Research Article
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An analysis of dose distribution in rapid arc and IMRT radiotherapy plan in the case of head and neck cancer using γ- index

Abstract

Introduction: In general, intensity-modulated radiation therapy (IMRT) is still an advanced method of planning in radiotherapy which enhances dose distribution conformity by modulating the intensity of the radiation beam in each treated sub volumes. It has been reported that IMRT and Rapid Arc, treatment plans provide highly conformal dose distribution with good sparing of normal tissues.

Aim: The main purpose of this study was to analyze dose distribution in Rapid Arc and IMRT plan in head and neck cancer using gamma-index, Global maximum dose, monitor units, and dose coverage to the targets.

Materials and methods: In this study,13 patients of head and neck cancer were randomly taken for analysis. For all these patients, IMRT and Rapid Arc plan were generated by Varian's eclipse treatment planning system (TPS), version 10.0.0. There were 7-9 beams used in IMRT plan while 2 arcs in Rapid Arc. Portal dosimetry plan was created and executed for each radiotherapy plan before executing on patients.

Result: All the IMRT and Rapid Arc Plans were analyzed for dose distribution. The mean of $V_{95\%}$ is found 97.89% and 97.47% for Rapid Arc and IMRT plans respectively. Mean Standard deviation has been found 1.93 in Rapid Arc and that of 1.70 in IMRT plan

Conclusion: The current study advises, Rapid Arc has no significant advantages over IMRT treatment delivery technique in the respect of dose coverage to targets, dose to OARs, standard deviation and area Gamma index(γ); except treatment time.

Keywords: rapid Arc, isodose line, gamma index, target

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Introduction

In general, intensity-modulated radiation therapy (IMRT) is still an advanced method of planning in radiotherapy which enhances dose distribution conformity by modulating the intensity of the radiation beam in each treated sub volumes. IMRT technique is able to minimize dose to surrounding critical organs and can be safely delivered with a minimal risk of side effects. However, treatment time and exposure of normal tissue to low doses are significantly higher in IMRT rather than conventional radiotherapy. Precise and accurate dose distribution to the tumor geometry is usually achieved with combinations of several intensity-modulated fields distributed among different beam directions.[1–5]

The technical fusion of IMRT and Arc modalities resulted in the Rapid Arc® (Varian Medical Systems) technique which provides comparable or sometimes even better dosimetric parameters of dose distribution than IMRT alone. Beam intensity is modulated continuously during gantry rotation around the targets. The algorithm for dose calculation in RapidArc takes care about angular velocity of the gantry, dose rate (MU/min) and movement of collimator's leaves (MLC).

It has been reported that IMRT and Rapid Arc treatment plans provide highly conformal dose distribution with good sparing of normal tissues. However, the duration of the therapeutic session in Rapid Arc is reported to be even 8 times shorter in comparison to therapeutic time of the other dynamic techniques, which benefits the quality of treatment delivery. Therefore, RapidArc is presented by some authors as a fast and simple treatment modality, with precision that matches or exceeds dose conformity of the IMRT technique.[6–9] However, unambiguous analysis should be done to point whether RapidArc plans are superior to the IMRT in respect to dosimetric parameters for a specific patient plan.

With the advancement in radiation therapy techniques such as volumetric modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT), the three dimensional (3D) dose distribution for radiation therapy has become more conformal and complex. All these features raise a great challenge for the quality assurance (QA) of the dose distribution, which commonly consists of both point dose and 2D plane dose measurements and an urgent need for 3D dosimetry has also been stated.[10,11] γ index method, which is the standard method for planar dose verification in IMRT and VMAT patient specific quality assurance(QA), it calculates the quantity gamma for each point of interest using preselected dose difference (DD) and distance to agreement (DTA) criteria, and then uses the gamma value to determine the outcome (pass–fail) of the IMRT QA.[12,13] The same preselected DD and DTA criteria are also seen in other dose comparison techniques, such as the NAT or the δ-envelope.[14] Moreover, it has become general practice to use the passing percentage of γ (the percentage of γ values ≤1 for a set of DTA/DD criteria) to determine whether two dose distributions agree.[15]

Aim

The main purpose of this study was to comparatively analyze dose distribution in Rapid Arc and IMRT plan in head and neck cancer using gamma-index, Global maximum dose, monitor units, and dose coverage to the targets.

