J. Korean Soc Ther Radiol Oncol 2002;20(1):24～33

# Improved Breast Irradiation Techniques Using Multistatic Fields or Three Dimensional Universal Compensators

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**Purpose**: In order to improve dose homogeneity and to reduce acute toxicity in tangential whole breast radiotherapy, we evaluated two treatment techniques using multiple static fields or universal compensators.
**Materials and Methods**: 1) Multistatic field technique: Using a three dimensional radiation treatment planning system, Adac Pinnacle 4.0, we accomplished a conventional wedged tangential plan. Examining the isodose distributions, a third field which blocked overdose regions was designed and an opposing field was created by using an automatic function of RTPS. Weighting of the beams was tuned until an ideal dose distribution was obtained. Another pair of beams were added when the dose homogeneity was not satisfactory. 2) Universal compensator technique: The breast shapes and sizes were obtained from the CT images of 20 patients who received whole breast radiation therapy at our institution. The data obtained were averaged and a pair of universal physical compensators were designed for the averaged data. DII (Dose Inhomogeneity Index: percentage volume of PTV outside 95～105% of the prescribed dose), $D_{max}$ (the maximum point dose in the PTV) and isodose distributions for each technique were compared.
**Results**: The multistatic field technique was found to be superior to the conventional technique, reducing the mean value of DII by 14.6% ($p$ value<0.000) and the $D_{max}$ by 4.7% ($p$ value<0.000). The universal compensator was not significantly superior to the conventional technique since it decreased $D_{max}$ by 0.3% ($p$ value=0.867) and reduced DII by 3.7% ($p$ value=0.260). However, it decreased the value of DII by maximum 18% when patients' breast shapes fitted in with the compensator geometry.
**Conclusion**: The multistatic field technique is effective for improving dose homogeneity for whole breast radiation therapy and is applicable to all patients, whereas the use of universal compensators is effective only in patients whose breast shapes fit inwith the universal compensator geometry, and thus has limited applicability.

**Key Words**: Breast radiotherapy, Dose homogeneity, Intensity modulated beam, Compensator

## Introduction

Two wedged tangential beam technique is generally used in whole breast radiotherapy of patients who received a breast-conserving surgery. This technique, which commonly uses two tangential parallel opposed beams with a lateral and/or medial wedge, conventionally delivered radiation based on two-dimensional (2-D) treatment planning predictions which use the data of body contour and the location of the lung only on the central plane. The three-dimensional (3-D) analysis of this 2-D technique demonstrated that there could exist large dose inhomogeneity inside the target volume. Moreover, the degree of inhomogeneities could readily exceed the ICRU recommended range (7% to −5% of the prescribed dose).[1～8] This inhomogeneity is partially due to the complicated 3-D shape of the breast and in part due to the fact that the treatment volume is composed of radiologically different tissues. The variation of the body contour along the superior-inferior direction of the breast causes the decrease of source-skin-distance (SSD) from the dose prescription plane, and consequently, higher doses are irradiated in these regions. The existence of low density tissues in the lung causes a lower attenuation rate of the primary beam

This work supported by: National mid- and long-term nuclear R&D program.
Submitted November 17, 2001, accepted February 4, 2002
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and, thus, additional high dose regions in medial and lateral aspects of the breasts are produced. These overdose of radiations is believed to cause many side effects such as the inferior cosmetic results, breast pains, and pneumonitis.[9~13)]

During the last few decades, many researches have been performed and many techniques which improve the dose homogeneity have been proposed. All the proposed techniques can be understood as a method being able to modulate the intensities of the beam in a desired pattern within the treatment volume while keeping the tangential arrangement of the beams.

Among the proposed techniques, the most traditional one is using physical compensators fabricated directly or indirectly from the image information of CT for the patient body contour.[14~16)] Dosimetric compensators are also used in order to take account into radiologically different tissue characteristics in the treatment volume.[17~19)] Despite that these custom made compensators promise a superior dose homogeneity, their implementation is impractical at many institutions. Recently, as inverse planning softwares become available, the intensities of beams are computed in a sophisticated way by using an inverse radiation treatment planning system (RTPS) and the intensity modulated beams are delivered with static or dynamic multileaf collimators.[20~21)] Forward planning method also demonstrates that a better homogeneity can be attained by using eight or more fields whose shapes are determined from the information of the three-dimensional pre-planned isodose distributions or electronic portal images (EPI).[22~26)] Although these methods are capable of reducing the inhomogeneities, they have limitations in applying to routine clinical procedures for many institutions since an additional inverse planning module or intensive time investment to planning are required.

Therefore, in this study, we investigate the capability of two techniques for improving the dose homogeneity while being still effective in terms of time and cost. The first is a multistatic field technique that employs multiple subfields together with the conventional wedged fields. The second is using 3-D universal compensators which compensate the shape irregularity of the breast along the superior and inferior directions as well as the transverse direction.

