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Contralateral Breast Dose Reduction Using a Virtual Wedge

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Purpose: To evaluate the contralateral breast dose using a virtual wedge compared with that using a physical wedge and an open beam in a Siemens linear accelerator.
Materials and Methods: The contralateral breast dose was measured using diodes placed on a humanoid phantom. Diodes were placed at 5.5 cm (position 1), 9.5 cm (position 2), and 14 cm (position 3) along the medial-lateral line from the medial edge of the treatment field. A 6-MV photon beam was used with tangential irradiation technique at 50 and 230 degrees of gantry angle. Asymmetrically collimated 17×10 cm field was used. For the first set of experiment, four treatment set-ups were used, which were an open medial beam with a 30-degree wedged lateral beam (physical and virtual wedges, respectively) and a 15-degree wedged medial beam with a 15-degree wedged lateral beam (physical and virtual wedges, respectively). The second set of experiment consists of setting with medial beam without wedge, a 15-degree wedge, and a 60-degree wedge (physical and virtual wedges, respectively). Identical monitor units were delivered. Each set of experiment was repeated for three times.
Results: In the first set of experiment, the contralateral breast dose was the highest at the position 1 and decreased in order of the position 2 and 3. The contralateral breast dose was reduced with open beam on the medial side (2.70±1.46%) compared to medial beam with a wedge (both physical and virtual) (3.25±1.59%). The differences were larger with a physical wedge (0.99±0.18%) than a virtual wedge (0.10±0.01%) at all positions. The use of a virtual wedge reduced the contralateral breast dose by 0.12% to 1.20% of the prescribed dose compared to a physical wedge with same technique. In the second experiment, the contralateral breast dose decreased in order of the open beam, the virtual wedge, and the physical wedge at the position 1, and it decreased in order of a physical wedge, an open beam, and a virtual wedge at the position 2 and 3.
Conclusion: The virtual wedge equipped in a Siemens linear accelerator was found to be useful in reducing dose to the contralateral breast. Our additional finding was that the surface dose distribution from the Siemens accelerator was different from a Varian accelerator.

Key Words: Virtual wedge, Contralateral breast, Tangential irradiation

Introduction

The radiation dose to the contralateral breast during primary breast irradiation is of concern as the secondary breast cancer can be induced from low to moderate radiation dose. The fact that breast cancer can be induced by irradiation[1~3] has led to the speculation that the cancer incidence of the contralateral breast may be increased by radiation scattered from curative radiation to the affected side. Although the carcinogenic effect of scattered radiation to contralateral breast is still controversial, some studies have reported slightly increased incidence of cancer in contralateral breast.[4~9]

Extensive studies were performed to investigate the dose to

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the contralateral breast, and also to develop methods to reduce it.[10~13] Previous studies have shown that the radiation dose to the contralateral breast varies from a few percent to over 10% of the prescribed dose depending on the applied treatment technique. In order to reduce the dose to the contralateral breast, it has been recommended that the half beam with a custom-made block and the wedge filter on the medial side should not be used, unless custom-made breast shields are employed.[12,13]

Previous studies have shown that the surface dose within a radiation field is increased with a virtual wedge (Siemens Inc., US) or a dynamic wedge (Varian Inc., US) compared to conventional physical wedge.[14,15] This is due to the fact that physical wedge blocks the scattered radiation passing through the gantry head and the collimators. Additional studies evaluating the contralateral breast dose with a dynamic wedge for a Varian machine have reported the reduced contralateral dose with dynamic wedge versus physical wedge.[16,17] However, these studies have incorporated the increase of monitor unit associated with the use of the wedges, either virtual or physical, in their experiments as their results were normalized to a target dose. Thus, it has not been clarified whether the increased dose of the contralateral breast was due to the use of the wedge or due to the increase in monitor unit. Furthermore, the Siemens Primus machine differs from Varian machines in many aspects, such as gantry clearance, the distance from the collimators to the isocenter, and the leakage scattered form the gantry head and the collimators. Therefore, the scatter effect to the contralateral breast may be different for each machine type.

To evaluate and analyze the cause of the difference, the radiation dose to the contralateral breast was measured and intercompared among Siemens-type virtual wedged beam, a physical wedged beam, and an open beam.

