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Dosimetric Comparison of Intensity Modulated Radiation Therapy (IMRT) and Rapid Arc in Cervix Carcinoma

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ABSTRACT

In this study, the comparison of dosimetric parameters for IMRT and RA while treating the patients suffering from cervical carcinoma are analyzed. A total number of 20 patients were selected, out of which, 10 were treated with IMRT and the other 10 with RA. As per Radiation Therapy Oncology Group (RTOG), OARs were also marked on CT images and oncologist did the contouring for Planning Target Volume (PTV), Clinical Target Volume (CTV), and Gross Target Volume (GTV). The dosimetric parameters include verity of Index and Coverage which were calculated for the plans' calculation and OARs doses. Two samples of paired T-tests have been performed to find the difference of dosimetry for RA and IMRT plans. In the RA and IMRT planning, 0.96 is the conformity index mean values. The results shows that the mean value for Paddick Conformity Index was 0.93 while New Conformity Index value was 1.06.

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1. Introduction

Around the globe, cervix carcinoma is the fourth most common gynaecological threat. Due to this kind of carcinoma illness, developing nations are generally affected. The GLOBOCAN 2013 report agreed that almost 70% of worldwide burden cascade is in developing nations. For the administration of cervix carcinoma, external radiotherapy is acknowledged as a standard of care (Torre, Siegel, Ward, & Jemal, 2016). The purpose of radiotherapy for cervix carcinoma is to attain an ideal adjust among most extreme measurements to the tumor and to reduce the chance of muddling the organs at risk (OARs) (Parkin, Bray, Ferlay, & Pisani, 2001).

Basically, cervical cancer begins in women's cervix, which is the lower contract portion of the uterus. The uterus holds the developing baby amid pregnancy. The cervix interfaces the lower portion of the uterus to the vagina and with the vagina shapes the birth canal. There are three types of treatment options namely; surgery, radiation therapy, and chemotherapy.

Radiotherapy accepts fundamental analytics for the administration of 50% of cancer patients and almost 40% of cured claim their malignancy required radiotherapy. For a portion of patients, there could a chance to utilize radiation treatment instead of surgery, pointing organ assurance (Adegoke, Kulasingam, & Virnig, 2012; Barton & Delaney, 2010). To treat the cervix cancer, a customary procedure of box strategy or high energy photon (2-dimensional) with AP/PA fields have been reported (Gupta et al., 2009). It has been observed that the use of customary method delivered superfluous dosages to adjacent basic organs, subsequently driving to treatment related complications which were an enormous issue, especially considering the high rate of remedy versus survival of illness. The most widely utilized strategy of treatment planning is 3-dimensional conformal radiotherapy (3-D CRT), where high rates of side impacts have been observed when combined with chemotherapy (Peters III et al., 2000; Samper-Ternent, Zhang, Kuo, Hatch, & Freeman, 2011). IMRT can reduce the radiation dose to OARs, and supply predominant coverage to the planning target volume (PTV) (Guy et al., 2016). In 2015, Guy et al. reported that in terms of quality indices, especially OARs when compared with 3D-CRT, the intensity modulation techniques have numerous preferences (Guy et al., 2016). Furthermore, the progressed frame of IMRT is RA that delivers a precise dose with a gantry rotation of 360^o in a single or multi-arc treatment. Over a long period of time for the treatment of cancer, IMRT has been replaced by RA. When compared with IMRT, RA can reduce the number of monitor units which are required to provide medicine (Fenkell et al., 2008). Rapid Arc is a Volumetric Arc Therapy (VMAT) modality that allows rapid delivery of highly conformal dose distributions. In 2010, Benthuysen et al. shared that for treating capacity, RA is more promising. It was observed that for advisor moment and monitor units, RA is much proficient as compared to IMRT (Van Benthuysen, Hales, & Podgorsak, 2011). Similarly, in 2017, Yadav et al., concluded that RA permits far better correspondence, the high dose volume to Planning Target Volume (PTV) when compared with 3D-CRT. It may offer assistance to reduce the chance of inferior cancer (Yadav et al., 2017).

In this study, we present a systematical comparison of dosimetric parameters for IMRT and RA of the patients with cervical carcinoma.

