How to Cite:
Singh, S., & Pradhan, A. (2022). The analysis of coplanar and non-coplanar intensity-modulated radiotherapy planning for esophageal cancer. *International Journal of Health Sciences*, *6*(S6), 9404–9413. https://doi.org/10.53730/ijhs.v6nS6.12525

The analysis of coplanar and non-coplanar intensity-modulated radiotherapy planning for esophageal cancer

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Abstract---Purpose: The analysis of coplanar intensity modulated radiotherapy (IMRT) and non-coplanar IMRT for the esophageal cancer. Methods: in my study 27 esophageal cancer cases, ten of them were cervical and upper thoracic (Group A) and seventeen were mid and lower thoracic (Group B). Gross target volume (GTV), clinical tumor volume (CTV), and organs at risk (OAR) were contoured by the oncologist in the eclipse treatment planning system. For every case, one coplanar plan & two non-coplanar plans have been generated by the similar general objective function. A descriptive dose-volume histogram (DVH) equation between three plans was then taken out in a table form. Results: 1) In Group A cases with PTV volume less than 100cc, the mean dose and dose gradient of non-coplanar plan were much better than those in coplanar plan. 2) In Group B cases, the conformity index (CI) for coplanar and two non-coplanar plans were 0.68 ± 0.15, 0.43 ± 0.14, and 0.69 ± 0.16, respectively. The V5, V10, V20, and the mean dose to the lung were less in the non-coplanar plans compared to ones in coplanar plan. However, the non-coplanar plans resulted in an increment in a dose to the heart, but the dose was within heart toxicity limit. Conclusion: For Group A cases, the non-coplanar IMRT plan have low dose gradient and better mean dose than the coplanar IMRT plan. For Group B cases, the non-coplanar IMRT might lessen dose to the lung tissue, thus lessen the possibility of radiation pneumonia to esophageal cancer patients. The disadvantages of non-coplanar IMRT is that, even within toxicity tolerance, it could deliver a much dose to the heart and spinal cord

Manuscript submitted: 9 April 2022, Manuscript revised: 18 June 2022, Accepted for publication: 27 July 2022

compared to the coplanar plan. Therefore, for patients with cardiology and neurology concern, non-coplanar IMRT should be used with caution.

Keywords---esophageal carcinoma, Coplanar IMRT, Non-Coplanar IMRT.

Introduction

Radiation therapy is the modern treatment facility for the fatal esophageal cancer. The aim of radiotherapy for esophageal carcinoma is to damage cancer cell inside the required cancer volume whereas saving the natural tissues. In the latest years, intensity-modulated radiation therapy (IMRT) has been widely handled esophageal cancer. IMRT challenged to be better than Three Dimension Conformal Radiotherapy (3DCRT) in the way of dose conformity in Planning Treatment Volume (PTV) and the natural tissue saving. Still, relies on the volume and site of the esophageal carcinoma, the natural lung tissue can be irradiate to sharp doses of radiation. Many literatures proof that the occurrence and sternness of radiation pneumonia were linked to the irradiation to natural lung tissue in esophageal cancer. For example, Wang et al. investigated that, between 100 cases, 49% of them have grown sternness pneumonia, in which 27% have grade 1, 16% have grade 2, 6% have grade 3 pneumonia. On medical ground, diminishing the spin-off effect of radiotherapy is another solution to increase the endurance rate. Since non-coplanar IMRT plan normally takes larger treatment time and it need difficult patient positioning, the mostly esophageal cancer plans are planned with coplanar IMRT, and docters have still want to discover the viability of non-coplanar IMRT in curing esophageal carcinoma. This research was to clarifies the treatment method for the esophageal carcinoma and increase the curement excellence by researching the dosimetric affect of non-coplanar IMRT in this medical centre. furthermore, the goal of this investigation is to maintain radiotherapy treatment tactics for upcoming medical practices, particularly for esophageal cancer.

Methods and Materials

Patient Selection

Twenty-seven cases of esophageal cancer were registered in this investigation. Ten of them had cervical & upper thoracic cancers (Team A), & the rest seventeen cases had middle and lower thoracic cancers (Team B). Average age of cases was 57 years (span, 45 - 70 years), & the average PTV was 111.91cc (span, 28.6cc - 231.17cc). Every cases in this investigation had tumors placed far from the distal esophagus and gastro-esophageal joint.

Simulation

Both Team A & Team B patients were simulated with thermoplastic mask. Patients were simulated on a computed tomography (CT) scanner (Phlipps – Brilliance2.0) With slice width of 5-mm from mandible to the diaphragms. This

expanded CT scan volume was utilized to totally shown the non-coplanar fields in treatment planning system (TPS). The obtained CT images covered the whole esophageal and upper pelvis.

