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The Effects of Using Thermoplastic Mask in head and Neck Radiotherapy

Soo-Kil Kim, Tae-Sig Jeung*, Sang-Wook Lim†

Biophysics, Kosin University College of Medicine, Busan, Korea
**Radiation oncology, Kosin University College of Medicine, Busan, Korea*
†Radiation oncology, Kosin University College of Medicine, Busan, Korea

Abstract

Purpose: Perforated thermoplastic masks are widely used in radiotherapy(RT) of head and neck malignancies. But consequently low-density materials may be introduced in high-energy photon beams and cause the increase in skin dose. The purpose of this study was to measure the skin dose when thermoplastic mask are present in the beam for patient immobilization, as well as to estimate the radiobiological damage of normal and critical organs.

Methods: Dosimetric studies were conducted to investigate the possible causes of the skin reactions, such as the bolus effect of the thermoplastic mask, the use of conventional opposed-lateral fields and CT examination for RT plan. The effect of mask on 6 MV photon beams was described in terms of thermo-luminescent dosimeter (TLD) in anthropomorphic phantom. In each measurement, 12 TLD dosimeters were placed at the lateral and medial surfaces of the head and neck of the phantom. The skin doses were measured with and without mask on the head of the phantom.

Results: The skin doses with the mask were consistently higher than those without mask in radiotherapy treatment with opposed fields. The average dose increase was about 12% owing to the bolus effect of the mask. The skin dose of normal and critical organ was around 10% and 16% of target organ's value respectively. One CT scan contributed to add an increase in skin dose by about 7 cGy .

Conclusion: Radiobiological consequences of introducing thermoplastic mask into the high-energy photon beams were evaluated based on the measured surface doses. Using thermoplastic fixation and high-energy photons of 6 MV increase the dose to the skin considerably. But the effects of CT for RT plans could be negligible. A skin dose measurement of normal and critical organ shows that the conventional RT treatment technique couldn't protect them enough from radiation. In an effort to provide optimal treatment of superficial tumors with high photon beam, however, a compromise should be drawn between beam heterogeneity and the potential immobilization loss caused by cutting beam portals out of the mask in certain clinical situations.

Key words : radiotherapy, opposed fields, thermoplastic mask, skin dose increase, TLD

Introduction

The introduction of high-energy photon beams in radiotherapy has resulted in more homogeneous dose distributions combined with a major reduction in surface doses, known as the skin-sparing effect. Contaminating electrons deteriorate the skin-sparing, and several factors may increase the electron contamination, such as reduced source-skin distance, increased field size or introduction of material into the beam close to the patient.[1] Radiotherapy of head and neck malignancies requires accurate and reproducible setup techniques. To this end, several brands of perforated thermoplastic immobilization masks have become available. These facilitate setup reproducibility by providing rigid landmarks and minimizing potential patient movement during treatment.

The low density of these materials allows for treatment with beam portals going through the material without changing the dose significantly. The skin-sparing effect of high-energy photon beams may, however, be compromised or lost.[2] Due to the lack of electron equilibrium at the surface in high-energy photon beams, TLDs are used to measure doses in the build-up region.

This study was to measure the skin dose when perforated thermoplastic masks are present in the beam for patient immobilization, as well as to estimate the radiobiological

교신저자 : Soo-Kil Kim
ADD : 602-702, 34 Amnam-dong Seo-gu, Busan, Korea, Biophysics, Kosin University College of Medicine,
TEL : 051-990-6427
E-mail : affipany@kosinmed.or.kr

damage of normal and critical organs for the conventional RT with opposed-lateral fields. And to study the effects of the CT for RT plan, third generation CT equipment was used to irradiate a human phantom on which TLDs had been placed on specific locations, and the estimated doses were compared with the RT experimental measurements.

Materials and Methods

Dosimeters

Experimental doses were determined with LiF rod dosimeters (TLD-100), approximately 6mm length, 1mm diameter. All dosimeters had previously been tested for homogeneity. This was done by irradiating all the dosimeters with the same dose(100 cGy) and then rejecting those with readings that deviated more than 10% when compared with the mean value.

Thermoplastic masks

Perforated thermoplastic immobilization masks are made of polycaprolactone baded plastics and have a thickness of approximately 2.5 mm and 1.5mm before and after stretched. The brand of thermoplastic is Aquaplast (WFR Aquaplast Corp., Wychoff, NJ); the 25cm x 25cm size was used throughout this experiment. A sheet of Aquaplast was heated in a water bath, stretched on a head of human phantom, and allowed to cool.