## Material and Methods

### 1. Multistatic field technique

Multistatic field technique has the same concept as forward Intensity Modulated Radiation Therapy (IMRT) in that it modulates the beam intensities based on the pre-planned dose distribution. Multistatic field subdivides the radiation dose which was conventionally delivered from one port, into a couple of fields. The procedure is described in the followings

(1) Determine an optimal conventional treatment plan using a 3-D RTPS (Adac Pinnacle 4.0). For the plan, we used patients CT images which cover from 2 cm above the superior boarder of the treatment region to 2 cm below the inferior boarder. Planning Target Volume (PTV) was drawn to encompass the breast tissue, allowing a margin to avoid build up and penumbra regions. The wedge angle and the dose weights of two tangential beams were determined to provide the best dose homogeneity in the PTV within the constraint of maintaining $V_{<95}$ (normalized volume receiving less than 95% of the prescribed dose) less than 5% in the dose-volume-histogram (DVH). We selected 4 MV or 6 MV of the photon beam energy according to each patient's breast size. In the dose calculations, density correction was made to estimate accurately the actual dose delivery to the lung and to the PTV. Conventional wedges compensate the body contour only on the transverse section and thus, overdose regions were observed in the superior and inferior regions of the breast.

(2) After choosing either medial or lateral tangential field, we copied the field. The edge of the copied field was modified in beam's eye view, to block the region exceeding 105% of the prescribed dose and after that, the opposed field was created by copying and opposing the newly designed field. Note that the wedge is still used in the subfield.

(3) The half of the overdose percentage in the region was set to the initial beam weight of the subfield. And then the weight was iteratively tuned until a satisfactory DVH was attained.

(4) When a satisfactory DVH was not obtained, one more pair of fields were added and step (2) and (3) were repeated. The schematic diagram of the above mentioned beam splitting method is illustrated in Fig. 1. The designed multi-

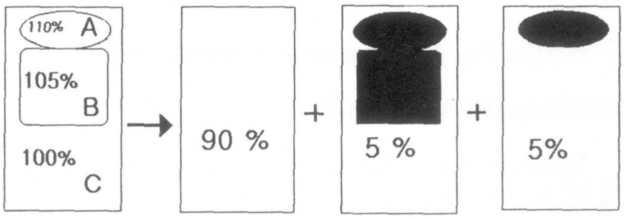



**Fig. 1.** Schematic diagram explaining the beam splitting method. While 100% of the prescribed dose needs to be irradiated to region C, the doses in region A and B which receive the 110% and 105% of the prescribed dose respecltively, need to be reduced. The first subfield which has 5% of the beam weight is designed to block region A and B. The second subfield with 5% of beam weight is designed to block the region A additionally. The number at the center of each subfields indicates the beam weight.

ple fields can be delivered by using blocks or multileaf collimators.

**2. The Use of Universal Compensators**

A pair of universal compensators were designed from the CT image data of 20 patients who received whole breast radiation therapy between 1999 and 2000 in Yonsei Cancer Center.

Breast shape and size of each patient were measured in the following method. On the transverse central plane of the treatment region, the origin of the body coordinates was located at the center of the plane. A horizontal axis (h) and an vertical axis (v) were drawn from the origin (Fig. 2A). Two intersection points, which were the intersection of h axis and the body contour and the intersection of v axis and the body contour were connected, and the middle of the connected line was taken as the origin of the second coordinates (h’, v’). The distances from the h’ axis to the chest wall and to the breast contour were measured at every 3 cm on the second coordinates (Fig. 2B). Same procedure was repeated on the superior and inferior consecutive slices of 1cm thickness of the CT images by translating the first coordinates. When the body coordinate was translated, the origin of the first coordinates was maintained at the same position on the transverse plane (Fig. 2A). The measured data were averaged and interpolated so that they have 1cm intervals. A pair of universal compensators for the obtained data were designed by using a missing tissue compensation method which was described in detail in other literature.[27~29] These physical compensators took into account the beam divergency and the attenuation difference which varied with