2. Materials and Method

2.1. Treatment Planning and Selection of Patients

Through Obstetrics stage IB-IVA and Federation of Gynecology, 20 number of patients (aging between 23 to 76 years) were confirmed suffering from cervix carcinoma. After institutional review board approval, these 20 patients were selected for localized cervical cancer therapy treatment. Ten patients were originally treated with IMRT while the others with RA technique. In 28 fractions, the recommended dose was 50.4 Gy (1.8 Gy each day). The important aim was to provide 95% of the recommended dose to the 95% of the planning target volume (PTV) in any case for all the plans and then to decrease the OAR (bladder, rectum, and small bowl) dosage. During optimization, the physicist and the oncologist amend precedence for better results. Both plans were optimized for 6 MeV photon energy.

As per Radiation Therapy Oncology Group (RTOG), OARs were also marked on CT images and oncologist did the contouring for Planning Target Volume (PTV), Clinical Target Volume (CTV), and Gross Target Volume (GTV). For all treatment plans, delivery of isodose and optimization, the Eclipse Radiation Treatment Planning System (ERTPS), (Eclipse Aria 11, Varian Associates, Palo Alto, CA) with pencil beam and Helios contrary planning software has been used (Iqbal, Isa, Buzdar, Gifford, & Afzal, 2013). For delivering treatment, Varian DHX (Varian medical system, Palo Alto, CA) with 120 leaf millennium MLC has been used.

Table 1
Patient's Characteristics N = 20

Patient's Age	
Median (Year)	56
Range (Year)	32-76
Stage	
IIA	4
IIIA	2
IVA	3
IB	3
IIB	4
IIIB	4

2.2. Quality Parameters

To assess various dosimetric parameters of OARs and PTV, Eclipse TPS created a dose volume histogram. The analyzed dosimetric parameters included the followings.

i. Conformity Index (*CI*)

The conformity index is defined as the ratio of ref. isodose volume to the target volume (Shaw et al., 1993).

$$CI = \frac{Ref.isodose.volume}{Target\ volume} \quad (1)$$

(The 95% of isodose volume was taken as reference volume of the PTV according to ICRU reports.)

ii. New Conformity Index (*NCI*)

$$NCI = \frac{(TV \times PIV)}{(TV_{PIV})2} \quad (2)$$

Where,
TV_{PIV} = Volume of PIV
TV = Total Volume of the target (Nakamura et al., 2001)

iii. Paddick Conformity Index (*PCI*)

$$PCI = \frac{(TV_{PIV})2}{TV \times PIV} \quad (3)$$

Where,
TV = Total Volume of the target (Paddick, 2000)

iv. Homogeneity Index (*HI*)

Homogeneity index is defined as the ratio of difference dose delivered to 1% of the PTV and dose delivered to 99% of the PTV to the prescribed dose (Kataria, Sharma, Subramani, Karrthick, & Bisht, 2012).

$$HI = \frac{D_{1\%} - D_{99\%}}{PerscriptionDose} \quad (4)$$

Where,
$D_{1\%}$ = Dose delivered to 1% of the PTV
$D_{99\%}$ = Dose delivered to 99% of the PTV

v. Radical Dose Homogeneity Index (*rDHI*)

If one take the ratio of the minimum dose to the maximum dose delivered to the target volume then the results will be radical dose homogeneity index (Oliver, Chen, Wong, Van Dyk, & Perera, 2007).

$$rDHI = D_{min}/D_{max} \quad (5)$$

Where,
D_{min} = Minimum dose
D_{max} = Maximum dose

vi. Moderate Dose Homogeneity Index (*MDHI*)

The *MDHI* is the ratio between two quantities; one is dose reaching 95% of the target and other is dose reaching 5% of the target volume (Oliver et al., 2007).

$$MDHI = \frac{D_{95\%}}{D_{5\%}} \quad (6)$$

Where,
$D_{95\%}$ = Dose delivered to 95% of the PTV
$D_{5\%}$ = Dose delivered to the 5% of the PTV

vii. Uniformity Index (UI)

The uniformity index which is the ratio of $D5_{\%}$ to the $D95_{\%}$ (Sheng, Molloy, Larner, & Read, 2007).

$$UI = \frac{D_{5\%}}{D_{95\%}} \quad (7)$$

Where,
$D_{5\%}$ = Dose given to the 5% of the PTV
$D_{95\%}$ = Dose given to 95% of the PTV

viii. Gradient Index (GI)

The gradient index is defined as the ratio of half prescription isodose volume to the prescription isodose volume (Paddick & Lippitz, 2006).

