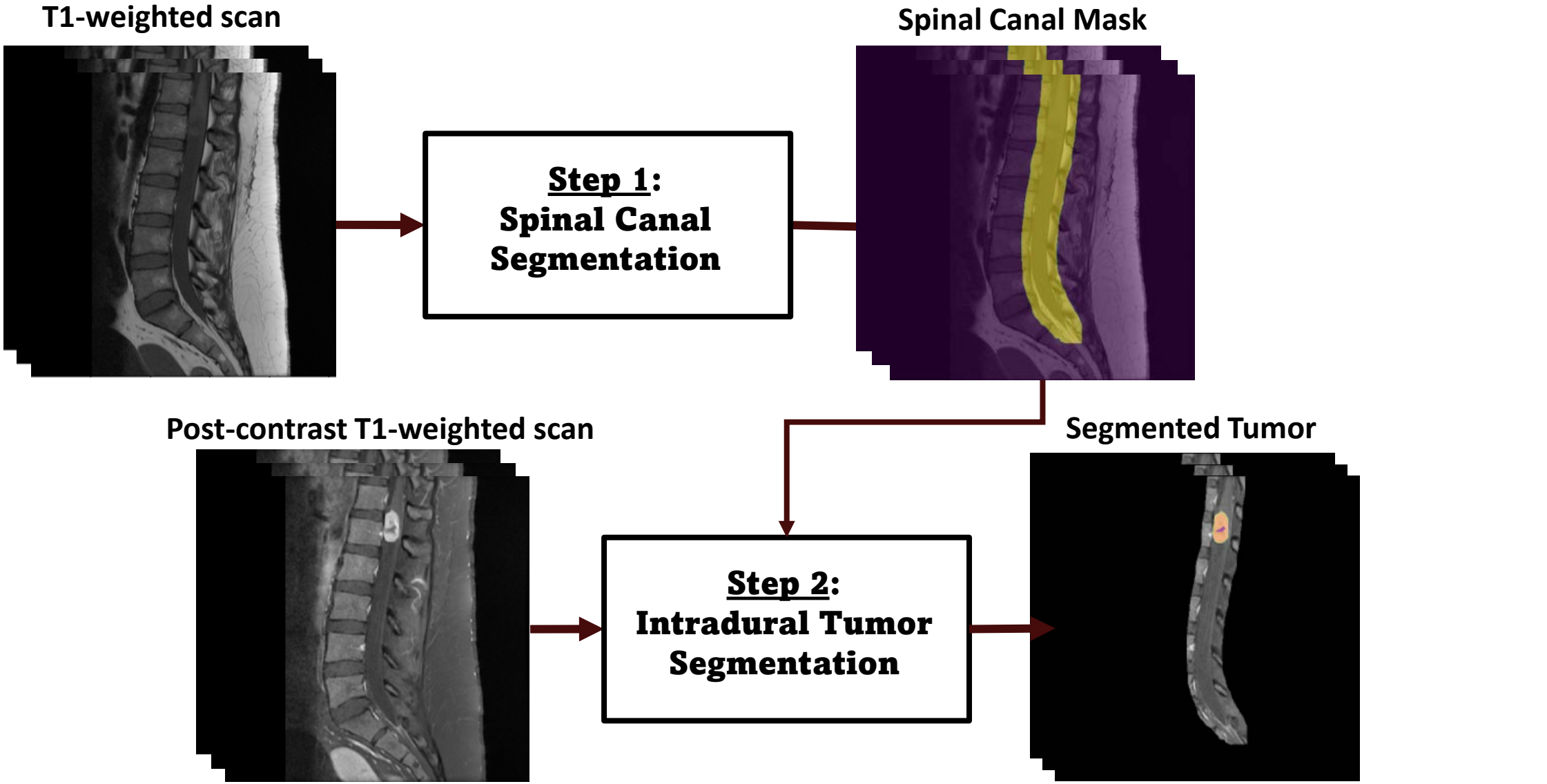
HITACHI

Methods

Methods: Baseline Framework



Methods: Proposed Framework

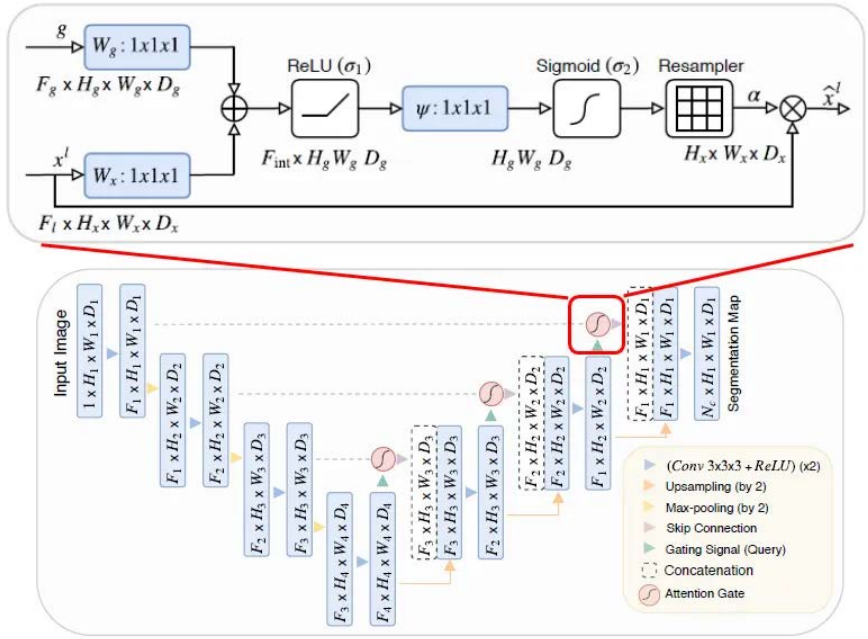


Methods: Proposed Framework - Spinal Canal Segmentation

T1-weighted scan

Spinal Canal Segmentation

Attention U-Net Model



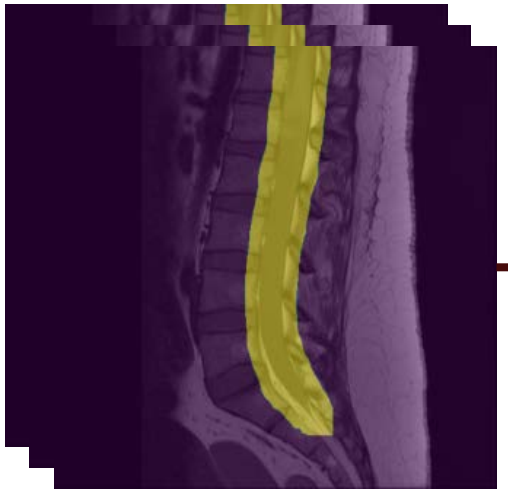
Spinal Canal Mask

Photo from: https://sh-tsang.medium.com/review-attention-u-net-learning-where-to-look-for-the-pancreas-biomedical-image-segmentation-e5f4699daf9f

