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Stereotactic Radiotherapy For Patients Withs Metallic Implants On Vertebral Body: A dosimetric comparison

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Abstract

Objective: Metallic implants have impacts on dose distribution of radiotherapy. Our purpose is evaluating impact of metallic implants with different dose calculation algorithms on dose distribution.

Material and Methods: Two patients with metallic implants on vertebral body were included in this study. They were treated with stereotactic radiotherapy. The data of the patients were retrospectively re-calculated with different TPSs and calculation algorithms. Ray-Tracing (Ry-Tc), Monte-Carlo (MC), Acuros XB (AXB) and analytical anisotropic algorithms (AAA) were compared.

Results: Ry-Tc, AAA and AXB underestimated minimum and maximum doses of target volumes and critical organs compared with MC.

Conclusion: MC seems more reliable for dose calculations in patients with metallic implants but more studies with more number of patients should be done to identify the best dose calculation algorithm for patients with metallic implants.

Keywords: Prostheses and Implants, Stereotactic Body Radiotherapy, Monte-Carlo method, Acuros XB

Introduction

Various metallic spinal implants have been used for bone stability on patients with spinal metastases or primary spinal tumors. The radiation therapy has been widely used to treat metastatic or primary spinal tumours.

Recently, spine stereotactic radiotherapy (SRT) is frequently used in the management of spinal tumors. SRT offers a highly conformal and high dose per fraction. The tolerance dose of spinal cord is a limitation factor for prescription dose.

To deliver ablative radiotherapy CyberKnife® (CK)-based SRT is an effective method. Ray Tracing (RyTc) and Monte Carlo (MC) algorithms are dose calculation algorithms which are used by Multi Plan (MP), Cyberknife® Accuray treatment planning system.

In the lung cancer, RyTc algorithm has been shown to be less accurate than MC algorithm in terms of dose calculation due to the inhomogeneus tissue density at the lung-tumor interface and the small fields employed (1-3). Because of these limitations RTOG advises MC calculations for lung cancer cases.

However it is not known that how other sites are affected by different calculations of different algorithms.

The effects of metallic implants on dose calculation have been studied by the several authors. One analysis of dose profiles using metallic rods showed that the TPS overestimated the attenuation effect (4). These data were from relatively simple experimental model or an old TPS such as analytical anisotropic algorithm (AAA) (5).

Acuros XB, a new dose calculation algorithm based on photon and electron transport, has been installed in Eclipse TPS.

AXB uses a technique to solve the linear Boltzmann transport equation (LTBE) and directly accounts for the effects of heterogeneities on dose calculations (6-8).

The purpose of this study was to evaluate the dose calculation accuracies of AXB, AAA, MC and RyTc on two patients with metallic spinal implants.

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Material and Method

Patients

This is a retrospective study which was conducted on CT data sets, collected from two patients who underwent spine SBRT at Ankara Oncology Training and Research Hospital. First patient had renal cell carcinoma with bone metastasis and metallic implant was inserted on 11th and 12th thoracal, 1st and 2nd lumbar vertebra. Second patient had recurrent schwannoma and metallic implant was inserted on 11th and 12th thoracal and 1st lumbar vertebra. The implants were consisted of the corpus and the roots. These parts were contoured separately as corpus and the root. The corpus of the implants included a titanium alloy which composed of 6.09 % Aluminium, 0.2% Iron, 0.1% Oxygen and 4.17 % Vanadium. The roots of the implants included a titanium alloy which composed of 6.12 % Aluminium, 0.18% Iron, 0.12% Oxygen, 4.19% Vanadium. The relative electron dansities of implants were calculated.

Gross tumor volumes (GTV) were deliniated as the T1 contrast enhancement lesion on MRI. The planning target volume (PTV) was obtained by an isotropic expansion of the GTV by 2 mm. Spinal cord was contoured from the T2 flair as offered by RTOG 0631. Planning organ at risk volume (PRV) was defined as the spinal cord plus a 2 mm expansion to account for set-up errors. The PTV volume was 432.5 cm^3 for the first patient and 470,7 cm^3 for the second patient.

Treatment Planning

The prescription dose was 22.5 Gy over 5 fractions for first patient and 25 Gy over 5 fractions for second patient with a goal at least 80 % of PTV received the prescription dose. Treatment plans were produced using RyTc algorithm.

The patients were treated with these plans and the data was retrospectively analyzed with different TPSs and calculation algorithms. Multi Plan Treatment Planning System V3.5 with RyTc, Monte-Carlo dose calculation algorithms and Eclipse. Treatment Planning System V.13.0 with Acuros XB, AAA dose calculation algorithms were used for to create new plans. All doses of targets volumes and critical structures which were individually calculated from these TPSs and these dose calculation algorithms were compared and recorded.

