Original Article

Comparison of Rapid Arc and Intensity-modulated Radiotherapy Plans Using Unified Dosimetry Index and the Impact of Conformity Index on Unified Dosimetry Index Evaluation

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Abstract

The aim of this study was to evaluate the impact of conformity index in the unified dosimetry index (UDI) score for two different planning techniques namely intensity-modulated radiotherapy (IMRT) and Rapid Arc. Rapid Arc and IMRT plans of 57 patients were evaluated and compared using UDI score which incorporates four indices. To determine the impact of conformity index on the IMRT and Rapid Arc plans, UDI at conformity index one of all plan (UDI_{unit_CI}) score was calculated by assuming conformity index is equal to one. Mean and standard deviations of all indices were calculated. Rapid Arc technique plans of different treatment sites of all patients scored lesser UDI than IMRT plans, and the conformity index of Rapid Arc plan was significantly better than IMRT plan. The average dose gradient, homogeneity, coverage, and conformity index of all sites with Rapid Arc plans were 0.212 ± 0.05, 1.123 ± 0.03, 0.959 ± 0.03, and 1.056 ± 0.09; with IMRT plans were 0.190 ± 0.05, 1.113 ± 0.04, 0.950 ± 0.04, and 1.172 ± 0.16, respectively. UDI score value with actual conformity index of Rapid Arc and IMRT plans differed significantly ($P < 0.001$). However, UDI_{unit_CI} score values with assumed conformity index equal to one did not differ significantly ($P = 0.528$). In the comparison of IMRT and Rapid Arc plans using the UDI score, the impact of conformity index was significant.

Keywords: Conformity index, intensity-modulated radiotherapy, Rapid Arc, unified dosimetry index

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Introduction

The basic principle of radiotherapy is to deliver higher and uniform dose to tumour and to reduce dose to organ at risks (OARs) as low as possible which reduces the morbidity and in turn improves the quality of life of patients. Although the conventional techniques provide better tumor coverage, there is some limitation in achieving OARs tolerance dose.

To overcome this difficulty, modern delivery techniques such as intensity-modulated radiotherapy (IMRT) and Rapid Arc have been used widely. These techniques can deliver a higher dose to tumor and limit the dose to OARs. The degree of confirmed dose delivery using these techniques improves the plan quality. Usually, plan quality has been evaluated using various dosimetry indices. Most of the articles contain conformity index, coverage index, homogeneity index, and dose gradient (DG) index for plan evaluation. The conformity can be determined in many ways using a different definition.[1] An ideal plan is defined as one with full uniform dose coverage; exact conformed to the target and step-wise fall-off dose outside the target.[2-5] Akpati *et al*.[6] introduced one more approach called unified dosimetry index (UDI) that computes an overall score which integrates contribution from all four dosimetry components mentioned above. The UDI score of each plan can be ranked and selected the least scored plan as a better plan. There are fewer articles published that employed UDI score. This study utilized UDI score for the comparison of IMRT and Rapid Arc plans of various sites and also studied the impact of conformity index on UDI-based plan evaluation.

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Materials and Methods

Dose coverage is defined as 100% of the planning target volume (PTV) receiving the prescribed dose. It gives a measure of how well the PTV is covered by the prescribed dose. Dose conformity, on the other hand, is defined as the ratio of the total volume of all tissues receiving prescribed dose versus the PTV. Dose conformity gives a measure of how well the prescribed dose is confined to the PTV. DG is defined as the ratio of the volume receiving the prescribed dose and the volume receiving half the prescribed dose. Homogeneity index (HI) is defined as the ratio of the maximum dose at any point 2 mm beyond the PTV (D_{Max}) to the prescribed dose.[6]

The mathematical logic-based UDI formula is:

$$UDI = (\prod_{k=1}^{4} W_k \ [|1.0 - DI_k| + 0.1]) \times 10^4 \quad (1)$$

Where DI_k is dosimetry index of each index of the four indices and W_k denotes weighting factors that reflect the relative importance of the four components.