Methods: Proposed Framework –Tumor Segmentation

Post-contrast T1-weighted scan

Spinal Canal Mask

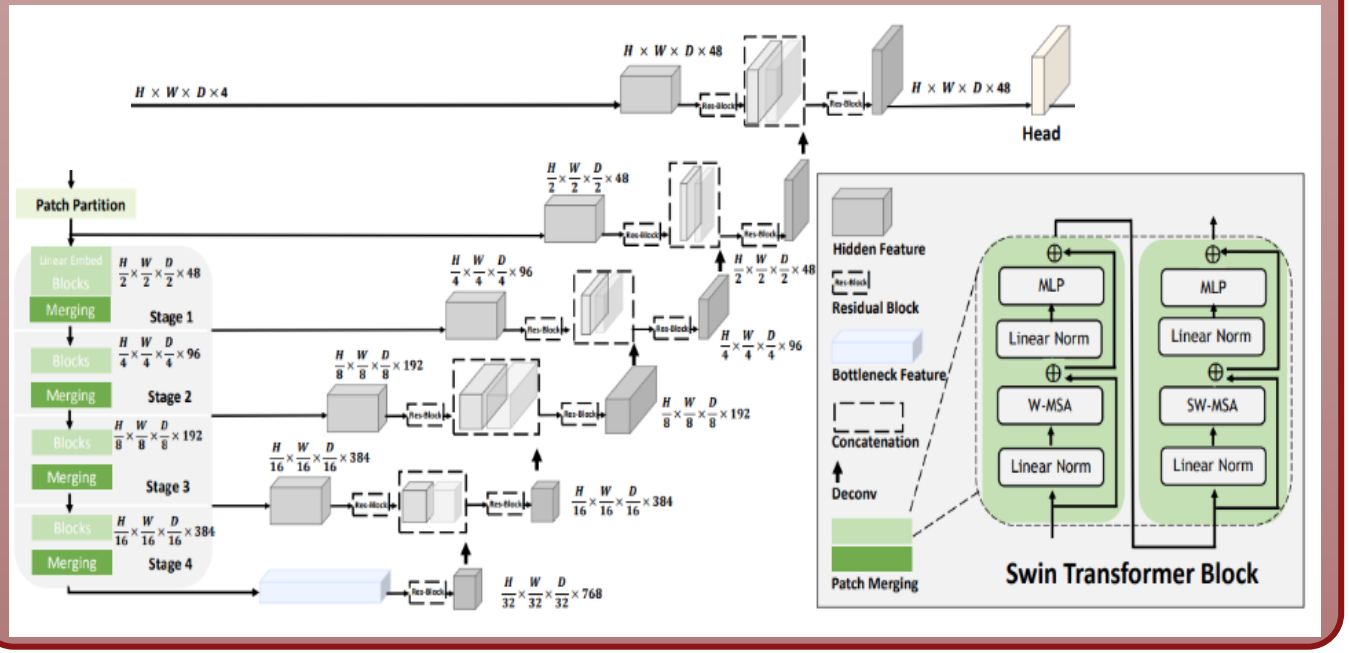


Intradural Tumor Segmentation

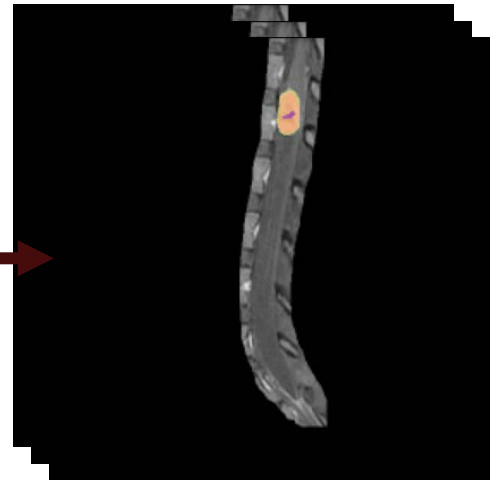
Image Preprocessing

Mask Scans

Swin UNETR Segmentation Model [1]



