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Reduction of Electron Contamination Using a Filter for 6MV Photon Beam

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Purpose : Secondary electrons generated by interaction between primary X-ray beam and block tray in megavoltage irradiation, result in excess soft radiation dose to the surface layer. To reduce the surface dose from the electron contamination, electron filters were attached under the tray when a customized block was used.

Materials and Methods : Cu, Al or Cu/Al combined plate with different thickness was used as a filter and the surface dose reduction was measured for each case. The measurement to find optimal filter was performed with 10cm×10cm field size and 78.5cm source to surface distance. The measurement points are positioned with 2mm intervals from surface to maximum build-up point. To acquire the effect of field size dependence on optimal electron filter, the measurement was performed from 4cm×4cm to 25cm×25cm field sizes.

Results : The surface dose was slowly increased by increasing irradiation field but rapidly increased beyond 15cm×15cm field size. Al plate was found to be inadequate filter because of the failure to have surface dose kept lowering than the dose of deep area. Cu 0.5mm plate and Cu/Al= 0.28mm/1.5mm combined plate were found to be optimal filters.

By using these 2 filters, the absorbed dose to the surface layer was effectively reduced by 5.5%, 11.3%, and 22.3% for the field size 4cm×4cm, 10cm×10cm, and 25cm×25cm, respectively.

Conclusion : The surface dose attributable to electron contamination had a dependence on field size. The electron contamination was increased when tray was used. Specially the electron contamination in the surface layer was greater when the larger field was used. 0.5mm Cu plate and Cu/Al=0.28mm/1.5mm combined plates were selected as optimal electron filters. When the optimal electron filter was attached under the tray, excessive surface dose was decreased effectively. The effect of these electron filters was better when a larger field was used.

Key Words : Electron filter, Electron contamination, Surface dose, Optimal filter, Absorbed dose

INTRODUCTION

The aim of radiation therapy is to deliver a large amount of radiation to a tumor, while administering the smallest possible dose to normal tissue. When a patient is treated using a megavoltage photon, the surface dose is smaller than

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the internal areas. As photon energy increases, the surface dose decreases and the point of maximum dosage moves deeper. This property of high energy photon beams called 'the skin-sparing effect' is decreased or lost if the photon beams are contaminated by secondary electrons[1-5]. Electron contamination is caused by the air, the collimator jaws, the beam flattening filter, and blocking tray. The blocking tray is the most important culprit of electron contamination[2]. To reduce excess dosage to the surface layer, the secondary electron must be removed. To do this, an electron filter can be used or there should the an appropriate distance from the scattering material to the patient. Generally, it is known that the most effective material for an electron filter is a medium atomic number metal.

The purpose of this study is to look for an optimal electron filter to reduce electron contamination for 6MV X-ray. There have been many studies on electron contamination using Co-60 teletherapy[1, 3-9], 2MV[10], and 4MV photon[11, 12], but, however, few studies are performed for 6MV photon. Al, Cu and Cu/Al bimetallic plates with different thicknesses were used as a filter and the decrease of dose on the surface and the build-up region of the solid phantom was examined. The field size dependence on the effect of optimal electron filter was also tested.

MATERIALS AND METHODS

NEC LINAC(NELAC 1006, NEC) was used to generate a 6MV X-ray beam. Electrometer(Victoreen 500, OEM) and PTW ionization chamber (PTW N23343, 0.125cc) were utilized as dosimeters. A polystyrene phantom, 25cm×25cm×25 cm in size, which has a groove to locate the PTW chamber, in side, was used. The thickness of the lucite tray was 0.5cm.

1. Looking for an optimal electron filter

Experimental conditions were 10cm×10cm field size, 78.5cm SSD(Source to Surface Distance), and 31.8cm TSD(Tray to Surface Distance). Filters used in this study were six Cu plates(0.28, 0.5, 0.8, 1.0, 1.23, 1.5mm), six Al plates (0.3, 0.5, 1.0, 1.5, 2.0, 2.5mm) and three Al/Cu bimettalic plates (Cu/Al=0.28mm/2.0mm, Cu/Al=0.28mm/1.5mm, Cu/Al=0.5mm/2.0mm) in different thicknesses. First, we measured the dose at the maximum build-up point(1.5cm), and then measured the dose from surface to 1.4cm depth by 2mm interval. All measurements were done for each case, without tray, with tray, and tray/filter. Each measured dosage were analyzed as a ratio to the dosage of condition of open field without tray. The order of combined filter was tray-Cu-Al. Optimal electron filter was selected by comparing the reduction of electron contamination to depth dose reduction. Fig. 1 shows schematic diagram for the experimental set up.

