The Effect of Aquaplast on Surface Dose of Photon Beam

Do Hoon Oh, M.D. and Hoon Sik Bae, M.D.

Department of Therapeutic Radiology, Kangdong Sacred Heart Hospital
College of Medicine, Hallym University, Seoul, Korea

= Abstract =

Purpose: To evaluate the effect on surface dose due to Aquaplast used for immobilizing the patients with head and neck cancers in photon beam radiotherapy

Materials and Methods: To assess surface and buildup region dose for 6MV X-ray from linear accelerator(Siemens Mevatron 6740), we measured percent ionization value with the Markus chamber medel 30-329 manufactured by PTW Frieburg and Capintec electrometer, model WK92. For measurement of surface ionization value, the chamber was embedded in 25×25×3cm^3 acrylic phantom and set on 25×25×5cm^3 polystyrene phantom to allow adequate scattering. The measurements of percent depth ionization were made by placing the polystyrene layers of appropriate thickness over the chamber. The measurements were taken at 100cm SSD for 5×5cm^2, 10×10cm^2, and 15×15cm^2 field sizes, respectively. Placing the layer of Aquaplast over the chamber, the same procedures were repeated. We evaluated two types of Aquaplast: 1.6mm layer of original Aquaplast(manufactured by WFR Aquaplast Corp.) and transformed Aquaplast similar to moulded one for immobilizing the patients practically. We also measured surface ionization values with blocking tray in presence or absence of transformed Aquaplast. In calculating percent depth dose, we used the formula suggested by Gerbi and Khan to correct overresponse of the Markus chamber.

Results: The surface doses for open fields of 5×5cm^2, 10×10cm^2, and 15×15cm^2 were 7.9%, 13.6%, and 18.7%, respectively. The original Aquaplast increased the surface doses upto 38.4%, 43.6%, and 47.4%, respectively. For transformed Aquaplast, they were 31.2%, 36.1%, and 40.5%, respectively. There were little differences in percent depth dose values beyond the depth of Dmax. Increasing field size, the blocking tray caused increase of the surface dose by 0.2%, 1.7%, 3.0% without Aquaplast, 0.2%, 1.9%, 3.7% with transformed Aquaplast, respectively.

Conclusion: The original and transformed Aquaplast increased the surface dose moderately. The percent depth doses beyond Dmax, however, were not affected by Aquaplast. In conclusion, although the use of Aquaplast in practice may cause some increase of skin and buildup region dose, reductioin of skin-sparing effect will not be so significant clinically.

Key Words : Aquaplast, Surface dose, 6MV X-ray, Skin-sparing effect

INTRODUCTION

Immobilization of patients during radiotheray is very important to improve reproducibility and accuracy of daily treatment. Plastic masks are commonly used to immobilize the patients with head and neck cancers. But these plastic masks are likely to increase skin dose due to effect as a buildup bolus. Recently, some investigators suggested that they were responsible for partial reduction of skin-sparing effect of megavoltage photon beams[1,2].

We performed this study to evaluate the effect of Aquaplast on surface and buildup region dose for 6MV X-ray.

MATERIALS AND METHODS

To assess surface and buildup region dose for 6MV X-ray from linear accelerator(Siemens Mevatron 6740), we measured percent ionization value with the Victoreen/Nuclear Associates model 30-329 ion chamber manufactured by PTW Frieburg(the Markus chamber). The chamber was embedded in $25\times25\times3cm^3$ acrylic phantom and set on $25\times25\times5cm^3$ polystyrene phantom to allow adequate scattering. The measurements of percent depth ionization was made by placing the polystyrene layers of appropriate thickness over the chamber. The ionization values were recorded using Capintec electrometer, model WK92, with a digital readout. The ionization values of surface and entire build-up region were measured for field sizes of $5\times5cm^2$, $10\times10cm^2$, and $15\times15cm^2$, typical of head and neck radiotherapy, at 100cm SSD. Simply placing the layer of Aquaplast over the chamber, the same procedures were repeated. We evaluated two types of Aquaplast: 1.6mm layer of original Aquaplast(manufactured by WFR Aquaplast Corp.) and transformed Aquaplast similar to moulded one for immobilizing the patients practically. Also we measured the surface ionization values with acrylic tray(6mm thickness) at 43cm of tray-to-surface distance in presence or absence of transformed Aquaplast.