Segmented Tumor



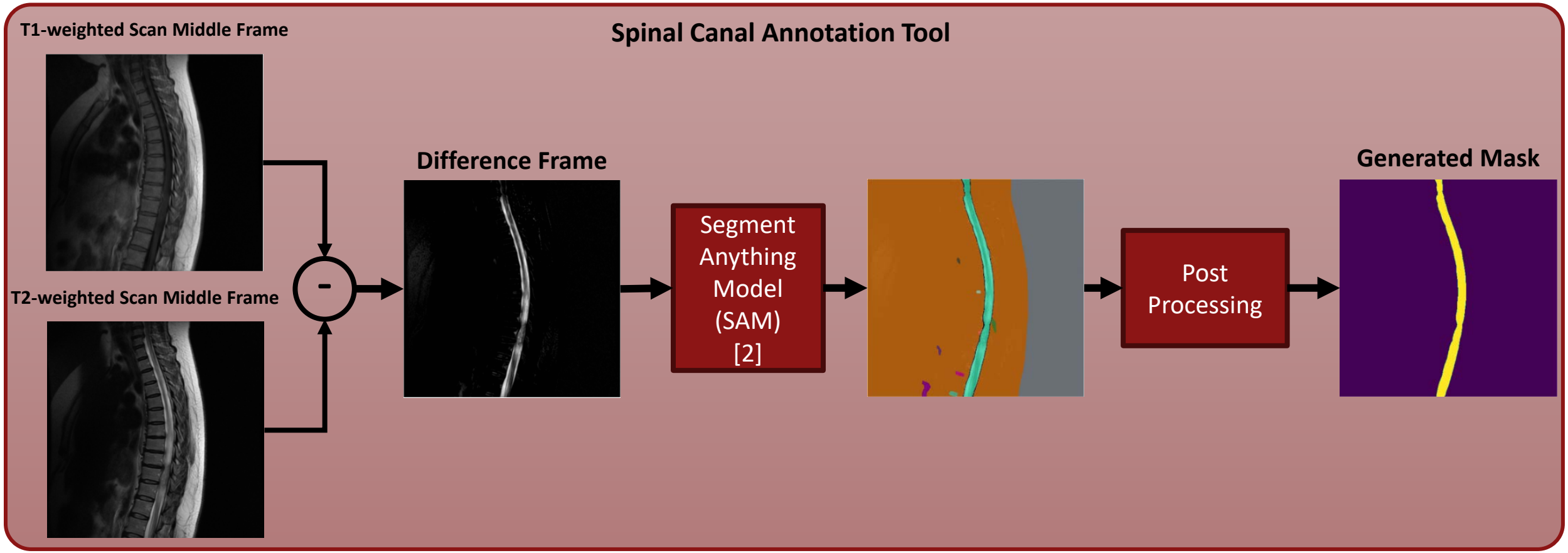
Prediction Annotation

Stanford MEDICINE | School of Medicine

[1]: Hatamizadeh, Ali, et al. "Swin unetr: Swin transformers for semantic segmentation of brain tumors in mri images." International MICCAI Brainlesion Workshop. Cham: Springer International Publishing, 2021.

Methods: Proposed Framework - Data Annotation Process

- **Tumor Segmentation:** Manually annotated the tumors using 3D Slicer tool[1] which were later verified by the spinal neurosurgical expert
