Journal of Radiological Science and Technology, 40(1), 63-70
eISSN 2384-1168 ISSN 2288-3509
http://dx.doi.org/10.17946/JRST.2017.40.1.10

<원저>

Comparison of Setup Deviations for Two Thermoplastic Immobilization Masks in Glottis Cancer

- 성문암 세기변조방사선치료에서 두 가지 열가소성 마스크에 대한 환자위치잡이 오차 평가 -

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— Abstract —

The purpose of this study was compare to the patient setup deviation of two different type thermoplastic immobilization masks for glottis cancer in the intensity-modulated radiation therapy (IMRT). A total of 16 glottis cancer cases were divided into two groups based on applied mask type: standard or alternative group. The mean error (M), three-dimensional setup displacement error (3D-error), systematic error (Σ), random error (σ) were calculated for each group, and also analyzed setup margin (mm). The 3D-errors were 5.2 ± 1.3 mm and 5.9 ± 0.7 mm for the standard and alternative groups, respectively; the alternative group was 13.6% higher than the standard group. The systematic errors in the roll angle and the x, y, z directions were 0.8°, 1.7 mm, 1.0 mm, and 1.5 mm in the alternative group and 0.8°, 1.1 mm, 1.8 mm, and 2.0 mm in the alternative group. The random errors in the x, y, z directions were 10.9%, 1.7%, and 23.1% lower in the alternative group than in the standard group. However, absolute rotational angle (*i.e.*, roll) in the alternative group was 12.4% higher than in the standard group. For calculated setup margin, the alternative group in x direction was 31.8% lower than in standard group. In contrast, the y and z direction were 52.6% and 21.6% higher than in the standard group. Although using a modified thermoplastic immobilization mask could be affect patient setup deviation in terms of numerical results, various point of view for an immobilization masks has need to research in terms of clinic issue.

Key words : Setup error, Thermoplastic, Mask, Tomotherapy, IMRT, Glottis

Ⅰ. INTRODUCTION

The intensity-modulated radiation therapy (IMRT) of patients with glottis cancer openly used in clinic when compare to the three-dimensional conformal radiation therapy (3D-CRT) technique because with respect to reducing later toxicity after treatment[1,2]. Quality of the treatment has be superior in recently because that an accuracy of tumor targeting through use the image-guide radiation therapy (IGRT) modalities, such as the electronic portal imaging device (EPID), cone-beam computed tomography (CBCT), and megavoltage CT (MVCT)[3] during the treatment. However, treatment volume of glottis

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Received 8 February 2017; Revised 14 March 2017; Accepted 20 March 2017

cancer is smaller than other disease, such as the laryngeal, tonsil, and hypopharyngeal cancer in neck area. Osman et al.[4] investigated accuracy of the treatment for 10 early glottis cancer patients by using CBCT images, reported that high targeting precision by using daily image-guided system (*i. e.*, IGRT) for a single vocal cord irradiation. However, it is necessary that consider for the dosimetric effect from small targeting error and geometric uncertainties including the three-dimensional (3D) coordinates: x, y, and z directions and rotation angles of axis: roll, pitch, and yaw, which could be differ each treatment units in institution[5].

In IMRT treatment, the uncertainty could be affect to variation of the prescription dose, expectation of target coverage, and treatment quality. Again, verification and correction of the treatment uncertainty factors including the patient's positioning, immobilization devices, treatment setup, motion of the patient and tumor, and an another specific problems in treatment process. In special, the geometric uncertainty of patient immobilization and localization system need to verify in first before treatment, and should be consider reducing uncertainties as possible.

In general, a thermoplastic immobilization mask is mostly used for patients with the head-and-neck (H&N) cancer, and important in using IMRT or stereotactic radiosurgery (SRS)[6]. Correcting of the setup deviations could be considerably through use of advanced IGRT system. A number of studies have evaluated a thermoplastic immobilization mask for H&N cancer, and reported the accuracy and reproducibility of these mask[6-15]. Gilbeau et al.[7] evaluated the setup accuracy of patients with brain or H&N tumors through compared to three different thermoplastic masks, and reported that thermoplastic masks provide an accurate patient immobilization based on results where setup variations are reduced when 4 or 5 FP (fixation points) masks are used, Sharp et al.[10] compared two types of thermoplastic masks, in terms of reproducibility, patient comfort, tolerability, and skin damage, and recommended that the smaller mask did not compromise the reproducibility of the setup. In addition, Velec et al.[12] analyzed setup errors including the systematic and random errors for H&N IMRT patients that compared for standard thermoplastic masks (SM) and skin-sparing mask (SSMs), which modified with low neck cutouts. There were no significant differences for theses errors. They recommended that cutout masks could be used in H&N patient with an effort to reduce skin toxicity, as well as no different setup errors.

