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Homogeneity Index: Effective tool for evaluation of 3DCRT

Azza Helal [1], Abbas Omar [2]

(1) Medical Physics Unit, Radiology and Intervention Dept., Faculty of Medicine, Alexandria University
(2) Clinical Oncology Dept., Faculty of Medicine, Alexandria University

Correspondence Author
Dr. Azza Helal, PhD
Medical Physics Unit, Radiology and Intervention Dept.,
Faculty of Medicine, Alexandria University, Alexandria, Egypt
Email: helals2002@yahoo.com

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Abstract

Homogeneity index (HI) is a simple scoring tool that quantifies dose homogeneity in the target volume. It is therefore used to evaluate and compare the dose distributions of various treatment plans.

Aim

This study aimed to analyze and compare HI using different formulae in patients with malignant tumors in different regions of the body. It also aimed to find the factors that might influence the homogeneity index.

Methods

The patients were divided into five groups according target location and two groups based on prescribed dose. The mean of HI was calculated and compared for each group using four different formulae. The association between the mean value of HI and the volume of PTV was tested. To find if the prescribed dose has an influence on the value of HI Wilcoxon Signed-Ranks test of SPSS (version 18) used to compare the two groups of prescribed dose.

Results

HI values calculated using formulae A & D were higher than those calculated using formulae B & C. Liver and parotid showed the lowest HI values while chest wall showed the highest HI values. There was a positive correlation between volume of target and some of HI. The best homogeneity was seen by all formulae in the group receiving highest dose.

Conclusion

HI is used for early evaluation of the plan then the plan evaluation is completed with visual inspection of dose distribution & DVH. The parameters of best homogeneity of dose distribution are high prescribed dose, small volume of tumor and simple geometry.

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Introduction

Radiotherapy aims to deliver a therapeutic homogeneous dose distribution to target volume while minimizing the dose to critical organs. The dose distribution can be evaluated using dose-volume histograms (DVHs) and isodose lines. However the large volume of data contained in these histograms and lines are difficult to interpret and time consuming.[1]

So it is essential to find simple and fast tools that analyze dose distribution of treatment plans and help to choose optimum plan which provides maximum homogeneous tumor coverage and protects critical organs at the same time. These tools include conformity index (CI) and homogeneity index (HI) [1]

Homogeneity index (HI) is a fast simple scoring tool that analyzes and quantifies dose homogeneity in the target volume. It is therefore used to evaluate, compare the dose distributions of various treatment plans and choose the best plan among available plans [2-4]. It can also serve as a guide for development of future technology and treatment protocols as it can compare various devices or techniques. [5] This in turn, will help us to find the means by which treatment plans can be improved in future. [6]

Although HI basically indicates the ratio between the maximum and minimum dose in the target volume and the lower value indicates better homogenous dose distribution within this volume various formulae have been also described for its calculation.[7]

Although improvements in the homogeneity should improve local control and decrease complications but there is limited information regarding possible correlation between clinical data and HI and no studies till date suggest that the plans with better HI are associated with a better clinical outcome as compared to those plans with inferior HI. [8-12] Also there is a few data regarding factors affecting this index.[13]

Aim

This study aimed to analyze and compare HI using different formulae in patients with malignant tumors in different regions of the body. It also aimed to find the factors that might influence the homogeneity index.

Methods

A retrospective analysis of treatment plans for 50 patients with different sites of malignant tumors including liver (HCC), parotid, whole breast, post-mastectomy chest wall (PTV & supraclavicular region (SC) were performed (ten patients for each site). Target volumes and organs at risk were outlined. All the plans were created according to the standard protocols followed in Alexandria Clinical Oncology Department. HCC was treated using 3-5 beams according to position of the lesion. Parotid was planned using two wedged oblique fields and direct open lateral field. Whole breast was treated using medial and lateral wedged tangential fields. Chest wall was treated using matched supraclavicular and medial and lateral wedged tangential fields. The dose was prescribed at ICRU normalization point. [14,15]. The dose prescribed was different according to tumor site; 60 Gy for liver and parotid and 50 Gy for chest wall and whole breast. The aim of the plan was to keep adequate target coverage. It was achieved by; adjusting the MLCs edge by adequate margin around PTV, change the energy, gantry & wedge angle and adjusting the weighting of the beams. Dose volume histograms and its statistics were analyzed. Then HI was calculated using four different formulae;

