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The Enhancement of Skin Sparing by Tray Materials for High Energy Photon Beam

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The skin sparing effect associated with high energy x-ray or gamma ray beams may be reduce or lost under certain conditions of treatment. Current trends in using large fields. Shield carrying trays, compensating filters, and isocentric methods of treatment have posed problems of increased skin dose which sometimes become a limiting factor in giving adquate tumor doses. We used the shallow ion chamber to measure the phantom surface dose and the physical treatment variables for Co-60 gamma ray, 4MV and 10 MV x-ray beam. The dependence of percent surface dose on field sizes, atomic number of the shielding tray materials and its distance from the surface for 4, 10MV x-rays and Co-60 gamma ray is qualitatively similar. The use of 2 mm thick tin filter is recommended for situations where a low atomic number tray is introduced into the beam at distances less than 15 cm from the surface and with the large field sized for 4 MV x-ray beam. In case of Co-60 gamma ray, the lead glass tray is suitable for enhancement of skin sparing. Also, the filter distance should be as large as possible to achieve substantial skin sparing.

Key Words: Skin sparing effect, Tin filter, Lead glass, Skin dose

INTRODUCTION

One of the most desirable features of high energy x-ray or gamma-ray beams is the skin sparing effect, but in some situations, this effect may be reduced or even lost if the beam is excesively contaminated with secondary electrons[1,2,3]. These electrons arise from photon interactions with the collimating system and with any other scattering medium in the path of the beam[4,5,6]. The skin dose for high energy radiation such as 4, 10 MV x-rays is ordinarily low for fields as large as 30×30 cm and an air gap of 20 cm from the scatterer to skin surface. The problem, however, arises when low atomic number absorbers such as a Lucite shadow tray for supporting shielding blocks, compensators or other auxillary fixtures are introduced into the beam[7,8,3]. This is important especially in the isocentric method of treatment in which these absorbers are brought dose to the skin surface[5,9,10]. Various aspects considered are the effects of field size, absorber to surface distance and atomic number of the absorber[11,12,13].

METHODS

The high energy x-ray is incident on a polystyrene phantom through the shadow tray and measured with radiation detector on the skin surface as shown in figure 1. The data reported here obtain to the Toshiba 4 MeV, NEC 18 MeV linear accelerator and CGR cobalt-60 teletherapy unit[14,15]. Data were taken using a parallel plate chamber (PTW/marcus) (diameter=5 mm, plate separation=2 mm) and the chamber window of 2.3 mg/cm^2 thickness, and then the ionization charge was meausred with a Capintec electrometer (model 591) as KAPM dosimetry protocol[16,17,18].

For maximum buildup measurements, the ion chamber was built into a polystyrene (ρ=1.09 g/cm^3) block (30×30×10 cm) and the chambers front surface was maintained at a constant position of SSD=100 cm several 30×30 cm polystyrene sheets were added onto the phantom surface to decide the dose buildup regions. The absorber sheets (15×15 cm^2) were maintained by shielding tray at a chosen constant height above the surface for spoiler dosimetry. The ionization data were corrected to 80~100 cm SSD by an inverse square factor and an approximation considered adequate for the purpose of this study. The chamber polarity effect affected the chamber reading by less than 0.5 %. Therefor, for absorber thicker than 1 g/cm^2 only positive voltage (300 V) was applied, for thinner region of absorber layers, the average charge collected for positive and negative voltage was assumed as a true value.

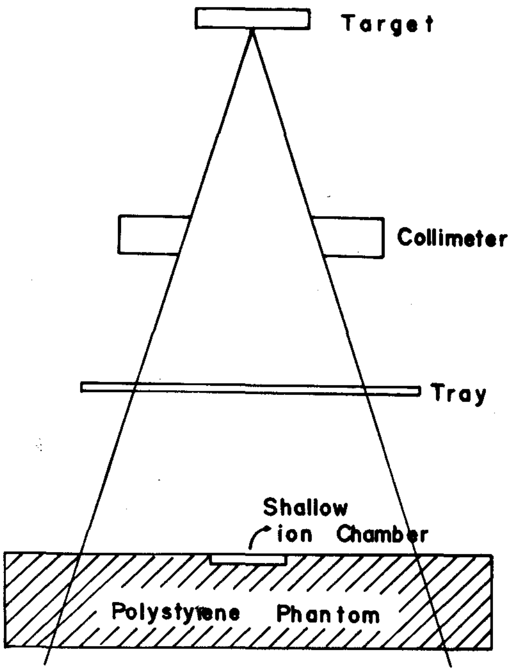

Fig. 1. Schematic diagram of experimental arrangement to mesureing the surface dose.