As seen in the previous findings, each institution can be used various thermoplastic masks, which can contribute to setup uncertainties, and magnitudes of the uncertainties differ from institution to institution. We should be consider improvement that the thermoplastic immobilization mask with regard to reducing setup uncertainties and superior of patient comfort during treatment. Therefore, the purpose of this study was compared to the patient setup deviation of two different type thermoplastic immobilization masks for glottis cancer in IMRT.

II. METHODS AND MATERIALS

1. Treatment simulation and planning

We selected 16 patients with glottis cancer who were treated by using IMRT technique in Tomotherapy (Accuray Inc., Sunnyvale, CA, USA). All patients underwent treatment simulations for treatment planning by using CT simulator (Somatom Emotion, Siemens, Munich, Germany). The CT slice thickness was 3 mm with in-slice resolution of 512 × 512 pixel. A field of view was 500 mm and a scan length was at the level of the frontal sinus with the supra-clavicle lymphnode (SCL) area. Moreover, all patients were used the thermoplastic mask (5-PT HEAD AND NECK SHOULDER, Orifit, Belgium) that allowed fixation of the head and both shoulders.

All patients were divided into two groups (standard (n=8) and alternative group (n=8)) based on different two type of the thermoplastic immobilization mask. Figure 1 shows the patients with fixed a thermoplastic

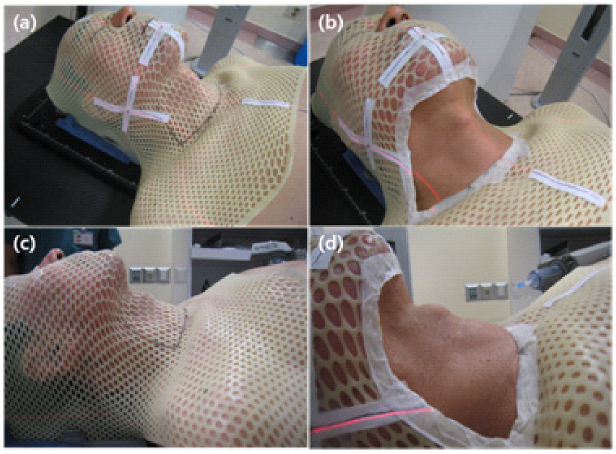

Fig. 1 Two type of a thermoplastic immobilization masks; standard type (a and c) and alternative type (b and d) with neck area cutouts

immobilization mask whether standard of modified with neck cutouts in glottis (*i. e.*, alternative) area during treatment simulation. Consequently, we planned to enroll 16 patients in this study, and randomize them to be treated in standard or alternative type. Planning kilovoltage CT (kVCT) images in a Tomotherapy planning system (Hi-Art II, Tomotherapy, USA) were acquired for all patients. The IMRT plan used at 1.0 cm field width and a 0.250 pitch with a prescribed dose of 70 Gy in 35 fractions.

2. Patient setup error and treatment correction

The verification and correction of setup errors should be used to verifying via the image registration (or image fusion) with the planning kVCT and daily MVCT images before treatment[3]. Daily MVCT scans included the planning target volume (PTV) as target lesion in whole neck and were acquired by using a coarse mode with a 6-mm reconstruction slice thickness. The daily setup errors were verified IGRT technique with daily MVCT scans, and corrected be these data, which are 3D translational directions (lateral: x, longitudinal: y, and vertical: z) and rotational direction (axis of lateral direction: roll). We applied same method that used in our institution for correction of these errors and acquiring data, which studied this issue and analyzed various clinical sites[16]. A total of 16 planning kVCT images and 570 daily MVCT images were analyzed from all patients in this study. All daily setup errors were respectively recorded and analyzed.