All ionization values were normalized to the maximum depth ionization value. It has been noted that, when megavoltage photon beams are used, relative ionization measurements in buildup region are approximately equal to relative dose measurements[3]. The Markus chamber, one of the parallel plate ion chambers, however, overresponds to some degree in the buildup region and appropriate correction of readings of those is required[4,5].

Recently, Gerbi and Khan[5] proposed a fomula for correcting the readings of several parallel plate ion chambers in the buildup region by comparing the results obtained by using an extrapolation chamber.

This formula is:

$$P'(d,E)=P(d,E)-\xi(0,E)\exp[-\alpha(d/dmax)]\ (\%),$$

where: $P'(d,E)$ is the corrected reading and $P(d,E)$ is the uncorrected reading at the depth d, expressed as percentage of the dose at dmax; $\xi(0,E)$ is the overresponse, in percent, of the chamber at the surface of the phantom(for Markus chamber and 6 MV X-ray, $\xi(0,E)=10.6\%$)[5]; α is the constant of proportionality equal to the fractional change in the overresponse, in percent, of the chamber per unit change in d/dmax(We used the value of $\alpha=5.5$ because that value produced the minimum mean error between $P'(d,E)$ and the percent depth dose obtained using the extrapolation chamber)[5]; dmax is the depth at which we find the maximum ionization value; d is the depth of the measurement(for $d<dmax$). The point of measurement was considered at a depth d equal to the sum of the depth in the phantom and the thickness of the Aquaplast.

RESULTS

The percent depth dose curves for $5\times5cm^2$, $10\times10cm^2$, and $15\times15cm^2$ fields with or without Aquaplast at SSD=100cm are shown in Fig. 1. The surface dose and buildup region dose were moderately increased by Aquaplast but