For ideal plan, unified index (UDI) is equal to 1:

$$UDI = UDI\ (C) \times UDI\ (CF) \times UDI\ (HI) \times UDI\ (DG) = 1.0 \quad (2)$$

Where C-coverage index (DI_1), CF-conformity index (DI_2), HI (DI_3) and DG-gradient index (DI_4). Akpati *et al*.[6] used the following equations to calculate all indices and explained full detail about UDI and method of calculation.

$$\text{Coverage Index (C)} = PTV_{PI}/PTV \quad (3)$$

$$\text{Conformity Index (CF)} = DV_{PI}/PTV \quad (4)$$

$$HI = D_{Max}/D_{PI} \quad (5)$$

$$\text{DG Index (DG)} = DV_{PI}/DV_{HPI} \quad (6)$$

Where PTV is the PTV; PTV_{PI} = PTV receiving the prescribed isodose (PI); DV_{PI} = Dose volume of the PI; DV_{HPI} = dose volume of the half the prescribed dose; D_{Max} = Maximum dose at any point 2 mm beyond the PTV; D_{PI} = Dose value of the PI.

Using this approach, we compared two different techniques IMRT and Rapid Arc. CT data of 57 patients (13 Ca. Prostate, 12 Ca. Endometrium, 6 Ca. Cervix, and 26 Ca. Oesophagus) were utilized in this study. IMRT and Rapid Arc plans were generated by inverse planning method using Eclipse treatment planning system (V-10.0.39, Varian Medical Systems, USA). All plans use 6MV photon energy and optimized by assigning the target and OAR goals.

The plans were evaluated using all four indices separately. The UDI scoring values of all plans were ranked and lesser value scored plan considered as a better plan for the patient. For determining the impact of conformity index in the comparison of IMRT and Rapid Arc plan, a UDI score of the plans was calculated by assuming confidence interval = 1 UDI at conformity index one of all plan (UDI_{unit_CI}), and it was compared against the UDI score calculated with actual conformity index. Mean and standard deviations of all indices were calculated, and statistical analysis was performed using SPSS (version 16.0.0, SPSS, Chicago, USA).

Results

Table 1 shows an overview of the mean and standard deviations of DG index, HI, coverage index, conformity index, UDI score and UDI_{unit_CI} score for IMRT and Rapid Arc techniques planned for each site of the patients. Table 2 shows the mean and standard deviations of the different indices for all 57 patients compared.

It is observed that the conformity index and UDI of Rapid Arc plan were significantly better than IMRT plan. The average DG index, HI, coverage index and conformity index of all sites with Rapid Arc plans were 0.212 ± 0.05, 1.123 ± 0.03, 0.960 ± 0.03, and 1.056 ± 0.09; with IMRT plans were 0.190 ± 0.05, 1.113 ± 0.04, 0.950 ± 0.04, and 1.172 ± 0.16, respectively.

Figures 1-3 show the radar graph of UDI scores from Rapid Arc and IMRT plans of various treatment sites. In the figures, the lowest score denotes the minimum deviation from an ideal dosimetry plan (toward to one), and highest score denotes the maximum deviation from an ideal dosimetry plan (outward from one). The radar graph shows that Rapid Arc plans are better than IMRT plans for all treatment sites.