Results

In this study different calculation algorithms were compared retrospectively on the patients with metallic spinal implants. Minimum and maximum doses on target volumes and on critical structures were underestimated at Ry-Tc algorithm compared to MC algorithm. Minimum doses of PTVs were 1% underestimated for both patients. Maximum doses of PTV were underestimated 2% for the first patient and 8% for the second patient. Maximum dose of PRV spinal cord was underestimated 2% for the first patient and 3% for the second patient. Minimum and maximum doses of target volumes and critical structures were underestimated at AAA algorithm compared to AXB algorithm. Minimum doses of PTV were underestimated 3,7% for the first patient and 1,7% for the second patient. The maximum doses of PTV were underestimated 1,8% for the first patient and 2,8% for the second patient. The maximum dose of PRV spinal cord was underestimated 1,9% for the first patient and 2% for the second patient. The isodoses were calculated by the AAA and AXB algorithms on Eclipse TPS are shown in figures 1 and 2 respectively. The PTV coverages and critical organ doses that were obtained from each TPS and calculation algorithm are presented in table 1 and 2.

Table 1: Results of VARIAN Eclipse TPS AXB13 and AAA algorithms

		Patient 1		Patient 2	
		Acuros XB	AAA	Acuros XB	AAA
PTV	Dmin %	74.3	70.6	81.7	80
	Dmax %	121.5	119.7	124,8	122
	Dmean(Gy)	24.2 Gy	24.2 Gy	27.7 Gy	27.4 Gy
PRV spinal cord	Dmax (Gy)	21.5 Gy	21.1 Gy	23.6 Gy	23.1 Gy

Eclipse TPS: Eclipse Treatment planning system, **AXB13:** Acuros algorithm, **AAA:** Analytical anisotropic algorithm

Table 2: Results of Cyberknife® Accuray TPS MC and RyTc

		Patient 1		Patient 2	
		MC	RyTc	MC	RyTc
PTV	Dmin %	94	93	80	79
	Dmax %	122	120	136	128
	Dmean(Gy)	24.1 Gy	24 Gy	28.1 Gy	27.1 Gy
PRV spinal cord	Dmax (Gy)	24.6 Gy	24.2 Gy	23 Gy	23.9 Gy

Accuray TPS: Accuray Treatment planning system, **MC:** Monte Carlo algorithm, **RyTc:** Ray- Tracing algorithm

Figure 1: The isodose curve for first patient calculated both by AXB and AAA algorithms

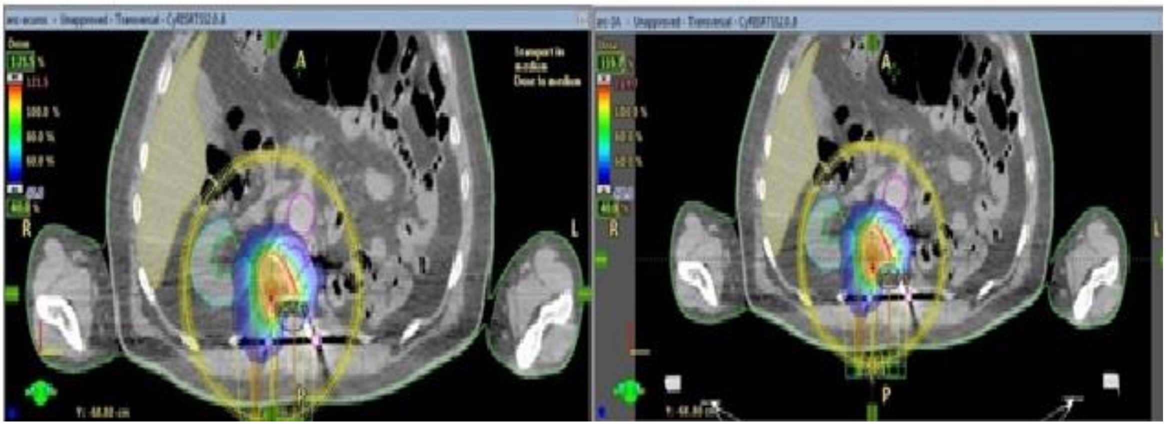
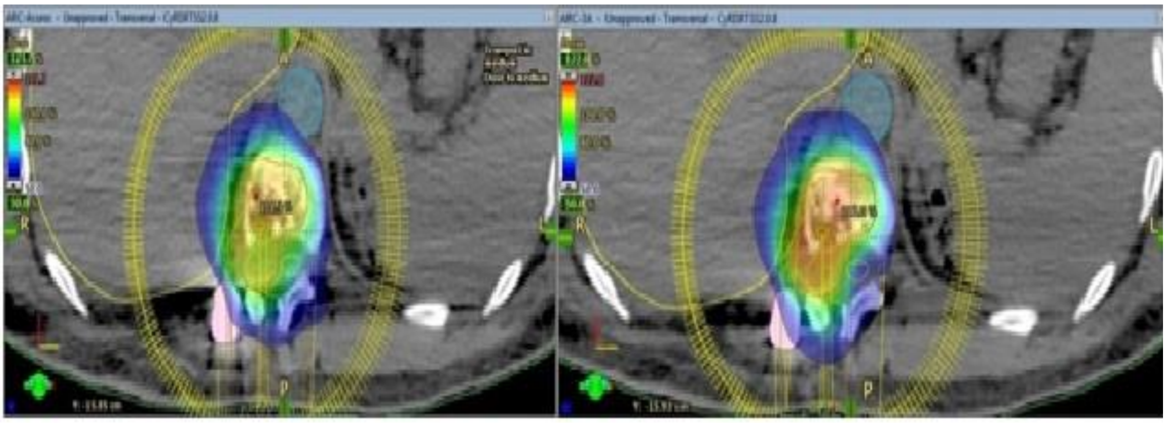


