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Revisiting Treatment of Spine Metastases in the Era of Acuros

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Abstract

Accurate dose calculation is essential for evaluating plan quality in spine radiotherapy, particularly in postoperative patients where surgical hardware and tissue heterogeneity can significantly affect dose distribution. This study investigated whether treatment quality metrics and clinical goals previously considered acceptable using the Anisotropic Analytical Algorithm (AAA) remain valid when recalculated with Acuros XB (AXB) for postoperative spine metastases treated with 3D conformal radiotherapy (3DCRT).

Clinical treatment plans originally calculated with AAA were retrospectively recalculated using AXB while maintaining identical beam arrangements and monitor units to assess the impact of algorithm selection on target coverage, dose heterogeneity, and spinal cord dose.

The findings demonstrate that dose calculation algorithm selection can substantially influence the perceived quality of spine treatment plans, with AAA potentially masking clinically meaningful dose variations, particularly in postoperative cases. These results highlight the importance of using advanced dose calculation algorithms such as AXB to more accurately assess treatment quality and support informed clinical decision-making in spine radiotherapy.

Introduction

Spinal metastases are among the most common sites of metastatic disease and are frequently treated with external beam radiotherapy to provide pain relief, preserve neurologic function, and maintain spinal stability. Depending on disease extent and clinical presentation, treatment techniques range 3DCRT, IMRT, and SBRT. Accurate dose calculation remains fundamental for achieving adequate target coverage while respecting the tolerance of the spinal cord

The choice of dose calculation algorithm plays an important role in treatment planning, particularly in anatomically heterogeneous regions. The AAA has been widely used in clinical practice; however, its accuracy is limited near interfaces between tissues of different densities and in the presence of high-density materials. In contrast, AXB, has demonstrated improved agreement with measurements and Monte Carlo calculations in heterogeneous media, including bone, air cavities, and regions containing implants. These differences are especially relevant in postoperative spine radiotherapy, where high density implanted hardware introduces substantial heterogeneity that can perturb dose distributions and affect target coverage and spinal cord dose.

It remains unclear whether treatment quality metrics previously considered acceptable with AAA remain valid when recalculated using AXB. This study evaluates the dosimetric impact of recalculating postoperative and non-operative spine metastasis treatment plans with AXB to determine how algorithm selection influences the interpretation of plan quality and achievement of clinical treatment objectives.

Methods and Materials

The study included 41 clinical postoperative and non-operative spine metastasis treatment plans (postoperative, n = 20; non-operative, n = 21) involving cervical, thoracic, lumbar, and sacrum spine lesions. All patients were treated with 3DCRT which is the main palliative treatment technique at UCI. Clinical plans originally calculated with AAA were retrospectively recalculated using AXB while maintaining identical beam geometry, monitor units, and optimization parameters to isolate the effect of the dose calculation algorithm.

Dosimetric comparisons were performed between AAA and AXB using clinically relevant plan quality metrics, including PTV V95%, MSV95% (minimum spared volume receiving less than 95% of the prescription dose), which quantifies target cold spots, spinal cord V105%, and the heterogeneity index (HI), calculated as

$$HI = \frac{D_{max} - D_{min}}{D_{mean}})$$

where D_{max}, D_{min}, and D_{mean} represent the maximum, minimum, and mean target doses, respectively.

Dosimetric differences between AAA and AXB were evaluated separately for postoperative and non-operative cohorts to assess the impact of surgical instrumentation and tissue heterogeneity on treatment plan quality.

Table 1. Post Operative Spine metastasis with implanted high-density hardware.

	MVS 95%		V95%		Cord 105%		Heterogeneity	
	AAA	AXB	AAA	AXB	AAA	AXB	AAA	AXB
Mean	2.1%	8.1%	98.3%	92.8%	24.1%	31.6%	27.3%	47.7%
± Standard Deviation	2.1%	6.7%	2.1%	6.7%	22.2%	29.2%	20.1%	19.1%

Table 2. Non Operative Intact Spine metastasis.