3. Data analysis

The mean error (M), 3D setup displacement error (3D-error), systematic error (Σ), random error (σ) were calculated for all patients. Here, 3D-errors is mean that the magnitude of the displacement from each coordination directions including x, y, and z direction in daily setup error, which calculated by using follow formula: $\sqrt{x^2+y^2+z^2}$. The systematic and random errors were calculated by the standard deviation and root-mean-squire (RMS) for each group. In addition, setup margin (mm) of the PTV was analyzed from calculated data by as equation: $2.5\Sigma + 0.7\sigma$. These values were calculated as explained by van Herk[17]. We also calculated absolute value of roll angle to verify magnitude of rotational errors. Statistically significant difference between the setup deviations of the two groups were determined by using the independent t-test. Differences were considered statistically significant for $P<0.05$.

III. Results

The critical results of this study are comparison the setup deviations for the standard and alternative groups depend on applied different thermoplastic mask types. Table 1 shows the patient setup deviations as key points of this study.

The groups means (M) in the x, y, z directions and the roll angles for the standard group (and the alternative group) were 3.5 mm (4.1 mm), 0.6 mm (0.8 mm), 0.2 mm (0.0 mm), and 0.1° (−0.1°), respectively. The mean absolute values of roll angles were 0.8° and 0.4° for the standard and alternative group, respectively. Moreover, the 3D-errors were 5.2 ± 1.3 mm and 5.9 ± 0.7 mm for the standard and alternative

Table 1 Setup deviations of the two groups (standard vs. alternative) with applied different thermoplastic masks

Directions	Standard group				Alternative group				*P*-value
	Mean (M)	Systematic (Σ)	Random (σ)	Margin (mm)	Mean (M)	Systematic (Σ)	Random (σ)	Margin (mm)	
X (mm)	3.5	1.7	1.8	5.5	4.1	1.1	1.6	3.8	0.003
Y (mm)	0.6	1.0	1.8	3.7	0.8	1.8	1.8	5.7	0.184
Z (mm)	0.2	1.5	2.9	5.7	0	2.0	2.7	6.9	0.591
3D-error (mm)	5.2	1.3	2.2	N/A	5.9	0.7	1.7	N/A	0.001
Roll (°)	0.1	0.8	0.8	N/A	-0.1	0.8	0.9	N/A	0.026
Abs (Roll)	0.8	0.4	0.7	N/A	0.9	0.4	0.7	N/A	0.001

Note: 3D-error = three-dimensional setup displacement.

groups, respectively; the alternative group was 13.6% higher than the standard group. In addition rotational angles (*i. e.*, roll) in the alternative group was 12.4% higher than in the standard group.

The systematic error (Σ) in the x, y, z directions the roll angle for the standard group (and the alternative group) were 1.7 mm (1.1 mm), 1.0 mm (1.8 mm), 1.5 mm (2.0 mm), and 0.8° (0.8°), respectively. In x direction, the systematic error was 38.0% lower in the alternative group than in the standard group. Furthermore, the 3D-error and absolute roll angle were 43.9% and 20.1% lower in the alternative group than in the standard group. Overall, the systematic error in the alternative group was smaller than in the standard group, excluding in the x direction.

The random error (σ) in the x, y, z directions an the roll angle for the standard group (and the alternative group) were 1.8 mm (1.6 mm), 1.8 mm (1.8 mm), 2.9 mm (2.7 mm), and 0.8° (0.9°), respectively. The random errors in the x, y, z directions were 10.9%, 1.7%, and 7.0% lower than in the alternative group than in the standard group. Overall, the random error in the alternative group was smaller than in the standard group, excluding in the roll angle.

For calculated PTV setup margin, the alternative group in x direction was 31.8% lower than in standard group. In contrast, the y and z direction were 52.6% and 21.6% higher than in the standard group. Lastly, statistically significant difference in the x direction, 3D-error, roll angle, and absolute roll angle were noted between the standard and the alternative group, as shown in Table 1 ($P<0.05$).