Table 1: Mean and standard deviations of dose gradient index, homogeneity index, coverage index conformity index, unified dosimetry index score and unified dosimetry index at conformity index one of all plans score of each treatment site

Technique	Mean±SD		
	Prostate (*n*=13)	Esophagus (*n*=26)	Cervix and endometrium (*n*=18)
DG_index			
RapidArc	0.206±0.04	0.204±0.06	0.223±0.02
IMRT	0.185±0.04	0.171±0.06	0.211±0.03
HI_index			
RapidArc	1.103±0.02	1.135±0.02	1.118±0.03
IMRT	1.088±0.05	1.127±0.03	1.112±0.03
Coverage_index			
RapidArc	0.944±0.03	0.947±0.03	0.973±0.02
IMRT	0.936±0.05	0.893±0.09	0.983±0.01
Confirmity_index			
RapidArc	0.977±0.05	1.003±0.04	1.152±0.07
IMRT	1.110±0.11	1.045±0.21	1.300±0.11
UDI			
RapidArc	43.072±15.22	43.133±13.34	60.183±17.87
IMRT	57.266±20.96	120.532±227.82	90.602±41.03
UDI_{unit_CI}			
RapidArc	28.322±6.73	32.660±7.66	24.723±6.66
IMRT	28.635±12.21	46.469±35.35	22.217±5.21

DG: Dose gradient, HI: Homogeneity index, UDI: Unified dosimetry index, UDI_{unit_CI}: Unified dosimetry index at conformity index one of all plans, IMRT: Intensity-modulated radiation therapy, SD: Standard deviation

Discussion

The method of UDI score-based plan evaluation and comparison of different techniques plans can be useful for establishing a benchmark.[6] Although many numbers of indices have been proposed for plan evaluation, it is difficult to understand as to which system is better or useful. The radiation therapy oncology group has suggested that a quality treatment plan has to evaluate using three separate indices of dose coverage, conformity, and homogeneity.[1] The UDI used here incorporates all four dosimetry indices into a single overall score. In this study, the plans of similar techniques were analyzed and compared to find a better plan for patient treatment using this UDI score.

Conformity index may vary according to the isodose selected. The conformity index can be reduced while selecting lower isodose level as the reference, and therefore increasing the volume of reference isodose.[7] Therefore, in the evaluation of different techniques, this index would help to take clinical decision.

It is observed that the conformity index was significantly higher with Rapid Arc plan than IMRT ($P < 0.001$). While considered the conformity index as unit, the UDI_{unit_CI} of both plans did not differ significantly ($P = 0.527$). However, the UDI score values of both planning techniques were calculated with actual conformity index was better with Rapid Arc than IMRT significantly ($P < 0.001$). Subsequent effect of better conformity index, better DG index could be achieved with Rapid Arc plans. Therefore, critical structure dose (especially prescribed dose region) was controlled with Rapid Arc plan significantly than IMRT plan ($P < 0.011$). The dose-volume histogram values of different critical structures in the treatment of different sites were controlled significantly with Rapid Arc plans than IMRT.

From Figures 1-3, it is noted that the UDI score spikes for few plans. This result was observed in the bulky patients and whose tumor size is relatively large. The conformity index was relatively lesser due to the higher dose spillage outside the target.

For all plans studied, the coverage index, HI did not differ significantly between both IMRT and Rapid Arc. The same results were observed in various studies.[8-12] Therefore, it can be concluded that the higher degree of confined dose delivery of Rapid Arc technique provides better treatment plans when compared with IMRT.

Table 2: Mean and standard deviations of dose gradient index, homogeneity index, coverage index conformity index, unified dosimetry index score, and unified dosimetry index at conformity index one of all plans score of all patients

Technique	All sites (n=57), mean±SD
DG_index	
RapidArc	0.212±0.05
IMRT	0.190±0.05
HI_index	
RapidArc	1.123±0.03
IMRT	1.113±0.04
Coverage_index	
RapidArc	0.960±0.03
IMRT	0.950±0.04
Confirmity_index	
RapidArc	1.056±0.09
IMRT	1.172±0.16
UDI	
RapidArc	46.055±16.31
IMRT	74.463±40.44
UDI_{unit_CI}	
RapidArc	27.877±6.54
IMRT	29.443±10.44

DG: Dose gradient, HI: Homogeneity index, UDI: Unified dosimetry index, UDI_{unit_CI}: Unified dosimetry index at conformity index one of all plans, IMRT: Intensity-modulated radiation therapy, SD: Standard deviation