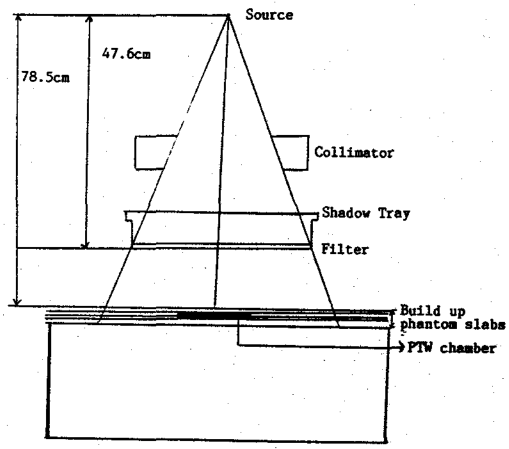

Fig. 1. Schematic diagram of irradiated system utilized in this study.

2. Field size dependence on the effect of an optimal electron filter

After selecting 0.5mm Cu plate and the bimetallic plate Cu/Al=0.28mm/1.5mm in thickness as optimum filters, we measured field size dependence for each of the filters. Dose changes were tested at each point(surface, 2, 4, 10, 15mm depth) for field size variation when the optimal electron filter was used. The range of field size was 4cm×4cm-25cm×25cm with five steps.

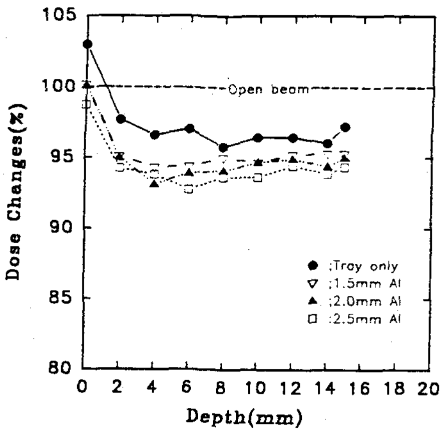

Fig. 2. Dose changes(in percent) with a tray and Al plate filters relative to that of the open field.

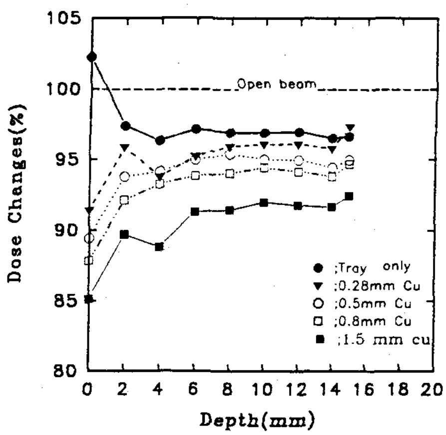

Fig. 3. dose changes(in percent) with a tray and Cu plate filters relative to that of the open field.

RESULTS

1. Contamination Reduction from Al Plates

Fig. 2 represents the dose changes relative to the open beam at the surface and underlying depth to the maximum build up point at 2mm interval.

The surface dose increased to 102.9% when the tray was used. The dose decreased lower than 98% of the standard open beam at 2mm depth and were nearly kept on being constant up to 15mm build up depth after 2mm depth. There was 4% reduction of electron contamination at surface layer and 2.6% dose reduction at the point of maximum build-up as the most thickened Al-plate, 2.5mm plate thickness, in this experiment was used. If the Al-plates were used as an electron filter, it was impossible to acquire the efficiency of electron contamination reduction.

2. Contamination Reduction from Cu Plates

Fig. 3 represents the dose changes relative to the open beam when the Cu-plates in various thickness are used. The surface dose decreased gradually as the plate thickness increased. The doses below 2mm depth were however constant independent of plate thickness as observed in the experiment with the Al-plates. As seen in graphs of Fig. 3, when tray was used, the surface dose increased to 102.3% and the depth dose from 2mm to 15mm depth decreased to 96.3-97.4% without the large variation. For the 0.28mm thickness plate, the surface dose decreased to 91.4%, and the doses at the depth of 2mm, 4mm and 15mm were 95.8% 93.8% and 97.3% respectively. For the of 0.5mm thickness plate, surface dose decreased 89.5%, and the dose at the depth of 2mm, 4mm, and 15mm were 93.8%, 94.1% and 95.0% respectively. The optimum electron filter thickness was thought to be 0.5mm because it reduced the electron contamination to the surface of the phantom with a considerable extent, while minimizing the depth dose reduction and keeping on constant in reduction rate.

