Cancer Management and Research

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ORIGINAL RESEARCH

Evaluation of the Position Error of Wearing Surgical Masks During Radiotherapy in Head and Neck Cancer Patients

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Purpose: Wearing a mask during the coronavirus disease 2019 epidemic (COVID-19) is a preventive way to reduce droplet and aerosol transmission. The purpose of this study was to evaluate the position error of wearing a surgical mask during radiotherapy in head and neck cancer patients.

Patients and Methods: We collected and analyzed 2351 kV X-ray image records of 81 patients with head and neck cancer who underwent image-guided radiotherapy (IGRT). Patients with/without a surgical mask were divided into the head-neck (HN) mask group and head-neck-shoulder (HNS) mask group. The position error in the X (left-right), Y (superior-inferior), Z (anterior-posterior), 3D (three dimensional) vectors, as well as the pitch and yaw axes were compared between the four groups.

Results: We found that patients wearing surgical masks in the HN mask group showed no significant differences in the mean position error of the different types of headrest ($p>0.05$). In the HNS mask group, only the type C headrest group showed significant differences ($P < 0.05$). The X axis values were -0.05 ± 0.07 and -0.11 ± 0.01 cm ($P = 0.04$), and the pitch axis values were $0.34\pm0.29°$ and $0.83\pm0.08°$ ($P = 0.01$).

Conclusion: The mean position error of most patients wearing surgical masks was not greater than patients without a surgical mask. Patients wearing while receiving treatment is a low-cost and easy-to-implement prevention method.

Keywords: COVID-19, head and neck cancer, image-guided radiotherapy, setup error

Introduction

Coronavirus disease 2019 (COVID-19) was first reported in Wuhan, China in December 2019,[1] which is caused by severe acute respiratory syndrome coronavirus (SARS-CoV-2). The virus can be transmitted from person to person through various routes such as droplets, aerosols and fomites.[2,3] Radiation therapy is the main treatment for many malignant tumors, but the course of treatment for patients may take several weeks. Cancer patients are more susceptible to infection than healthy people because radiation therapy may cause systemic immunosuppression in patients.[4] Therefore, these susceptible patients need to be protected from SARS-CoV-2 without interrupting treatment or extending the duration of radiation therapy. This is a serious problem that must be faced.

Prior to the start of the COVID-19 pandemic, it was not standard practice in our department for patients to wear surgical masks during radiotherapy. Considering that the main route of transmission of coronavirus is droplets and aerosols from patients with COVID-19, wearing a mask during medical treatment is a preventive method to reduce droplet and aerosol transmission.[5] In our department meeting, we discussed that there might be a risk of exposure via asymptomatic COVID-19 infected patients in clinical practice in the future. Starting from April 2020, we first allowed the wearing of surgical masks during radiotherapy for head and neck cancer patients with a high risk of infection, mainly

Received: 29 July 2022
Accepted: 29 October 2022
Published: 5 November 2022

to minimize virus contamination and reduce the exposure risk to radiation therapists. The purpose of this study was to evaluate the position error of wearing a surgical mask during radiotherapy in head and neck cancer patients.

Materials and Methods

This study was approved by the institutional review board at our institution (No. 202101085B0). The need for informed consent from each patient was waived by the institutional review board because this study was non-invasive and utilized routine treatment data based on patient data confidentiality and compliance with the Declaration of Helsinki. We collected and analyzed 2351 imaging records of 81 patients with head and neck cancer (HNC) who underwent image-guided radiotherapy (IGRT) in our department between January 2020 and May 2021. All patients were subjected to an energy of 6 or 10 megavolts (MV) of volume modulated arc therapy (VMAT). The characteristics of all patients are shown in Table 1. All patients underwent planning CT simulation in the supine position with a GE Discovery RT 16 Slice CT Simulator (GE Healthcare, Waukesha, USA) using a 2.5 mm slice thickness. Images results were then sent to a RayStation 8B treatment planning system (TPS; Raysearch Laboratories AB, Stockholm, Sweden), which performed target delineation and designed the treatment plan. The patient immobilization currently methods used are mainly S-Type thermoplastic masks, which was used to divide patients into the head and neck (HN) group and the head-neck-shoulder (HNS) group according to the fixed area. The selection criteria for the immobilization mask depends on the doctor's clinical considerations and preferences. Type B/C Timo headrests (CIVCO, Kalona, USA) are commonly used clinically and are shown in Figure 1.

First, during the preparation of the HN immobilization devices, the metal strips of the medical mask for nose clipping were removed by radiation therapists. Secondly, before immobilization mask molding, it must be confirmed that it should completely cover the patient's nose and mouth and there is no gap. The patient's breathing should be confirmed to avoid discomfort. Finally, the anatomical reference points of the patient's face and the position of the mask were delineated on the thermoplastic mask.

Timo headrests are constructed of durable polyurethane foam with a washable coating. The main difference is that the height of the headrest is different, so the comprehensive range of neck angulations is also different. The selection criteria

Table 1 Patient Characteristics

Characteristics	With Mask n=38, n (%)	Without Mask n=43, n (%)
Age (mean, SD)	60.5 (13.1)	53.7 (12.8)
Gender		
Male	22 (57.8)	24 (55.8)
Female	16 (42.1)	19 (44.1)
Thermoplastic mask type		
HN	20 (52.6)	39 (90.7)
HNS	18 (47.4)	4 (9.3)
Headrest type		
Type B	27 (71.0)	38 (88.4)
Type C	11 (28.9)	5 (11.6)
Treatment fraction (mean, SD)	28.6 (6.6)	29.3 (5.3)
Treatment dose (Gy) (mean, SD)	58.3 (10.4)	57.6 (10.5)
Diagnosis		
Oropharynx	7(18.4)	4(9.3)
Hypopharynx	2(5.3)	1(2.3)
Oral cavity	4(10.5)	6(14.0)
Brain	21(55.3)	26(60.5)
Nasopharynx	2(5.3)	1(2.3)
Other	2(5.3)	5(11.6)

Abbreviation: SD, standard deviation.

