Analysis of Dosimetric Indices for Evaluating Intensity Modulated Radiotherapy Plans of Head and Neck Cancer Patients

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INTRODUCTION

Since the commencement of radiation therapy, the delivery of correctly measured radiation dose to the target volumes has always been intended by ensuring the safety of normal parts of the body. Radiotherapy causes damage to the malignant parts, enhances quality of survival, extends the duration of one’s life and provides feasibility for procuring palliation [1]. Among the various treatment modalities, radiation therapy is known as a widely adopted treatment modality for all cancer patients specifically those suffering from head and neck malignancy [2]. This cancer originates in lips, mouth, nose, pharynx and parotid glands. Owing to the extent and anatomical position of this form of cancer, it is very hard to operate them so radiotherapy is preferentially used [3,4].

With further advancements in imaging techniques and radiation dose computing software, it provided the feasibility of visualizing the spatial distribution of radiation doses within the target regions and speeding design of radiotherapy plans. The dose distribution in a whole treatment plan can be summarized and visualized by the help of dose volume histograms (DVH) which are both cumulative or differential [5]. DVHs assist in calculating the dose parameters like minimum dose, maximum dose, mean dose and modal radiation dose. Such a large data may present complications in analyzing the treatment plans instead of clarifying them. To avoid the complications, certain tools are employed in constructing optimum treatment plans like conformity indices (CIs) and homogeneity indices (HIs) which enable us to choose the best plan among others with homogeneous target coverage and maximum sparing of critical regions simultaneously [6]. These indices can integrate all the data and evaluate the quality of treatment plan.

An optimum radiotherapy plan greatly relies on the correct specification on target volumes to gain uniformity in target dose distribution and accuracy in radiation dose reporting. In the reports 50 and 62, provided by ICRU (The International Commission on Radiation Units and Measurements) for external beam radiation therapy, treatment planning volumes like GTV (gross tumor volume), CTV (clinical target volume), PTV
(planning target volume), organs at risk (OARs), planning risk volumes (PRV) and remaining volumes at risk (RVR) were interpreted. CTV encloses GTV along with those regions which are prone to microscopic ailments. PTV surrounds CTV to permit internal motion of target and other movements due to respiration and treatment setup variation. Further, OARs are healthy tissues whose sensitivity to radiation can notably effect therapeutic plans, PRVs take into account the motion of organs at risk during radiotherapy and RVRs helps in the evaluation of late radiation therapy effects [1,7,8]. Treatment planning for IMRT involves the identification and contouring of target volumes (TV) and OARs. ICRU report 83, links closely to the above given reports and thenotions for TV and OAR are described and broaden in detail for IMRT in this report [9]. It discusses about the use of dose volume histograms for specifying the absorbed doses, the set of treatment objectives and the recommendations of the median absorbed dose.

Several authors have presented their work on the calculations of CIs and HIs of target volumes located in various parts of the body by applying various techniques of beam delivery which is given in the literature [10-14]. There is a meager amount of data related to the computation of radical and moderate dose homogeneity indices.

So, this exploration is intended to assess the radical dose and moderate dose homogeneity indices along with other dosimetric quantities like homogeneity and conformity index of planning target volume (PTV) of head and neck cancer patients. Radiation dose is targeted to the tumor through IMRT mode as it possesses the ability of shaping highly conformal beam dose distribution around complex shaped target volumes in head and carcinomas besides sparing the critical parts [15].

MATERIALS AND METHODS

A group of 20 patients suffering from head and neck carcinomas was brought under this sort of investigation. These patients were gone through IMRT using 6MV photon beam from DHX linear accelerator Clinac DHX (Varian Medical Systems Inc., Palo Alto, CA) placed in SKMCH (Shaukat Khanum Memorial Cancer Hospital and Research Centre). Treatment plans were generated using eclipse treatment planning software and on the data sets of computed tomographs of each patient. All the patients were laid in supine position on the treatment couch. This cross-sectional analysis was planned to calculate the homogeneity and conformity indices by RTOG [16], radical dose homogeneity indices (rDHI) and moderate dose homogeneity indices (mDHI) by Oliver [17] for the planning target volumes (PTV) by observing the DVHs of each patient. The following formulas were used for calculating the above mentioned dosimetric indices for PTVs.

**Radical Dose Homogeneity index**, $rDHI = \frac{D_{\text{min}}}{D_{\text{max}}}$

Where $D_{\text{min}}$ and $D_{\text{max}}$ are the minimum and maximum doses respectively within the target volume

**Moderate Dose Homogeneity Index**, $mDHI = \frac{D_{95\%}}{D_{5\%}}$

Where $D_{95\%}$ and $D_{5\%}$ are the 95% and 5% respectively of the target volumes taking dose

Homogeneity $= D_{\text{mean}}/PD$

Where PD is the prescription dose

Conformity Index $= PIV/TV$

Where PIV is the prescription is dose volume and TV is the target volume.

