

# Conformity Index and Homogeneity Index of the Postoperative Whole Breast Radiotherapy

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## Abstract

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**BACKGROUND:** The treatment of breast cancer involves a multidisciplinary approach in which radiotherapy plays a key role.

**AIM:** The conformity index and the homogeneity index are two analysis tools of a treatment plan using conformal radiotherapy. The purpose of this article is an analysis of these two parameters in the assessment of the treatment plans in 58 patients undergoing postoperative radiotherapy of the whole breast.

**MATERIALS AND METHODS:** All 58 patients participating in the study had a conservatively treated early-stage breast cancer. The treatment was performed using a standard regimen of fractionation in 25 fractions up to a total dose of 50 Gy. Dose-volume histograms were generated for both plans with and without segmental fields.

**RESULTS:** Pair samples t-test was used. The technique with segmental fields allowed us more homogeneity distribution when compared to standard two tangential field techniques. The HI values were  $1.08 \pm 0.01$  and  $1.09 \pm 0.01$  for segment and technique with two tangential fields ( $p < 0.001$ ). The DHI values were  $0.92 \pm 0.02$  and  $0.901 \pm 0.01$  for segment and technique with two tangential fields ( $p < 0.001$ ). The CI values were  $1.38 \pm 0.02$  and  $1.43 \pm 0.3$  for segment and technique with two tangential fields ( $p = 0.0018$ ).

**CONCLUSION:** The results showed that the conformity and the homogeneity index are important tools in the analysis of the treatment plans during radiation therapy in patients with early-stage breast cancer. Adding segment fields in the administration of radiotherapy in patients with conservatively treated breast cancer can lead to improved dosage homogeneity and conformity.

## Introduction

The treatment of breast cancer involves a multidisciplinary approach in which radiotherapy plays a key role. Conservative surgical treatment is the most commonly used surgery in the treatment of early-stage breast cancer. More randomized studies in the last two decades have confirmed the effectiveness of the combined way of treating breast cancer using conservative surgery and postoperative radiotherapy [1]. The postoperative radiotherapy in the conservatively treated breast cancer with a standard fractionation regime is considered as a standard in the treatment. Since the very beginning of the radiotherapy until today the main goal is a homogeneous delivery of the maximum dose in the target volume with minimal involvement of the organs at risk. Progress made during the last decades in the medical technology, and the dosimetry software

systems enable us to achieve these goals. As a result of these achievements today we can visualize the dose distribution in the target and organs at risk and create different treatment plans for the same patient. Dose distribution in these plans can be displayed and analyzed in the form of isodose curves and dose-volume histograms (DVH) by which we can define certain parameters and make a qualitative and quantitative analysis of the generated plans.

However, a large number of data contained in the dose-volume histograms, the large number of curves and lines can complicate the analysis of a radiation plan and therefore emerges the need to use a tool that simply can provide an analysis of the coverage of the target volume with an appropriate dose and dose homogeneity in it. The conformity index and the homogeneity index are two analysis tools of a treatment plan using conformal radiotherapy [2].

The purpose of this article was to present the three parameters – the conformity index and the homogeneity indexes in breast cancer patients undergoing postoperative radiation treatment of breast and to assess the impact of adding the segment fields onto these parameters in the plans for 58 patients undergoing conservatively treated breast cancer.

## Materials and Methods

The study involved 58 patients with previously surgically and oncologically treated breast cancer who had a clear defined indication for a breast treatment under recommendations by the Radiation Therapy and Oncology Group (RTOG), to administer selective radiotherapy. All patients participating in the study had a conservatively treated early-stage breast cancer.

Radiotherapy treatment was performed using 3D conformal radiotherapy. The target volume and prescription dose were defined by 50-62 recommendations of the ICRU (International Commission on Radiation Units and Measurements). Thus, the target volume of the breast should be covered by 95% of the prescribed dose, or by 95% isodose line. PTV in patients with a conservative surgical treatment includes glandular breast parenchyma excluding 5mm from the superficial skin area, which is also defined by the study protocol as PTV- eval.

To indicate the target volumes and organs at risk Varian SomaVision™ software was used. The three-dimensional conformal radiotherapy plans were calculated using the system Varian Eclipse™ for treatment planning.

All plans in the study were created by the clinical protocol of the institution. The computerized tomography was used to define the target volume and organs at risk and other structures of interest. The target volumes as the Clinical target volume (CTV) and the planned target volume (PTV) were defined according to the definition by the International Commission on Radiation Units and Measurements (ICRU) Report 50.