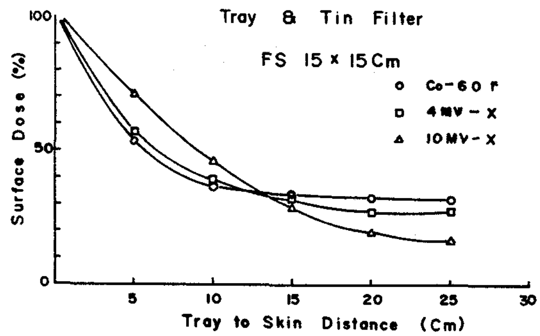

Fig. 2. Effect of lucite shadow tray on surface dose to the distance from the surface of Co-60, 4, 10 MV x-ray.

RESULTS

1. Effect of Lucite Tray

When an absorber of thickness greater than the maximum range of the secondary electrons is introduced into the beam, the electrons originating from the collimating system and incident on the absorber are almost completely absorbed. However the photon beam transmitted through the absorber is still contaminated with electrons because of photon interactions with the absorber. Before reaching the skin surface, these electrons suffer further interactions in air with the result that some of them are absorbed or scattered. The remaining electrons deposit their energy on the skin surface and the underlying tissues. Fig. 2 gives the effect of electron contamination on the skin region when an 1 cm thick lucite shadow tray was introduced into the beam at various distances from the surface. The relative surface dose increased with the decreasing absorber to surface distance and the point of maximum dose build up moved closer to the surface. Fig. 3 gives the skin surface dose increase with increasing field size.

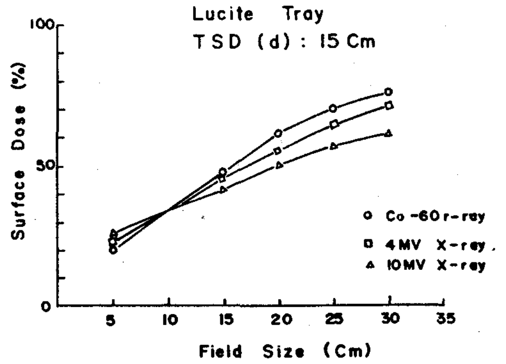

Fig. 3. Surface dose of phantom by lucite tray to field sizes for Co-60, 4, 10 MV x-rays.

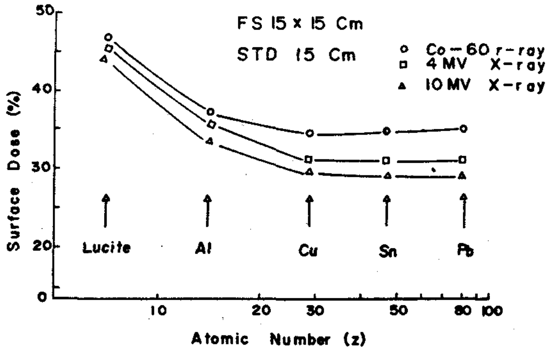

Fig. 4. Variation of percent surface dose with atomic number of absorber mounted underneath the lucite shadow tray.

2. Effect of Atomic Number

The emission of secondary electrons from the shielding tray and their subsequent scattering

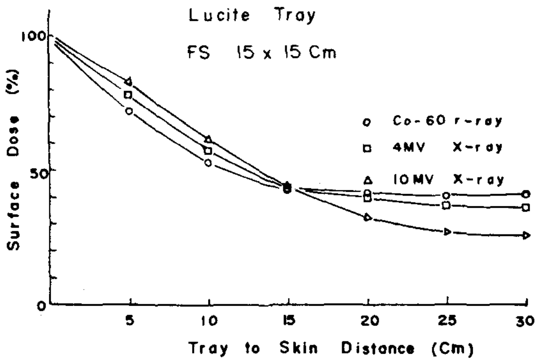

Fig. 5. Percent surface dose as distance from skin to lucite tray with tin filter for Co-60, 4, 10 MV x-ray.

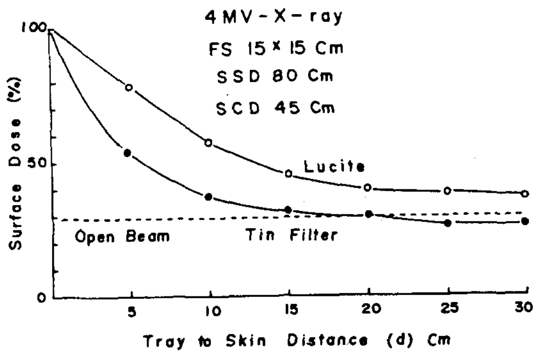

Fig. 7. Percent surface dose of shadow tray and tray with tin filter as distance from tray to skin for 4MV x-ray.