3. Contamination Reduction from Al/Cu Plates

Fig. 4 represents the dose changes with Al/Cu bimetallic plate filters with three different combinations of Al and Cu thickness. Curve shape on dose variation according to depth were similar for each of three different filters. There was a variation in dose with the thickness of Cu out of Al/Cu bimetallic plates. The surface dose was increased to 102.3% as tray was used comparing to the open beam. The surface doses decreased to 90.0%, 88.9% and 88.1% for Cu/Al=0.28mm/1.5mm, 0.28mm/2.0mm and 0.5mm/2.0

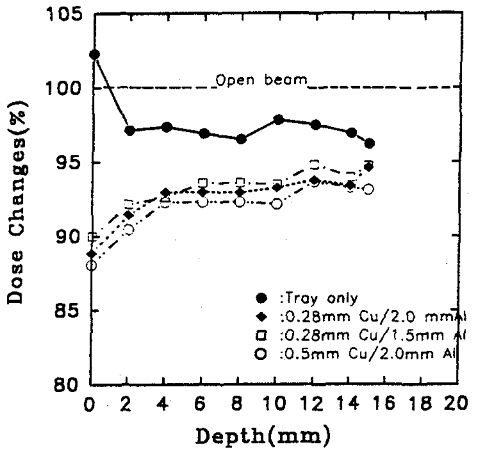

Fig. 4. Dose changes(in percent) with a tray and Cu/Al plate filters relative to that of the open field.

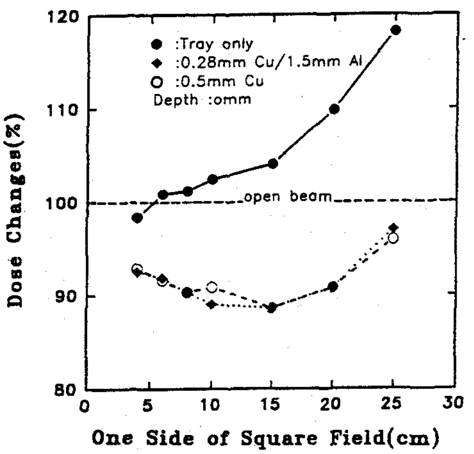

Fig. 5. Dose changes(in percent) at surface with a tray and two optimal filters relative to that of the open field in various field sizes.

mm respectively.

4. Field size dependence on the effect of electron filter

Fig. 5 represents the surface dose changes with two optimal filters, 0.5mm Cu and Cu/Al=0.28 mm/1.5mm plates, comparing to the open beam with various field sizes. For 4cm×4cm field, when the tray was used, the surface dose was decreased to 98.4% of the open field case. The surface dose was larger for the larger field size. For 25cm×25cm field, the surface dose was increased to 118.2%.

Situation was different for the optimal filters. For the Cu filter, 0.5mm in thickness, the surface dose decreased to 92.9%, 88.6%, and 95.9% for 4cm×4cm, 15cm×15cm, and 25cm×25cm, respectively.

And the larger the field size was increased, the greater the dose reduction of the surface layer was increased.

With the Cu/Al=0.28mm/1.5mm filter, the surface dose change with various field size was similar to that of 0.5mm Cu plate case. Fig. 6 represents the absorbed dose changes using two optimal filters relative to the open field with various field size for different measuring depth upto the dmax. As the tray was used, the absorbed doses at depth of 2 and 4mm were higher than that of open field beyond 20cm ×20cm field. For the optimal electron filters, dose reductions of 4-7.5% and 5.5-8.5% for the measuring point of 2 and 4mm, respectively, were found. At the depth of 2 and 4mm, for two optimal electron filters, field size dependence on absorbed dose change was minimal.

At 10 and 15mm depths, when the tray was used, dose was not higher than that of open field regardless of field size. Dose reduction was found for two optimal filters, 5-6% and 3.5-6% for 10 and 15mm depths, respectively.

Field size dependence on dose reduction was not significant for two optimal electron filters at the depth of 10 and 15mm. There was little difference of dose variation between two optimal electron filters at any depth.

DISCUSSION

Conventional radiation therapy uses often tray and shielding block.