Contouring

The gross tumor volume (GTV) was drawn by the doctor. The clinical target volume (CTV) was drawn with a 5 mm in radial orientation & 3 to 5 cm superior-inferior direction, which is according to clinical protocol. The PTV was explained as an extra 5 mm margin along the CTV. The organ at risk (OAR) are the spinal cord, lung, & heart.

Treatment Planning

In each case, one coplanar IMRT plan (referred as Plan 1) and two non-coplanar IMRT plans (referred as Plan 2 and 3) were arranged in the eclipse TPS, version 13.5.1 (Truebeam, stx, USA). Specifically, the coplanar plan (Plan 1) was taken as the basic plan with 3 to 5 fields plan. For Team A patients, if the plan 1 has three beams, we make an field arrangement of one posterior-anterior (PA) and two anterioroblique (AO) field (gantry angle at 180˚ ± 10˚, 55˚ ± 12˚, and 312˚ ± 12˚). If it is a four-beam Plan 1, we utilize one PA, one anterior-posterior (AP), & two anterior oblique (beam angle at 0˚, 60˚ ± 12˚, 235˚ ± 12˚, and 312˚ ± 12˚). In the Same way, five-field Plan 1 contained of one AP, two AO, & two PO beams (beam angle at 0˚, 60˚ ± 10˚, 132˚ ± 12˚, 235˚ ± 12˚, and 312˚ ± 12˚). For Team B patients, if it is a three-beam Plan A, one AP and two PO (beam angle at 0˚, 128˚ ± 12˚, and 228˚ ± 12˚) were utilize; Now it is four-beam Plan 1, one PA, one AP, and two AO or one parallel-opposed oblique beams (beam angle at 0˚ and/or 180˚, 52˚ ± 12˚ and/or 310˚ ± 10˚, 130˚ ± 10˚ and/or 230˚ ± 10˚) were created; if it is five-beam Plan 1, one AP, one PA, two AO, and one PO beams (beam angle at 0˚, 52˚ ± 12˚, 128˚ ± 12˚, 180˚ ± 8˚, and 312˚ ± 12˚) were created.

The table angle was always positioned to 0˚. For every case, the non-coplanar Plan 2 was changed with the basic Plan 1 by switching one or two of the coplanar fields in Plan 1 over the non-coplanar fields. For Plan 2, the sum of fields were 3 to 5, & the gantry angle of the non-coplanar field was arranged as 328˚ or 32˚ or 152˚, & table angle was arranged to 90˚. The non-coplanar Plan 3 was utilizing the same field factors as in the Plan 2, by supplement of two more non-coplanar fields with gantry angles of 328˚ & 32˚, so, composing the sum of 5 to 7 fields in Plan 3. Every single IMRT plan were planned with 6 MV X-ray beam. The median dose recommended to the PTV was 60 Gy in 30 fractions. Dose to the OARs, such as the lung, spinal cord, and heart, were minimized to the standard QUANTEC protocol. The aim of the treatment planning is to match the standard planning criteria; Dose to the 95% (D95%) of the PTV volume get the Given dose (60 Gy); D100% of the PTV should be greater than 57 Gy; D5% of PTV came less than 63 Gy. The spinal cord dose was tolerated upto 45 Gy for 0.1cc. For the total lung, the V5, V20, and mean dose were predicted to be less than the 50%, 25%, & 13 Gy, correspondingly (in conclusive % of the lung volume at 5 & 20 Gy). For the heart, the planning targets were to put V40 lower than 40% & mean dose lower than 30 Gy (in conclusive % of the heart volume). Each & Every plan was

calculated using superposition formulism by a dose calculation grid size of 0.2 cm. 2.5.

Plan Evaluation

Each plan was examined with regard to the dose distribution, dose-volume histograms (DVHs), and further dosimetric factors explained below. Assessment of treatment plans were assess on doses delivered to the PTV & OARs. The dose division of PTV was assessed by examining the maximum dose, mean dose, and minimum dose. To examine the plan excellence with regard to the dose released to the tumor, the conformity index (CI) and heterogeneity index (HI) were calculated.