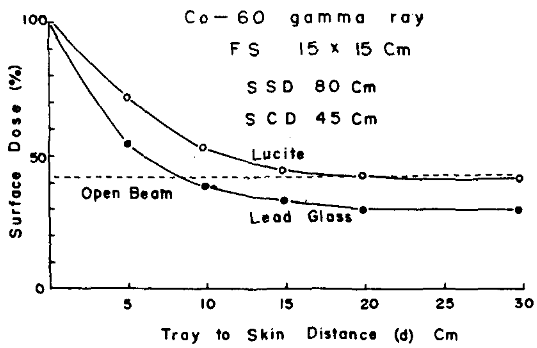

Fig. 6. Percent surface dose of shadow tray and tray with tin filter as distance from tray to skin for Co-60 gamma ray.

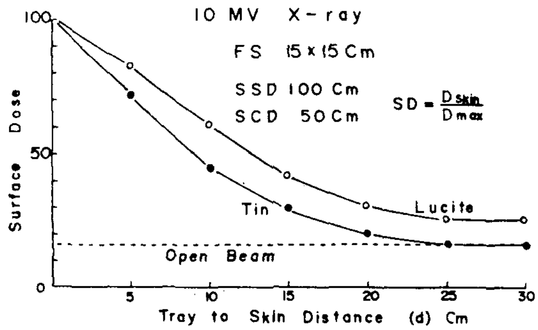

Fig. 8. Percent surface dose of shadow tray and tray plus tin filter as distance from skin to tray for 10 MV x-ray.

within the tray depend upon the energy of the photons and the atomic number Z of the shielding tray. It has been shown that gamma ray absorbers of medium atomic number give less electron scatter in the forward direction than either the low or the very high atomic number materials. This affect is demonstrated in Fig. 4. For Co-60 gamma ray and 4, 10 MeV x-rays, the percent surface dose represents the surface dose as percentage of peak dose at depth and has been plotted against log Z to show agreement with the theoretical relationship discussed by Hine[9,10].

The decrease in percent surface dose with atomic number represents by the part of the curve to the left of the minimum is due to the increase in electron scattering in the absorber with atomic number resulting in less forward scatter of electrons. The slightly rise in the curve at the higher atomic number is caused by production of photoelectrons and electron pairs for high atomic number absorbers in addition to the already present Compton electrons. The minimum of the curve occurs for the atomic number corresponding to the tin absorber and this provides a basis for using tin as electron filter for high energy x-ray.

3. Enhancement of Skin Sparing

The effectiveness of tin in reducing electron contamination produced by low atominc number absorbers such as a lucite shadow tray is demonstrated in Fig. 5. By introducing a tin filter underneath the shadow tray, the percent surface dose is reduced by 10~15% when the shadow tray distance from the surface is less than 20 cm. Fig. 6 is shown the skin dose by Co-60 gamma ray. There is a steep rise in percent surface dose as the shadow tray is brought closer to the surface. The surface dose of lucite and lead glass to be exceeding 50%

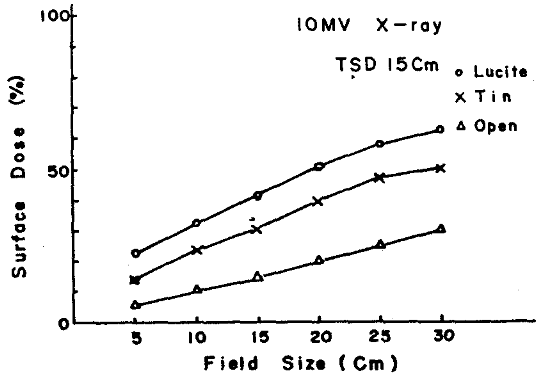

Fig. 9. Percent surface dose as a field size to shadow tray and tray plus tin filter for Co-60, 4 MV and 10 MV x-ray.

for distances is below 14 cm and 7 cm respectively. Fig. 7, 8 is shown to the percent surface dose of the lucite shadow tray and tray plus tin filter as distance from skin to tray for 4, 10 MV x-ray. The improvement in skin sparing with tin filter depends on the filter distance from the surface and the percent surface dose with field size is represented in Fig. 9. With a filter to surface distance of 15 cm, the tin filter is effective in skin sparing for 10 MV x-ray beam.

In conclusion, the dependence of percent surface dose on field size, atomic number of the shielding tray and its distance from the surface for 4, 10 MV x-rays and Co-60 gamma ray is qualitatively similar. The use of a 2 mm thick tin filter is recommended for situations where a low atomic number tray is introduced into the beam at distances less than 15 cm from the surface and with the large field sizes for 10 MV x-ray. In case of Co-60 gamma ray, the lead glass tray is suitable for enhancement of skin sparing. Also, the filter distance should be as large as possible to achieve substantial skin sparing. Although the percent surface dose for 10 MV x-ray is ordinarily lower compared to Co-60 gamma ray, the exit dose is highter. For parallel opposed fields the surface dose per field should be maintained less than that for cobalt-60, if skin sparing comparable the cobalt is desired.