- **Spinal Canal Segmentation:** Developed a unique algorithm which automatically segmented the canal for a group of training examples



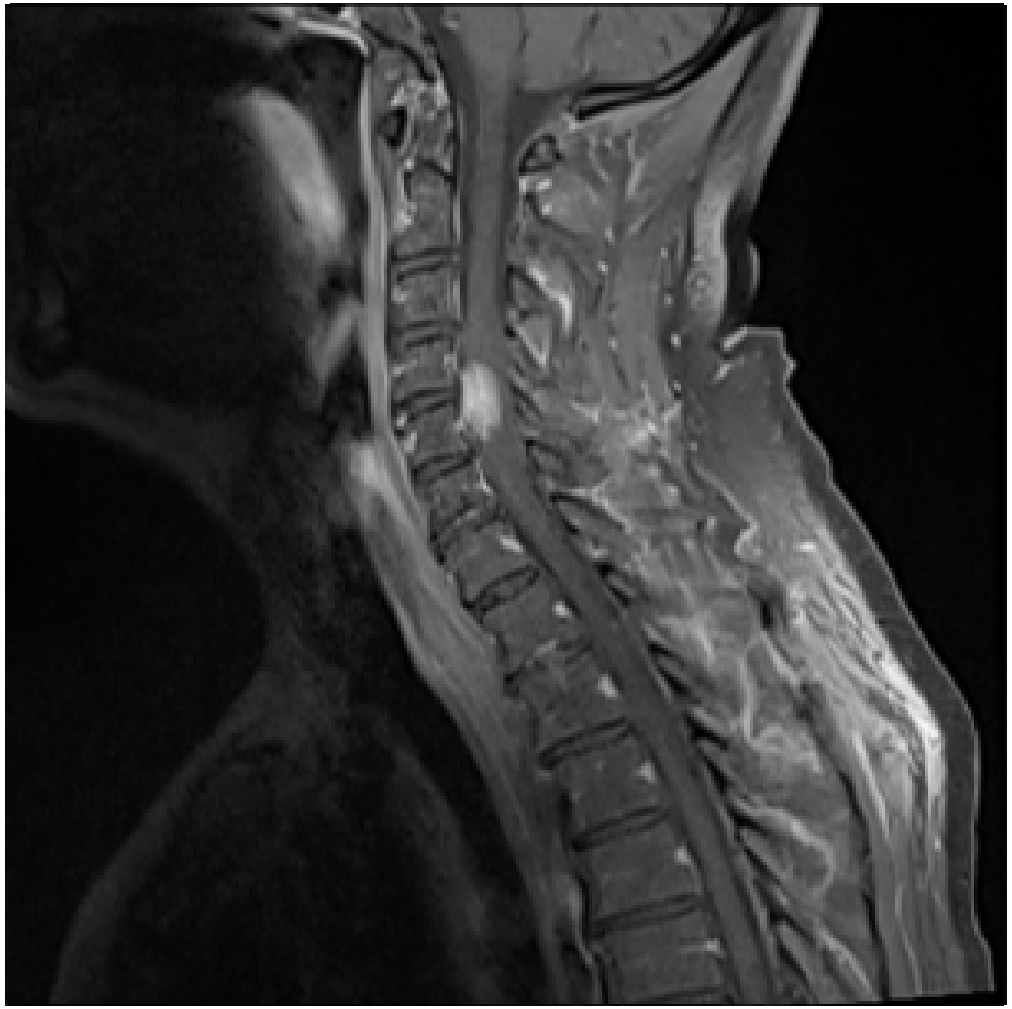
[1]: Pieper, Steve, Michael Halle, and Ron Kikinis. "3D Slicer." *2004 2nd IEEE international symposium on biomedical imaging: nano to macro (IEEE Cat No. 04EX821)*. IEEE, 2004
[2]: Kirillov, Alexander, et al. "Segment anything." arXiv preprint arXiv:2304.02643 (2023).