$$CI = (VT_{ref}/ V_{ref}) *(VT_{ref}/ V)$$

$$HI = D_{5\%}/D_{95\%}$$

where, TV is the volume of PTV; TVref is the volume of PTV engraved by the 95% prescription isodose cloud; V_{ref} is enclosed by the 95% recommended isodose chart. The CI is usually 0 - 1, with a larger value showing better conformity. where, D5% and D95% shows the dose delivered to 5% and 95% volume of the PTV, correspondingly. Higher HI values show doses increasing the recommended dose, a higher degree of dose heterogeneity in the PTV. To estimate the impact of IMRT on natural lung tissue, heart, & spinal cord irradiation, we evaluated various dosimetric indices, including V5, V10, V20, and V30 for the natural lung & mean dose given to the natural lung (MLD). The clarification after utilize V5-V30 for the natural lung evaluation in equating the distinct plans were referenced on inspection that lung tissue try to have a minimal dose tolerance. We also tabulated V30, V40, V45, V50, and V55 for the heart, with mean dose and D1cc volume of spinal cord dose.

Statistical Analysis

All plans were equated by mean statistics. Quantile-quantile graph indicates the data to be approximately naturally dispensed, so the dissimilarity between means were tested for importance by a two-tailed paired Student's t-test. According to null hypothesis, there was no major change between the coplanar IMRT practice & the non-coplanar IMRT treatment practice. Statistical importance was put at $P < 0.05$.

Results

Group A

Patients table 1 indicates the doses to the PTV, CI, and HI for three distinct IMRT plans (1, 2,3). The outcome indicated that all three distinct plans are too similar. I further categorize this Team patient into two parts build on the PTV volume: First part comprises the patients with PTV volume within 100cc, & the second part comprises with PTV volume over 100cc. In this part with PTV volume less than 100cc, the PTV mean doses (cGy) were 6492.37 ± 284.97, 6348.12 ± 274.58,

6348.00 ± 274.66 for Plans 1, 2 & 3 consequently. The PTV average dose of Plan 2 was nearby to the given dose and indicates statistical changes equated with Plan 1 (P = 0.034). The HI of Plan 2 was nearby 1, & indicated statistical changes equated with Plan 1 (P = 0.018). For thorough assessment of the Plan 1, 2, & 3 are indicated in Table 2. 3

Group B

Patients Table 3 indicates that the CI for Plans 1, 2, & 3 were 0.63 ± 0.17, 0.43 ± 0.12 and 0.69 ± 0.13, consequently. The CI of plan 2 have less statistical difference inspite of basic Plan 1 (P = 0.001). Plan 3 & Plan 1 has no statistical change (P = 0.798). For thorough assessment of the all 3 plans are lined up in Table 3. The OAR study is indicated in Table 4, Figure 1, and Figure 2. The outcomes indicated that the lung V5(%), V10(%), V20(%), V30(%), and average lung dose (ALD) (cGy) of basic Plan 1 were 41.92 ± 9.12, 28.92 ± 9.23, 15.97 ± 4.49, 7.62 ± 4.69, & 884.79 ± 192.87, consequently. The outcomes were constant with the verdict by the isodose spread as lung V5(%), V10(%), V20(%), V30(%), and ALD (cGy) were minimize to 16.31, 10.57, 5.79, 2.32 and 246 utilizing the Plan 2 (P < 0.000). Table 5 indicated the dosimetric outcomes of the heart. The V30(%),V40(%), V45(%), V50(%), V55(%), and ALD (cGy) of Plan 1 were 18.92 ± 10.27, 12.98 ± 12.01, 9.13 ± 9.42, 5.92 ± 6.41, 3.33 ± 5.08, and 1727.79 ± 1026.02, consequently. Equating to these values in Plan 1, the Plans 2 had an increment of 11.12 for V30(%), 9.85 for V40(%), 7.89 for V45(%), 5.91 for V50(%), 4.2 for V55(%), and 627.12 for ALD with statistical importance (P < 0.05). Moreover, when equating to the Plan 1, the Plan 3 also indicated an increment in V30(%), V40(%), V45(%), but not in V50(%), V55(%), and ALD when a non coplanar beam was used. The spinal cord D1cc (cGy) of basic Plan 1 was 3129.63 ± 741.8. equated to Plan 1, both the Plan 2 and 3 had little greater dose; conversely, all sets of plans had D1cc ≦ 4500 cGy for the spinal cord.