Figure 2: The isodose curve for second patient calculated both by AXB and AAA algorithms



Discussion

This study shows that the differences of the dose distributions between different calculation algorithms on patients with metallic spinal implants.

There are some problems that must be taken into account for the dose calculation on patients with metallic spinal implants. The electron densities of metallic implants are different from the tissue and computed tomography and the radiotherapy planning systems cannot identify them. Metallic implants cause artifacts on CT scans. It is difficult to deliniate the target volume and critical structures on these artifacted CT scans. It also causes dose distribution inaccuracies on TPSs.

The pencil-beam algorithm has the limitation for accurately calculating the dose contribution of the 3-D scatter doses from the metal. Various authors have investigated the effect of metallic implants on radiation therapy, and efforts have been made to reduce these effects. Newhauser et al. suggested a method to reassign HU values in the regions containing artifacts to the HU values in artifact-free regions of tissue (10).

The calculation of dose with TPS mainly depends on relative electron density, which is derived from CT value. A large artifact may occur when scanning a metal implant with high density, which will result in error in CT calculation. We contoured the roots and the corpus of the metallic implants separately and reassign the HU values of them for AAA and AXB. In the other hand we inserted the relative electron densities of the metallic implants in Accuray TPS for RyTc and MC calculations. So we aimed to reduce the scattering effects of the metallic implants.

In Roberts et al study it has been showed that the accuracy of dose calculation varied with errors up to 20% because the TPS, in which the pencil-beam algorithm was used, overestimated the attenuation for a titanium prosthesis (11).In addition same relationship was found between MC and Acuros XB, that differences up to 12% in DVH analysis were seen (12).We observed dose calculations varied up to 8%.

But in this study the TPSs of the MC and AXB13 that we have used were different so the difference observed between MC and AXB may not reflect the accurate results.

In clinical, Monte Carlo method is the unique method able to calculate the dose accurately near a high-Z inhomogeneity (13). There are various papers that showed the different dose distribution between the calculation algorithms in TPS. Xiao et al. recalculated the plans with a heterogeneity corrections algorithm and showed that the PTV V60 decreased on average by 10.1% (14). Wu et al. also compared the RyTc plans and re-calculated MC plans. They showed the PTV D95% decreased from 50.0 Gy to 42.9 Gy in MC plans and in small peripheral tumors incline to be greater (15). All of these dosimetric studies showed that the actually delivered dose to the target was 10 to 14% lower in the RyTc plans. We also observed that RyTc underestimated the doses of target volume and critical organs compared to MC. The underestimated doses of the critical organs especially like in spinal cord may cause unexpected side effects.

In Ojala et al. study the authors declined that the AXB algorithm is a reliable dose calculation algorithm for patient plans with hip implants that contain beams traversing the implant, but the use of AAA is not encouraged (12). In this study we could not observe significant difference between the doses of metallic implant corpus and roots when calculated with AAA and AXB 13. So we cannot say that AAA is not encouraged for the patients with metallic implants.

In this study, original plan was calculated with RyTc and recalculated with the MC model, AAA and AXB13 algorithm. RyTc, AAA and AXB underestimated the doses of target volumes and critical organs compared to MC. AXB was very close to MC. Comparison of the isodose curves in the implant and elsewhere confirms that the deviations between the MC model and the AXB algorithm were small, while the MC model producing higher doses.

