

Automated Definition of the Clinical Target Volume for Spine Metastasis Treated with Stereotactic Body Radiation Therapy

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ABSTRACT

Purpose: Spine stereotactic body radiation therapy (SBRT) is an emerging standard of care for patients with symptomatic spinal metastatic disease. The accuracy of target volume delineation is of critical importance for safe and effective spine SBRT. The adjacent normal tissues, including the spinal cord, are often closely approximated to the target and thus inadequate target coverage can result in local failure, and excessive target coverage can result in unnecessary and serious toxicity. Algorithmic tools can assist in improving target delineation practices. We developed a semi-automated method for CTV expansion based on internationally published guidelines from the International Spine Radiosurgery Consortium (ISRC).

Methods: The automated CTV are expanded only into the spinal segments located near the segment(s) containing the lesion. First, the patient's spinal curvature is approximated with a polynomial curve fit to the centroids of segmented vertebrae using the deep learning model from RayStation (research version 2025). Secondly, the spinal segments were defined using a rotated coordinate grid where the vertebra aligns the superior-inferior axis to the tangent vector of polynomial curve. Finally, an inverse transformation defines the spinal segments in the original patient's CT image. The automated CTVs were validated by comparison to clinical CTVs for three patients with spine metastasis lesions in the T7, L3, and T12 vertebrae using the dice similarity.

Results: Dice similarity coefficients for the three patients were 0.88, 0.88, and 0.90, respectively. The surface dice with 2 mm tolerance was 0.91, 0.86, and 0.91. It took an average of 50 seconds to generate a CTV, compared to an estimated 20 minutes for manual CTV delineation.

Conclusion: We have developed a CTV delineation approach for bony spine expansion that combines vertebral segmentation and algebraic spine segment calculations. This approach has the potential to support CTV delineation practices within the emerging treatment paradigm of spine SBRT.

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BACKGROUND

- Spine stereotactic body radiation therapy (**SBRT**) is an emerging standard of care for patients with symptomatic spinal metastatic disease.
- The **accuracy of target volume delineation** is of critical importance for safe and effective spine SBRT.
- The adjacent normal tissues, including the spinal cord, are often closely approximated to the target and thus inadequate target coverage can result in local failure, and excessive target coverage can result in unnecessary and serious toxicity.
- Algorithmic tools can assist in **improving target delineation** practices.

Objective

To develop an algorithmic method for CTV expansion based on **internationally published guidelines** from the International Spine Radiosurgery Consortium (ISRC).