Discussion

In external beam radiotherapy, the choice of beam parameters has a major role when we planned the IMRT plan. The choice of beam angle is selectively significant as the beam angle directly influence the patient position and treatment plan excellence, particularly in the patients where the PTV is engraved with various OARs [1]. Beam angle choice in IMRT plan calculation has been examined by various hospitals[1-5]. Allen [5] and Tucker [6] investigated that non-coplanar IMRT can majorly improve the dose dissemination when PTV is nearby to the spinal cord. Bedford et al. [7] showed that, by inverse planning formulism to produce three to six field non-coplanar plans without intensity-modulation might gives better rectum saving in conformal prostate plan equating to a 3-field coplanar plan. Olivier et al. [8] investigated that utilizing non-coplanar beams in three-dimensional conformal radiotherapy (3DCRT) and IMRT may severely minimize the dose to the heart in irradiation of middle and lower lung cancer.

Liu et al. [8] equated and evaluated the 3DCRT plans with coplanar beam anterior field and non-coplanar beam anterior field assess the dose dispersal in the PTV and OARs in curing thoracic cases in the circumstances of the PTV length 18 cms. The investigation [9] showed that the utilization of non-coplanar field may

give better dose dispersal on tumor volume and minimize the dose to spinal cord. this is good research, which told the dose distribution over thoracic tumor and OARs in the coplanar IMRT and non-coplanar IMRT in descriptive way for a big group of patients (n = 45). In My research, for Group A patients, we observe that Plan 2 generates the mean PTV dose near by to the given dose and HI was about to 1, this indicates some positive advantage of utilizing non-coplanar IMRT plan. As we can say that non-coplanar field may minimize the impact of the dose dispersal to the body surface upto some limit, particularly when the tumor volume is relatively small.

Radiation pneumonia is the major concern to constraint medical therapy impact and our aim was to minimize the dose to the lung. Graham [10] told that the entrance and degree of radiation pneumonia are very much linked with radiation volume and dose. There was a good relation with the degree of the radiation pneumonia & the V20, V30, mean dose of lung. Along with, Allen et al. [11] & Tucker et al. [12] showed that, with the increment of V5, the decrement of radiation pneumonia will grow. In my research, non-coplanar IMRT plans might be an advance device to minimize irradiation volume of lung. conversly, as indicates for Plan 2, decrement in the irradiation of lung can also minimize the conformity of plan. The cause we get that, equate to Plan 1, the volume of PTV engraved with the 95% given isodose volume was same, but the 95% recommended isodose volume majorly rise. Utilizing Plan 3, it was possible to bound the irradiation of lung without minimizing the conformity of plan.

We also get that non-coplanar IMRT plans grown the dose to the heart while lessen dose to the lung. In equating our record with those from other research on forecast of radiation damage to the heart, we got that two kinds of non-coplanar IMRT plans examined. in this investigation may met the heart medical limits, which conventionally have been suitable [13, 14]. According on these outcomes, it indicates that noncoplanar IMRT Plan 3 gave better advantage. It will lowering the strict acute toxicity of lung without generating the radiation damage to heart. In my investigation, the delivery method was only to the IMRT. Now a days, the volumetric intensity modulated arc therapy (VMAT) method is accessible for the treatment of carcinoma. The VMAT has too much glamorized since VMAT have monitor units and treatment time in comparison to IMRT. currently, Rana et al. used the VMAT planning method on thoracic carcinoma treatment plans to examined the effect of dose computation formulism by means of dosimetry [15] & radio biologically also [16]. The data by these research [15,16] of Rana et al. indicated that the, VMAT have a good possibility of minimizing dose to the lung tissue and heart while giving fine tumor coverage for the thoraic carcinoma cases. Since Rana et al. [15,16] utilized the coplanar arcs in their findings, it would be fascinating to future assessment the effect of non-coplanar arcs on dosimetric outcomes of esophageal carcinoma treatment plans created by the VMAT method.

Conclusion

For cervical and upper thoracic (Group A) cases, the non-coplanar IMRT plan have low dose gradient and better mean dose than the coplanar IMRT plan. For middle and lower thoracic (Group B) cases, the non-coplanar IMRT can diminish the irradiation to the lung, thus lessen the possibility of radiation pneumonia to

the esophageal carcinoma cases. The disadvantage of non-coplanar IMRT is that, even within toxicity limit, it will spread the much dose to the heart and spinal cord.

Table 1
Averaged dosimetric outcomes of target volume in Group A patients

S.no.	Dmax (cGy)	Dmin (cGy)	Dmean (cGy)	CI	HI
Plan 1	6808.73 ± 773.00	5098.82± 932.19	6238.42 ± 624.28	0.77 ± 0.15	1.13 ± 0.05
Plan 2	6619.36 ± 471.28	5145.25 ± 1023.37	6192.27 ± 568.82	0.76 ± 0.17	1.10 ± 0.07
Plan 3	7013.12 ± 821.23	5223.71 ± 919.32	6337.71 ± 644.15	0.82 ± 0.08	1.12 ± 0.09
T value	1.11* - 0.74#	−0.68* - 4.17#	1.47* - 0.85#	0.66* - 0.78#	1.11* - 0.82#
P value	0.341* 0.492#	0.547* 0.056#	0.241* 0.447#	0.562* 0.487#	0.337* 0.481#

Note:* = Plan 2 compared with Plan 1; # = Plan 3 compared with Plan 1.