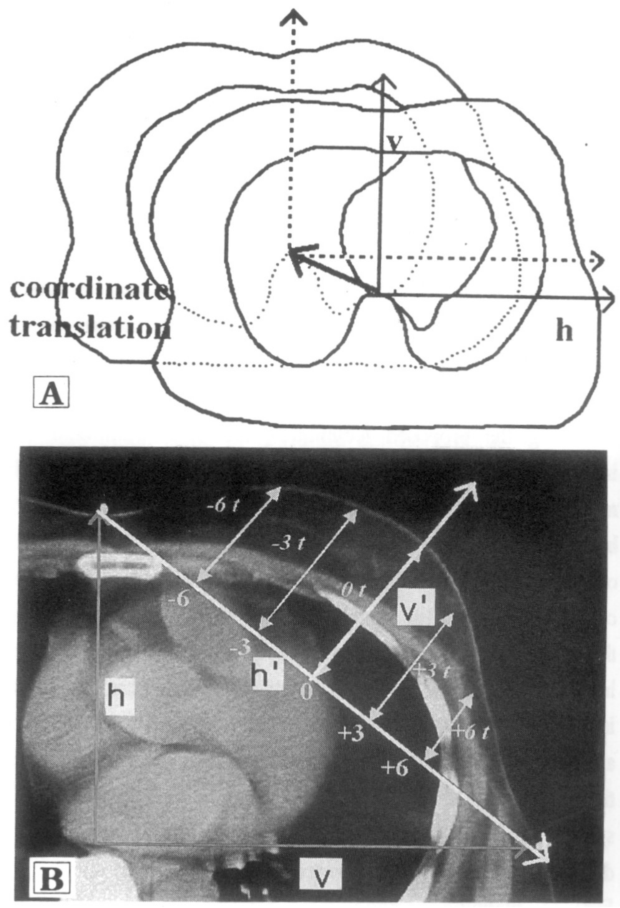



**Fig. 2.** Schematic diagram of coordinates setting. (A) The first coordinates setting on the body center. (B) The second coordinates setting to measure breast shape and size.

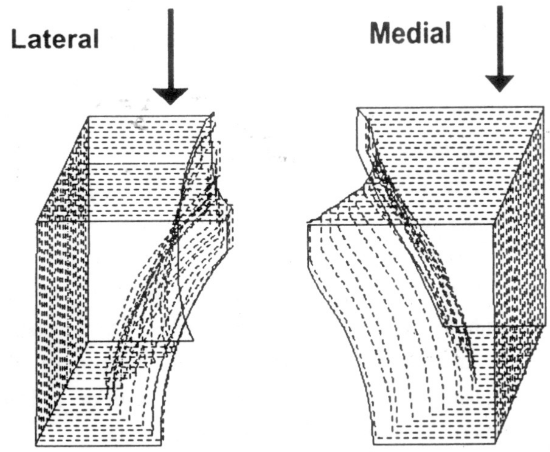
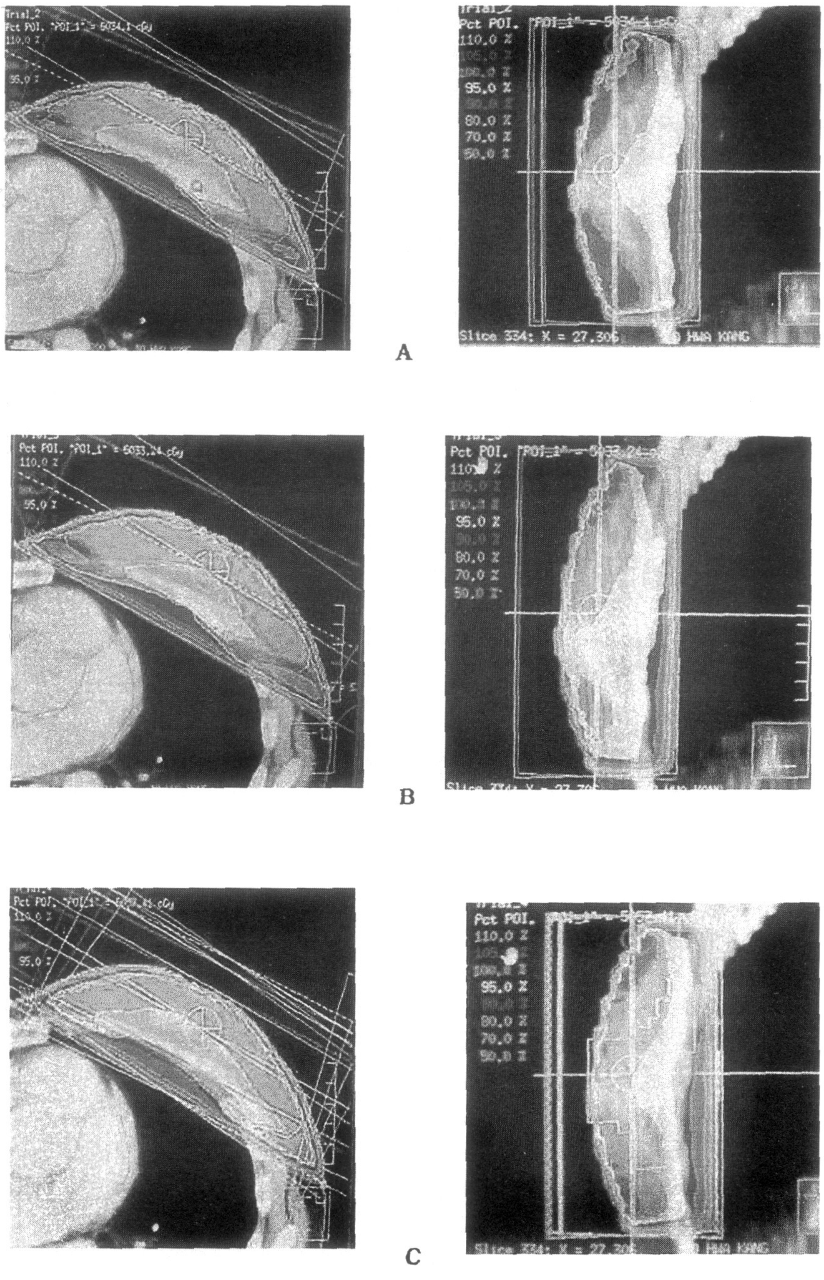