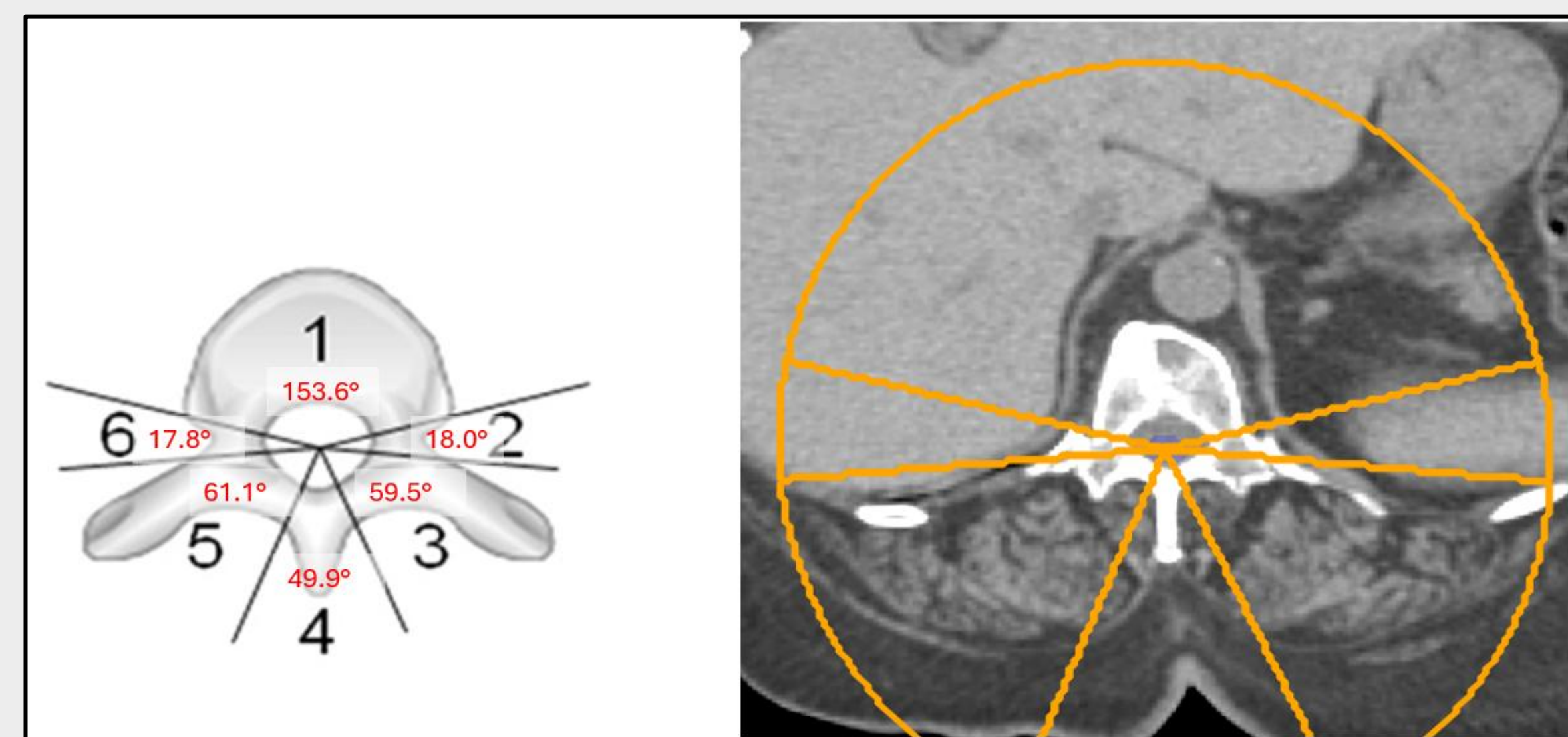
METHODS AND MATERIALS

- The bony expansion of the CTV includes the **elective** vertebral segments located near the segment(s) containing the lesion.
- Elective vertebral segments are included in CTV delineation on a patient-specific basis using a three-step process:

1. **Segmentation of the vertebrae** on the patient's CT scan using a deep learning model from RayStation (research version 2025).
2. Estimation of the patient's **spinal curvature** to accurately define the vertebral segments.
3. Inclusion of potentially involved vertebral segments in a lesion-to-CTV **expansion algorithm**.

- The automated method was tested on for three patients with spine metastasis lesions in the T7, L3, and T12 vertebrae
- Model CTVs are compared to physician-delineated CTVs using the Dice and Surface Dice Similarity coefficients.