Materials and methods

In this study,13 patients of head and neck cancer were randomly taken for analysis of dose distribution within targets. For all these patients, IMRT and Rapid Arc plans were generated by Varian's eclipse treatment planning system (TPS), version 11.0. 6MV photon was used in all plans. DVH was generated for each plan and analyzed for dose coverage to the targets. $V_{95\%}$ and $D_{95\%}$ are recorded and tabulated in Table 1 & Table 2 respectively.

Table 1 Volume of target in % covered with 95%of prescribed dose

V95(%)	
RapidArc	**IMRT**
97.4	97.66
94.52	94.43
99.95	98.63
99.1	93.23
97.22	97.66
93.76	93.08
98.42	98.42
98.92	99.69
99.99	99.89
99.58	98.98
97.34	96.48
100	99.76
96.49	99.26

Table 2 Radiation dose in %, covering 95% target volume

D95(%)	
RapidArc	**IMRT**
96.4	96.45
92.69	94.43
97.84	96.43
96.72	94.55
96.18	95.95
94.67	94.64
96.1	98.4
96.46	97.02
98.88	97.44
98.08	97.52
96.13	95.02
99.58	96.34

There were 7-9 beams used in IMRT plan while 2 arcs in Rapid Arc. Portal dosimetry plan was created and executed for each radiotherapy plan before executing on patients. Gamma index (γ) was calculated for both competitive plans IMRT and Rapid Arc; and analyzed for different parameters.

It is defined for every point in the test distribution a distance measure from the reference distribution:

$$\gamma D_T, D_R(y) = \min_{\chi} \sqrt{\left(\frac{y-\chi}{\delta}\right)^2 + \left(\frac{D_T(y) - D_R(\chi)}{\Delta}\right)^2}$$

Where Δ and δ are normalization factors for positions and dose, respectively. Normalization factors can also be regarded as weighting factors for DTA and DD, and should be proportional to the measurement errors for measured distributions or bin size for calculated distributions. In radiotherapy applications, the common acceptance for DQA is that DTA be less than 3mm.

And DD less than 3% of the maximal dose. The convention is to define the normalization factors using the acceptance, e.g. δ=3mm and Δ=3% of the maximal dose. Then, dose quality is considered acceptable.

Area Gamma value of all plans was calculated and analyzed before execution the plan over the patients. This is displayed in Figure 1. In the first group of analysis, target coverage with $V_{95\%}$ to $V_{93\%}$ were analyzed, after that dose to OARs analyzed for their mean and maximum values. During the planning, our priority was to achieve $V_{95\%}$ for the target first, then to spare the critical organs. In second group of analysis, we analyzed the area gamma–values of all plans. Portal dosimetry plans were generated in TPS and all plans were exposed to Varian's portal dosimeter, software version 11.0.55 (Varian Medical System, Inc, USA), placing the detector at 100cm from isocentre.

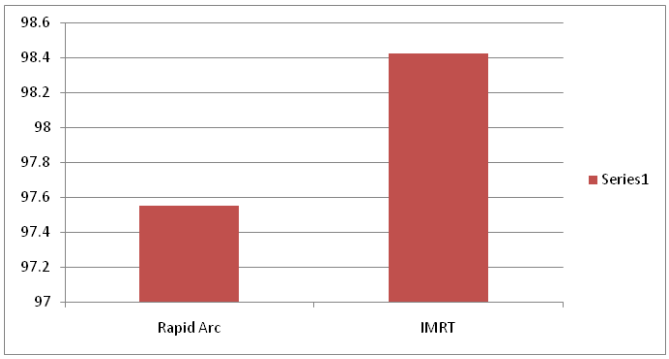

Figure 1 Illustrating the mean of area gamma index obtained after portal dosimetry.

Standard deviation was also calculated and tabulated in Table 3. Monitor Units of all IMRT and Rapid Arc plans were recorded and displayed in Figure 2.

Table 3 Illustrating Standard Deviation of prescribed dose to targets in %

STD(%)	
Rapid Arc	**IMRT**
2.3	2
3.4	3.2

Table Continued....