$$GI = \frac{\frac{1}{2}PIV}{PIV} \quad (8)$$

Where,
PIV = Prescribed isodose volume.

ix. Coverage

Coverage index is the ratio between the minimum dose delivered to the prescription dose delivered to the target volume (Shaw et al., 1993).

$$Coverage = \frac{D_{min}}{Prescribed\ Dose} \quad (9)$$

Where,
D_{min} = minimum dose reaching the target

3. Statistical Analyses

In statistical analyses, two samples paired t-test has been performed to find the difference of dosimetry between RA and IMRT plans for cervix carcinoma. The results were analyzed by taking the assistance of statistical package of social sciences software (SPSS, version 20), in which the $p < 0.05$ was considered to get statistically significant and accurate results.

4. Results

4.1. Organs at Risk (OARs)

Rectum, bladder, and small bowel were marked as OARs and reported for dose. Table 2 presents the calculated results of both techniques IMRT and RA. The results revealed that by using the RA technique, the OARs dose decreases comparing to IMRT except for the dose to the small bowel. Technically, it is more convenient for the radiation therapy department to reduce the time and number of monitor units, where RA technique is found more promising.

Table 2
Dose Comparison of IMRT and RA to OARs

	IMRT			Rapid Arc		
	Rectum	**Bladder**	**Small bowel**	**Rectum**	**Bladder**	**Small bowel**
D_{mean}	115.12	125.91	43.82	110.31	123.20	63.22
$D_{100\%}$	2.60	8.68	0.67	2.42	4.53	1.83
$D_{70\%}$	19.71	23.76	8.55	18.06	23.08	12.83
$D_{50\%}$	36.48	36.25	18.00	33.77	38.05	22.30
$D_{30\%}$	48.34	47.01	27.21	46.09	47.52	32.74
$D_{10\%}$	49.88	50.98	40.79	49.74	50.01	46.62

4.2. Comparative Analysis of IMRT and RA

Since the *CI* is used to measure how well the dose distribution covers the size and shape of the target. Under the calculation of both techniques, we calculated the mean value of *CI* up to 0.96, as presented in table 3. Similarly, in 2000, Paddick proposed a *CI*, considering the position of the prescription volume with respect to the target volume to get perfect conformity score (Nakamura et al., 2001). Therefore, by using the formula of Paddick *CI*, our calculated mean value is 0.93 for both techniques.

Furthermore, Nakamura et al., proposed a New Conformity Index considering the location of Prescription volume (Nakamura et al., 2001), and by using the formula our mean calculated values of New Conformity Index is 1.06 for both techniques by using the equation 2. T-test conducted for the comparative analysis of both techniques showed that the results are insignificant which means that implementation of both the techniques gave the same favorable results in terms of conformity as shown in table 3

The Homogeneity Index (*HI*) is an objective tool to examine the uniformity of dose delivery in the target volume which is an important quality indicator for plans. For Homogeneity of dose, two indices are used. The first one is the Radical Dose Homogeneity Index (*rDHI*) which is defined as the minimum dose divided by maximum dose with calculated mean values of 0.68 and 0.66 for IMRT and RA techniques respectively. The second is a Moderate Dose Homogeneity Index (*MDHI*), which is less affected by steep dose gradients near field borders or to small hot spots (Oliver et al., 2007). The calculated mean values are given in table 3 for both techniques and their comparison has also been presented in Fig.1 (i-ix). The statistical analyses showed that the results are significant which means that there is a slight difference between IMRT and Rapid Arc planning treatment.