**Fig. 3.** Designed 3-D universal compensators for the left breast. The beam is directed from the top to bottom on the plane. The compensators were designed to be located on the block tray which is 65 cm apart from the source. The material is paraffin of mass density of 0.95 $g/cm^3$.

the distance between the source and the compensator location. The designed 3-D compensators are illustrated in Fig. 3. The designed geometry was entered to the Adac Pinnacle 4.0 in order to validate the effectiveness of the compensator.

For the evaluation of current experimental techniques, we generated three different plans utilizing conventional technique, universal compensator technique and mutistatic technique for each patient. The dose homogeneity of the three



A

B

C

**Fig. 4.** Isodose distribution for patient No. 8 on the transverse central plane (left) and the reconstructed sagittal plane (right). yellow=95%, red=100%, blue=105%, skyblue=110% of the prescribed dose. (A) conventional plan, (B) universal compensator plan, (C) multistatic field plan. Multistatic plan improve the dose homogeneity about 5~10% on the central axial and sagittal planes. Universal compensator plan improve the dose homogeneity 5~10% on central plan but somewhat overcompensate on the sagittal plan.

techniques were evaluated by comparing their isodose distributions and the cumulative DVHs quantitatively. For the quantization of DVHs, we measured two quantities, the percentage volume irradiated less than 95% ($V_{<95}$) and the percentage volume irradiated greater than 105% ($V_{>105}$) of the prescribed dose, and computed the dose inhomogeneity index ($DII = V_{<95} + V_{>105}$). The maximum point dose in the PTV ($D_{max}$) were measured as well. The effects to the lung were evaluated by measuring the volumes which received greater than 50% and 100% of the prescribed dose.

## Results

### 1. Comparison of Isodose Distributions

#### 1) Multistatic field technique

For the analysis, we compared isodose distributions of conventional treatment plan with multistatic treatment plan on axial and sagittal planes of treatment region. For all patients studied, the dose distributions on the central axial and sagittal planes were improved, compared with the conventional ones (Fig. 4). On the central axial plane, the percentage doses normalized to the prescribed dose were reduced about 5～10% in the medial and lateral aspects of the PTV as shown in Fig. 4. On superior and inferior regions of the sagittal plane, the dose homogeneity were improved about 5～10%. The maximum dose in the PTV ($D_{max}$) was reduced about 1.7～8.2% as shown in Table 1.

#### 2) Universal compensators

Among 10 patients studied, 3 patients showed a significant improvement and 3 patients changed for the worse. For the rest of patients the dose homogeneity was similar to the conventional plan.

When the compensator improved the dose homogeneity as presented in Fig. 4 (patient No. 8 in Table 1), it was improved as much as multistatic field plan, reducing the high dose region by maximum 10%, from 110% to 100%. High dose regions were reduced by 5%, from 110% to 105% and from 105% to 100% in medial and lateral aspects of the PTV as well as on the sagittal plane. However, when the compensator worsened the dose homogeneity, the medial and lateral apexes of the PTV received extremely high dose, increasing the maximum dose in the PTV ($D_{max}$) up to 5.6% while central apex of the breast being severely underdosed (Table 1).

### 2. Comparison of DVHs

#### 1) Multistatic field technique

Graphic representation of the DVHs which correspond to patients No. 8 and No. 4 are illustrated in Fig. 5 and 6, respectively, and the analysis of DVHs for all patients are summarized in Table 1 and 2. The statistics are given in Table 3.