Prescription dose (PD) of 6000cGy (Figure 1a) was given in 30 fractions with 200cGy dose in each fraction. Similarly, PD of 5400cGy was delivered in 27 fractions with 200cGy (Figure 1b) dose in each of the fractions, PD of 5000cGy and 3025cGy (Figure 2a) was given in 25 and 11 fractions with 200cGy (Figure 2b) and 275cGy in each fraction respectively. The planning organs at risk volumes (PRVs) are the spinal cord, left and right parotids.

RESULTS

The dosimetric indices of PTVs computed from the DVHs of twenty head and neck cancer patients are listed in the table displayed below. The mean, standard deviations and coefficient of variance of all of these quantities are also enlisted.

The values of homogeneity ranges from 1.05 to 1.2 given in Table (1), thus, all of these values are in satisfactory limits.

In the light of guidelines presented by RTOG in 1993, conformation quality is established by the extent of values of conformity index (CI). Almost all the values of conformity index came between 1 and 2, which showed that the radiation treatment meet the specified standards of plan of radiotherapy. Cis of three patients exceeded the normal limit. Two plans showed CI up to 2.5 (minor deviation) whereas in one plan CI exceeded 2.5 (major deviation).

The conformity indices of most of the patients remained within the normal limits of 1.0 to 2.0 except the few whose CIs went beyond 2 with values 2.08, 2.22 and 2.86. The deviation of 2.08 and 2.22 are considered to be minor deviations from the normal range but 2.86 come under major deviation. All the homogeneity values were within the limits as suggested by RTOG and none of the value showed deviation greater than two.

Radical dose homogeneity index varied from the minimum value of 0.18 to the maximum value of 0.61. Similarly, moderate dose homogeneity index had a range from 0.84 to 0.92. The coefficient of variances were 4.35%, 24%, 2.20% and 20% for homogeneity, rDHI, mDHI and conformity index respectively. The cumulative and differential DVHs of two of the twenty patients are shown below.

DISCUSSION

The IMRT planning of head and neck cancer patients is very complicated due to emergence of hot spots and cold spots which are the maximum doses and the minimum doses respectively within the target volumes. The causes of their occurrence and the techniques for controlling hot spot and cold spot doses are discussed in the literature [18-21].

In accordance with the statement of Pushpraj Pathak and Sanjeev Vashisht, the perfect homogeneous dose in the planning target volume is shown by the spikes in the differential dose volume histogram (dDVH) whereas in cumulative DVH the perfect homogeneous distribution of dose is depicted by the steep drop of the cumulative dose volume histogram (cDVH) line [22].
Both dosimetric quantities like conformity and homogeneity indices (mDHI and rDHI) cause rapid evaluation of the treatment plan as they indicate the radiation dose distribution in an effective way [23]. According to Tejinderkataria et al., homogeneity index (HI) is such a dosimetric tool that determines uniformity of distribution of radiation doses in the target sites [6]. In their exploration, they determined that HI show dependence on the prescription doses, extent and geometry of the target volumes when they calculated and compared homogeneity indices in the cases of brain cancer, abdominal and thoracic cancer. Moreover, high radiation doses and target volumes of little extent and simple geometry yield smaller values of HI (approaching 0) which indicate better homogeneity of doses. Similar findings were shown by Azza Helal and Abbas Omar, by calculating HI using formulas different from that used by kataria et al., for parotid and liver cancer cases [24].

As stated by Yoo et al., the conformity of radiation dose is an evaluation of dose appropriate to the target volume which is covered by PD [25]. RTOG expressed conformity index as the ratio of prescription is dose volume to the target volume [26].
According to the guidelines given by RTOG, CI values not greater than 1 show that PTV is not covered completely by reference dose. CI equal to 1 leads to an ideality. The values of CI exceeding 2 depict the complete coverage of PTV but the volume of reference dose surrounds healthy cells as well. Only the CI values between 1 and 2 points meet the specified standards of plans of radiotherapy [27].

In this exploration, mean of rDHI from the cohort of 20 patients, came 0.45 through IMRT whereas in the study carried out by Hyo Chun Lee et al., the mean of rDHI was 0.89 during the treatment of breast cancer through TomoDirect by employing integrated boost technique simultaneously with a mean dose of 58.90 Gy for tumor [28]. Mike Oliver et al gave an analysis that moderate dose homogeneity index is independent of steep dose gradients close to the borders of the field when they were carrying out a study on radiotherapy planning by comparing...
Table 1: Dosimetric indices of PTVs of head and neck cancer patients.