Materials and Methods

A humanoid phantom (Alderson Rando Phantom) and diodes (Isorad-p, Sun Nuclear Corp., USA) were used to measure the doses to the contralateral breast. Experimental phantom setup was different from the actual patient setup in that patient's arm is normally raised and no extremity was attached to the phantom. Diodes used in this experiment were calibrated to the dose at the depth of maximum dose in water by irradiating the diodes with their sensors at 100 cm from the target using a 6 MV photon beam. The diodes were aligned with the long axis along the cranio-caudal direction to minimize their directional dependencies and were placed at 5.5 cm (position 1), 9.5 cm (position 2), and 14 cm (position 3) along the medial-lateral line, respectively, from the medial edge of the field as shown in Fig. 1.

Tangential irradiation technique with an asymmetric collimator jaw was used. For the first set of experiment, four different treatment setups were devised and executed, accordingly. These could be divided into two groups depending on the use of either physical wedge or virtual wedge. The physical wedge group consisted of the setup with a 30-degree wedge on the lateral side only and another with a 15-degree wedge on both sides. Identical setups were used for the virtual wedge group. The employed beam energy, field size, and the gantry rotation angles were 6 MV, 17×10 cm (asymmetrically collimated), and 50 and 230 degrees, respectively. The weight of the medial beam was 17% higher than that of the lateral beam for the optimal isodose distribution. For all four plans, dose was prescribed to the 100% isodose line that covers the entire breast except some skin build-up regions. As the same weighting ratio was used for the medial and lateral beams, the coverage of the isodose line was nearly identical for all four setups.

The second set of experiment was carried out to clarify the

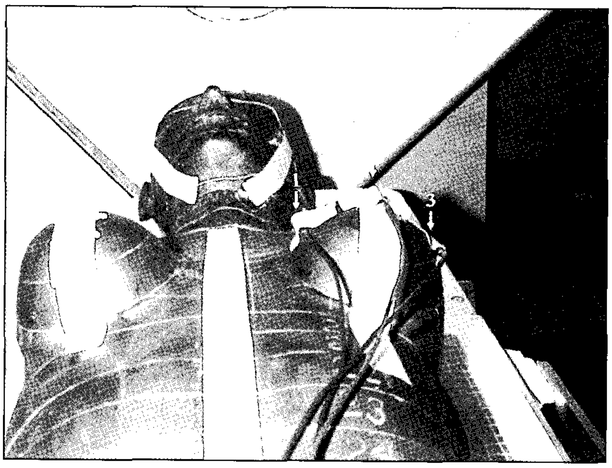

Fig. 1. Phantom and diodes setup for measurement of the doses on the contralateral breast and the breast under treatment. The directional dependence of the sensitivity of diodes was adequately considered in their setup. The diodes with the proper build thickness were calibrated to detect the dose at maximum depth for 6 MV X-rays. From the medial side toward the lateral side, the positions of the diodes are noted as positions 1, 2, and 3, consecutively.

Table 1. Relative Doses in Percentage (Normalized to the Prescribed Dose) Measured on the Surface of the Contralateral Breast*

	Physical wedge		Virtual wedge	
	Lateral side (0°+30°)	Both sides (15°+15°)	Lateral side (0°+30°)	Both sides (15°+15°)
Position 1	4.55±0.00*	5.51±0.00	4.34±0.03	4.45±0.00
Position 2	2.50±0.00	3.69±0.03	2.38±0.00	2.49±0.00
Position 3	1.29±0.03	2.12±0.06	1.13±0.03	1.22±0.00

*mean±standard deviation

Table 2. Doses Measured in cGy on the Surface of the Contralateral Breasts when 400 Monitor Units were Used

	Open	Physical wedge 15°	Physical wedge 60°	Virtual wedge 15°	Virtual wedge 60°
Position 1	20.10±0.10*	18.13±0.06	13.50±0.00	18.63±0.06	15.23±0.06
Position 2	12.43±0.06	13.90±0.00	12.40±0.00	11.63±0.06	9.7±0.06
Position 3	6.60±0.00	8.87±0.06	9.40±0.00	6.37±0.06	5.7±0.00

*mean±standard deviation

source of the dose to the contralateral breast, whether it was from scattered photons or electrons, from and/or through the wedges, collimators, and gantry components. The same setup was used as explained above. Breast under treatment was irradiated with same monitor unit, which was 400 MU irrespective of the beam status, open, physical-wedged, or virtual-wedged beams. Fifteen degree and sixty degree wedges were used for the setups with wedges. All experiments were repeated three times. Mean value and standard deviation were calculated from each diode reading.