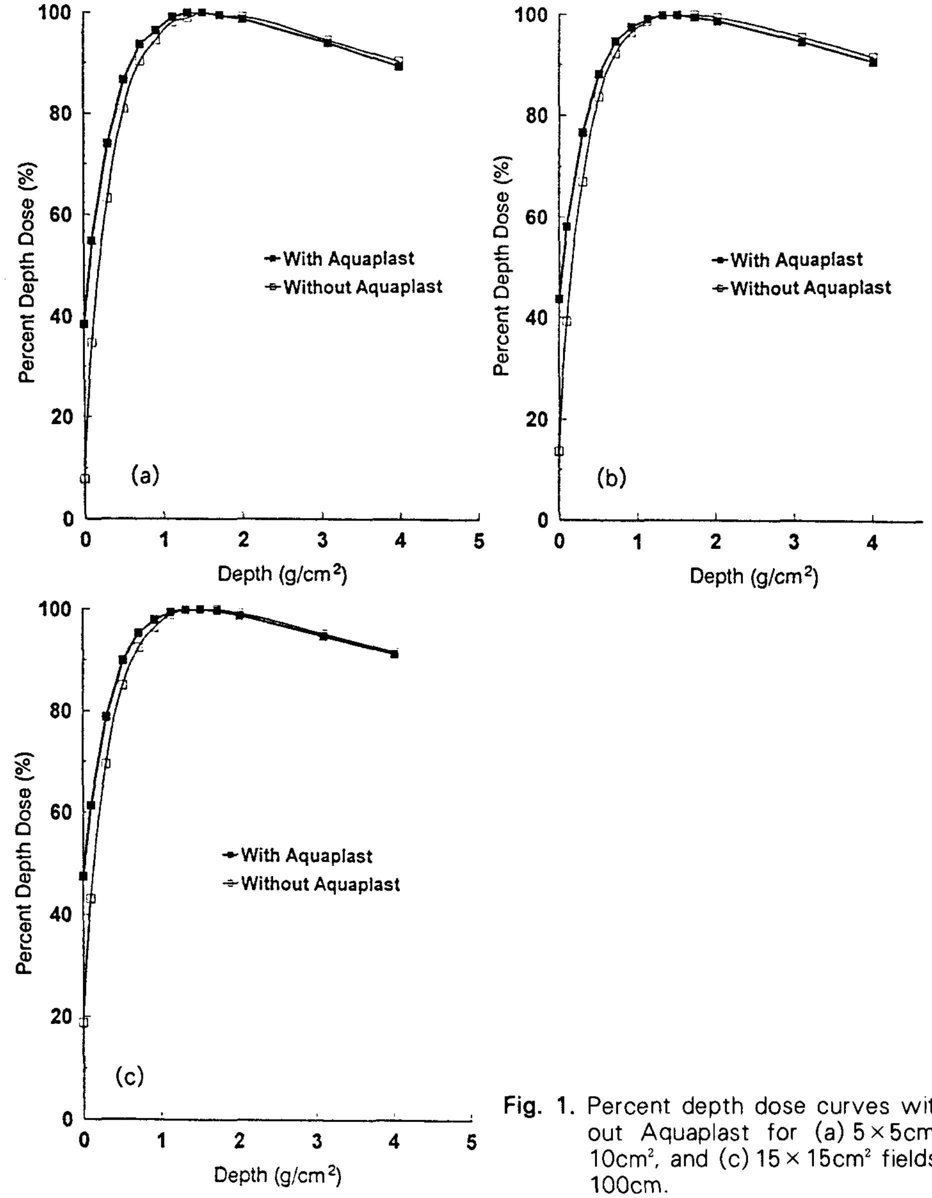

Fig. 1. Percent depth dose curves with or without Aquaplast for (a) 5×5cm², (b) 10×10cm², and (c) 15×15cm² fields at SSD=100cm.

percent depth doses beyond Dmax were not affected significantly.

The surface doses as a function of field size are illustrated in Table 1 and Fig. 2. For open fields of 5×5cm², 10×10cm², and 15×15cm², surface doses were 7.9%, 13.6%, and 18.7%, respectively. The original Aquaplast caused the increase of the surface doses, which were 38.4%, 43.6%, and 47.4%, respectively. With transformed Aquaplast, they were 31.2%, 36.1%, and 40.5% for each field size.

Increasing field size, the blocking tray increased the surface dose by 0.2%, 1.7%, and 3.0% without Aquaplast and 0.2%, 1.9%, and 3.7% with transformed Aquaplast(Table 1).

Table 1. Surface doses as a Function of Field Size at SSD=100cm

	Surface dose(%)		
	5×5cm²	10×10cm²	15×15cm²
Open	7.9	13.6	18.7
With tray	8.1	15.3	21.7
With transformed Aq*	31.2	36.1	40.5
With transformed Aq* and tray	31.4	38.0	44.2
With original Aq*	38.4	43.6	47.4

*Aq: Aquaplast

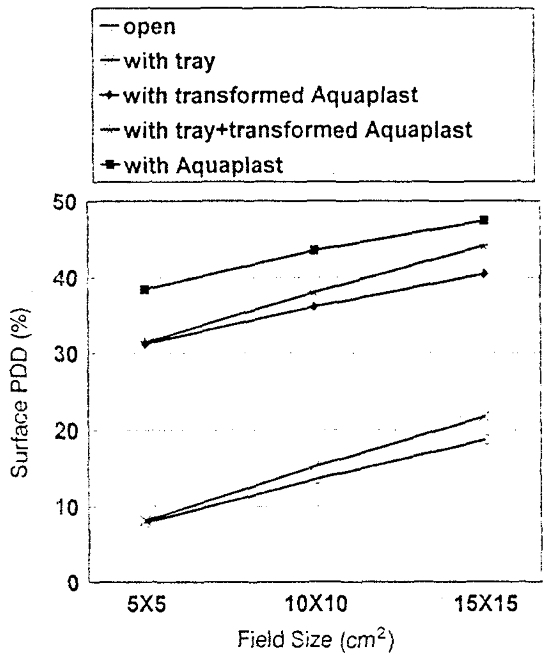

Fig. 2. Surface doses as a function of field size at SSD=100cm(open, with tray, and with or without Aquaplast).

DISCUSSION

The phenomenon of dose buildup gives rise to what is clinically known as the skin-sparing effect, which is the one of the most desirable features of megavoltage photon beams. Skin dose is the result of electron contamination of the incident photon beam as well as the backscattered radiation from the medium. These electrons arise from photon interactions in the air, in the collimator, and in any other scattering material in the path of the beam[6]. If the beam is contaminated with secondary electrons by various sources, the skin sparing effect may be reduced significantly. Also it is well recognized that the skin dose and dose distribution of buildup region depend on beam energy, field size, and geometrical parameters including SSD, and skin to tray distance[6-11].