The target volume was determined by a radiological oncologist while the treatment planning preceded the following goals: the medium coverage of the planned target volume to be 95% of the prescribed dose while the maximum dose in the target volume to be not greater than 107% of the prescribed dose. The target volume selected for calculating the homogeneity index is the planned target volume for evaluation (PTV-eval). The treatment was performed using standard regime of fractionation in 25 fractions up to a total dose of 50Gy.

Dose-volume histograms were generated and

evaluated in cooperation with the medical physicist until the desired plan was reached. The angles of the rays, the angles of the filters and the weight ratio were used to optimize the coverage of the planned target volume and to minimize the dose to the ipsilateral lung, heart and contralateral breast. The irregular breast contour not always reaches the required homogeneity of isodose schedule in the target volume. In the case where it was impracticable to reach the appropriate dose schedule using two tangential fields, segment fields were added by the need for better dose coverage.

After creating the dose-volume histograms and using the required parameters the Conformity index of radiation was calculated. It is defined as a ratio between the volume covered by the reference isodose which according to ICRU is 95% isodose and the target volume designated as planned target volume (PTV) equ 1

$$\text{Conformity index}_{\text{RTOG}} = V_{\text{RI}} / \text{TV} \quad (\text{equ 1})$$

Where  $V_{\text{RI}}$  = Reference isodose volume and  $\text{TV}$  = Target volume.

Dose homogeneity index (DHI) is defined as a ratio between the dose reached in 95% of the PTV volume ( $D_{\geq 95\%}$ ) and the dose reached in 5% ( $D_{\geq 5\%}$ ) of the PTV volume.

$$\text{i.e. DHI} = D_{\geq 95\%} (\text{within PTV}) / D_{\geq 5\%} (\text{within PTV}) \quad (\text{equ 2})$$

HI (Homogeneity index) is a ratio between the maximum dose in the target volume and the reference isodose.

$$\text{Homogeneity index}_{\text{RTOG}} = I_{\text{max}} / \text{RI} \quad (\text{equ 3})$$

Where  $I_{\text{max}}$  = maximum isodose in the target, and  $\text{RI}$  = reference isodose.

Pair samples t-test was used for comparison. A p value of 0.05 was considered to be significant.

## Results

The mean values of homogeneity index for both techniques are outlined in Table 1. The technique with segmental fields allowed us more homogeneity distribution when compared to standard two tangential field techniques. The HI values were  $1.08 \pm 0.01$  and  $1.09 \pm 0.01$  for segment and technique with two tangential fields. The difference was significant  $p < 0.001$ .

**Table 1: Comparative analysis of homogeneity index (HI)**

Type of treatment	Variable	Descriptive Statistics HI			p value
		Mean ± SD	SD Error	min - max	
Conservative	Segment	1.08 ± 0.01	0.0011	1.06 – 1.1	t = 13.7 P < 0.001
	Without segment	1.09 ± 0.01	0.0013	1.07 – 1.12	

t (Student t-test).

The mean values of dose homogeneity index for both techniques are outlined in Table 2. Technique with segmental fields allowed us more dose homogeneity distribution when compared to standard two tangential field technique. The DHI values were  $0.92 \pm 0.02$  and  $0.901 \pm 0.01$  for segment and technique with two tangential fields. The difference was significant  $p < 0.001$ .

**Table 2: Comparative analysis of dose homogeneity index (DHI)**

Type Of Treatment	Variable	Descriptive Statistics (DHI)			P Value
		Mean $\pm$ SD	SD Error	Min - Max	
Conservative	Segment	$0.92 \pm 0.02$	0.0022	0.88 – 0.96	$t = 10.6$ $P < 0.001$
	Without Segment	$0.901 \pm 0.01$	0.0019	0.85 – 0.93	

t (Student t-test).

The mean values of dose conformity index (CI) for both techniques are outlined in table 3. Technique with segmental fields allowed us more conformity distribution when compared to standard two tangential field technique. The CI values were  $1.38 \pm 0.02$  and  $1.43 \pm 0.3$  for segment and technique with two tangential fields. The difference was statistically significant ( $p = 0.0018$ ).

**Table 3: Comparative analysis of conformity index (CI)**

Type of treatment	Variable	Descriptive Statistics CI rtog			p value
		Mean $\pm$ SD	SD Error	min - max	
Conservative	Segment	$1.38 \pm 0.2$	0.026	1.14 – 2.17	$t = 3.28$ $P = 0.0018^{**}$
	Without segment	$1.43 \pm 0.3$	0.037	1.17 – 3.04	

t (Student t-test).