DISCUSSION

The skin dose can be reduced by using gamma ray absorbers of medium atomic number Z in the range of 30~80. Such absorbers are commonly known as electron filters since their introduction in the photon bean reduces the secondary electron scatter in the forward direction. Hine[9,10] studied the scatttering of electrons produced by gamma rays in materials of various atomic numbers. He showed that the medium atomic number absorbers give less electron scatter in the forward direction than either the low or the very high Z materials. Sayliar, Quillin[1] and Khan[7] applied the results of Hines study to the design of electron filters for the purpose of improving skin dose for Co-60 teletherapy units. Later it was shown that such fiters not only reduce the surface dose but also improve the buildup characteristics of large fields. Fig. 4 is a plot of relative surface dose as function of log Z. These data are plotted in this manner to show agreement with the theoretical relationship discussed by Hine. As Z increases, the surface dose falls to a shallow minimum due to increase electron scattering in the absorbers. Further increases in Z result in increased surface dose due to increased production fo photoelectrons and a electron pairs in addition to the Compton electrons. The minimum occurs at about Z=50 which is the atomic number of tin. These results qualitatively agree with those obtained for 4 MV x-ray beams.

The reduction of skin dose is possible by increasing filter skin distance and decreasing field sizes. We have used a tin sheet mounted underneath a lucite tray which could be slipped under the lucite tray at the end of the treatment setup. In this arrangement the tin filter must face the patient surface.

The thickness of an electron filter should be at least equal to the maximum range of secondary electrons. For Co-60, this thickness is abuout 0.5 g/cm^2 or 0.9 mm of tin(ρ=5.75 g/cm^3). For higher energies, thickness less than the maximum range of electrons may be used for practical reasons.

The number of Compton electrons produced per gram of various materials decreases only slightly with increasing atomic number Z of the absorber. However, the relative number of secondary electrons emitted from a converter in the forward and backward direction varies strongly with Z. The scattering of secondary electrons produced by monochromatic ganmma ray in materials of various Z has been studied as a fuction of the gamma ray energy.

The results obtained with the various photon energies, the backscattering factor has been found to be a linear function of low (Z+1) for the high energy gamma rays and the backscattered secondary electrons follow curve up to copper, while the values obtained with tin and lead are somewhat higher. The production of photoelectrons, in addition to the Compton electrons, becomes more pronounced for the lower energy gamma rays. Because of the increased backscattering with increasing Z, the intensity of Compton electrons emitted in the forward direction decreases with log (Z+1). for high atomic number materials the additional emission of photoelectrons again becomes apparent. On the studies for the ratio of forward to backward emission of secondary electrons from various absorber as a function of the photon energies, the ratio of forward to backward emission increases rapidly with increasing photon energy for aluminum and copper absorbers, Leads, however, emits about equal amounts of secondary electrons in both directions rather independent of the photon energy.

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= 국문초록 =

고에너지 광자선치료에서 고정판 흡수물질을 이용한 피부보호효과의 향상

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종양치료를 위하여 고에너지 X-선 또는 감마선을 인체에 조사할 경우 피부 표면 선량이 최대지점 선량의 30~60%에 불과 함으로 피부보호 효과(Skin sparing effect)를 얻을 수 있는 장점을 갖고있다. 그러나 종양특성과 발병위치에 따라 조사면을 크게 하거나 선속내에 차폐물질 또는 보상여과판을 설치하여 치료할 경우 피부보호 효과가 감소되거나 없어지는 경우가 있고 이것은 종양치료에 중요한 요인이 되고 있다.

연세 암전문병원에 설치된 코발트 60 원격치료기와 선형가속기에서 발생되는 4 MV 및 10 MV x-선에 대한 피부선량을 측정하였으며 차폐물 고정판(Tray) 구성 물질의 종류와 조사면의 크기 및 피부와 고정판간의 거리에 따른 피부선량의 변화를 평가하였다.

방사선 조사면이 15×15 cm^2 이상 넓고 피부와 collimator 간의 거리가 30 cm 이상일 때 피부 표면선량은 코발트 -60, 4, 10 MV에서 각각 최대선량의 40, 30, 20%로 감소하였으며 조사면의 크기와 차폐 고정판의 물질에 따라 증감하였다.

차폐물을 고정시키는 고정판을 Lucite로 제작하고 고정판과 피부간의 거리를 약 15 cm 이상 간격을 주면 표면선량을 50%로 줄일 수 있었고 주석, 구리, 납등을 부착시키면 전방산란 선량비율이 감소되어 피부선량은 35%로 피부보호 효과를 얻을 수 있었다.

방사선의 전방산란비율은 에너지와 흡수물질의 원자번호에 관계되며 납과 주석이 각각 코발트-60 감마선과 4~10 MV x-선의 전방산란비를 가장 크게 감소시켰다.