As can be seen in Fig. 1, the increase of surface buildup region dose by Aquaplast was moderate. But the shift of point of maximum dose toward surface was not remarkable and percent depth doses beyond Dmax were not significantly affected by the presence of the Aquaplast. In consistent with this study, Fiorino et al[2] revealed that the increase of surface and buildup region dose by several plastic masks was evident. The degree of increasing effect was related to the thickness of layers. But the values at Dmax were practically independent of the plastic layers(differences lower than 0.5%) and also for depth dose values beyond the buildup, for all the plastic masks.

In the buildup region for megavoltage photon beam, percent depth dose increases rapidly within the first few millimeters and then gradually achieves its maximum value. Thus, any material placed directly on surface, although its thickness is substantially less the depth of maximum dose, is likely to increase surface and buildup region dose significantly.

The surface doses of 6MV X-ray from Mevatron 6740, in this study, were comparable to those of several linear accelerator models; for 10×10cm² field size, 13% for AECL Therac 6[12], 12.1% for Siemens Mevatron 67[13], and 12.5% for Varian Clinac 6/100[7]. Aquaplast and transformed Aquaplast caused moderate increase of surface doses. This effect was essentially independent of field size(Fig. 2). Recently, Fiorino et al[1] suggested skin-sparing reduction effect of various commercially available thermoplastics. They reported that for $10 \times 10cm^2$ field at 100cm SSD with 6MV X-ray, surface doses were 41.4 % and 60.0% with unmoulded layers of 2mm and 3.2mm Orfit; surface dose without plastic materials was 14.6%. The increasing effect of Aquaplast, in this study, was less than thermoplastics evaluated by Fiorino. Furthermore, the surface doses with transformed Aquaplast were consistently less than those with original Aquaplast by 7-8% for various field sizes. This finding might be resulted from the difference in thickness and perforation of thermoplastics, which were obviously important with respect to surface dose. Fiorino et al[2] also reported that the skin doses for moulded masks were somewhat lower than those for unmoulded masks.

The blocking tray caused a slight increase of surface dose for open field, which was consistently true for fields with transformed Aquaplast. The effect of blocking tray increased as the field size increased(Fig. 2). It is well known that with blocking tray, the depth dose of buildup region increases and point of Dmax shifts toward to surface[6,8]. This effect is predominantly caused by secondary electrons and greatly dependent upon SSD and tray-to-surface distance. This phenomenon may be due to the limited range of the electrons scattered from the tray[6]. Therefore, the increase of surface dose by tray may not be significant if the tray-to-surface distance and SSD are long enough as in this study(tray-to-surface distance was 43cm and SSD was 100cm).

In conclusion, although the use of Aquaplast in practice may cause some increase of skin and buildup region dose, reduction of skin-sparing effect will not be so significant clinically in typical conditions for head and neck irradiation.

REFERENCES

1. **Fiorino C, Cattaneo GM, Del Vecchio A, et al.**: Skin dose measurements for head and neck radiotherapy. Med Phys 1992; 19:1263-1266
2. **Fiorino C, Cattaneo GM, Del Vecchio A, et al.**: Skin-sparing reduction effects of thermoplastics used for patient immobilization in head and neck radiotherapy. Radiother Oncol 1994; 30:267-270
3. **Andreo P, Brahme A.**: Stopping power data for high-energy photon beams. Phys Med Biol 1986; 8:839-858
4. **Velkley DE, Manson DJ, Purdy JA, Oliver Jr. GD**: Build-up region of megavoltage of photon radiation sources. Med Phys 1975; 2:14-19
5. **Gerbi BJ, Khan FM.**: Measurement of dose in the buildup region using fixed-separation plane-parallel ionization chambers. Med Phys 1990; 17:17-26
6. **Khan FM**: The physics of radiation therpay. 2nd ed. Baltimore: Williams & Wilkins, 1994; 180-182, 323-332
7. **Purdy JA**: Buildup/surface dose and exit dose measurements for a 6-MV linear accelerator. Med Phys 1986; 13:259-262
8. **Rao PS, Pillai K, Gregg EC**: Effect of shadow trays on surface dose and build-up for megavoltage radiation. Am J Roentgenol 1973; 117: 168-174
9. **Gagnon WF, Grant WIII**: Surface dose from megavoltage therapy machines. Radiology 1975; 117:705-708
10. **Chamberlain EC, Baily NA**: Entrance and exit absorbed dose characteristics for a 6-Mev X-ray generator. Radiology 1964; 82:267-271
11. **Klein EE, Purdy JA**: Entrance and exit dose regions for a Clinac-2100C. Int J Radiat Oncol Biol Phys 1993; 27: 429-435
12. **Tannous NBJ, Gagnon WF, Almond PR**: Buildup region and skin dose measurements for the Therac 6 linear accelerator for radiation therapy. Med Phys 1981; 8:378-381
13. **Horton JL**: Dosimetry of the Siemens Mevatron 67 linear accelerator. Int J Radiat Oncol Biol Phys 1983; 9:1217-1223

