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Research Paper

Conformity and Homogeneity Indexes for Cancer of the Pelvic Region Treated with Three-Dimensional Conformal Radiation Therapy at the National Hospital, Abuja, Nigeria

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Abstract

Anorectal, bladder, cervix and prostate cancers form 32.98% of cancer cases treated with three-dimensional conformal radiation therapy (3DCRT) at the National Hospital Abuja. Conformity Index (CI) and Homogeneity Index (HI) have been identified as efficient tools for performing independent evaluation of radiotherapy treatment plans. This study aims to verify the influence of location of Tumour site, Total volume of the Planned Target Volume (PTV) and Energy of photon beam on Conformity and Homogeneity Indexes. It also aims to establish CI and HI as veritable tools for plan evaluation in the Centre. Forty (40) patients managed with radiation therapy between May and December 2018, were selected for this study. The PTV was delineated based on the recommendations of ICRU 50 and 62. The HI was evaluated according to ICRU 83and CI was evaluated according to the recommendations of ICRU 62. All cases were radical cases and treated with four beams at different direction (box technique). All plans were performed, reviewed and approved on Monaco 5.11 treatment planning system. In all, the percentages of anorectal, bladder, cervix and prostate cases selected were 17.50%, 15.00%, 42.50% and 25.00% respectively. A retrospective analysis of the CI and HI was done using Microsoft Excel 2013.The ideal value of Homogeneity Index (HI) is 0 (zero) while that of Conformal Index (CI) is 1 (unity). The cases were grouped into 2, 4 and 4 for volume of PTV, Tumour site location and energy respectively. The mean CI is 0.95 ± 0.05 while the mean HI is 0.168 ± 0.164 for the total number of cases. Uterocervix has the best CI and HI of 0.9708 ± 0.0244. The difference between the CI and HI of PTV below 1000 cm^3 and above 1000cm^3 is 0.0125 and 0.0016 respectively. The combination of 6MV and 10MV for AP/PA and lateral fields shows the best CI and HI of 0.971 and 0.1046 respectively. However, when tested statistically using paired t-test and ANOVA, these means were found not to be statistically different ($p > 0.05$).The result from this study suggests that HI and CI are not influenced by the size of the PTV, Tumour site location or energy. Conformity and Homogeneity indexes were further confirmed to remain effective tools in the analysis of treatment plans.

Keywords: Anorectal; 3DCRT; ICRU; Conformity index.

Introduction

Three-dimensional conformal radiation therapy (3D-CRT) is based on 3-D anatomic information that uses treatment fields that conform as closely as possible to the target volume in order to deliver adequate dose to the tumour and minimum possible dose to normal tissue [5]. It is the treatment technique used to treat malignant and benign tumours at the Radiotherapy Centre of the National Hospital Abuja, Federal Capital

Territory, Nigeria. It houses Elekta Synergy LINAC with 80 leaves MLCs, a CT simulator and Monaco 5.11 treatment planning system.

Of the 545 patients treated during the first year of operation, anorectal, bladder, cervix and prostate cancer form 32.98% of the total cancer cases treated with 3D-CRT.

Dose homogeneity and dose conformity are independent specifications of the quality of the absorbed dose distribution. Dose homogeneity characterizes the uniformity of the absorbed-dose distribution within the target volume. Dose conformity characterizes the degree to which the high-dose region conforms to the target volume, usually the PTV [7].

The Conformity Index (CI) is calculated as the quotient of the treated volume and the volume of the PTV. It is used as part of optimization procedure and signifies that the treated volume totally encompasses the PTV [6]. The ideal value for CI tends towards Unity (1)

$$CI = \frac{Volume\ \ covered\ \ by\ 95\%\ Isodose}{Total\ Volume\ \ of\ PTV} \quad (1)$$

Several definitions of a Homogeneity Index have been proposed but the preference depends on radiotherapy modality used by individual clinician. However, ICRU 83 suggests the quotient of the difference between the dose at 98% and 2% isodose to the dose at 50% isodose [7]. An HI of zero indicates that the absorbed-dose distribution is almost homogeneous.

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}} \quad (2)$$

This study aims to evaluate the influence of the total volume of PTV, location of tumour site and energy of the photon beam used on CI and HI. It also aims to establish CI and HI as treatment plan evaluation and audit tools in the Centre.

Materials and Methods

Forty (40) cancer patients having tumours in their pelvic region were retrospectively selected from the clinical database. 17.5% for anorectal cancer, 15% for bladder cancer, 25% for prostate cancer and 42.5% for uterocervical cancer.

The target volumes such as Gross Tumour Volume (GTV), Clinical Target Volume (CTV), Planning Target Volume (PTV), Organ at Risk (OAR) and Planning Risk Volume (PRV) were delineated using ICRU 50 and 62 [6, 5]

Treatments were performed with radical intent with a mean dose of 48.095 Gy and 24.45 average numbers of fractions. They were all planned using four beams at different direction (box technique) on Monaco 5.11 treatment planning system.