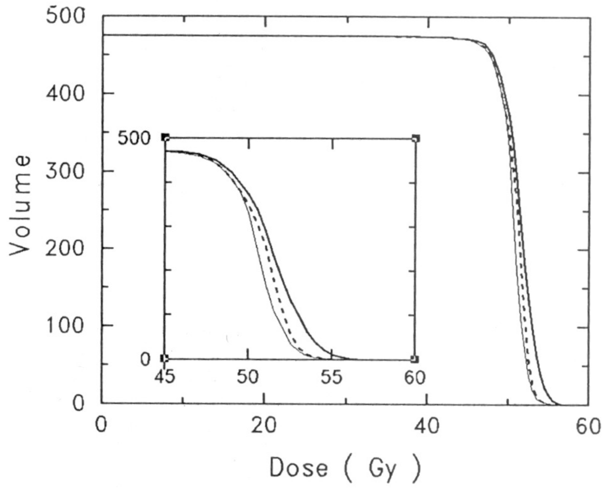



**Fig. 5.** DVH in the PTV of patient No. 8. Thick solid line; conventional plan, thin solid line; universal compensator plan, dotted line; multistatic field plan. Multistatic field plan and compensator plan reduce the high dose volume.

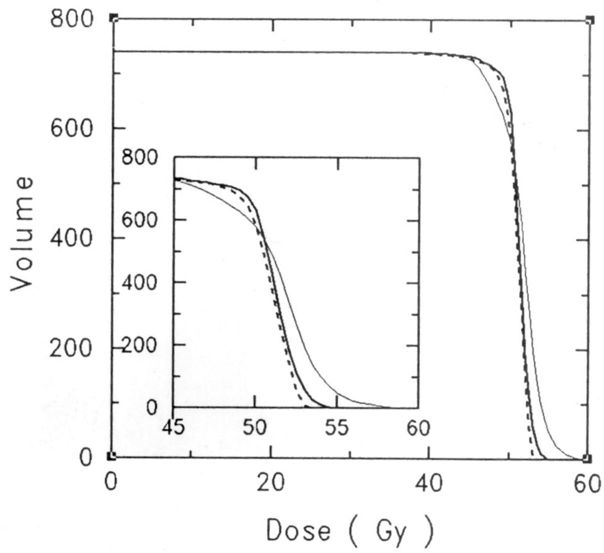



**Fig. 6.** DVH in the PTV of patient No. 4. Thick solid line; conventional plane, thin solid line; universal compensator plan, dotted line; multistatic field plan. Compensator plan increases the high dose volume.

$V_{<95}$ and $V_{>105}$ in Table 1 are normalized to the total planning target volume and $L_{>50}$ and $L_{>100}$ in Table 2 are normalized to total lung volume. The dose data are normalized to the prescribed dose of 50.4 Gy.

The analysis of the DVHs demonstrated that the multistatic field technique significantly improved the dose homogeneity; that is, the mean value of DII was reduced from 23.6% to 9.0% and mean value of $D_{max}$ was reduced from 113.7% to 109.0% (Table 1 and 3). The multistatic technique maintained the minimum dose about the same as those of the conventional wedged technique, but it reduced the maximum point dose in the PTV and the volume received more than 105% of the prescribed dose. As for the dose in the ipsilateral lung, the multistatic field technique did not reduce 50% of the prescribed dose irradiation but it reduced the high dose irradiated (dose>100%) volume to the lung.

The number of added subfields deviated from 1 to 4 depending on the size and shape irregularity of the breast. However, adding only two more subfields was enough to reduce the high dose region for 5 out of 10 patients.