＝국문초록＝

Aquaplast가 광자선의 표면선량에 미치는 영향

한림대학교 의과대학부속 강동성심병원 치료방사선과

오 도 훈 · 배 훈 식

목 적 : 두경부종양 환자의 방사선치료시 두경부의 고정에 흔히 이용되는 Aquaplast가 광자선의 표면선량에 미치는 영향을 알아보기 위하여 이 실험을 시행하였다.

재료 및 방법 : 6MV X-선(Siemens Mevatron 6740)의 표면선량과 선량증가영역의 선량을 PTW Frieburg 제작의 Markus chamber와 Capintec Model WK92 Electrometer를 이용하여 측정 하였다. 25×25×5cm³ 크기 아크릴판의 중앙에 고정된 전리함을 25×25×5cm³ 크기의 폴리스티렌 팬톰 위에 올려 놓고 표면선량을 측정한 후 적당한 두께의 폴리스티렌 팬톰판을 올려가면서 선량증가영역의 선량을 측정하였다. 1.6mm 두께의 Aquaplast(WFR Aquaplast Corp. 제작)를 원형 그대로, 그리고 실제 환자의 고정시와 비슷한 정도로 변형시킨 상태로 전리함 위에 올려 놓은 후 각각 같은 방법으로 선량을 측정하였다. 또 트레이를 장착한 후 변형된 Aquaplast가 있는 상태에서와 없는 상태에서 각각 표면선량을 측정하였다. 모든 측정은 SSD 100cm에서 시행하였으며 5×5cm², 10×10cm², 15×15cm²의 세 가지 크기의 조사면에 대하여 각각 측정하였다. 표면선량과 선량증가영역의 선량 백분율은 Markus chamber의 과반응을 교정하기 위하여 Gerbi와 Khan이 제시한 식을 이용하여 구하였다.

결 과 : 5×5cm², 10×10cm², 15×15cm²의 조사면에서 표면선량은 각각 7.9%, 13.6%, 18.7% 이었고 원형 그대로의 Aquaplast가 있을 경우 표면선량은 각각 38.4%, 43.6%, 47.4% 이었으며 변형된 Aquaplast가 있을 경우의 표면선량은 각각 31.2%, 36.1%, 40.5% 이었다. 최대선량점 이상의 깊이에서는 거의 비슷한 선량 백분율을 보였다. 트레이는 조사면의 크기가 증가함에 따라 Aquaplast가 없을 경우 0.2%, 1.7%, 3.0%의 표면선량 증가에 기여하였으며 변형된 Aquaplast가 있을 경우 0.2%, 1.9%, 3.7%의 표면선량 증가를 보였다.

결 론 : Aquaplast를 사용하지 않았을 경우에 비하여 Aquaplast를 원형 그대로 사용하였을 경우 약 30%, 실제 환자의 고정시와 비슷한 정도로 변형하였을 경우 약 22%의 표면선량 증가를 가져왔으며 최대선량점 깊이 이상에서의 선량 백분율에는 거의 영향을 미치지 않았다. 실제 환자에서의 Aquaplast의 사용은 피부 및 선량증가영역의 선량을 약간 증가시키지만 임상적으로 크게 문제가 되지는 않을 것으로 생각된다.