Human phantom

The experimental TLD measurements were made in a solid human phantom (Alderson Research Laboratories, Stanford, CT) that represents the head, thorax, and pelvic region of an adult and which consists of a natural skeleton covered with plastic substances to simulate the issues of muscles and lungs. The phantom is divided into transverse slabs with spaces to house the TLDs. In this study, only the head and neck were used and were irradiated with the technique employed in a conventional RT of the head and neck cancer.

Radiation treatment

Treatment plan included an iso-centric technique using anterior and opposed-lateral fields with 6MV photons. To avoid any potential overlap between the beams in the eyes, a block(Fig. 1) was placed on block tray to protect around eyes in the anterior field. The treatments were delivered to the human phantom with 12 TLDs placed on the head and neck surfaces(Fig. 2). Human phantom was immobilized using head mask made of 3-mm-thick perforated thermoplastic(Fig. 3). The skin doses were measured with and without the head mask. A total of 1500 cGy was delivered to the surface of head and neck phantom with a combination of photons both anterior and laterally.

One simple computed tomography (CT, Philips Tomoscan LX, Eindhoven, Netherlands) scan was also performed on the head and neck regions of the human phantom.[4] The dosimeters were placed on 12 positions analogous to those used in the RT phantom

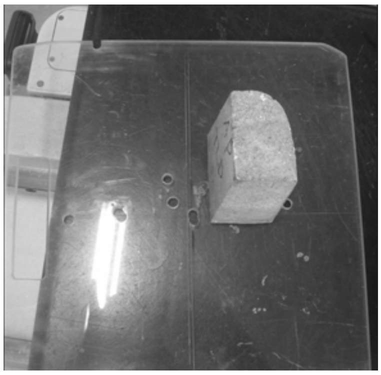

Fig.1. Cerabond block placed on block tray to protect around right eye in the anterior field.

Fig.2. Head and neck of human phantom immobilized by thermoplastic mask.

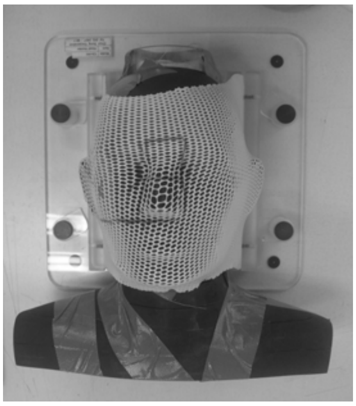

Fig.3. Human phantom showed the locations of 12 TLDs for irradiation.

Results

Table 1 shows the TLD measured doses for RT treatment with and without the mask respectively. The measured skin doses with the mask were consistently higher than those without the mask. The average dose increase was about 12% owing to the bolus effect of the mask, which resulted in a reduced skin-sparing advantage with the use of megavoltage radiation. But as shown in table 1, the differences measured by TLD 2, TLD 5 and TLD 10 have negative values compared with the differences in the TLDs of other locations. The effect of stretched thermoplastic on the phantom's surface is an interesting variation in TLD responses. A likely reason for the low-dose readings at these particular locations could be, because the TLD was placed at the hole of the mask.

Table 1. Variation of TLD measurements for depending on the presence of mask on human phantom.

Location	With mask (cGy)	Without mask (cGy)	Difference* (%)
TLD 1	91	68	34
TLD 2	60	69	-13
TLD 3	473	465	2
TLD 4	121	88	37
TLD 5	70	79	-12
TLD 6	560	493	13
TLD 7	644	475	35
TLD 8	344	298	15
TLD 9	66	49	35
TLD 10	48	54	-11
TLD 11	18	18	0
TLD 12	18	18	0
Average			12

* Dose difference =100(dose with mask − dose without mask)/ dose without mask

Table 2 normalized the skin doses of the organs of the head phantom to target organ(right cheek) without mask. It shows that the skin dose of left temple and left cheek (normal organs) were 87% and 63% of target organ respectively. These results of left parts on face had very high doses than we were expected in this RT treatment.

The CT examination for treatment plan was performed on human phantom with TLD in order to assess the increase of dose on the skin without mask and to verify the delivered dose during treatment sessions. The skin doses from the CT scan are given in Table 3. The average skin dose for one simple CT scan was 7 cGy. It was negligible compared to 1500 cGy of one fraction of RT treatment.

Discussion

Since the era of megavoltage RT, skin reactions have not been observed as frequently, unless there was a large amount of electron contamination of the beam or bolus material overlying the skin. Except for the folds of skin or for tangential beams (breast or chest wall irradiation), the epidermis no longer receives a high dose with megavoltage beams. However, even when optimal conditions of megavoltage irradiation are met, about 25% of the patients receiving RT using parallel opposed lateral fields will still

Table 2. Dose to the skin of the head and neck normalized by target organ using anterior and opposed -lateral portals with 6 MV photons.