**Table 1. A Dose-Volume Histogram Analysis in PTVs of Treatment Plans for 10 Patients**

| Patient | PTV | Conventional | | | | Universal compensator | | | | Multistatic fields | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | volume ($cm^3$) | $V_{<95}$* | $V_{>105}$† | DII‡ | $D_{max}$§ | $V_{<95}$ | $V_{>105}$ | DII | $D_{max}$ | $V_{<95}$ | $V_{>105}$ | DII | $D_{max}$ |
| 1. | 340.3 | 8.9 | 8.8 | 17.7 | 113.8 | 22.2 | 0.0 | 22.2 | 106.5 | 10.7 | 2.6 | 13.3 | 111.2 |
| 2. | 359.2 | 3.3 | 21.8 | 25.1 | 115.6 | 10.4 | 13.0 | 23.4 | 110.5 | 3.3 | 9.0 | 12.3 | 111.1 |
| 3. | 483.1 | 5.0 | 16.8 | 21.8 | 113.1 | 5.7 | 13.3 | 18.9 | 111.1 | 6.9 | 3.8 | 10.7 | 110.4 |
| 4. | 740.9 | 4.5 | 26.4 | 30.9 | 115.8 | 12.0 | 23.6 | 35.6 | 118.7 | 4.4 | 1.3 | 5.7 | 109.1 |
| 5. | 238.7 | 5.0 | 10.2 | 15.2 | 109.2 | 5.3 | 8.7 | 14.1 | 113.0 | 5.2 | 0.6 | 5.8 | 107.5 |
| 6. | 389.2 | 4.0 | 16.3 | 20.3 | 113.2 | 17.9 | 8.5 | 26.4 | 113.7 | 4.6 | 4.0 | 8.6 | 108.6 |
| 7. | 395.3 | 3.8 | 28.2 | 32.0 | 111.8 | 6.2 | 7.8 | 14.0 | 113.0 | 5.8 | 3.7 | 9.5 | 107.6 |
| 8. | 475.0 | 4.1 | 20.4 | 24.5 | 113.1 | 5.9 | 4.2 | 10.1 | 114.3 | 5.7 | 5.5 | 11.2 | 110.0 |
| 9. | 402.0 | 1.7 | 31.9 | 33.6 | 116.1 | 4.0 | 16.7 | 20.7 | 122.6 | 2.8 | 2.7 | 5.5 | 107.3 |
| 10. | 401.1 | 4.4 | 10.6 | 15.0 | 114.9 | 7.0 | 6.2 | 13.2 | 111.0 | 6.7 | 1.0 | 7.7 | 106.8 |
| Mean | | 4.5 | 19.5 | 23.6 | 113.7 | 9.7 | 10.2 | 19.9 | 113.4 | 5.6 | 3.4 | 9.0 | 109.0 |
| S.D | | 1.8 | 7.7 | 6.8 | 2.1 | 6.1 | 6.7 | 7.6 | 4.6 | 2.2 | 2.5 | 2.8 | 1.6 |

*$V_{<95}$ : percentage volume irradiated less than 95% of the prescribed dose.
†$V_{>105}$ : percentage volume irradiated more than 105% of the prescribed dose.
‡DII : Dose Inhomogeneity Index = $V_{<95}+V_{>105}$, §$D_{max}$ : The maximum point dose in the PTV

**Table 2. A Dose-Volume Histogram Analysis in the Lung of Treatment Plans for 10 patients**

| Patient | Conventional | | | Universal compensator | | | Multistatic fields | | |
|---|---|---|---|---|---|---|---|---|---|
| | $L_{>50}$ (%) | $L_{>100}$ (%) | $DS_{max}$ (%) | $L_{>50}$ (%) | $L_{>100}$ (%) | $DS_{max}$ (%) | $L_{>50}$ (%) | $L_{>100}$ (%) | $DS_{max}$ (%) |
| 1. | 7.3 | 3.1 | 109.3 | 6.7 | 0.2 | 100.8 | 7.1 | 2.8 | 106.9 |
| 2. | 2.4 | 0.0 | 93.8 | 2.3 | 0.0 | 94.0 | 2.5 | 0.0 | 94.0 |
| 3. | 7.6 | 1.3 | 119.4 | 7.7 | 1.2 | 111.2 | 7.5 | 1.2 | 110.5 |
| 4. | 22.6 | 5.4 | 106.3 | 23.5 | 13.6 | 112.7 | 22.0 | 4.2 | 105.2 |
| 5. | 12.1 | 1.9 | 105.9 | 12.2 | 1.4 | 106.5 | 12.0 | 1.4 | 103.2 |
| 6. | 13.8 | 1.9 | 109.1 | 13.3 | 1.2 | 111.7 | 14.1 | 1.0 | 106.5 |
| 7. | 9.7 | 1.7 | 107.5 | 9.6 | 2.1 | 108.7 | 9.4 | 0.0 | 101.3 |
| 8. | 7.5 | 1.4 | 110.3 | 7.3 | 0.5 | 107.9 | 7.0 | 0.9 | 107.1 |
| 9. | 17.9 | 5.0 | 111.5 | 18.2 | 8.2 | 118.7 | 17.6 | 0.5 | 104.0 |
| 10. | 3.9 | 0.0 | 101.2 | 3.9 | 0.1 | 102.8 | 3.7 | 0.0 | 100.0 |
| Mean | 10.5 | 2.2 | 107.4 | 10.5 | 2.9 | 107.5 | 10.3 | 1.2 | 103.9 |
| S.D | 6.3 | 1.8 | 6.7 | 6.5 | 4.5 | 7.0 | 6.2 | 1.4 | 4.6 |

*$L_{>50}$ : percentage lung volume irradiated more than 50% of the prescribed dose.
†$L_{>100}$ : percentage lung volume irradiated more than 100% of the prescribed dose.
‡$DS_{max}$ : the maximum point dose in the lung

### 2) Universal compensators

The analysis of DVHs of the universal compensator plans gave similar results as the isodose analysis. The total volume outside the prescribed limits was reduced for 3 patients but increased for 3 patients. The mean value of DII reduced by 3.7% from 23.6% to 19.9% (Table 1, Table 3) and the $D_{max}$ was only reduced by 0.3% from 113.7% to 113.4%.