Secondary electrons generated by the tray, block, and collimating jaws, etc. result in excessive dose to the surface layer[1-5]. To reduce these secondary electron, moderate electron filters can be used. And it is well known that the skin

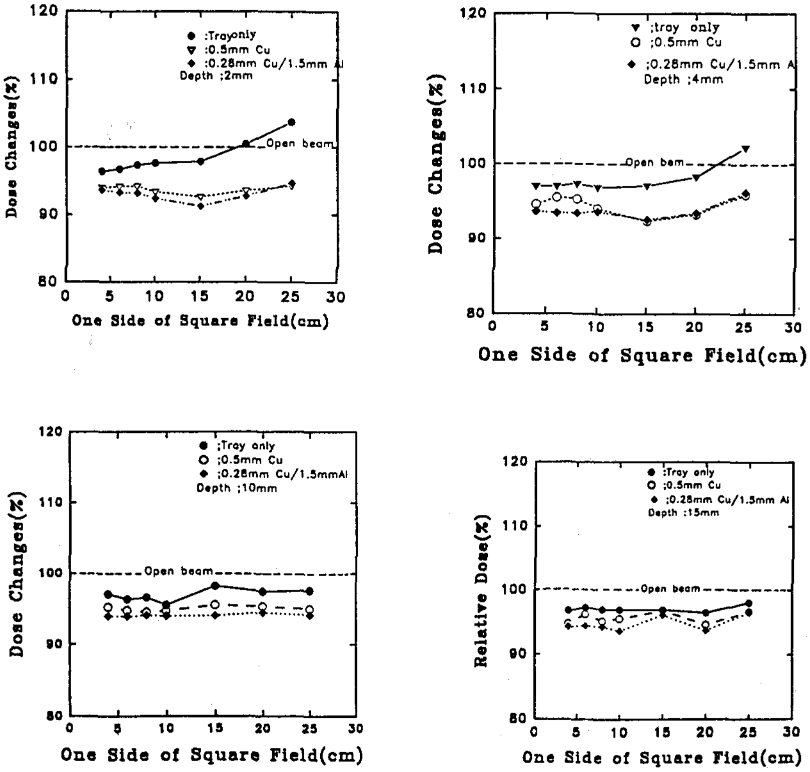

Fig. 6. Dose changes(in percent) at various depth with a tray and two optimal filters relative to that of the open field in various field sizes.

sparing is enhanced by moving the electron filter farther away from the skin[2, 13]. Khan et al.[2], and Hine[14] reported that an electron filter which has a medium atomic number absorbs secondary electrons effectively. In principle, the thickness of electron filter should be equal to the maximum range of the secondary electron. However, it is needed to select the thickness of filter, because the reduction of primary beam is also increased with the increase of the electron filter thickness[2, 7]. To acquire the optimal electron filter in this study, Al plate, Cu plate, and Cu/Al bimetallic plates with various thickness were used. As seen in Fig. 2, 3, and 4, the surface layer receives excessive dose as the blocking tray is used, which means that the tray is a source of electron contamination. Al plates can not be used as an electron filter because the surface dose was higher than the dose at the dmax(Fig. 2). As seen in Fig. 3 and 4, 0.5mm Cu plate or Cu/Al=0.28mm/1.5mm plates droped the surface dose, increased as using tray, to be the lowest. The absorbed dose sharply increased from surface to 2mm depth, increased slowly in the range of 2mm to 6mm depths, and was constant beyond 8mm depth. It seems that these behaviors of absorbed dose depend on the energy spectrum of the secondary electron generated by the tray. For these characteristics, if the 0.5mm Cu or Cu/Al 0.28mm/1.5mm plate is used as an electron filter in conventional radiation therapy, the reduction of electron contamination will be achieved.

At the same time, the skin sparing effect is achieved effectively, because the surface dose is much smaller than that of open field. It is supposed that the soft X-ray included in the primary beam is also absorbed by these filters.

Also these electron filters, 0.5mm Cu and Cu/Al=0.28mm/1.5mm do not affect significantly on the dose delivering to deep area. For these characteristics 0.5mm Cu or Cu/Al=0.28mm/1.5mm plate was selected as the optimal electron filters.