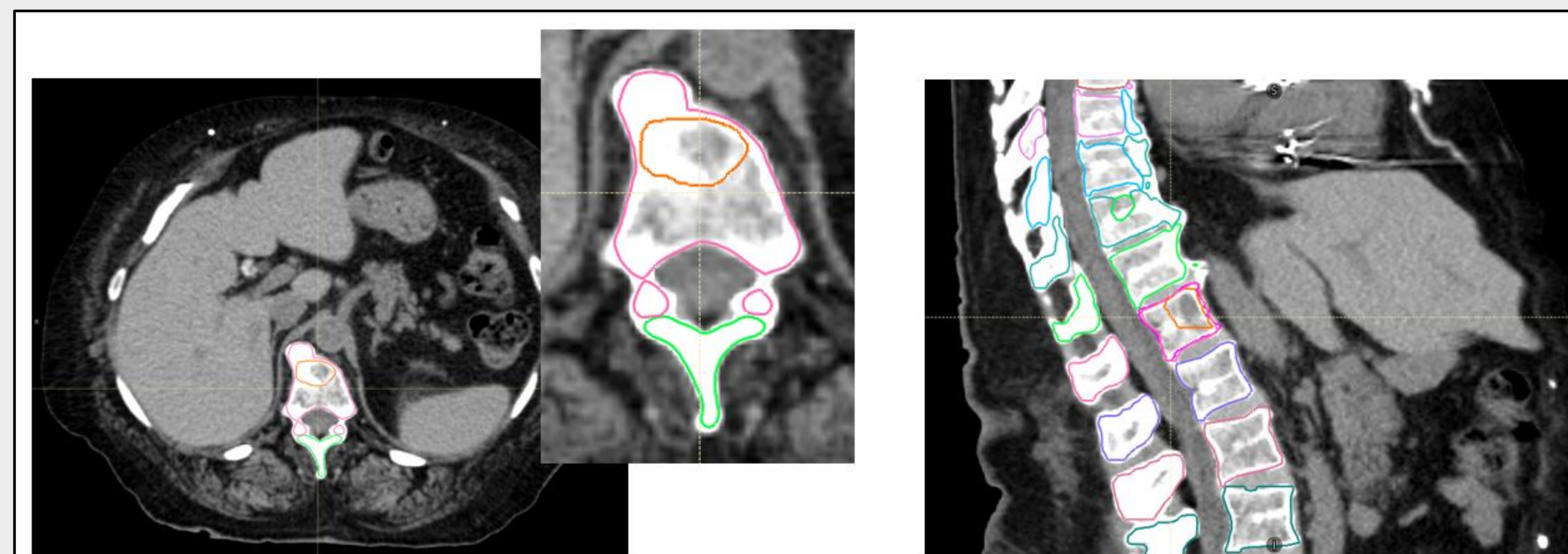
International Spine Radiosurgery Consortium (ISRC) definition of spinal segments