Even though the inhomogeneity index (DII) were improved, the maximum point dose in the PTV were either about the same as the conventional plan or increased for some patients due to the irregular shape of breast caused by the surgery. As for the ipsilateral lung, the compensator gave about the same level of radiation to the ipsilateral lung for 8 patients while the irradiated volume of the prescribed dose was increased for 2 patients.

## Discussion and Conclusions

In the current study, we demonstrated that the multistatic field technique was superior to the conventional one in increasing the dose homogeneity throughout the PTV for all patients studied. In particular, this technique was effective especially in reducing the high dose regions by decreasing $V_{>105}$ more than 6% (Table 1), and thus can decrease the probability of complications and improve the cosmesis of the breast.

In the ipsilateral lung, the volume receiving 100% of the prescribed dose in the multistatic technique was reduced about half on average, but the small difference of the irradiated ipsilateral lung volumes (average 1% reduction of irradiated volume) seems unlikely to be of clinical significance.

Other studies which used intensity modulated beam incorporating an 3-D dose calculation together with full CT data reported similar results. For example, the use of optimized intensity profiles obtained by an inverse planning algorithm, reported about 8% reduction of high dose region along the superior-inferior direction and 30% reduction in surrounding soft tissues.[21] Forward IMRT techniques which computed the shaped beam profile from the information of EPI and added 3 or 4 pairs of subfields to the conventional wedged fields, also reported the reduction of the high dose region in the PTV by 9% on average.[23, 24] Using 4 pairs of the fields whose profiles were computed by the equivalent path length method are shown to be effective since it reduced the high dose region by 1.4% (−10% mean lung dose).[25] The study which added just one pair of shaped wedged subfields to the open wedged field also demonstrated that the high dose region could be reduced to as much as 7%.[26]

Compared with the reported results in other studies (ref, 21～26) the dose homogeneity improvement in the present study is higher although smaller number of subfields (1～2 pairs) are utilized. The reason for this is that conventional plans showed a relatively large dose variance in our study and thus, dose homogeneity was considerably improved by using the multistatic field technique. The causes for this high inhomogeneity can be explained as follows : Most of patients, specifically 80% of patients, were planned with 4 MV energy while 6 MV or higher energy was used in other studies. The second cause was that the breast shapes of some patients became severely distorted after the breast-conserving surgery. Therefore, the use of multistatic field technique would be beneficial to patients whose dose distribution in the breast is highly inhomogeneous.

For most radiotherapy departments, the time used for the planning procedure and the delivery of treatment are important issues. The current multistatic field technique uses relatively smaller number of subfields since wedges are incorporated into subfields, and thus, does not increase the planning time that much. The time required to design additional fields varies depending on the skill of the planner. In the present study, it took about 5～10 minutes in designing

Table 3. Analysis of the Differences between the Three Treatment Delivery Methods. ANOVA Test in SPSS for window (version 10.0) was Used

| Comparison | $V_{<95}$* | $V_{>105}$† | DII‡ | $D_{max}$§ |
|---|---|---|---|---|
| | *p* value | | | |
| Conventional vs compensator | 0.010 | 0.014 | 0.260 | 0.867 |
| Conventional vs MFT | 0.227 | 0.000 | 0.000 | 0.000 |
| Compensator vs MFT | 0.063 | 0.008 | 0.001 | 0.010 |
| | Difference in mean volume (%) | | | |
| Conventional vs compensator | 5.2 | −9.3 | −3.7 | −0.3 |
| Conventional vs MFT ‖ | 1.1 | −16.1 | −14.6 | −4.7 |
| Compensator vs MFT | −4.1 | −6.8 | −10.9 | −4.4 |

*$V_{<95}$ : percentage volume irradiated less than 95% of the prescribed dose.
†$V_{>105}$ : percentage volume irradiated more than 105% of the prescribed dose.
‡DII : Dose Inhomogeneity Index = $V_{<95}+V_{>105}$
§$D_{max}$ : the maximum point dose in the PTV
‖MFT : Multistatic Field Technique.

one pair of subfields. Most of the increased time in planning varies heavily depending on the dose computation speed which, in turn, relies on the quality of the computer hardware.

The treatment delivery time will increase. But the increment will be acceptable even though blocks are used for subfields delivery. This is because the monitor units are similar to those of the conventional technique and other machine parameters such as the gantry angle and the wedge settings are the same as those of conventional treatment. In addition, if multileaf collimators is used for blocked subfields, the increment of delivery time would be insignificant.