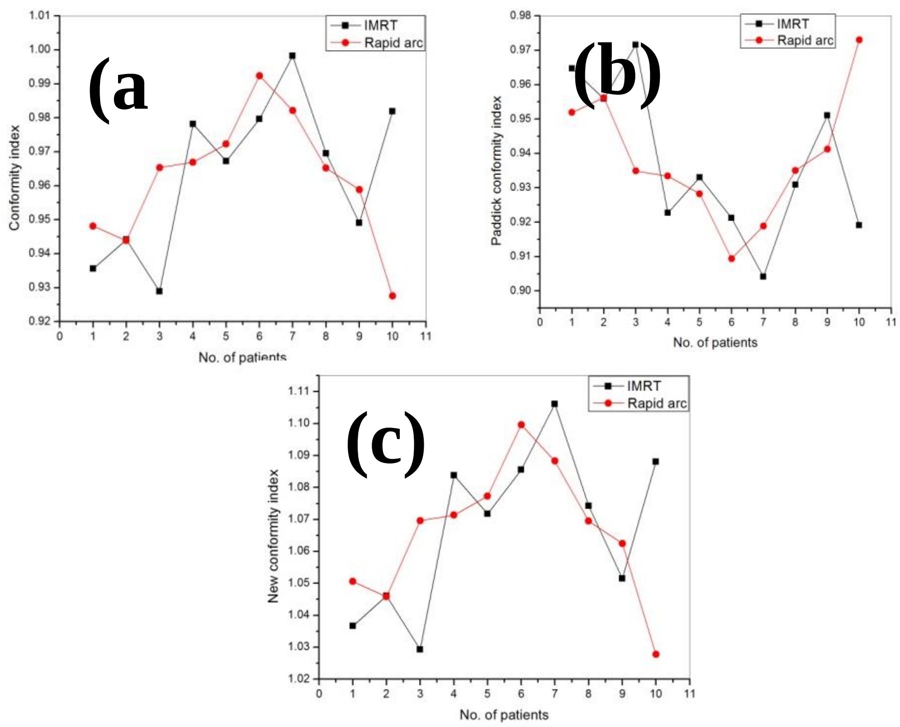

Figure 1 (a-c): shows the Comparative Analyses of *CI, PCI, NCI* of IMRT and RA

To assess the uniformity of all the plans, a *UI* was used. The mean calculated values are 1.11 and 1.09 for IMRT and RA techniques respectively Statistical analysis shows that a significant result that means the value of *UI* of RA is slightly better than that of IMRT. Whereas, for both techniques, *GI* has 1.03 mean value. Statistically, the results are insignificant which shows that there is no difference between IMRT and RA treatment planning. For IMRT the Coverage, which is defined as, the D_{min} divided by the prescribed dose has a value of 0.81 and for RA is 0.83 as mean value. Statistically, the results are insignificant.