Table 2
Average dosimetric outcomes of PTV less than 100cc in Group A patients

S.no.	Dmax (cGy)	Dmin (cGy)	Dmean (cGy)	CI	HI
Plan1	7118.68 ± 574.37	5393.02 ± 882.37	6529.32 ± 287.23	0.74 ± 0.21	1.12 ± 0.05
Plan2	6798.31 ± 369.48	5423.07 ± 1047.86	6355.02 ± 271.81	0.73 ± 0.22	1.09 ± 0.05
Plan3	7384.86 ± 419.66	5536.37 ± 823.27	6662.67 ± 48.62	0.78 ± 0.13	1.11 ± 0.08
T value	2.02* - 0.74#	0.32* - 4.13#	5.07* - 0.84#	0.37* - 0.97#	3.33* - 1.45#
P value	0.181* 0.538#	0.766* 0.056#	0.039* 0.484#	0.737* 0.428#	0.021* 0.207#

Note: * = Plan 2 compared with Plan 3; # = Plan 3 compared with Plan 1.

Table 3
Averaged dosimetric outcomes of target volume in Group B patients

S.no.	Dmax (cGy)	Dmax (cGy)	Dmax (cGy)	CI	HI
Plan1	6197.89 ± 1153.97	4414.13 ± 966.13	6231.92 ± 1172.03	0.68 ± 0.15	1.09 ± 0.06
Plan2	6155.71 ± 1022.99	4483.18 ± 1021.03	5381.51 ± 981.98	0.43 ± 0.14	1.10 ± 0.044
Plan3	6197.72 ± 1156.17	4481.52 ± 981.03	5829.12 ± 1054.07	0.69 ± 0.16	1.08 ± 0.07
T Value	0.81* - 1.41#	−0.78* - 1.51#	2.01* 1.02#	7.97* 0.26#	−0.81* - 0.82#
P value	0.431* 0.179#	0.439* 0.148#	0.063* 0.327#	0.001* 0.805#	0.435* 0.435#

Note: * = Plan 2 compared with Plan 1; # = Plan 3 compared with Plan 1.

Table 4
Averaged dosimetric outcomes of normal lung tissue in Group B patients

S.no.	V5 (%)	V10 (%)	V20 (%)	V30 (%)	MLD
Plan1	43.12 ± 8.04	28.85 ± 9.67	16.77 ± 4.92	7.56 ± 4.84	889.51 ± 193.53
Plan2	26.61 ± 10.17	20.09 ± 7.59	10.08 ± 4.31	5.37 ± 3.39	635.03 ± 245.55
Plan3	39.92 ± 7.98	24.91 ± 7.58	12.98 ± 5.08	5.51 ± 3.92	776.48 ± 187.15
T Value	7.51* 3.67#	5.81* 6.71#	6.97* 4.09#	2.32* 4.41#	6.87* 6.65#
P Value	0.001* 0.003#	0.001* 0.001#	0.000* 0.001#	0.020* 0.000#	0.000* 0.000#

Note: * = Plan 2 compared with Plan 1; # = Plan 3 compared with Plan 1.

Table 5
Averaged dosimetric outcomes heart in Group B patients

S.no.	V30 (%)	V40 (%)	V45 (%)	V50 (%)	V55 (%)
Plan1	18.92 ± 10.28	12.93 ± 12.18	9.29 ± 9.53	5.89 ± 6.48	3.29 ± 5.07
Plan2	29.95 ± 16.05	23.31 ± 16.94	16.98 ± 13.19	11.77 ± 10.13	7.37 ± 8.98
Plan3	22.17 ± 14.87	16.25 ± 14.71	10.69 ± 10.36	6.41 ± 7.17	3.74 ± 5.68
T Value	−5.31* - 2.27#	−5.37* - 2.22#	−5.97* - 2.85#	4.87* - 2.08#	−3.42* - 1.27#
P value	0.000* 0.021#	0.000* 0.042#	0.000* 0.009#	0.000* 0.056#	0.003* 0.226#

Note: * = Plan 2 compared with Plan 1; # = Plan 3 compared with Plan 1.

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