STD(%)	
Rapid Arc	**IMRT**
1	1.2
1.9	1.7
2.2	1.6
3.6	2.8
1.2	0.9
1.9	1.1
1	0.9
1.6	1.7
1.4	1.4
1	0.9
2.6	2.1

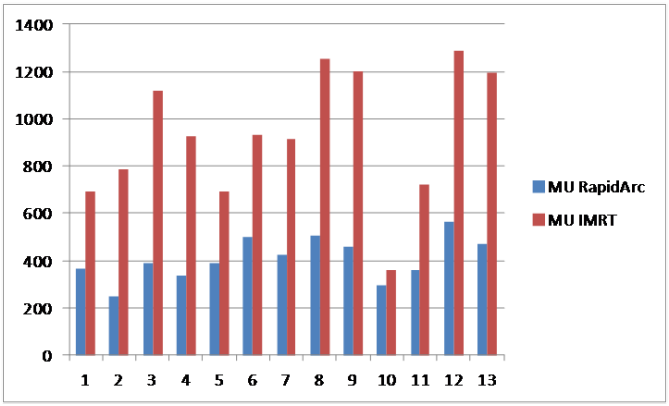

Figure 2 Illustrating monitor units (MU) in IMRT and rapid arc radiotherapy plans.

Results

All Rapid Arc and IMRT Plans have been analyzed for dose distribution. The mean of $V_{95\%}$ is found 97.89% and 97.47% for Rapid Arc and IMRT plans respectively. Mean Standard deviation is 1.93 in Rapid Arc and that of 1.70 in IMRT plan. Minimum STD is recorded as 0.9% in IMRT plan. The mean of $D_{95\%}$ is observed 96.57% and 96.30% in Rapid Arc and IMRT technique respectively. Mean of Global maximum dose is recorded as 105.3% in Rapid Arc and 103.7% in IMRT plan.

Total number of Monitor units is noted for all the plans. Mean of ∑MU for Rapid Arc is calculated 408.76(ranging from 251 to 566), and for IMRT is 928.53(ranging from 359 to 1286). Mean of area gamma index for IMRT plan is found 98.3% and for Rapid Arc is 97.55%

Discussion

In the current study 13 patients of head and neck cancer were taken randomly for analysis of spatial dose distribution. All plans were analyzed for $V_{95\%}$, $D_{95\%}$, mean dose to targets, maximum and minimum dose to OARs. We performed portal dosimetry of each plan before executing it over patient. Gamma index is also quantified for each plan and considered as one of the analyzing parameters. Area gamma index has been found better in IMRT technique as compare to Rapid Arc.

In this study, the dose coverage to the targets was almost same in both the modalities. Moreover, no significant difference was observed in dose received by OARs. It is easy to reduce hot spot and hyper dose in IMRT plan. Global maximum dose was observed comparatively less in IMRT technique. This is illustrated in Figure 3. Treatment time was reported less in Rapid Arc as compare to IMRT. Dose homogeneity was found slightly better in IMRT.

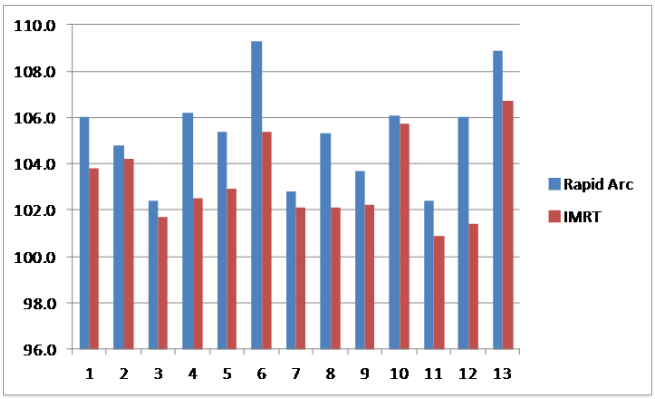

Figure 3 Global Maximum dose in IMRT and rapid arc radiotherapy plans.

