Analysis of Three-Dimensional Radiotherapy Treatment Plans in Palliative Spinal Bone Irradiation

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ABSTRACT

The study aimed to analyze dosimetric data of patients received palliative spinal bone irradiation using three-dimensional (3D) treatment planning with respect to International Commission on Radiation Units and Measurements (ICRU) Report 50 recommendations. 3D treatment plans of 53 patients treated for spinal bone metastasis were included in the study. Sixty treatment plans approved by three physicians were analyzed. The spinal cord, esophagus and intestines were contoured prospectively if located in the treatment fields. The mean of minimum, maximum and mean planning target volume (PTV) doses were 91.0 ± 4.6%, 117.7 ± 7.6% and 105.7 ± 3.9%, respectively. When the mean of minimum, maximum and mean PTV doses were compared according to the attending physicians, there was no statistically significant difference. When the treatment plans were compared according to the fields used, mean of minimum PTV doses were significantly lower and mean of maximum PTV doses were significantly higher in the single-posterior field plans than in the two-opposed field plans ($p< 0.001$). The mean doses to the spinal cord were lower in the two-opposed field plans than in the single-posterior field plans ($p< 0.001$). The mean doses of esophagus and intestines were higher ($p< 0.001$) in two-opposed field plans than in single-posterior field plans, however, less than the prescribed dose. Treatment plans of palliative spinal bone irradiation approved by three physicians did not accomplish the ICRU Report 50 recommendations, despite using 3D radiotherapy planning. However, two-opposed field plans resulted in a better dose distribution close to ICRU Report 50 recommendations with tolerable doses to the spinal cord, esophagus and intestines.

Key Words: Palliative radiotherapy, 3D radiotherapy, Spinal bone irradiation

ÖZET

Üç-Boyutlu Palyatif Spinal Kemik Radyoterapi Tedavi Planlarının Analizi

Bu çalışma ile üç-boyutlu tedavi planlaması kullanılarak palyatif spinal kemik ışınlaması yapılan hastaların dozimetrik verilerinin "International Commission on Radiation Units and Measurements Report 50" (ICRU-50) önerileri ışığında analizi amaçlandı. Spinal kemik metastazı nedeniyle tedavi edilmiş olan 53 hastanın üç-boyutlu tedavi planları çalışmaya dahil edildi. Üç doktor tarafından onaylanmış 60 adet tedavi planı analiz edildi. Spinal kord, ösefagus ve barsaklar, tedavi alanları içinde yer alıyor iseler prospektif olarak konturlandı. Minimum, maksimum ve ortalama PTV (planning target volume) dozlarının ortalamaları sırasıyla 91.0 ± %4.6, 117.7 ± %7.6 ve 105.7 ± %3.9 idi. Minimum, maksimum ve ortalama PTV dozlarının ortalamaları tedavi eden doktorlara göre karşılaştırıldığında, aralarında istatistiksel olarak anlamlı fark yoktu. Tedavi planları kullanılan alanlara göre karşılaştırıldığında, tek posterior alan planlarda iki karşılıklı alan planlara göre, minimum PTV dozlarının ortalamaları anlamlı düşük ve maksimum PTV dozlarının ortalamaları ise anlamlı fazla idi ($p< 0.001$).

Ortalama spinal kord dozları, iki karşılıklı alan planlarda tek posterior alan planlara göre daha az idi ($p< 0.001$). Ortalama özefagus ve barsak dozları, iki karşılıklı alan planlarda tek posterior alan planlara göre daha fazla ($p< 0.001$), ancak tarif edilen dozdan daha az idi. Üç doktor tarafından onaylanan palyatif spinal kemik ışınlama tedavi planları 3-boyutlu radyoterapi planlaması kullanılmasına rağmen ICRU-50 önerilerini gerçekleştiremedi. Bununla birlikte, iki karşılıklı alan planlar ile tek posterior alan planlara göre kabul edilebilir spinal kord, ösefagus ve barsak dozları ile birlikte ICRU-50 önerilerine yakın daha iyi doz dağılımı elde edildi.