The Dose Volume Histogram (DVH) was generated following the dose calculation for each patient. The statistics of the DVH was evaluated to obtain the volume covered by 95% isodose (V_{95}), the total volume of the PTV (V_{PTV}), the dose reached in 2% of PTV($D_{2\%}$), the dose reached in 98% of the PTV($D_{98\%}$) and the dose reached in 50% of the PTV ($D_{50\%}$).

V_{95}, V_{PTV}, $D_{2\%}$, $D_{98\%}$ and $D_{50\%}$ were used to compute HI and CI based on Equations (1) and (2) using Data Analysis Toolpak in Microsoft Excel 2016. Pair samples t-test and ANOVA were used for comparison. A p value of 0.05 was considered to be significant.

Results

The average values of HI and CI for all the cases selected are 0.1684 with a standard deviation of 0.1638 and 0.9506 with a standard deviation of 0.0503 respectively. This indicates that the radiotherapy treatment plans made in the department conform to international best standards. The tumour volume was classified into 2 namely; above 1000cm^3 and below 1000cm^3. Twenty-two (22) cases were found to be below 1000cm^3 while eighteen (18) cases to be above 1000cm^3.

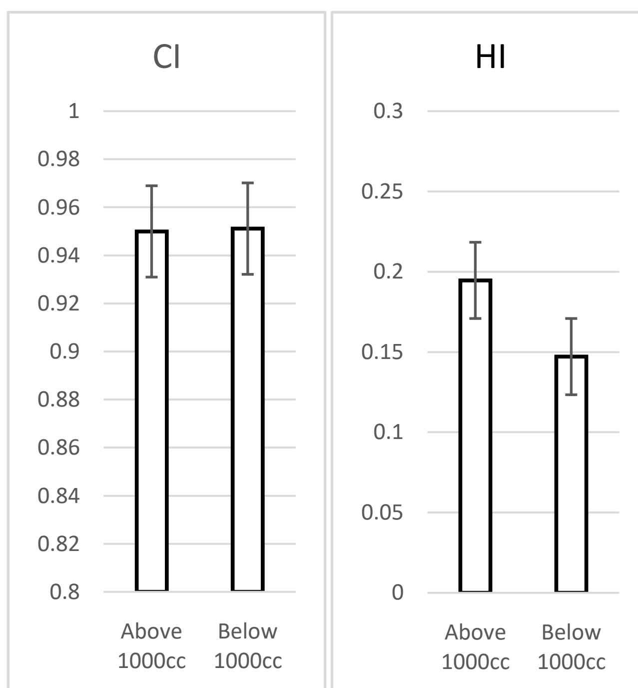

Figure 1. Plots of Average CI and HI for the volume of PTV.

The cases above 1000cm³ were observed to have an average CI of 0.9500 ± 0.0500 and HI of 0.1946 ± 0.2031 while the cases below 1000cm³ have an average CI of 0.9511 ± 0.0517 and HI of 0.1471 ± 0.1241.

From Figure 1 above, best CI was observed in cases below 1000cc as compared to the CI of cases above 1000cc. Also, the HI of cases below 1000cc looked better than cases above 1000cc. However, when analysed statistically using two sampled t-test of unequal variances, it was observed that the CI and HI of both cases are not significantly different ($p>0.05$).

The classification of the cases according to location of the tumour site was organised into four groups namely: anorectal, bladder, prostate and uterocervix. seven (7) cases for anorectal, six (6) for bladder, ten (10) for prostate and seventeen (17) for uterocervix. Anorectal cases have an average CI of 0.9421 ± 0.0513 and HI of 0.1750 ± 0.172, bladder has an average CI of 0.9580 ± 0.0180 and HI of 0.1302 ± 0.0512, prostate has an average CI of 0.9179 ± 0.0769 and HI of 0.2652 ± 0.2715. Finally, uterocervix has an average CI of 0.9708 ± 0.0244 and HI of 0.1224 ± 0.0577.

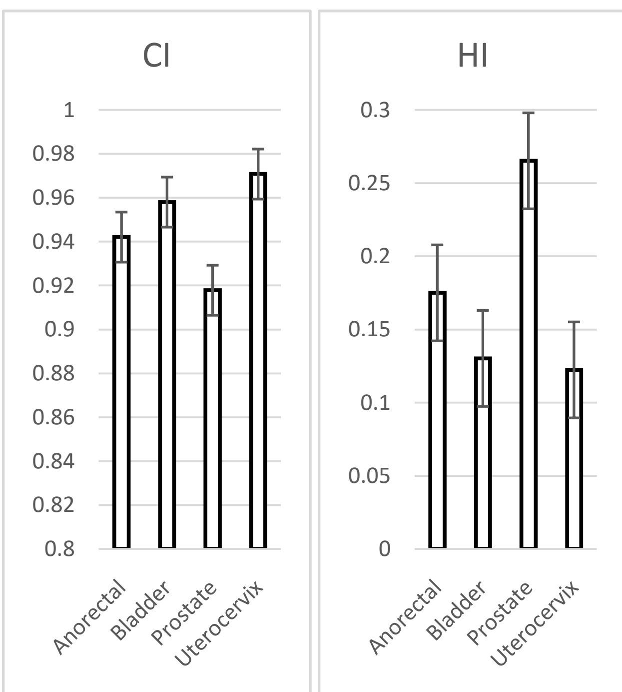

Figure 2. Plots of Average CI and HI for the Tumour Site Location.