Results

In the first set of experiment, the contralateral breast dose decreased in the order of the position 1 (mean±standard deviation, 4.71±0.47%), the position 2 (2.77±0.54%), and the position 3 (1.44±0.40%), and the wedge type (physical or virtual) and the use of a wedge on the medical side did not affect this results. The contralateral breast dose was reduced with the open beam on the medial side (2.70±1.46%) compared to the medial beam with a wedge (3.25±1.59%), both physical and virtual. The differences were larger in the physical wedge (0.99±0.18%) than the virtual wedge (0.10±0.01%) at all positions. The use of the virtual wedge reduced the contralateral breast dose by 0.12% to 1.20% of the prescribed dose compared to the physical wedge with same technique. Detailed data obtained from the experiments are enlisted in Table 1.

In the second experiment, a fixed monitor unit was delivered to clarify the scattering effect of the wedges used. As with the first experiment, the contralateral breast dose decreased in the order of position 1 (17.12±2.69%), position 2 (12.02±1.52%), and position 3 (7.39±1.64%). At position 1, the contralateral breast dose decreased in the order of an open beam, a virtual wedge, and a physical wedge. However, at position 2 and 3, it decreased in the order of a physical wedge, an open beam, and a virtual wedge. Details are enlisted in Table 2.

Discussion

Several factors contribute to the contralateral breast dose for tangential treatment of breast. These are photons and electrons scattered externally from the gantry head, collimators, and physical wedges and photons scattered internally in the body. In order to evaluate the dose to the contralateral breast, scattered beams that vary with the treatment plan need to be considered. In the treatment setup, the contralateral breast is relatively close to the physical wedge mounted on a gantry, which is tilted toward the contralateral side. The scattered radiation dose is directly correlated with the distance from the scattering object, such as collimators and wedges, to the contralateral breast and also with the identity of the scattering object. The identity of the scattering object includes the sizes of the field-shaping collimators and wedge angles. These features also affect the leakage radiation to the contralateral breast.

The quality and quantity of the internally scattered photons depend on the lateral beam characterized by employed wedge angle and field size. The variation in the type of wedges (physical or virtual wedges and the choice of wedge angles), even in a situation that delivers the same amount of dose to the target, entails variations in dose profiles within the ipsilateral breast. This will affect the dose distribution within the ipsilateral breast, and consequently the internal scattering directed towards the contralateral breast.

The aforementioned physical considerations are consistent with the results of this study. In this regard, the result that median and lateral dose to the contralateral breast increases with the physical wedge setup, basically shows that physical wedges after receiving scattered and leakage radiation from the collimators, in turn scatter radiation toward the contralateral breast except for the medial region. Furthermore, the radiation dose scattered from the wedges surpasses it scattered from the collimator which is shown by comparison with the open beam setup. These findings agree with the similar studies done with Varian machines.[10,14]

The finding in this study along with that by Fraass et al.[10] shows that the contralateral breast dose with the physical wedge was increasing as the measured point was located near the medial side. It was due to the radiation scattered from simply using physical wedges instead of open beams, and the increase in scatter and leakage radiation by the increased monitor unit associated with the wedge factor.

Throughout the contralateral breast, with a Varian-type machine and physical wedges, Fraass et al.[10] reported an increase in the scatter dose with an increase in wedge angles while maintaining the same monitor unit. However, as already mentioned in our results, a Siemens-type machine and physical wedges did not simply follow the same trend. This can partly be explained by the difference between Varian and Siemens machines with respect to the relative location of the measured points on the contralateral breast to the collimators and gantry head. In fact, the distance from the wedges to the positions 2 and 3 are much closer than that of the position 1.

This study has shown that virtual-wedged beam lowers collimator-scattered radiation dose than the open beam and that the difference becomes greater as wedge angle is increasing. This can be explained by the fact that effective field size is relatively small for virtual-wedged beams with moving collimators compared to that of an open beam.