Results

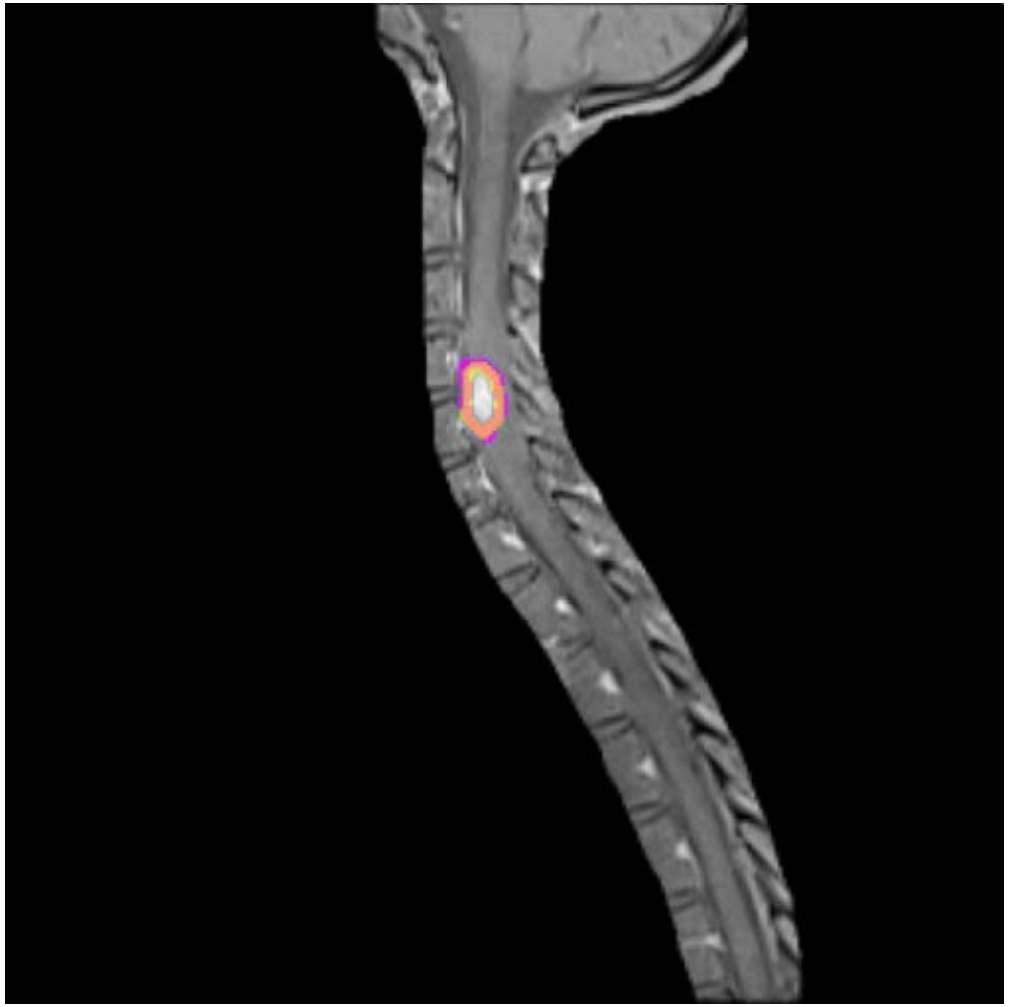
Segmentation Example

Prediction Annotation

Post-contrast T1-weighted scan



Masked post-contrast T1-weighted scan

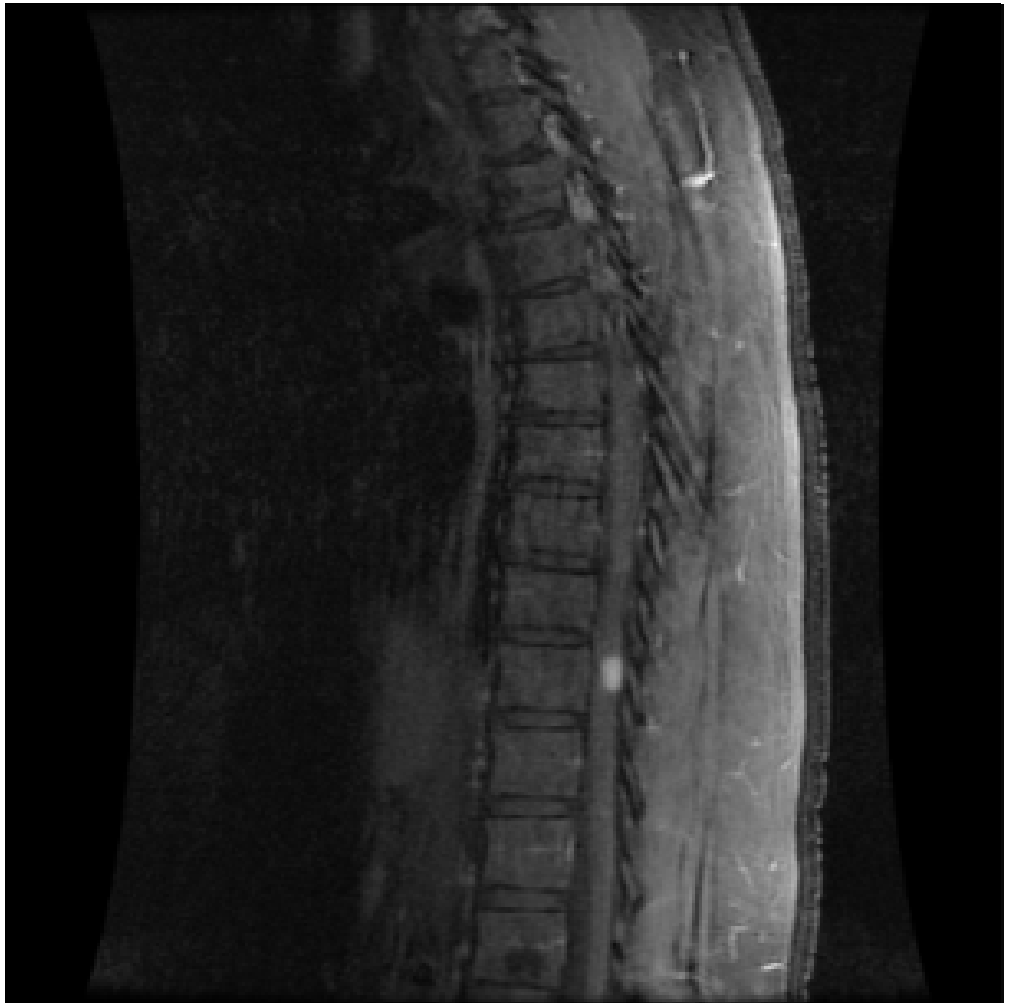


DICE = 0.88

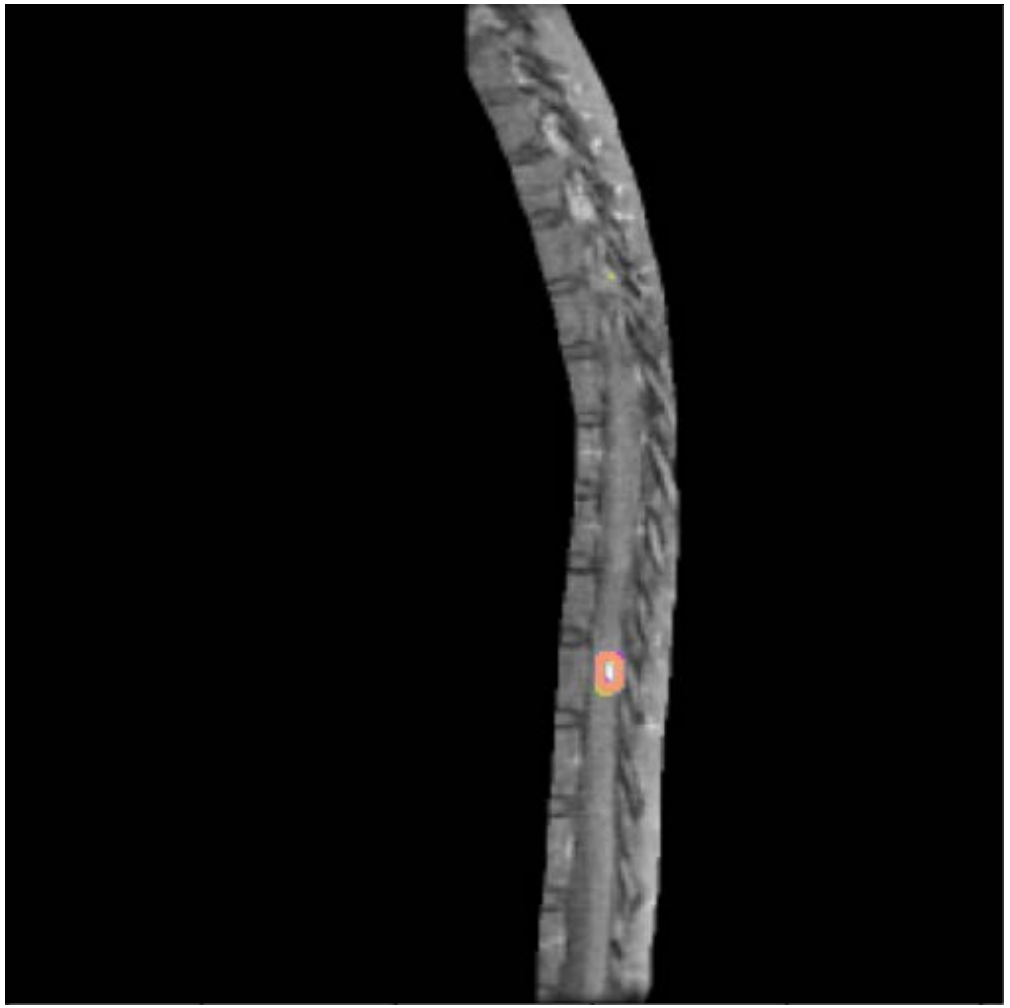
Segmentation Example

Prediction Annotation

Post-contrast T1-weighted scan



Masked post-contrast T1-weighted scan



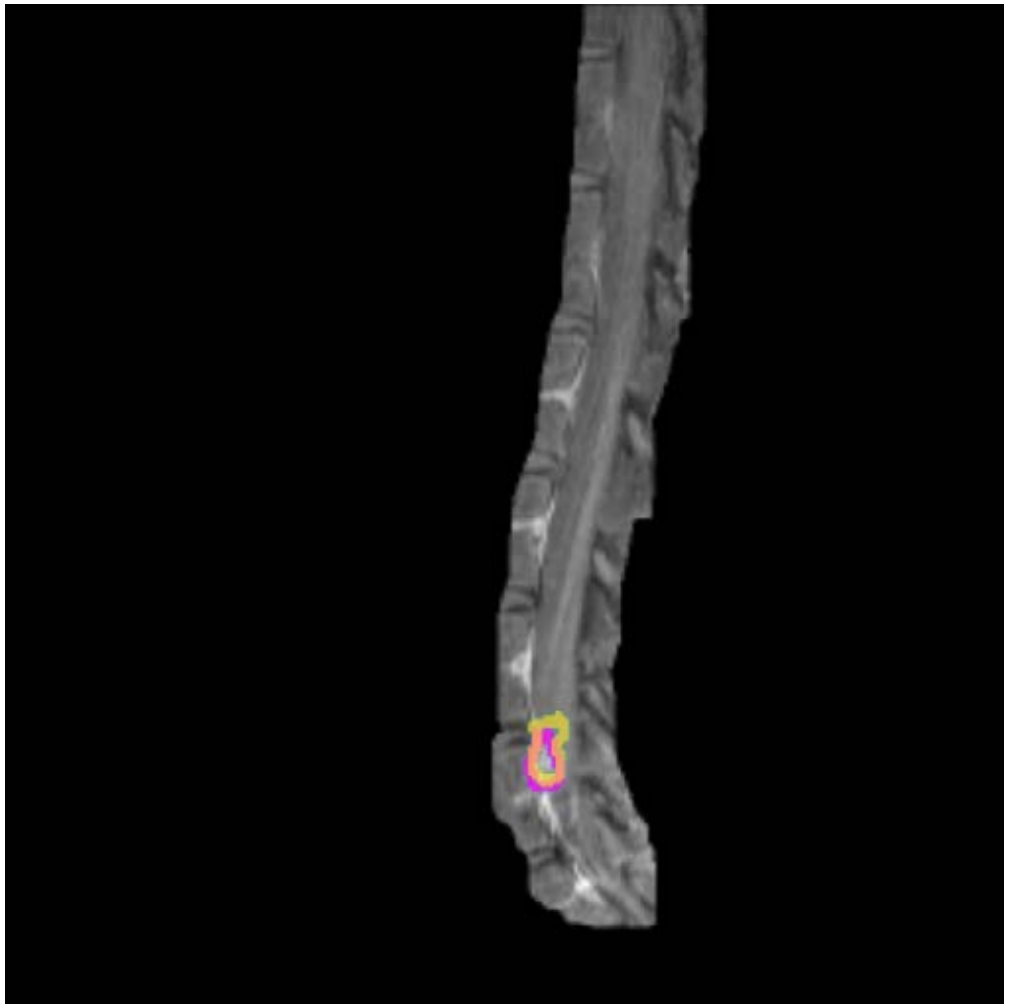
DICE = 0.78

Segmentation Example

Prediction Annotation

Post-contrast T1-weighted scan

Masked post-contrast T1-weighted scan



DICE = 0.65