The results of our study indicate that metallic implants nearby the target volume have a negative impact on dose distribution of radiotherapy. It is especially important when metallic implant is inserted to vertebra in terms of spinal cord dose. However, there is still controversy regarding the best method to determine correct radiation dose distribution. Future studies should focus on ways to avoid the scattering effects of metallic implants on dose distributions.

Conclusion

In our study we show that MC algorithm and Acuros XB algorithm give more reliable results on the patients with metallic spinal implants, so both could be used for the stereotactic radiotherapy plans of patients with the metallic implants. But more studies with more number of patients should be done to identify the acceptable calculation algorithm.

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Ethical issues: All Authors declare that Originality of research/article etc... and ethical approval of research, and responsibilities of research against local ethics commission are under the Authors responsibilities. The study was conducted due to defined rules by the Local Ethics Commission guidelines and audits.

References

1. Ding GX, Duggan DM, Lu B, Hallahan DE, Cmelak A, Malcolm A, et al. Impact of inhomogeneity corrections on dose coverage in the treatment of lung cancer using stereotactic body radiation therapy. Med Phys. 2007;34(7):2985-2994.
2. Das IJ, Ding GX, Ahnesjo¨ A. Small fields: nonequilibrium radiation dosimetry. Med Phys. 2008;35(1):206-215.
3. Wilcox EE, Daskalov GM, Lincoln H, Shumway RC, Kaplan BM, Colasanto JM. Comparison of planned dose distributions calculatedby Monte Carlo and Ray-Trace algorithms for the treatment of lung tumors with cyberknife: a preliminary study in 33 patients. Int J Radiat Oncol Biol Phys. 2010;77(1):277-284.
4. Roberts, R. How accurate is a CT-based dose calculation on a pencil beam TPS for a patient with a metallic prosthesis? Phys. Med. Biol.2001; 46: N227–34.
5. Han T, Mikell JK, Salehpour M, Mourtada F. Dosimetric comparison ofAcuros XB deterministic radiation transport method with Monte Carlo and model-based convolution methods in heterogeneous media. Med Phys. 2011; 38:2651–64.
6. Bush K, Gagne IM, Zavgorodni S, Ansbacher W, Beckham W. Dosimetric validation of Acuros XB with Monte Carlo methods for photon dose calculations. Med Phys. 2011; 38:2208–21.
7. Han T, Followill D, Mikell J, Repchak R, Molineu A, Howell R et al. Dosimetric impact of AcurosXB deterministic radiation transport algorithm for heterogeneous dose calculation in lung cancer. Med Phys. 2013; 40:51710–21.
8. Mißlbeck M, Kneschaurek P. Comparison between Acuros XB and Brainlab Monte Carlo algorithms for photon dose calculation. Strahlenther Onkol. 2012; 188:599–605.
9. Timmerman RD. An overview of hypofractionation and introduction to this issue of seminars in radiation oncology. Semin Radiat Oncol. 2008;18(4):215–22

10. Newhauser, W.D. Giebeler, A. Langen, K.M. Mirkovic D, Mohan R. Can megavoltage computed tomography reduce proton range uncertainties in treatment plans for patientswith large metal implants? Phys. Med. Biol.2008; 53:2327–44.

11. Roberts, R. How accurate is a CT-based dose calculation on a pencil beam TPS for a patient with a metallic prosthesis? Phys. Med. Biol.2001; 46:227–34.

12. Ojala JJ1, Kapanen M., Quantification of dose differences between two versions of Acuros XB algorithm compared to Monte Carlo simulations - the effect on clinical patient treatment planning. J Appl Clin Med Phys. 2015; 16(6):5642.

13. Moskvin V Cheng CW, Fanelli L, Zhao L, Das IJ. A semi-empirical model for the therapeutic range shift estima¬tion caused by inhomogeneities in proton beam therapy. J Appl Clin Med Phys. 2012;13(2):3631

14. Xiao Y, Papiez L, Paulus R, Timmerman R, Straube W L, Bosch W R, Michalski J and Galvin J M. Dosimetric evaluation of heterogeneity corrections for RTOG 0236: stereotactic body radiotherapy of inoperable stage I-II non–small-cell lung cancer Int. J. Radiat. Oncol. Biol. Phys.2009; 73 1235–42

15. Wu VW, Tam KW, Tong SM. Evaluation of the influence of tumor location and size on the difference of dose calcula¬tion between Ray Tracing algorithm and Fast Monte Carlo algorithm in stereotactic body radiotherapy of non-small cell lung cancer using CyberKnife. J Appl Clin Med Phys. 2013; 14:68–78.