<table>
<thead>
<tr>
<th>H/N Pt. No.s</th>
<th>PD (cGy)</th>
<th>Homogeneity</th>
<th>rDHI</th>
<th>mDHI</th>
<th>Conformity index</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>6000</td>
<td>1.11</td>
<td>0.61</td>
<td>0.88</td>
<td>1.59</td>
</tr>
<tr>
<td>2</td>
<td>6000</td>
<td>1.16</td>
<td>0.52</td>
<td>0.86</td>
<td>1.54</td>
</tr>
<tr>
<td>3</td>
<td>6000</td>
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<td>0.67</td>
<td>0.88</td>
<td>1.54</td>
</tr>
<tr>
<td>4</td>
<td>6000</td>
<td>1.15</td>
<td>0.56</td>
<td>0.84</td>
<td>2.86</td>
</tr>
<tr>
<td>5</td>
<td>6000</td>
<td>1.05</td>
<td>0.31</td>
<td>0.90</td>
<td>1.89</td>
</tr>
<tr>
<td>6</td>
<td>5400</td>
<td>1.12</td>
<td>0.50</td>
<td>0.88</td>
<td>1.89</td>
</tr>
<tr>
<td>7</td>
<td>6000</td>
<td>1.13</td>
<td>0.48</td>
<td>0.88</td>
<td>1.82</td>
</tr>
<tr>
<td>8</td>
<td>5000</td>
<td>1.20</td>
<td>0.50</td>
<td>0.86</td>
<td>2.22</td>
</tr>
<tr>
<td>9</td>
<td>6000</td>
<td>1.23</td>
<td>0.47</td>
<td>0.88</td>
<td>1.61</td>
</tr>
<tr>
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<td>0.53</td>
<td>0.90</td>
<td>1.43</td>
</tr>
<tr>
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<td>0.38</td>
<td>0.90</td>
<td>1.25</td>
</tr>
<tr>
<td>12</td>
<td>6000</td>
<td>1.20</td>
<td>0.49</td>
<td>0.88</td>
<td>1.33</td>
</tr>
<tr>
<td>13</td>
<td>3025</td>
<td>1.15</td>
<td>0.52</td>
<td>0.90</td>
<td>1.43</td>
</tr>
<tr>
<td>14</td>
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<td>0.38</td>
<td>0.90</td>
<td>1.30</td>
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<tr>
<td>15</td>
<td>5000</td>
<td>1.13</td>
<td>0.18</td>
<td>0.87</td>
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<tr>
<td>16</td>
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<td>0.30</td>
<td>0.87</td>
<td>2</td>
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<td>17</td>
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<td>0.40</td>
<td>0.91</td>
<td>1.66</td>
</tr>
<tr>
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<td>0.52</td>
<td>0.87</td>
<td>1.85</td>
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<tr>
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<td>0.43</td>
<td>0.92</td>
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<tr>
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<td>Mean</td>
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<td>0.45</td>
<td>0.88</td>
<td>1.74</td>
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<td>Std.Dev</td>
<td></td>
<td>0.05</td>
<td>0.11</td>
<td>0.02</td>
<td>0.36</td>
</tr>
<tr>
<td>CV%</td>
<td></td>
<td>4.35%</td>
<td>24%</td>
<td>2.20%</td>
<td>20%</td>
</tr>
</tbody>
</table>

whole breast radiotherapy against IMRT, tom therapy and 3DCRT [17].

CONCLUSION

The designing of optimum radiotherapy plans involves the accurate specification of the dosimetric indices and uniform and conformal distribution of the tumoricidal dose around the target sites. IMRT gives the feasibility of achieving homogenous beam dose distribution encircling the volumes of interest. In this study, 20 cases of head and neck cancer patients were brought in this study that were treated with IMRT by using 6MV beam from DHX linac and the dosimetric indices of their target were calculated. All the indices (mDHI, rDHI, CI) and homogeneity came within the limits as suggested by RTOG and Oliver with the exception of few cases which might be due to complex geometry, extent of tumor volume and low radiation doses. This exploration can be extended to the calculation of other indices by using beams of higher energy and other treatment techniques on different target volumes of small extent and simple geometry.

REFERENCES

13. Amin A, Kelaney E, M, Ekhambany SK, Guirguis OW. Impact of different IMRT techniques to conformity and normal improve tissue sparing in...


Cite this article