Anahtar Kelimeler: Palyatif radyoterapi, Üç-boyutlu radyoterapi, Spinal kemik ışınlaması

INTRODUCTION

Palliative bone irradiation is a well-recognized and effective modality in the symptomatic treatment of bone metastasis and prevention of complications while keeping skeletal integrity. [1,2]

CT-simulation and three-dimensional (3D) radiotherapy planning improves target volume definition and provides dose-volume information, thus expected to help to obtain a better dose distribution. Nonetheless, these techniques are not available in all centers or not used for palliative treatments. Palliative spinal bone irradiation is still performed using conventional simulation and two-dimensional (2D) radiotherapy planning usually with single-posterior field or two-opposed fields.[3]

Target dose heterogeneity and conformality may not be a major concern and recommendations of International Commission on Radiation Units and Measurements (ICRU) Report 50 may not be followed because many patients treated for palliative purposes have limited survival.[4] Quality of life and long term treatment related complications become more vital as the patients' survival increases.

The aim of this study was to analyze dosimetric data of patients received palliative spinal bone irradiation using three-dimensional (3D) treatment planning with respect to International Commission on Radiation Units and Measurements (ICRU) Report 50 recommendations.

METHODS and MATERIALS

3D treatment plans of 53 patients previously treated palliatively for spinal bone metastasis were included in the study. Sixty treatment plans approved by three physicians were analyzed.

A 6 detector helical CT (CT Brilliance, Philips Medical Systems, Netherlands) was used for CT simulation. Slice thickness of the CT scans was 5 mm. Precise PLAN®2.11 (Elekta, Crawley, UK) 3D treatment planning system (TPS) which uses an irregular field algorithm for photonbeam dose calculations and takes into account tissue inhomogeneity and uses an integration scheme to evaluate the scatter component of the dose was used for treatment plans.

Target volumes were delineated in CT slices. Clinical target volume (CTV) covered one vertebra above and below the involved vertebra(e) unless a previously treated junctional field was present. To define planning target volume (PTV), margins of 5-12 mm were added to the CTV. Treatment fields were created using multi-leaf collimators and by adding 7-10 mm to the PTV.

The prescription doses were normalized to clinically relevant points in the PTV. Treatment planning was performed using single-posterior (n= 31) (Figure 1) and two-opposed fields (n= 29) (Figure 2) with 6-18 MV photons. In two-opposed anterior-posterior field plans, beam weights were used as 1/1.5-3.0. Cumulative dose-volume histograms were created for each plan and the plans were assessed and approved by the physicians (AD, FA and MA).

Portions of the esophagus, intestines and spinal cord, whichever located in the treatment fields, were delineated prospectively for the study to analyze the critical organ doses.

Dosimetric data of treatment plans were analyzed by Kruskal-Wallis and Mann-Whitney U tests using Statistical Package for Social Sciences (SPSS), version 16.0. $p< 0.05$ was considered statistically significant. Values are expressed as percent of prescribed dose and mean (range) ± standard deviation (SD).

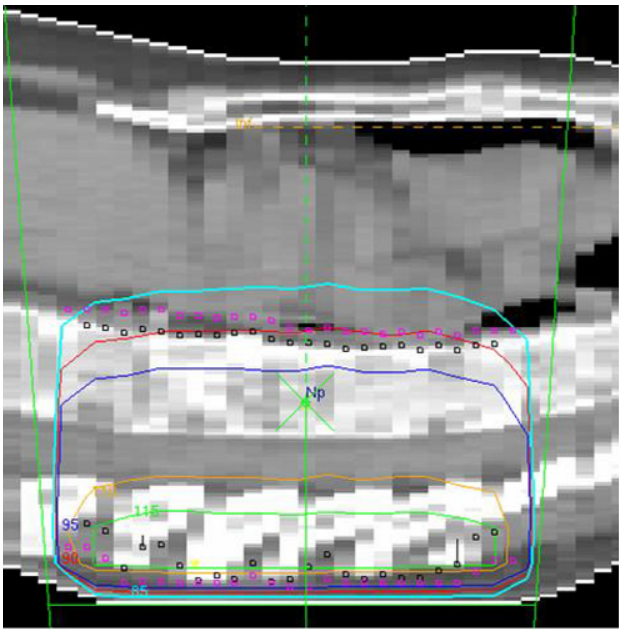

Figure 1. Dose distributions of single-posterior thoracal radiation field on sagittal plane.

The isodose lines shown as follows: 115% (green), 110% (orange), 95% (dark-blue), 90% (red) and 85% (light-blue).