Formula A: D_{max}/D_{min}; where D_{max} and D_{min} represent the maximum and minimum point dose in the target volume respectively. As the calculation of true minimum or maximum dose is sensitive to the dose-calculation parameters, such as grid size and placement, and the high dose gradient so it is not reliable to use the true minimum or maximum dose in practice as the doses may be very high or very low if only point doses are considered. This is the reason for choosing the maximum or minimum dose in a volume ($D_{5\%}$, $D_{95\%}$, $D_{2\%}$ & $D_{98\%}$ etc.) rather than at a point.[1]

Formula B: $D_{5\%}/D_{95\%}$; where $D_{5\%}$ and $D_{95\%}$ are minimum dose to 5% & 95% of the target volume respectively.[7]

For formula A & B the ideal value is 1 and it increases as the plan becomes less homogeneous.

Formula C: $D_{5\%}–D_{95\%}/D_p$; where $D_{5\%}$ and $D_{95\%}$ are the minimum dose in 5% and 95% of the target volume and D_p is the prescribed dose. [4]

Formula D: $D_{2\%}–D_{98\%}/D_p$; where $D_{2\%}$ and $D_{98\%}$ are the minimum dose to 2% and 98% of the target volume and D_P is the prescribed dose. [1,4,16]

For formula C & D; HI is more sensitive than for formula A & B. The ideal value is zero and it increases as homogeneity decreases.

This study had approval of Institutional Review Board as a retrospective one in which confidentially of records was considered

Statistical analysis

The patients were divided into 5 groups based on location of the target and 2 groups based on the prescribed dose. The mean of HI was calculated and compared for each group using the above mentioned four formulae. The association between the mean value of HI calculated by a particular formula for each group and the volume of PTV was tested. To find if the prescribed dose has an influence on the value of HI Wilcoxon Signed-Ranks test of SPSS (version 18) used to compare the two groups of prescribed dose. A P value of less than 0.05 was taken as statistically significant.

Results

The mean value of HI calculated using four different formulae for 50 cases; liver, parotid, whole breast and chest wall (PTV and supraclavicular region) were summarized in table 1. Analysis of HI by all formulae revealed that D_{max}/ D_{min} shows significantly higher HI values for all regions compared to $D_{5\%}/ D_{95\%}$ ($P < 0.0001$) and $D_{2\%}$-$D_{98\%}$ /Dp also shows significantly higher HI values for all regions compared to $D_{5\%}$-$D_{95\%}$ /Dp ($P < 0.0001$).

For all formulae, liver and parotid showed the lowest HI values while PTV and supraclavicular region showed the highest HI values. HI values for intact breast plans were laying in-between liver & parotid (with best homogeneity) and PTV and supraclavicular region (with worst homogeneity).

The analyses of the correlation between volume of PTV and mean of HI for each region showed a positive correlation between volume of PTV and some values of HI, some of them reached a significant value (Table 1).

The doses prescribed were 5000 cGy & 6000 cGy. Table 2 showed that the lowest values of HI by all the formulae (best homogeneity) were seen in the group receiving highest dose (6000 cGy) while the highest values of HI were seen in the group receiving lowest dose (5000 cGy). When analyzed

Table 1. Mean value of HI for different tumor location calculated using four different formulae and mean volume of PTV. It shows also r & p values for the correlation between volume of PTV and mean value of HI.