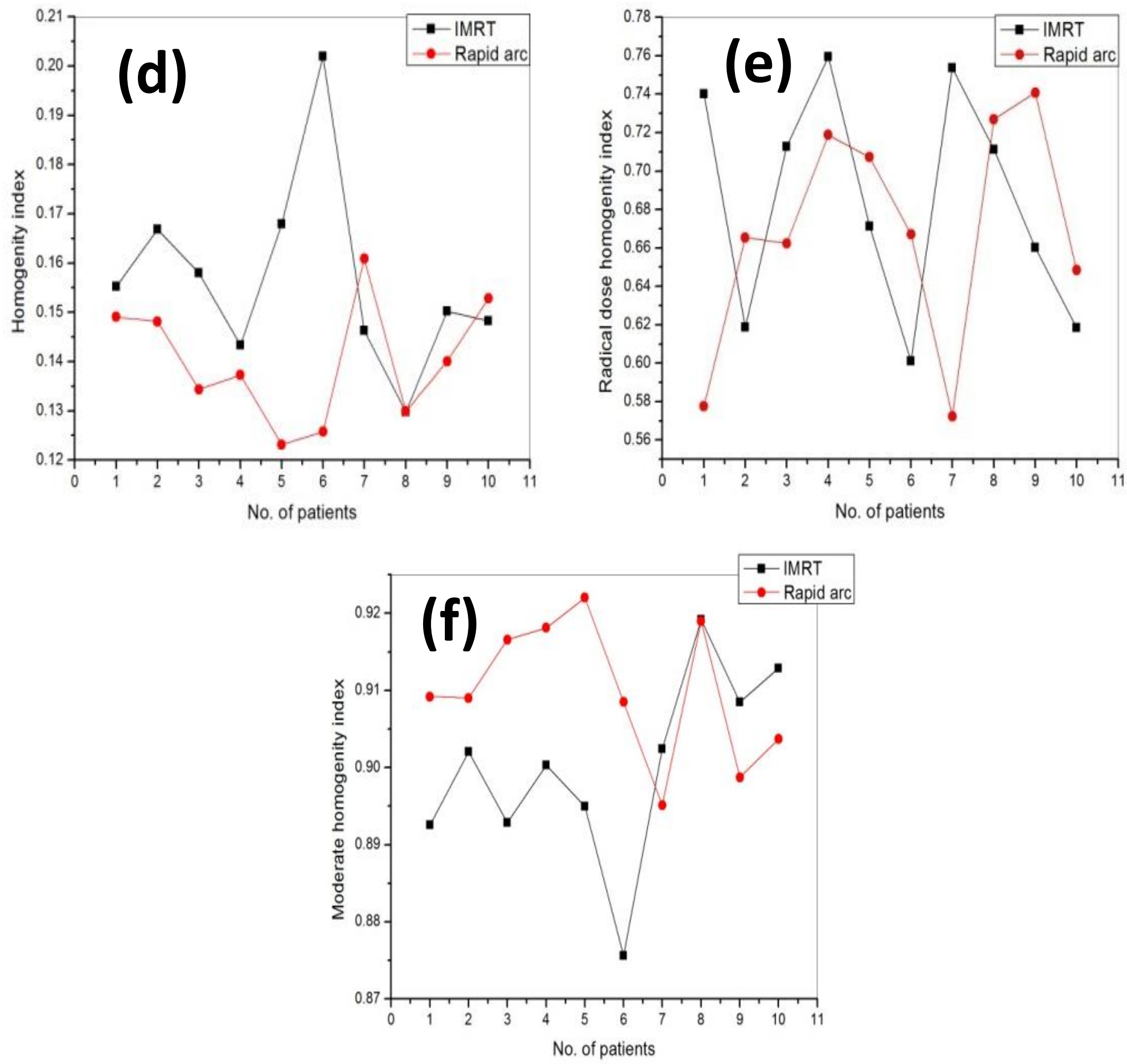

Figure 2 (d-f): Shows the Comparative Analyses of *HI, MDHI, RDHI* of IMRT and RA.

Table 3
Comparative Analysis of IMRT and Rapid Arc

	IMRT (Mean±S.D)	Rapid Arc (Mean±S.D)
CI	0.96±0.022	0.96±0.018
New CI	1.06±0.025	1.06±0.020
Paddick CI	0.93±0.022	0.93±0.018
HI	0.15±0.019	0.14±0.018
RDHI	0.68±0.059	0.66±0.058
MDHI	0.90±0.012	0.91±0.009
UI	1.11±0.015	1.09±0.010
GI	1.03±0.024	1.03±0.020
Coverage	0.81±0.058	0.83±0.057

5. Discussion

This study performs a dosimetric comparison of IMRT and RA techniques. The RA was not superior to IMRT in sparing of OARs or the coverage of PTV. When compared with IMRT, the RA procedure can reduce the number of monitor units which are required for treatment. In early radiotherapy treatments to examine the dose delivered to the tumor and OARs, the Dose Volume Histogram (DVH) tools are commonly used. But the disadvantages of DVH methodology are; a) it does not offer 3-D information, b) it also does not show, where inside the structure, the dose must be delivered, c) as the time passes and treatment progresses, DVH loses its precision if there is variation e.g. the tumor shrinks, the patients lose weight etc. To evaluate the quality of the treatment plan there is a need for parameters and tools. In the current study, the quality of treatment plan and OARs sparing can be evaluated by comparing *HI*, *CI*, *UI*, *GI* and coverage.