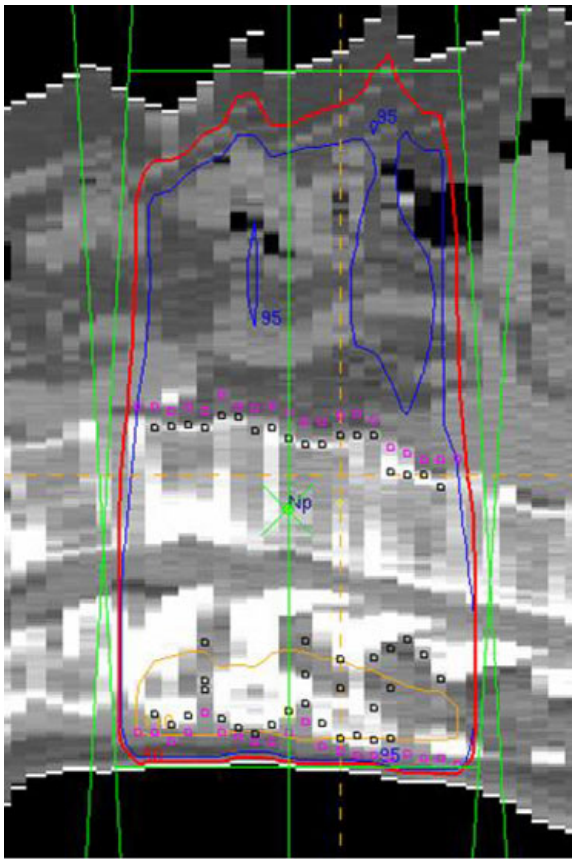

Figure 2. Dose distributions of two-opposed lumbar radiation field on sagittal.

The isodose lines shown as follows: 110% (orange), 95% (dark-blue) and 90% (red)

RESULTS

Treatment characteristics are shown in Table 1. Dose range of minimum, maximum and mean PTV doses according to the attending physicians were given in Table 2. There was no statistically significant difference between the mean values of minimum, maximum, and mean PTV doses when compared for each physician. When the treatment plans were compared according to the fields used, the mean of minimum PTV doses were significantly lower while the mean of maximum PTV doses were significantly higher in the single-posterior field plans than in the two-opposed field plans ($p< 0.001$) (Table 3).

The percent volumes of PTVs receiving 90%, 100%, 110%, 120% and 130% of prescribed dose were 98.5% ± 4.5%, 78.6% ± 13.5%, 24.0%± 20.5%, 3.6% ± 7.7% and 0.5% ± 2.3%, respectively for all plans.

The mean value of mean doses to the spinal cord were lower in the two-opposed field plans compared to the single-posterior field plans ($p< 0.001$) (Table 4). Maximum doses to the spinal cord were higher than 115% of the prescribed dose in 17 of 31 (54.8%) single-posterior field plans and higher than 120% of the prescribed dose in 10 of 31 (32.3%) plans. In two-opposed field plans, none of the doses to the spinal cord exceeded 115% of prescribed dose.

The mean dose to the portion of the esophagus in the treatment fields was 87.3% (80-94%) ± 3.9% in single-posterior field plans and 96.0% (90-103%) ± 4.3% in two-opposed field plans. The mean dose to the intestines located in the treatment fields was 75.5% (63-88%) ± 9.1% in single-posterior field plans and 92.1% (80-102%) ± 8.0% in two-opposed field plans. The mean values of mean doses to esophagus and intestines were higher ($p< 0.001$) in two-opposed field plans than in single-posterior field plans; however, lower than the prescribed dose.

Table 1. Treatment characteristics

Treatment Sites	
Cervical	5
Thoracal	19
Thoracolumbar	17
Lumbar	15
Lumbosacral	4
Patient Positions	
Supine	50
Prone	10
Radiotherapy Fields	
Opposed lateral	5
Single-posterior	31
Opposed anterior-posterior	24
Fractionations	
30 Gy in 10 fractions	27
20 Gy in 5 fractions	27
Single 8 Gy	4
35 Gy in 14 fractions	2

DISCUSSION

The results of this study showed that, treatment plans of palliative spinal bone irradiation approved by three physicians did not accomplish the ICRU Report 50 recommendations, despite using 3D radiotherapy planning. Physicians approved inhomogeneous and non-optimal plans. The mean values of minimum, maximum, and mean doses to the PTV were similar when compared according to the attending physicians.

A homogeneous dose to the target volume within the range of 95% to 107% of the prescribed dose is recommended by ICRU to obtain higher target doses and less radiation-induced normal tissue side effects.[4] In the present study, compared to the single-field plans, two-opposed field plans resulted in a better dose distribution close to ICRU Report 50 recommendations with tolerable doses to spinal cord, esophagus and intestines.