Figure 2 shows that the best CI and HI are demonstrated by uterocervix cases, while prostate cases perform the least. Statistical analysis using ANOVA for single factor reveals that there is no statistically significant difference between the means of the CI and HI for different location of the tumour ($p>0.05$).

For all the cases treated with respect to the energy used, they were classified into 6MV for all directions, 6 MV for AP/PA with 10MV for lateral, 10 MV for all directions and 10MV for AP/PA with 15MV for laterals. 6 MV has CI of 0.8504 and HI of 0.4755 (only one case, so no standard deviation), 6MV with 10MV has CI of 0.9710 ± 0.0301 and HI of 0.1046 ± 0.0559, 10MV only has CI of 0.9397 ± 0.0531 and HI of 0.1551 ± 0.1342, 10MV with 15MV has CI of 0.9603 ± 0.0460 and HI of 0.1725 ± 0.1842.

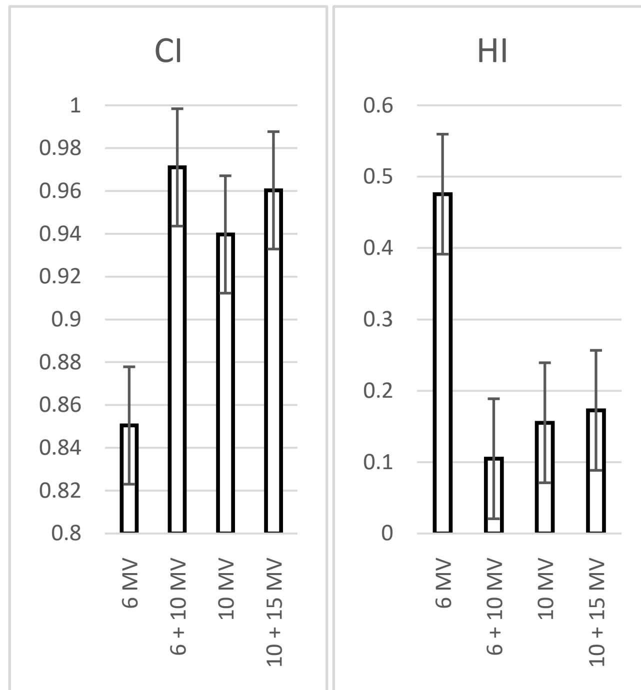

Figure 3. Plots of Average CI and HI based on energy of photon beam.

Figure 3 shows that the best CI and HI are observed when a combination of 6MV is used for AP/PA fields and 10MV for the laterals. However, 6MV alone shows poor performance of both CI and HI. This might not be unconnected with the small number of samples for this particular category.

Statistical analysis using ANOVA reveals that there is no significant difference in both the means of the CI and HI based on the energy used ($p>0.05$).

Discussion

The mean CI of 0.9506 and HI of 0.1685 obtained for all cases shows that plans made in the department have high conformity but fairly good homogeneity.

As regards volume of PTV, a trend is observed in the comparison of the two categories of target volume but upon statistical analyses, it was found that there is no difference in the means of the CI and HI. This indicate that irrespective of how large or small a target volume is, its CI and HI are unaffected. This is in agreement with Kataria *et al*. [3] and Colin *et al*. [9].

Similarly, a good trend is observed in the CI and HI of uterocervix when compared with others such as anorectal, bladder and prostate. However, statistical analysis reveals that there is no association between the location of tumour in the pelvis and their CI and HI. This also agrees with the report of Kataria *et al*. [3]. However it contradicts Knoos *et al*. [10] who found out that it is influenced by location when they compare the CI of pelvic tumours, lungs and advanced breast cancer.

Comparison of the CI and HI based on energy is a novel enquiry and it has been shown statistically that the CI and HI are independent of energy of photon beam used.

The trends of all the cases show a particular group of categories showing better CI and HI than the other but statistical analysis on all shows that the differences are not significant enough to show any association. However, further study with larger number of patients is encouraged and shall be explored in a further study.

Conclusions

This study aids the audit of treatment plans done in the Centre. It confirms the versatility of HI and CI as veritable tools in the evaluation of radiotherapy treatment plans. HI and CI are therefore, being proposed for adoption among other competing evaluation tools for all plans performed in the Centre. It further confirms the independence of HI and CI on the size of tumour volume, tumour site location and energy of photon beam.

Abbreviations

SI: Supero-inferior; XVI: X-ray Volume Imaging; EUD: Equivalent Uniform Dose; CMS: Computerized Medical Systems; DVH: Dose Volume Histogram; EPI: Electronic Portal Image.

Author Contributions

All authors contributed equally to this study and gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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