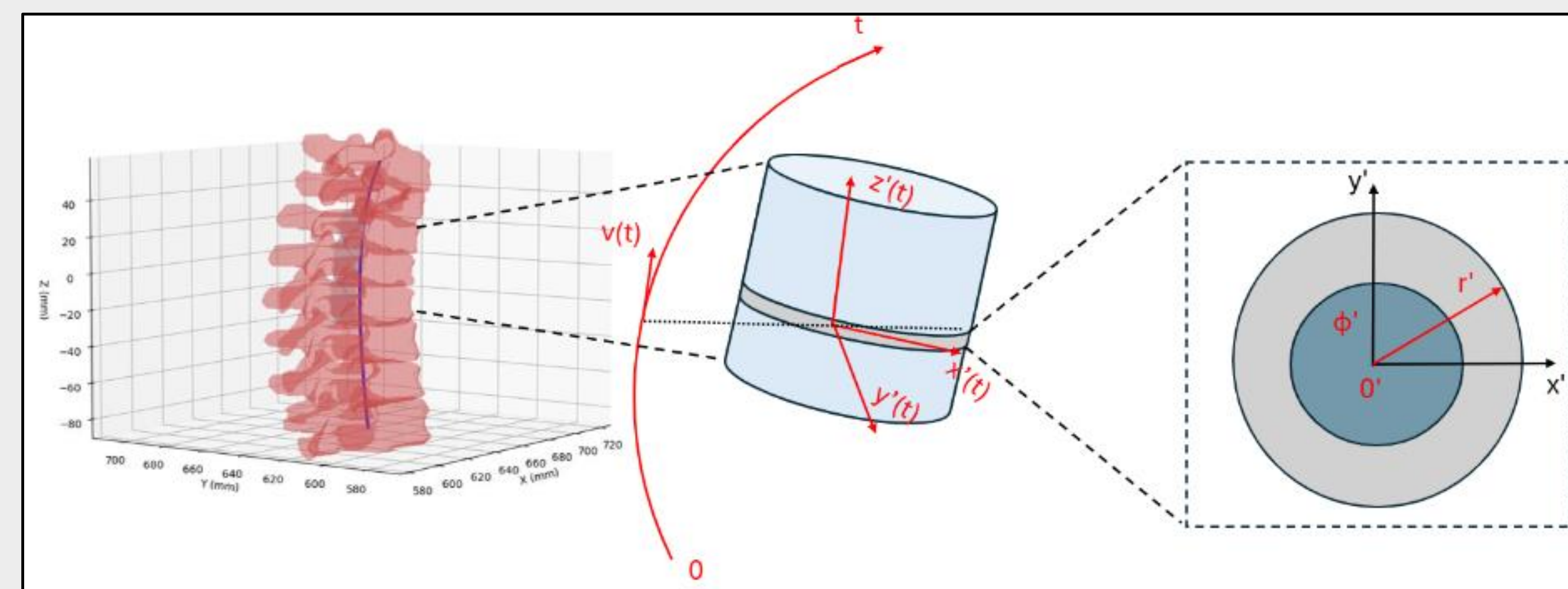
RESULTS

	T7	L3	T12
Dice	0.88	0.88	0.90
Surface Dice	0.91	0.86	0.91

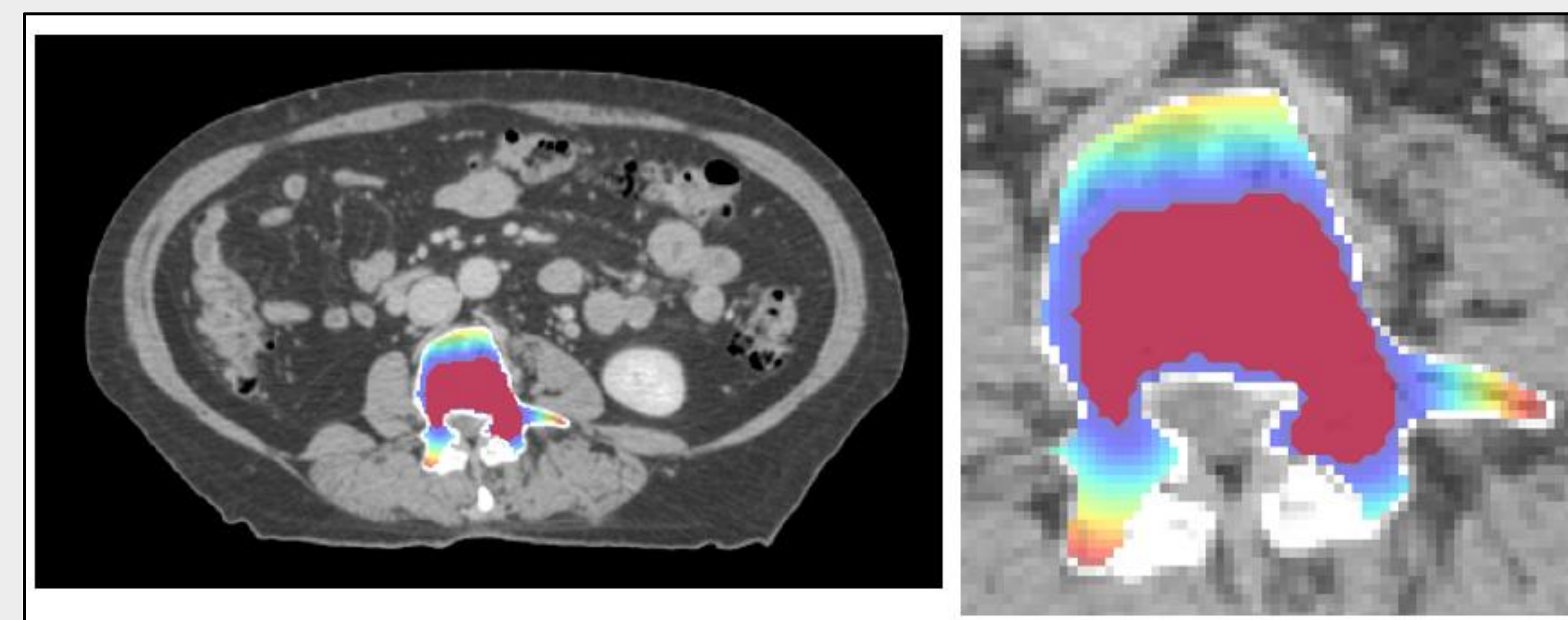
Auto-segmentation of vertebrae



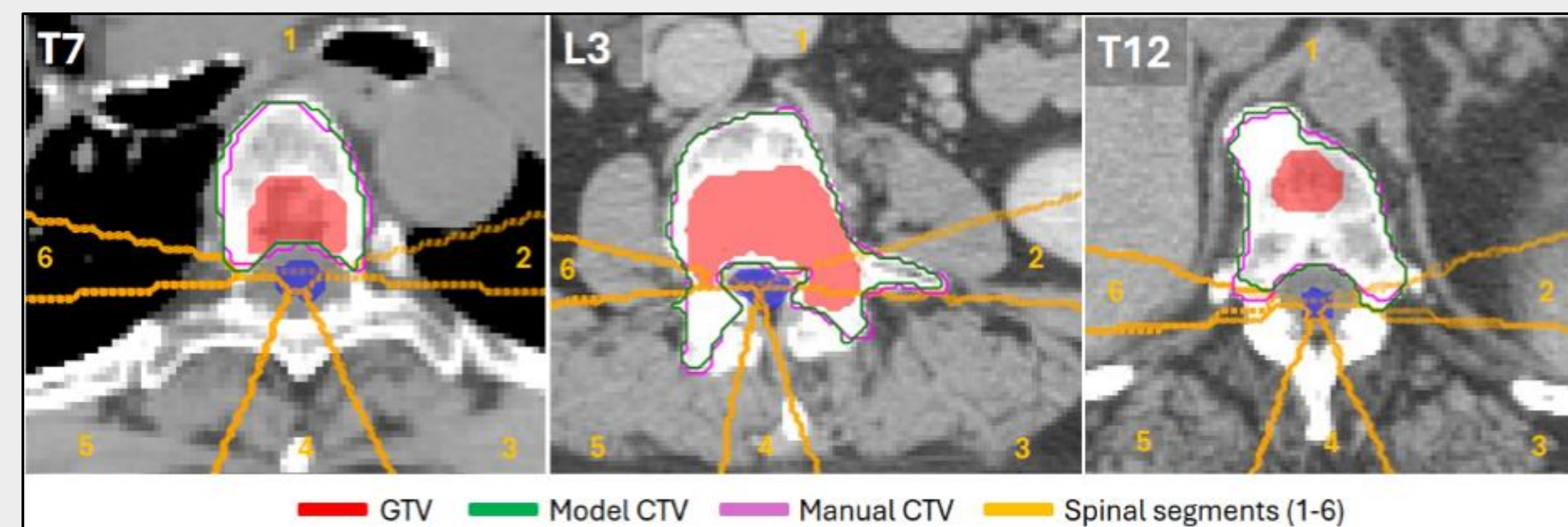
Model spinal curvature



Calculate 3D distance map ~ (tumor infiltration risk)⁻¹



Define Model Clinical Target Volume (CTV) and compare to physician-delineated CTV



REFERENCES

International Spine Radiosurgery Consortium (ISRC) guidelines (Cox B et al. IJROBP 2012)