## Discussion

The Homogeneity index (HI) and the Conformity index (CI) are two tools for analysis of treatment plans in the conformal radiotherapy. However, different definitions and formulas have been described by various authors and organizations, but none has been described as an ideal or near ideal for calculating the Homogeneity index [3, 4].

HI (Homogeneity index) which is a ratio between the maximum dose in the target volume and the reference isodose, was calculated according to the formula: Homogeneity index<sub>RTOG</sub> =  $I_{max}/RI$  (equ 3) Where  $I_{max}$  = maximum isodose in the target, and RI = reference isodose. The ideal value is 1, and it increases as the plan becomes less homogeneous.

Homogeneity index should not be viewed as a tool that could replace the qualitative analysis of the plan, section by section, as well as the detection of illogical high or low doses. It can be used as a supplement after a sufficient plan based on dose gradients and dosage distribution in the target volume,

and normal structures are already reached [5, 6].

Homogeneity index (HI) confirmed that the dosage distribution in the plans with segment fields is more homogeneous with a mean of 1.08, compared to the plans with conventional tangential fields where the mean is 1.09. This difference is statistically significant with a value of  $p < 0.001$  (Table 1).

The maximum PTV dose in plans with segment fields was reduced. The results attained in this study correlate with the results of previously published studies that suggest that the dosage distribution in plans with segment fields is better compared to the standard tangential fields [7-9].

Dose homogeneity index (DHI) is defined as a ratio between the dose reached in 95% of the PTV volume ( $D_{\geq 95\%}$ ) and the dose reached in 5% ( $D_{\geq 5\%}$ ) of the PTV volume.

$$\text{i.e. DHI} = D_{\geq 95\%} (\text{within PTV}) / D_{\geq 5\%} (\text{within PTV})$$

The analysis of DHI values resulted in a mean of 0.92 in plans using segmented fields, and 0.90 in plans without segmental fields, as confirmed in the analysis of HI, that the homogeneity of the dosage in plans using segmented fields is statistically significantly better than the dosage homogeneity in plans without segmental fields (Table 2).

Conformity index is introduced as an extension of section-by-section dosimetric analysis and dose-volume histograms and can be defined as an absolute value resulting from the ratio between a fraction of the tumour volume and the volume covered with the certain isodose line.

As in the case of the homogeneity index, the conformity index represents another tool that can help in the comparison and selection of the most appropriate treatment plan, as when it comes to conformal radiotherapy, and brachytherapy and stereotaxic radiotherapy too.

We used this tool in the study to compare the two plans generated for patients with breast cancer - the plans using two tangential fields and plans using additional segment fields.

Conformity index of radiation was defined by the RTOG definition as a ratio between the volume covered by the reference isodose, which according to ICRU is isodose of 95%, and the target volume designated as PTV (Planned target volume) and presented by the equation

$$CI_{rtog} = V_{ri}/TV$$

The conformity index can be easily interpreted. The conformity index equal to 1 corresponds to the ideal dose coverage or high conformity. The conformity index greater than one indicates that irradiated volume exceeds the target volume and covers part of the healthy tissue. In the case where the conformity index is less than one, it

means that the target volume is partially radiated. RTOG criteria define a range of conformity index values to determine the quality of conformity since the value up to 1 can rarely be reached. If the conformity index is between 1 and 2, the treatment is in accordance with the protocol; if it is between 2-2.5 and 0.9-1 it is considered that there is a minor deviation of the protocol; if it is greater than 2.5 and less than 0.9 it is considered as a severe deviation from the protocol [10, 11].

The analysis of 58 patients undergoing postoperative radiotherapy after previous conservative surgical treatment resulted in a mean of 1.43 for the conformity index in plans with two tangential fields and mean of 1.38 in plans with segment fields. It could be noted that there is a better conformity in the plan using segmented fields and that difference is statistically significant  $p = 0.0018$  (Table 3).

Regarding the clinical significance of the homogeneity index and the conformity index, there are several open questions concerning the weight of their interpretation and the limited information about a possible correlation between clinical data and these theoretical parameters. Essentially it would be logical that improving the homogeneity and the conformity should lead to better local control and reduction of complications by the radiation treatment, but so far there are no studies confirming that plans with better homogeneity index are associated with better clinical response or better local control over plans with inferior homogeneity index [11].

In conclusion, considering the analysis and the results, it can be concluded that the conformity index and the homogeneity index are important tools in the analysis of the treatment plans during radiation therapy in patients with early-stage breast cancer. Adding segment fields in the administration of radiotherapy in patients with conservatively treated breast cancer can lead to improved dosage homogeneity and conformity.

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