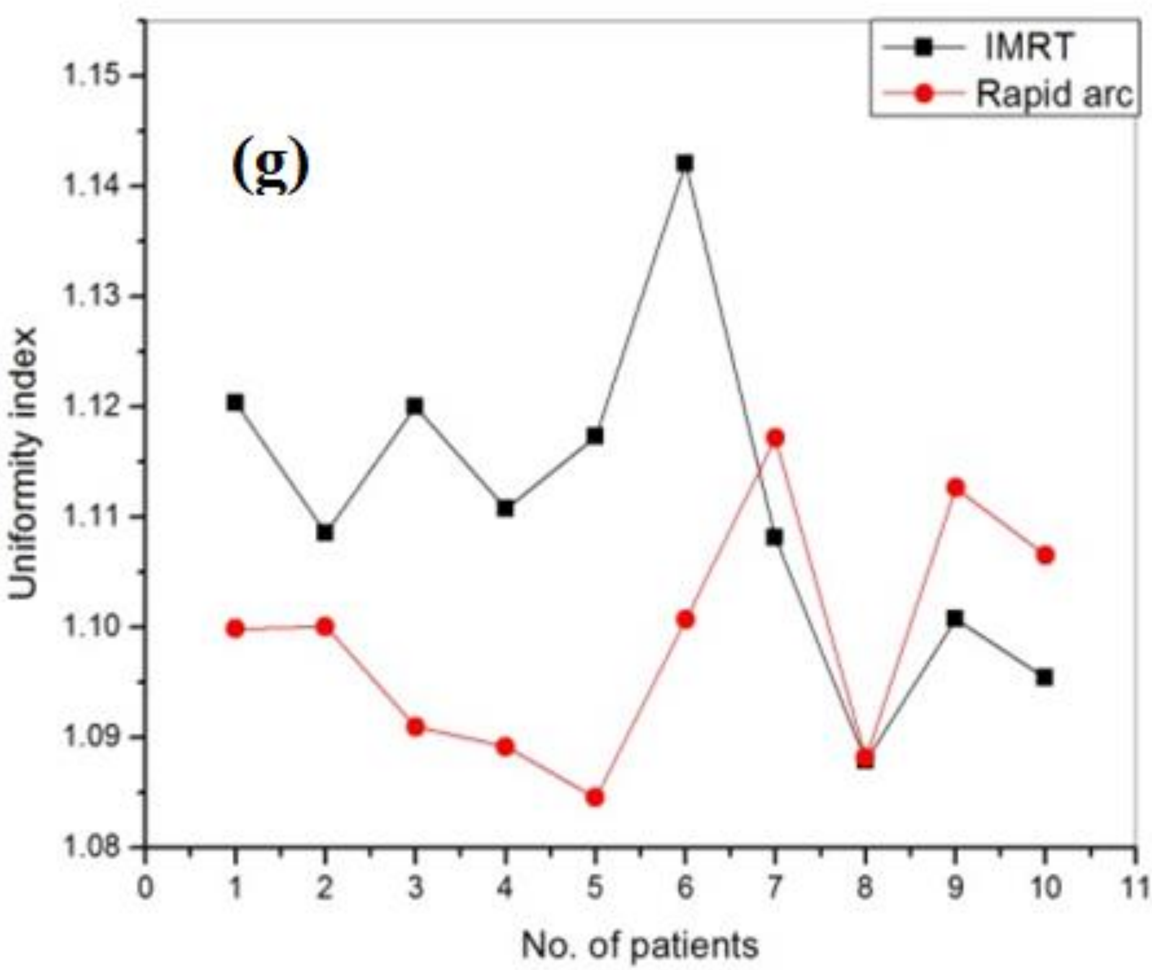

Figure 3 (g): Shows the Comparative Analyses of *UI* of IMRT and RA

It is normally accepted that conformity of a radio surgical plan is important for effective treatment as it represents the measure of how well the distribution of radiation follows the radio surgical target. Radiation Therapy Oncology Group (RTOG) criteria define that for a perfectly conformal plan the value will be unity. If the index value is between 0.9 and 1, this would mean that the target volume is partially irradiated (considered to be a minor violation) (Shaw et al., 1993). It can be noticed that there is a minor deviation from the protocol for the value of Conformity Index of both techniques. But nevertheless, be acceptable.