	Parts on head and neck	Corner of eyebrow	Center of eye	Temples	Cheeks	Lip corners	Skin over thyroids
Fraction	Left parts	15	17	87	63	11	4
*(%)	Right parts	14	19	98	100	10	4

* Dose fraction=100(skin doe of each organ on face / skin dose of target organ)

Table 3. The skin doses on human phantom by one simple CT examination

Parts on head and neck	Corner of eyebrow	Center of eyelids	Temples	Cheeks	Corner of Lip	Skin over thyroids
Left part (cGy)	6	9	6	6	9	9
Right part (cGy)	6	7	6	9	5	9

have observable skin reactions[5)]

Multiple reasons could contribute to the increase skin toxicity observed clinically treated with conventional RT. The phantom measurement showed that the mask had a bolus effect on the skin surface. And the oblique incidence of the lateral beam would lead to an increase in the path length through the mask and thus increase the build-up.[6)] Especially over the left cheek and left temple parts where the mask made lateral fields into oblique incident beams could show huge amount of skin dose. This problem will increase using overlaying material of polystyrene cradles or carbon fibre.[7)] Finally, skin dose to some parts of the head would be more than total prescribed dose at iso-center, since the portals are opposed. For clinical situations where the target volume is superficial, some consideration should be given to beam inhomogeneity caused by conventional opposed-lateral fields.

Conclusion

The skin dose from overlaying fixation material has been estimated using a TLD. The human phantom measurement showed that the mask had a bolus effect on the skin surface. Using thermoplastic fixation and high-energy photons of 6 MV increase the dose to the skin considerably. And skin dose measurements of normal and critical organs show that the treatment protocol couldn' t protect them enough from radiation.

Two conclusions may be drawn from the data: a) the magnitude of the beam perturbation effect under thermoplastic mask can become significant (>3% TLD difference) on skin doses of head, and b) there is a negligible effect on beam fluence by CT scan for RT plan. These perturbations are not likely to have major clinical significance, but have been incompletely described previously. In an effort to provide optimal treatment of superficial tumors with high photon beam, however, a compromise should be drawn between beam heterogeneity and the potential immobilization loss caused by cutting beam portals out of the mask in certain clinical situations

In the future, the results from this study combined with the modeling of surface doses from linear accelerators in different clinical settings are to be used to estimate skin doses and compare predicted and actual skin reactions in a prospective clinical study.

국문초록

목적: 머리와 목부위의 악성종양 치료에 구멍이 뚫린 열 프라스틱 마스크가 널리 사용되고 있다. 그러나 결과적으로 고에너지 광자에 **저**밀도의 물질이 유입되어 피부흡수선량이 증가하게 된다. 본 연구는 환자를 고정시키는 열 플라스틱 마스크가 광자선 내에 있을 때 피부선량을 측정하여 일반 조직기관과 위험기관 부위에 방사선생체 손상 정도를 측정하고자 한다.

방법: 열마스크의 볼루스 효과, 맞대응 측방향 조사야, 그리고 치료계획용 CT 스캔 등으로 인한 피부 반응에 대한 원인을 조사하기위하여 흡수선량 연구를 시행하였다. 6MV 광자내에서의 마스크의 효과를 인체 팬텀 상의 열형광 선량계(TLD)를 이용하여 구하였다. 매 측정시 머리와 목부위의 중양과 측면부위에 12개의 TLD를 부착시켰다. 인체 팬텀의 머리 부위에 마스크를 씌우거나 씌우지 않은 상태에서 피부선량을 측정하였다.

결과: 맞대응 조사야로 방사선 치료시 마스크를 씌웠을 때의 피부선량은 씌우지 않은 경우에 비해 일률적으로 높은 값을 보였다. 흡수선량의 평균 증가량은 약 12%였다.치료목표 부위와 비교하여 일반 기관 조직부위와 위험기관에서의 선량은 각 각 약 10%와 16%였다. CT의 1회 조사시 피부선량은 약 7cGy 증가하였다.

결론: 고에너지 광자선 내에서 열플라스틱 마스크를 사용하는 경우 방사선 생체학적 결과를 피부선량을 측정하여 도출해 내었다.열플라스틱 고정기의 맞대응 측면방향 고에너지 6MV 광자선 내에서의 사용은 피부선량을 현**저**히 증가시키며, RT 계획용 CT 효과는 치료용 방사선량에 비해 무시할 수 있을 정도이다. 기존의 RT 치료는 일반 조직부위와 위험조직 부위의 피부를 방사선으로부터 보호할 수 없는 것으로 보인다. 따라서 이에 대한 해결책으로 특정부위의 마스크를 잘라낸다면 고정력의 상실과 방사선의 불균등성 사이에서 적절한 절충이 이루어져야만 할 것이다.

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