	MVS 95%		V95%		Cord 105%		Heterogeneity	
	AAA	AXB	AAA	AXB	AAA	AXB	AAA	AXB
Mean	1.5%	7.0%	98.5%	93.0%	22.8%	21.4%	20.7%	25.2%
± Standard Deviation	2.6%	12.0%	2.7%	12.0%	33.1%	32.2%	6.5%	7.0%

Results

Recalculation with AXB revealed clinically meaningful dosimetric differences compared with AAA, with the largest impact observed in postoperative 3DCRT plans. In postoperative cases, AXB demonstrated reduced target coverage, increased target cold spots, higher spinal cord dose, and substantially greater dose heterogeneity.

Specifically, PTV V95% decreased from 98% ± 2% to 93% ± 7%, spinal cord V105% increased from 24% ± 22% to 32% ± 29%, and the heterogeneity index (HI) increased from 27% to 48%.

In non-operative cases, AXB also identified reduced target coverage and increased dose heterogeneity, although the magnitude of these changes was smaller.

PTV V95% decreased from 99% ± 3% to 93% ± 12%, spinal cord V105% remained comparable (23% ± 33% vs. 21% ± 32%), and HI increased from 21% to 25%.

Post-OP Spine Treatment with high density hardware

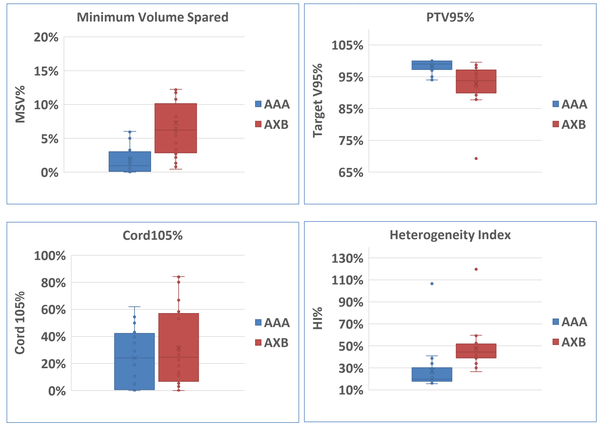

Chart 1. Metrics for evaluating target coverage, cold spot volume within the target, Cord sparing, and heterogeneity index in Post-OP palliative Spine Treatment with 3DCRT.

Non-OP Spine Treatment

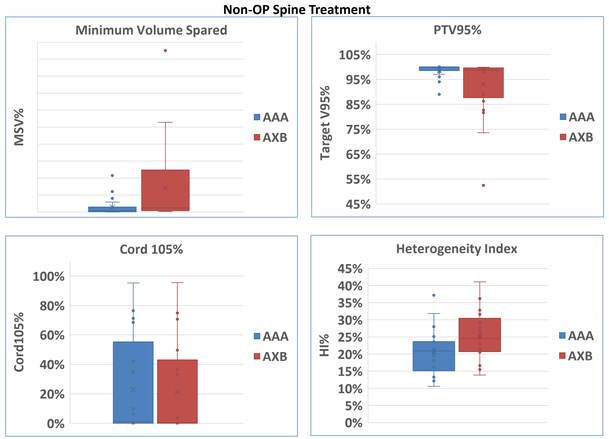

Chart 2. Metrics for evaluating target coverage, cold spot volume within the target, Cord sparing, and heterogeneity index in Non-OP palliative Spine Treatment with 3DCRT.

Conclusions

Recalculation palliative metastatic spine plans with AXB revealed clinically meaningful dosimetric differences compared with AAA, with the largest impact observed in postoperative 3DCRT plans. AXB demonstrated reduced target coverage, increased target cold spots, higher spinal cord dose, and greater dose heterogeneity, while non-operative cases showed similar but less pronounced changes.

These findings suggest that AAA may overestimate target coverage and underestimate dose heterogeneity, particularly in the presence of postoperative anatomical changes and high-density spinal instrumentation. The larger discrepancies observed in postoperative patients are consistent with previous reports showing that AXB provides more accurate dose calculations in heterogeneous tissues and around metallic implants than AAA.

Consequently, treatment plans previously considered acceptable using AAA may not accurately represent the delivered dose. These findings support the use of AXB for postoperative spine radiotherapy and suggest that historical treatment goals and dosimetric criteria established using AAA should be interpreted with caution.

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