Figure 2 shows distribution of the magnitudes of setup deviations for each group. For standard group, cased with x, y, and z directions with 0−1 mm accounted for 12.1%, 38.8%, and 35.9% of the group; cases with 1−3 mm accounted for 25.6%, 45.2%, and 38.8% of the group; case with 3−5 mm accounted for 35.9%, 13.5%, and 13.9% of the group; and cases with >5 mm accounted for 26.3%, 2.5%, and 11.4% of the group. Moreover, the roll angles was within 0−1° for 64.8% of the cases; 1−3° for 32.7% of the cases; and 3−5° for 2.5% of the cases. For alternative group, cased with x, y, and z directions with 0−1 mm accounted for 2.9%, 30.1%, and 28.3% of the group; cases with 1−3 mm accounted for 21.1%, 45.9%, and 38.0% of the group; cases with 3−5 mm accounted for 43.0%, 19.4%, and 20.4% of the group; and cases with >5 mm accounted for 33.0%, 4.7%, and 13.3% of the group. Moreover, the roll angle was within 0−1° for 58.1% of the cases; 1−3° for 39.4% of the cases; 3−5° for 2.2% of the cases; and >5° for 0.4% of the cases.

IV. DISCUSSIONS

Author has previously studied for glottis cancer including the setup deviations, local targeting errors, neck curvatures, and statistical analysis[18,19]. The focus of my work is the targeting error and thermoplastic immobilization mask as patients fixation by using IMRT technique in Tomotherapy.

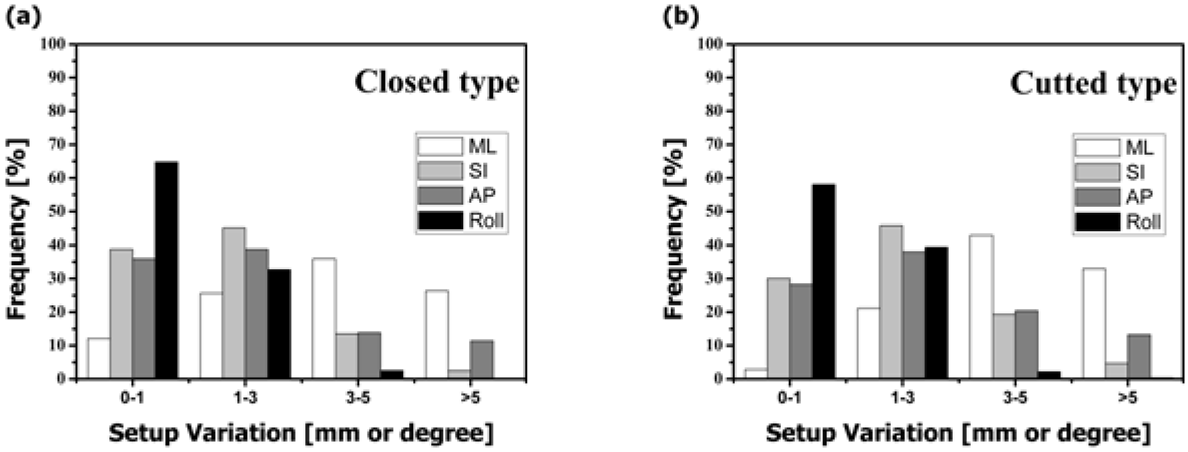

Fig. 2 Percentage of distribution in the treatment fractions of the setup deviations, the standard setup as closed type of the thermoplastic mask (a) and alternative group as modified (cutted) type (b), in all patients with the translational directions and roll angles

This study has simply designed to verify setup deviation. More, this target area of the glottis is smaller than another case in whole neck treatment. However, Tiong et al.[2] mentioned that since 2006, IMRT in glottis cancer was gradually introduced in our institution along with volumetric image-guidance (IGRT) protocols, and emphasized that IMRT can be safety for glottis cancers to ensure that there is no laryngeal displacement during daily setup[2]. Similarly, our institution has mostly using the IMRT technique for glottis cancer in Tomotherapy. Local setup variations with small tumor target should considering during the treatment, and has been checking uncertainties factors with respect to the flexibility and/or a rotational cervical spine in whole neck[4,20-23]. A thermoplastic immobilization mask should be appropriately using before treatment through considering parameters including the target size, location, radiation delivery methods, and patient conditions. In treatment simulation, the thermoplastic masks could be modifying with various types in terms of treatment accuracy and reproducibility. Li et al.[15] reported that “open face” thermoplastic masks could be readily adopted for use in clinic as a superior alternative to standard full head masks for claustrophobic patients. Velec et al.[12] and Kim et al.[9] studied an effort to reduce skin toxicity and possible treatment for patients who are claustrophobic or cannot tolerate a mask. In clinic, the thermoplastic mask to fixation can be changed according to various modified types.