In actual patient treatment setup, where same dose is delivered to the target volume regardless of beam arrangement, it is obvious that virtual wedge on medial side lowers dose to the contralateral breast than physical wedge, as physical wedges are associated with greater wedge factor than that of virtual wedges. Kim and associates reported the similar results that the virtual wedge decreased the contralateral breast dose by 1.35% to 2.55% of the prescribed dose in the TLD measurements.[18] It has been also shown from our first experiment that the virtual wedge lowers dose than combination of open and physical wedged beams.

McParland[16] and Weides et al[17] have shown the results with dynamic wedges, respectively, which were not in agreement with the above results with the Siemens-type virtual wedges. Their studies have shown that the dose increased with increase in dynamic wedge angle. One of the possible explanations for the difference between this study and other two studies is, authors believe, the relatively little monitor-unit changes brought with the wedges Siemens-type virtual wedges compared to that of dynamic wedges for the Varian-type accelerator.

Finally, this study has shown that the contralateral breast dose is greatest at the medial side. This can simply be explained by the difference in medial distance, as previously discussed. In summary, this study showed a useful feature of a Siemens-type virtual wedge equipped in a Primus treatment unit, which is, in essence, reduced dose to the contralateral breast than an open beam does, especially on medial side. In a clinical setup, this means smaller dose to the contralateral breast with a virtual wedge than a physical wedge or combination of a physical wedge and an open beam. This useful feature was made possible mainly due to the wedge factor being close to one. It has been also found in this study that the trend in the dose distribution on a contralateral breast with the Siemens machine is different from that of a Varian machine.

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Abstract

가상쐐기를 이용한 반대측 유방선량감소

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목 적: Siemens사 선형가속기에 장착된 가상쐐기를 이용하여 반대측 유방에 흡수되는 선량을 기존쐐기와 비교 연구하고자 하였다.

대상 및 방법: 반대측 유방선량을 인체모형에서 이극진공관을 사용하여 측정하였다. 이극진공관을 조사영역의 내측 경계선으로부터 반대쪽 외측방향으로 5.5 cm (1번 위치), 9.5 cm (2번 위치), 14 cm (3번 위치) 떨어진 곳에 위치하였다. 6 MV X-선을 이용하여 50도와 230도에서 17±10 cm의 비대칭조사영역을 사용하여 접면조사를 실시하였다. 첫번째 실험은 4가지의 치료방법을 시도하였다: (i) 개방 내측조사와 30도 기존쐐기를 사용한 외측조사; (ii) 15도 기존쐐기를 사용한 내측 및 외측조사; (iii) 개방 내측조사와 30도 가상쐐기를 사용한 외측조사; (iv) 15도 가상쐐기를 사용한 내측 및 외측조사. 두번째 실험은 개방조사, 15도 및 60도 기존쐐기 및 가상쐐기 모두를 사용하여 내측조사를 시행하였으며, 이때 동일한 모니터단위로 조사하였다. 모든 실험은 3회 반복되었다.

결 과: 첫번째 실험은 반대측 유방선량은 1번 위치, 2번 위치, 3번 위치의 순으로 감소한다. 또한 기존쐐기및 가상쐐기와 무관하게 내측에 쐐기를 사용한 경우(3.25±1.59%)보다는 사용하지 않은 경우(2.70±1.46%) 선량이 낮았고. 이러한 차이는 가상쐐기(0.10±0.01%)보다 기존쐐기(0.99±0.18%)의 경우 더 컸다. 가상쐐기의 사용은 같은 기법의 기존쐐기를 사용한 것에 비해 처방선량 대비 0.12~1.20%의 반대측 유방선량을 감소시켰다. 두번째 실험시 1번 위치에서는 개방빔, 가상쐐기, 기존쐐기 순으로 선량이 높았으며, 2, 3번 위치에서는 기존쐐기, 개방빔, 가상쐐기 순으로 선량이 높았다.

결 론: Siemens사 선형가속기에 장착된 가상쐐기를 사용할 경우 반대측 유방선량을 줄일 수 있으며, 위치에 따른 선량분포는 Varian사 것과 차이가 있었다.

핵심용어: 가상쐐기, 반대측 유방, 접면조사