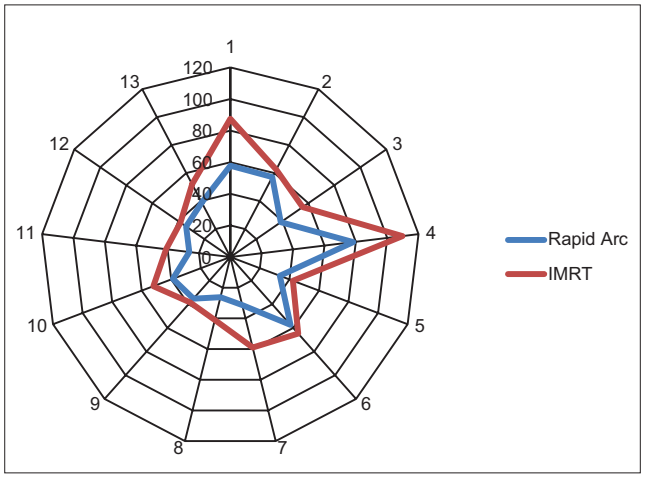

Figure 1: The unified dosimetry index score of each patient's Rapid Arc and intensity-modulated radiotherapy plans of Ca.Prostate.

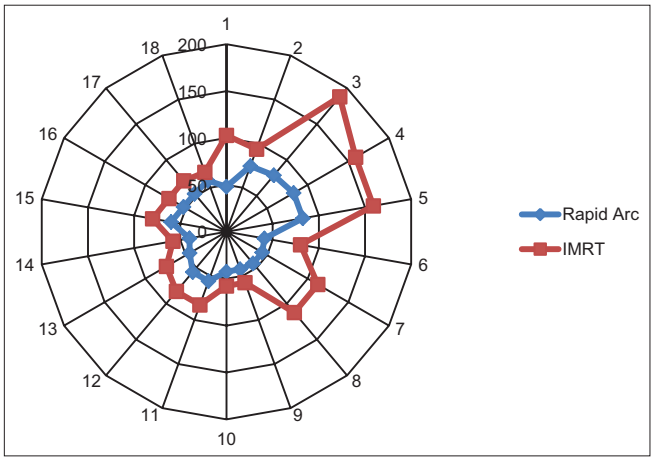

Figure 2: The unified dosimetry index score of each patient's Rapid Arc and intensity-modulated radiotherapy plans of Ca.Cervix and endometrium.

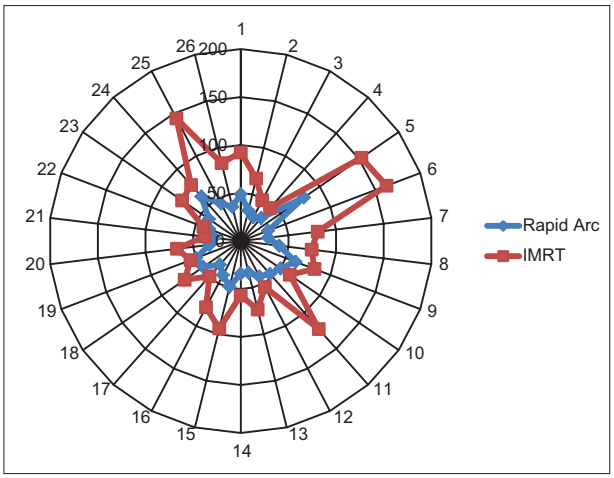

Figure 3: The unified dosimetry index score of each patient's Rapid Arc and intensity-modulated radiotherapy plans of Ca.lower third oesophagus.

Conclusion

For all compared treatment sites in this study, Rapid Arc plans scored better UDI value as well as better OARs sparing. In the comparison of IMRT and Rapid Arc plans using the UDI score, the impact of conformity index was significant.

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Conflicts of interest

There are no conflicts of interest.

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