Site	No of patients	D_{max}/D_{min}	$D_{5\%}/D_{95\%}$	$D_{5\%}$-$D_{95\%}$/ D_P	$D_{2\%}$ - $D_{98\%}$/ D_P	Volume of PTV
Liver R, p value	10	1.14 0.66, 0.035	1.08 0.53,0.116	0.07 0.53,0.111	0.10 0.66,0.038	691
Parotid R, p value	10	1.15 0.50, 0.138	1.08 -	0.08 -	0.11 -	109
Whole breast R, p value	10	1.20 -	1.10 -	0.09 -	0.13 -	1225
PTV R, p value	10	1.33 0.66, 0.039	1.13 -	0.12 -	0.18 0.56, 0.095	460
Supraclav. R, p value	10	1.30 -	1.18 -	0.16 -	0.20 -	26

Table 2. Mean values of HI of four formulae according to the dose prescribed.

P.D	No of patients	D_{max}/D_{min}	$D_{5\%}/D_{95\%}$	$D_{5\%}$-$D_{95\%}$/ D_P	$D_{2\%}$- $D_{98\%}$/ D_P
5000	30	1.27	1.13	0.13	0.17
6000	20	1.14	1.08	0.08	0.10
P value		<0.001	<0.001	<0.001	<0.001

statistically, significant difference in HI value was found between the groups.

Discussion

Both CI and HI are good indicators for dose distribution in the target volume so they are used to evaluate the optimum plans. Although many studies were focused on the CI and factors influence it, little studies were worked on HI and factors affecting.

In the current study HI calculated using D_{max}/D_{min} & $D_{2\%}$-$D_{98\%}$ /Dp showed higher values for all regions compared to those calculated using $D_{5\%}/D_{95\%}$ and $D_{5\%}$-$D_{95\%}$ /Dp respectively. So it is preferred to use $D_{5\%}/D_{95\%}$ and $D_{5\%}$-$D_{95\%}$ /Dp in plan evaluation. This is in accordance with the results of Kataria T, et al 2012[1] (they used $D_{1\%}$ instead of $D_{2\%}$.)

In the current study; for all formulae; liver and parotid showed best homogeneity because of simple geometry and high prescribed dose while PTV and supraclavicular region in chest wall irradiation showed worst homogeneity because of complex geometry and low prescribed dose. In Kataria T, et al 2012[1] study; best homogeneity was found in thoracic and abdominal cases while inferior homogeneity was seen in brain tumors. They attributed the results to various other factors as prescribed dose and target geometry rather than the location of the target. Since, in their study, the inferior homogeneity in case of brain lesions could be a reflection of the lower prescribed doses. In the current study the inferior homogeneity in case of breast and chest wall could be also due to complex geometry and low prescribed dose.

In the current study; a positive correlation between volume of PTV of each region and some of HI values was found. This means that the volume of PTV of these regions influence dose distribution homogeneity. This is supported by Kataria T, et al 2012[1] study; they suggested a trend towards improved homogeneity as the target volume reduces. In contrast to the results of this study, Collins et al 2006[6], found that HI was independent on shape, size and complexity of skull base tumors using cyberknife radiosurgery system.

The best homogeneity was seen by all formulae in the group receiving highest dose i.e., 6000 cGy, while the worst homogeneity was seen in the group receiving lowest dose i.e., 5000 cGy. This is in accordance with the results of Kataria T, et al 2012[1]. They suggested a trend towards improved HI as the prescribed dose increases as slight variation of dose across the target volume became significant in relation to the prescribed dose.

Conclusion

HI is a quick quality indicator for optimum plan; it gives a general overview about the dose gradient within the target. For plan evaluation, HI should be used in combination with visual inspection of dose distribution & DVH not replacing them as it does not provide us with the position of minimum or maximum point dose, the volume receiving these doses and it does not give any information about the dose within OARs so it should be used for early evaluation of the plan then the plan evaluation is completed with visual inspection of dose distribution & DVH.

The lowest values of HI were found in the group receiving the highest dose, HI also tends to decrease as the volume of PTV decreases. Tumor with complex geometry as chest wall showed highest values of HI. So in summary, the parameters of best homogeneity of dose distribution are high prescribed dose, small volume of tumor and simple geometry.

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