Dose distribution optimization meets objectives of the plan which assumes delivery of prescribed dose to targets and simultaneous sparing of normal tissues in vicinity. These tasks are rival and their simultaneous performance is sometimes hard to achieve desired results. So, it is difficult to decide whether dose distribution with acceptable OARs and unsatisfactory target coverage is more preferable than treatment plan with higher OARs doses but appropriate target coverage. Moreover, the decision making process based only on selected dose constraints which rejects the slope of the DVH curve at the lower dose ranges and does not take into account the dose homogeneity in the target.

Almost all research paper available in literature on this topic shows that Rapid Arc competes IMRT. But, the current study suggests, dose distribution to the target in Rapid Arc is slightly (0.43%) better than IMRT which is not significant at all. The only demerit of IMRT is that it takes 3-5 minutes additional time in treatment.

Prescribed dose distributions in the IMRT and Rapid Arc techniques shows complexity of higher order. Analysis and comparison between competitive treatment plans based on the spatial distribution of dose values and DVH curves remains, therefore, an ambiguous task for a physician. Large number of structures taken into account during planning additionally hampers the selection of the most favorable treatment plan.

The spatial dose distribution in target in both the techniques is displayed in Figure 4. Nothing significant difference is observed in Rapid Arc and IMRT plans in respect of spatial dose distribution. Dose to OARs is observed almost same in both the techniques. But it is easy to control spillage of dose outside the targets in IMRT technique as compare to Rapid Arc. User can also control OARs dose very easily in IMRT. After getting a good plan in TPS, its execution is more important. As the findings of this study says that IMRT plan execution is comparatively more reliable than Rapid Arc because mean percentage value of area gamma index (Area Gamma <1.0, Tolerance Value=95%) has been noticed more accurate in IMRT.

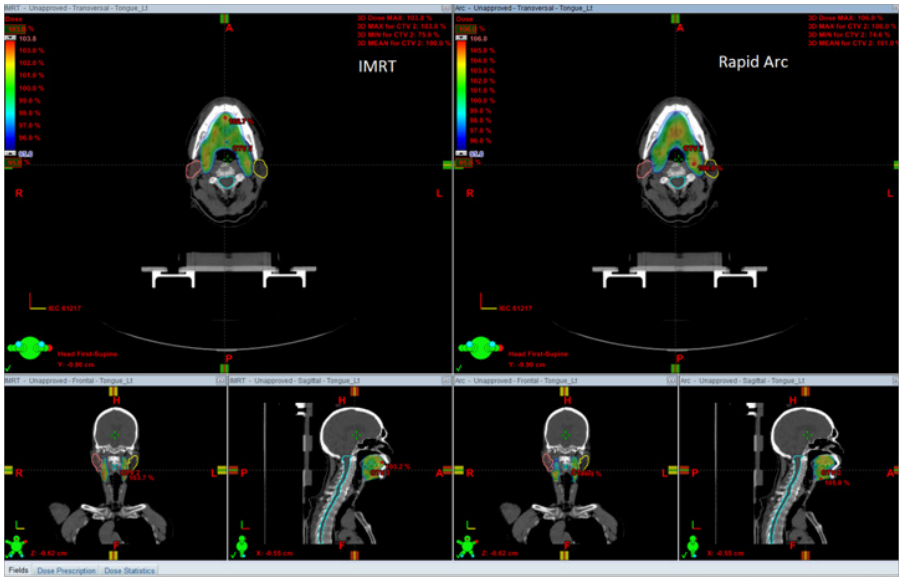

Figure 4 Illustrating 95% of prescribed dose coverage to target in IMRT and rapid arc radiotherapy plan.

Conclusion

The current study shows that Rapid Arc and IMRT are equivalent, and drag almost same result in the respect of dose coverage to targets, dose to OARs, standard deviation and area gamma index (γ); except treatment time. The only advantage of Rapid Arc, it curtails treatment time by 2-3 times on an average as compare to IMRT. But, hotspot has been found 3-5% less in IMRT plans. In respect of spatial dose distribution to the targets, both the techniques; IMRT and Rapid Arc, yield equivalent dosimetric results. Plan execution over patients has been one of the most important parts of radiotherapy. And execution of IMRT plan over patient is noticed more reliable as compare to Rapid Arc from accuracy of dose delivery view point in the treatment of head and neck cancer.

Acknowledgments

None.

Conflicts of interest

The author declares that there is no conflicts of interest.

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