Another concern is the scattered dose which the contralateral breast receives. This could cause late development of secondary malignancy in the contralateral breast. Although the dose scattered to the contralateral breast was not quantitatively analyzed in the current study, it is expected to be maintained about the same as the conventional technique if the subfield doses are delivered by multileaf collimators instead of cerrobond blocks.

Therefore, the multistatic field technique is evaluated as not only effective in improving the dose homogeneity but also practical in delivering treatment, and thus, it is able to be implemented in clinics for a routine three-dimensional breast radiotherapy treatment.

In the case of the universal compensators, however, the effectiveness varied patient to patient. In order to configure the relation between the breast volume and the compensator effectiveness, we compared the DVH analysis data for patients with similar PTVs which are drawn to be proportional to the breast volumes. As was seen in Table 1, the compensator effects were quite different even though the patients 6 and 7 and patients 9 and 10 have very similar PTVs. Thus, the breast shape as well as its size are considered as the determining factors for the compensator applicability. The dose homogeneity was significantly improved only when the breast shape fits in the compensator geometry. Otherwise, the dose homogeneity was worse than the conventional technique. Not only overall homogeneity was reduced but also a large and/or deep cold area could be produced, which is a serious problem since it can cause the loss of the tumor control. Therefore, this technique has limitation in its applicability and required thorough validation for its benefit in the planning process. In order to reduce this limitation and to increase the applicability, we may categorize breast sizes and shapes into several different groups and design several different compensators.

In terms of the efficiency in planning process, the planning time using universal compensators can be much shorter than the multistatic field technique by inputting the beam profile data of the universal compensators into the RTPS and storing as a pseudo-wedge.

In summary, we investigated the suitability of the multistatic field technique and the use of universal compensators to a routine 3-D whole breast radiotherapy. The multistatic field technique is evaluated suitable to be implemented as a routine treatment technique since it can achieve superior dose homogeneity to the conventional technique without intensive investment of time to planning and treatment.

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국문 초록

# Multistatic Field 또는 3차원 공용보상체를 사용한 유방의 방사선 조사법의 평가

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**목 적** : 유방보존 수술 후 행하는 방사선치료인 2문 대칭조사(two tangential field technique)시 나타나는 선량분포의 불균일성을 효과적으로 개선하기 위하여, multistatic fields의 사용법과 공용보상체 사용법을 제시하고 평가하였다.

**대상 및 방법** : 1) Multistatic field 방법 : 3차원의 치료계획용 software (RTP)를 이용하여, wedge를 사용한 2문 대칭조사의 최적의 치료계획을 시행한 후 beam's eye view상에서 과조사가 일어나는 부분을 가리워 주도록 blocked field를 설계하고, 그 beam에 대칭되는 beam을 만들었다. 기존의 2개의 tangential field와 추가된 field의 weighting을 최적의 선량분포를 갖도록 조절하였다. 2) 공용보상체 사용법 : 1999와 2000년에 본원에서 whole-breast radiotherapy를 받은 환자 20명의 유방의 크기를 측정하고 평균하여 표준 유방 모델을 만들었다. 이 모델에 대하여 공용보상체를 설계하고, 설계된 공용보상체의 geometry를 RTP에 입력한 후 환자의 치료 계획을 수행하였다. 2문 대칭조사 치료 계획과, multistatic fields의 경우 그리고 공용 보상체를 사용한 경우의 치료계획에서의 불 균일도(DII : 처방선량의 95-105%를 벗어나는 PTV의 부피의 백분율), 최대선량 값($D_{max}$) 그리고 등가선량 곡선을 각각 비교하였다.

**결 과** : Multistatic field 방법은 DII의 평균값을 14.6% ($p$ value<0.000) 낮추고 $D_{max}$를 4.7% ($p$ value<0.000) 낮춤으로써, 전통적인 2문 대칭 조사법보다 우수한 방법으로 확인되었다. 반면에 공용보상체의 사용은 평균 DII를 3.7% 낮추지만($p$ value=0.260) 평균 $D_{max}$는 거의동일 하여(0.3% 감소, $p$ value = 0.867), 전통적인 방법보다 우수성이 크게는 없는 것으로 평가되었다. 그러나 환자의 체곡선이 보상체와 잘 일치하는 경우에는 DII가 18% 까지 감소하였다.

**결 론** : Multistatic field 방법은 모든 환자에 대하여 선량분포의 균일성을 전반적으로 향상시키는 효과적인 방법으로 평가되는 반면 공용보상체의 사용은 보상체의 크기가 환자의 체 윤곽과 잘 일치하는 경우만 효과적으로, 적용의 범위에는 한계가 있는 방법으로 평가되었다.

**핵심용어** : 유방보존 수술 후 방사선치료, 선량분포, 세기변조 조사선, 보상체