An immobilization device is important to accurate during the treatment. We have modified a thermoplastic mask for glottis cancer through cutout mask in glottis area and lower neck, and guess that there were different setup deviation depend on two different masks in this study. In briefly, three major results has verified from analyzed data, as shown in Table 1. First is magnitude of the 3D-errors that alternative group was higher than in standard group with statistically significant different from all setup errors (P=0.01, P<0.05). These results were estimated high correlation between the translational directions (*i. e.*, x, y, and z direction) because of high magnitude different in x direction. There was statistically significant difference in x direction (P=0.003, P<0.05). However, the group means were less than 5 mm for each groups. For the systematic and random errors, the alternative group was lower than the standard group. Second is magnitude of the rotational errors including absolute value was less than 1°, as shown Table 1. Last is calculated PTV margin that magnitude requiring PTV margin in y direction was higher than in x and z direction. With regards to considering setup margin in y direction, there should be maintain checking at patient setup because due to that there can be mismatching because small target length during the image fusion between planning kVCT and daily MVCT images before treatment.

In addition, although the percentage distribution of treatment fraction was similar for each groups as shown Fig. 2, there were randomized variations for setup deviation in the standard and alternative thermoplastic masks. It seems that reproducibility of immobilization fixation was differing between in two masks type. Author have estimated that a modified thermoplastic mask has could be weakness of fixation because no perfectly contact with patient's skin in this study. Limitation of this study is small population data and no consideration for other rotational errors, such as pitch and yaw directions.

V. CONCLUSION

We verified the setup deviation through comparison between the standard thermoplastic mask and alternative modified mask for 16 patients with glottis cancer. There were statistically significant different in x direction, 3D-errors, and rotational angle. Furthermore, PTV margin in y and z direction should be considering in the alternative group compared with in the standard group. The patient setup uncertainty should be considering for glottis in IMRT when using modified thermoplastic immobilization mask for patients with claustrophobic and another situation for cutout mask during treatment. Although using a modified thermoplastic immobilization mask could be affect patient setup deviation in terms of numerical results, and various point of view for an immobilization masks has need to research in terms of clinic issue.

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•국문초록

성문암 세기변조방사선치료에서 두 가지 열가소성 마스크에 대한 환자위치잡이 오차 평가

정재홍

가톨릭대학교의과대학, 생체의공학교실

본 연구는 세기변조방사선 치료기술을 이용한 성문암 환자에게 사용되는 두 가지 상이한 열가소성 고정기구 마스크로 인한 환자위치잡이 오차를 비교 평가하고 자 하였다. 치료가 종료된 총 16명의 성문암 환자를 두 그룹으로 나누었고(기존마스크 vs. 변형마스크), 평균, 3D오차, 시스템과 랜덤오차를 구하여 환자위치잡이 오차를 비교하였다. 또한, 치료계획종양체적(PTV)에 대한 여백(margin)을 분석하였다. 3D오차에 대하여 기존그룹은 5.2 ± 1.3 mm고, 변형그룹은 5.9 ± 0.7 mm로써, 변형마스크가 변형보다 13.6% 높았다. 시스템오차는 기존그룹(변형그룹)에서 좌표 x, y, z방향은 각각 1.7 mm (1.1 mm), 1.0 mm (1.8 mm), 1.5 mm (2.0 mm)였고, 회전각(roll angle)은 0.8° (0.8°)였다. 랜덤오차는 변형그룹이 기존그룹에 비하여 좌표 x, y, z방향으로 10.9%, 1.7%, 23.1%로 낮았으나, 회전각은 12.4% 높았다. PTV여백에서 변형그룹은 좌표 x방향에 대하여 기존그룹에 비하여 31.8% 낮았으나, 반대로 좌표 y와 z방향에서는 기존그룹보다 각각 52.6%와 21.6%로 높았다. 성문암 세기변조방사선치료에서 변형된 마스크 사용은 고정기구의 변형으로 인한 환자위치잡이 오차는 수치적으로는 영향을 줄 수 있지만, 다양한 관점에서 고정기구 마스크에 대한 연구가 임상적인 측면에서 연구가 필요할 것으로 사료된다.

중심 단어: 환자위치잡이오차, 열가소성, 마스크, 토모테라피, 세기변조방사선치료, 성문