For the field size effect, the surface dose was less than that of open field for the 4cm×4cm field when the tray was used. Beyond 6cm×6cm field, the surface dose with the tray was larger than that of open field. This means that the secondary electrons generated by the tray reached to the surface layer for the fields larger than 6cm×6cm. From 6cm×6cm to 15cm×15cm field, the surface dose was slowly increased as the increase of field size and beyond 15cm×15cm, the surface dose was sharply increased due to a large number of secondary electrons, which result in the increase of surface dose. Specially the surface dose was increased 104.1%, and 118.2% for the field size 15cm×15cm, and 25cm×25cm, respectively. When 0.5mm Cu or Cu/Al=0.28 mm/1.5mm, filter was used, the surface dose was decreased by 5.5%, 9.2%, and 22.3% for the field size 4cm×4cm, 6cm×6cm, and 25cm×25cm, respectively, and therefore the surface dose is lowered enoughly using the optimal electron filters. Kahn et al. reported that the surface dose was decreased by 85.0% as Cu filter was used for the field size 25cm×25cm[2]. Purdy reported that the surface dose was decreased by 11.9% as 1.5mm Cu filter was used for the field size 40cm×40cm[15].

The electron contamination and its filtering effect on the field size in the build-up region were shown in Fig. 6. The secondary electrons affect mainly on the surface because the energy of the secondary electrons is low. For the field size larger than 20cm×20cm, the secondary electrons reached to 2mm depth, as a result there was the increase of dosage at 2mm depth. Beyond 25cm×25cm field size the secondary electrons affect up to 4mm depth. It resulted in the increase of dosage up to 4mm depth. Electron contaminations can be also reduced at 2 and 4mm depth as the optimal electron filter, 0.5mm Cu or Cu/Al=0.28mm/1.5mm, is used.

CONCLUSIONS

We studied the characteristics of Al, Cu, and Cu/Al filters to reduce electron contamination from blocking tray using 6 MV photon beam. Field size effect of electron contamination and in turn the surface dose was found.

The electron contamination was increased when the tray was used. Specially the electron contamination on the surface layer was increased when the large field was used. To verify the efficiency of the electron filters, the surface and depth dose was measured for various electron filters. The resultant 0.5mm Cu plate and Cu/Al=0.28mm/1.5mm combined plates were selected as optimal electron filters. When the optimal electron filter was attached under the tray, excessive surface dose was decreased effectively. The effect of these electron filters was better when a larger field was used.

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= 국문 초록 =

6MV 광자선에서 전자오염 감소에 관한 연구

고신의료원 방사선 종양학과

이철수 · 유명진 · 염하용

목 적 : 광자선과 블록을 얹는 트레이와의 상호작용에 의해 생성된 2차 전자는 피하층에 과도한 선량증가의 원인이 된다. 이런 전자오염으로 인한 표면선량을 감소시키기 위해 트레이 아래 전자필터를 부착하는 것이 유용하다.

대상 및 방법 : 두께가 다른 Cu판, Al판 그리고 Cu/Al 복합판을 사용하여 전자오염에 의한 표면선량을 감소시키는 효과를 측정하였다. 최적의 필터를 찾기 위해서 10cm×10cm 조사야와 SSD 78.5cm의 기하학적 모형으로 표면에서부터 최대선량 지점까지 2mm 간격으로 흡수선량을 측정하였다. 최적필터의 조사야 의존성을 구하기 위해서 4cm×4cm에서부터 25cm×25cm까지 조사면적을 변화시켜가며 흡수선량을 측정하였다.

결 과 : 표면선량은 조사면적을 증가시키면 서서히 증가하였고 15cm×15cm 조사면적 이상에서는 표면선량이 급속히 증가하였다. Al판을 사용했을 경우 표면선량이 최대선량 지점의 선량보다 낮게 유지되지 않으므로 Al판은 전자필터로는 부적합하였으며 0.5mm Cu판과 Cu/Al=0.28 mm/1.5mm 복합판이 최적 전자필터로 결정되었다. 두가지 최적필터의 경우 4cm×4cm 조사면에서는 표면선량을 5.5%(tray 사용할때 표면선량에서 filter 사용할때 표면선량을 뺀 것) 낮출 수 있었고 10cm×10cm에서는 11.3%, 25cm×25cm에서는 21.3%로 낮출 수 있었다.

결 론 : 전자오염에 기인한 표면선량은 조사면적에 의존하였고 트레이를 설치했을때 표면의 전자오염은 많았고 특히 조사면적이 클 때 표면의 전자오염은 더욱 증가하였다. 표면 및 build-up 영역의 선량 특성을 측정한 결과 0.5mm Cu판과 Cu/Al=0.28mm/1.5mm 복합판이 최적 필터로 결정되었다. 트레이 밑에 최적 필터를 부착하면 표면선량을 유효하게 감소시킬 수 있었고 필터의 효과는 조사면적이 클 때 더욱 좋았다.