We previously reported that two-opposed AP-PA field treatment plans provided a homogenous and intended dose distribution while single-posterior field radiotherapy plans did not, in thoraco-lumbar palliative spinal bone irradiation.[5] Results of the present study were comparable with our previous findings.

In spinal bone irradiation, maximum target volume doses above the prescribed dose may cause serious long term normal-tissue side effects in patients with long survival. In the present study, the mean of maximum doses to the spinal cord was 116.0% (107-123%) + 4.5% in single-posterior field plans. Maximum doses to the spinal cord were higher than 115% of the prescribed dose in 17 of 31 (54.8%) plans while higher than 120% of the prescribed dose in 10 of 31 (32.3%) plans.

In single-posterior field plans, tolerance doses of spinal cord may prevent selection of a deeper normalization point to provide a higher dose in the anterior part of the vertebral body, and this may exp-

Table 2. Dose range of minimum, maximum and mean planning target volume (PTV) doses according to the attending physicians

	* Mean dose (range) % ± SD			
Dose	**Physician (1)**	**Physician (2)**	**Physician (3)**	
Minimums	89.9 (76-98) ± 6.2	91.8 (84-97) ± 3.4	91.5 (87-96) ± 3.1	p= 0.732
Maximums	118.0 (109-134) ± 6.0	117.4 (104-135) ± 7.2	117.8 (106-139) ± 10.6	p= 0.959
Means	104.4 (97-111) ± 3.3	106.2 (100-112) ± 3.5	106.8 (100-117) ± 5.2	p= 0.192

* : as percent prescribed dose; SD: standard deviation

Table 3. The mean of minimum, maximum and mean planning target volume (PTV) doses according to the fields used

	*Mean dose (range) % ± SD		
Dose	**Single-posterior fields**	**Two-opposed fields**	
Minimums	88.4 (76-96) ± 4.6	93.9 (88-98) ± 2.5	p< 0.001
Maximums	122.3 (113-139) ± 6.6	112.8 (104-123) ± 5.0	p< 0.001
Means	107.2 (97-117) ± 4.3	104.1 (100-110) ± 2.7	p= 0.001

*: as percent prescribed dose; SD: standard deviation

lain the low PTV doses as well as the inhomogeneity. However, the reason why the physicians ignored the dose inhomogeneity and approved the single-posterior field plans may be explained by the unknown dose volume and treatment outcome relationship in palliative spinal bone irradiation. Additionally, limited survival expectancy for many metastatic patients may be another reason to accept under-dosing the target volume or dose heterogeneity.

In single fraction palliative radiotherapy, higher re-treatment rates have been reported compared to multifraction radiotherapy.[6-8] Many factors such as physician bias, primary site, pain severity, and duration of symptoms may effect decision for re-treatment. Inadequate dose coverage and inhomogeneity may also be responsible from the re-treatment decision.[9] Target volume dose coverage and homogeneity may affect treatment outcome. However, to the best of our knowledge, there is no data regarding dose-volume effect on radiotherapy outcome and yet we don't know whether not following ICRU recommendations has any influence on treatment outcome in terms of pain relief, duration of response and quality of life, in patients receiving palliative spinal bone irradiation. Further studies are needed to determine dose-volume effect on treatment outcome, particularly in patients with long life expectancies. Furthermore, dose-volume information of treatment plans may help to define the efficacy of various dose-fractionation schedules.

CONCLUSION

Treatment plans of palliative spinal bone irradiation approved by three physicians did not accomplish the ICRU Report 50 recommendations, despite using 3D radiotherapy planning. However, two-opposed field plans resulted in a better dose distribution close to the ICRU Report 50 recommendations with tolerable doses to the spinal cord, esophagus and intestines.

A homogenous dose distribution throughout the target volume should be obtained and ICRU Report 50 recommendations should be followed in order to

Table 4. The mean of minimum, maximum and mean spinal cord doses according to the fields used

	*Mean dose (range) % ± SD		
Dose	**Single-posterior fields**	**Two-opposed fields**	
Minimums	103.2 (94-110) ± 4.6	99.3 (94-103) ± 2.7	p= 0.002
Maximums	116.0 (107-123) ± 4.5	108.5 (102-115) ± 3.5	p< 0.001
Means	110.6 (103-117) ± 4.0	105.1 (100-111) ± 3.0	p< 0.001

*: as percent prescribed dose; SD: standard deviation

avoid long term normal tissue complications, particularly in cancer patients with long life expectancies. More conformal treatment planning techniques should be considered to reach this aim.

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