Quantitative Results: Spinal Canal Segmentation

Spinal Canal Segmentation			
	No. of testing cases	**Patient-level Sensitivity**	**Mean DICE**
Attention UNET-based model	150 (normal, tumor, fusion, cyst, osteotomy)	95%	0.85

Quantitative Results: Intradural Tumor Segmentation

Intradural Tumor Segmentation				
K-Fold Cross Validation (K = 4), No. of Tumor Cases: 84 cases				
Fold	**Patient-level Sensitivity**		**Mean DICE**	
	Baseline	**Proposed**	**Baseline**	**Proposed**
Fold 1	67%	80.9%	0.47	0.75
Fold 2	75%	90.5%	0.52	0.65
Fold 3	63%	85.7%	0.41	0.63
Fold 4	62%	82.6%	0.53	0.62
Average	66.8%	**84.9%**	0.48	**0.66**

Intradural Tumor Segmentation	
No. of Non-Tumor Cases (31 cases)	
Patient-level Specificity	
Baseline	**Proposed**
86%	**92%**

Challenges and Next Steps

Challenges & Next Steps

- **Limited tumor sub-type categories**

Employ semi-supervised techniques for tumor sub-type classification

- **Multiple manufacturers and variation in intensity distributions**

Develop an intensity histogram alignment to standardize the intensity distributions

Conclusion

- An AI-powered intradural spinal tumor diagnosis tool presented to assist the radiologist/surgeon in identifying these tumors in MRI scans
- For this purpose, an automated segmentation model proposed for segmenting intradural spinal tumors in MRI scans
- Quantitative and qualitative results for this segmentation model demonstrated on a cohort of surgical intradural tumor cases

Thank You!

Mirabela Rusu, PhD
Assistant Professor Of Radiology and, By Courtesy, Of Urology

Atman Desai, MD
Spine Neurosurgeon
Clinical Associate Professor, Neurosurgery

Greg Zaharchuk, MD
Professor of Radiology

Stanford MEDICINE | School of Medicine

IBIIS INTEGRATIVE BIOMEDICAL IMAGING INFORMATICS | STANFORD

MED

SCIT