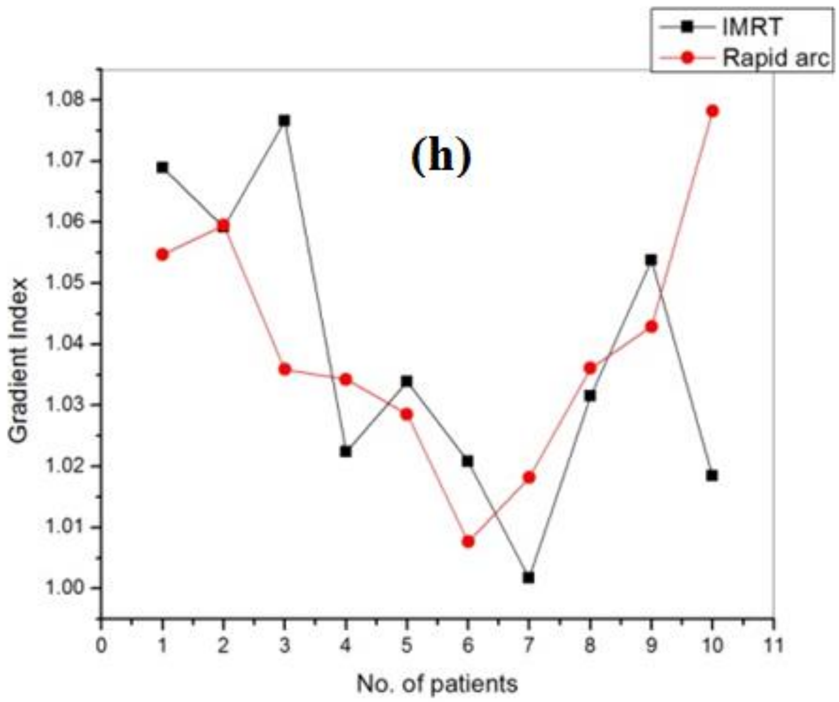

Figure 4 (h): Shows the *GI* Comparison of IMRT and RA

The *CI* described by Shaw et al., has a fundamental flaw, as the ratio does not consider the location of *PIV* relative to TV and plan would receive a perfect score whether *PIV* outlines the exact periphery of TV or missed TV altogether (Paddick, 2000). Paddick and Nakamura introduced new formulae for *CI* considering the position of the prescription volume with respect to the target volume. New *CI* values of both techniques are resulted to be in protocol defined by RTOG. Whereas, *PCI* values resulted in acceptable minor deviations from the defined protocol for IMRT and RA techniques.

Homogeneity is a tool to examine the uniformity of dose delivered to the target volume. For the homogeneous plan, the value of the homogeneity index will be close to zero (Kataria et al., 2012). The PTV has a more homogeneous dose if the value of the homogeneity index is smaller. For the homogeneity of dose, two indices are used. First one is *RDHI* and the second is *MDHI* and the values are shown in table.3.

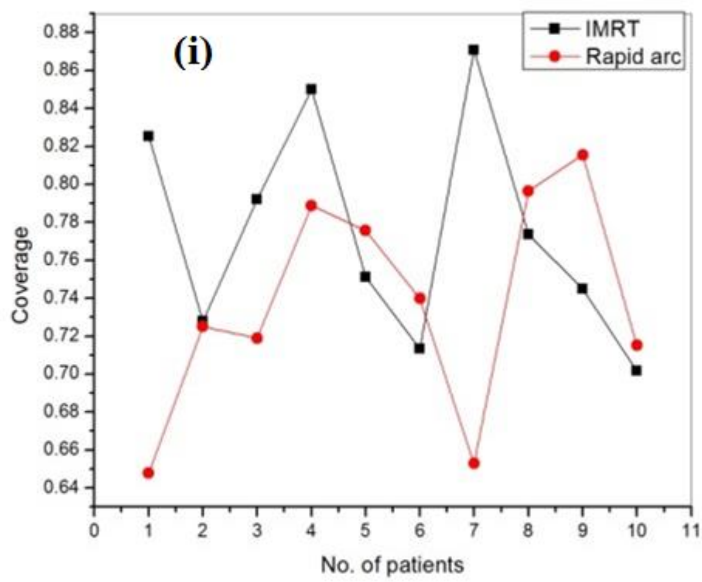

Figure 5 (i): Shows the Coverage Comparison of IMRT and RA

UI was chosen due to the proximity of the target volume and OAR's which frequently lie alongside so that there are no hotspots that could expand in the adjacent regions. The lesser the values the better the uniformity of the dose (Sheng et al., 2007). The value of *UI* of RA is slightly better than that of IMRT.

The *GI* is an influential tool that can be used to objectively measure the dose falling off the target. A promising *GI* reflects a steeper dose gradient and consequently, a lower applied radiation to the healthy tissues and organs. A *GI* < 3 normally reflects a reasonably selected prescription isodose (Paddick & Lippitz, 2006). The values given in table 3 give reasonable results.

According to RTOG radiosurgery guidelines, the ideal value for Coverage index is 0.9 and if Coverage is less than 0.9 then it is considered as a minor deviation while a value less than 0.8 means a major acceptable deviation (Shaw et al., 1993). The value of coverage in table 3 shows that there is a minor deviation but considerable to be acceptable.

6. Conclusions

An Intensity Modulated Radiation Therapy helps; dose intensification, improve target coverage, and reduction in the radiation dose to OARs. Whereas, Rapid Arc (RA) radiotherapy delivers a precise dose with a rotation of 360^{o} in a single or multi-arc treatment of gantry for the patients with cervical carcinoma.

The vital distinction between IMRT and RA is the capability to adjust the beam control. The plans of RA are much dependent on the optimization method, and the dosimetrist has less choice to alter the dose division before arc has been considered. For monitor units and radio therapist time, the RA is much beneficial than the IMRT.

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