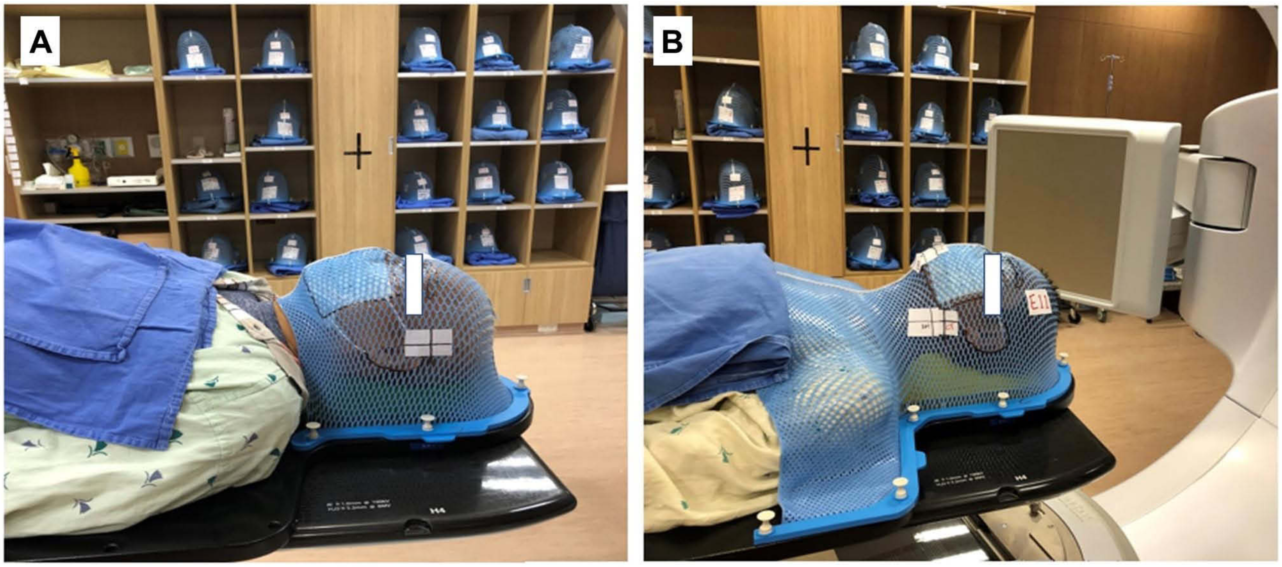

Figure 1 Patient Immobilization: (**A**) Head and neck (HN) mask and type B headrests. (**B**) Head-neck-shoulder (HNS) mask and type C headrest.

are based on the comfort and support of the patient when lying flat. In order to reduce the time spent in contact with the patient and in a confined space, we implemented the IGRT strategy and prioritized the use of faster kV imaging technology for patient position correction. Daily on-line image verification with two orthogonal high-resolution kV images and automatic couch corrections were performed using the On-Board Imager® (OBI) on the Edge™ radiosurgery system (Varian Medical Systems, Palo Alto, USA). Finally, the daily displacement error correction value of each patient was recorded. The coordinates of all axes are based on the supine position on the treatment couch. The X axis is the patient's right-left (RL) direction, positive toward the right and negative toward the left, the Y axis is the patient's superior-inferior (SI) direction, positive toward the head and negative toward the feet, and the Z axis is the patient's anterior-posterior (AP) direction, positive toward the abdomen and negative toward the back. Pitch is based on the Y axis, such that head raising is positive and foot raising is negative, while yaw is based on the Z axis, in which rotating clockwise is positive and rotating counterclockwise is negative. We used independent t-tests to evaluate the difference between the four groups. The statistical analyses were performed with IBM SPSS Statistics 22.0 (IBM Corp., Armonk, USA). A p-value less than 0.05 ($p < 0.05$) was considered statistically significant.

Finally, we calculated the required Planning Target Volume (PTV) margin for clinical data to provide a clinical reference for non-imaging guided patients. The PTV margin (M_{PTV})proposed by van Herk et al[6] was estimated as follows:

$$M_{PTV} = 2.5\sum + 0.7\sigma \tag{1}$$

The systematic error (Σ) was determined as the standard deviation of the mean value of each treatment record, and the random error (σ) was determined as the root mean square (RMS) of the standard deviation of the setup error for each patient.

Results

The box plots of the position error s for each axis of the entire patient with/without a surgical mask during radiotherapy are presented in Figure 2.

Although the medians of the X, Y and Z axes did not change much, the Z axis error range was significantly increased in the group without masks, which also means that the Z-axis error had a larger range of varied changes. The median error on the pitch axis increased and moved to a positive value, which was statistically significant ($p<0.01$). Further analysis showed that patients wearing surgical masks in the HN mask group had no significant differences in the average displacement error of the different types of headrests ($p>0.05$). In the HNS mask group, only the type C headrest group showed a significant difference ($P < 0.05$). The X axis values were −0.05±0.07 and −0.11± 0.01 cm ($P = 0.04$), and the pitch axis values were 0.34±0.29° and 0.83±0.08° ($P = 0.01$). The position errors and *t*-test results of the four groups are

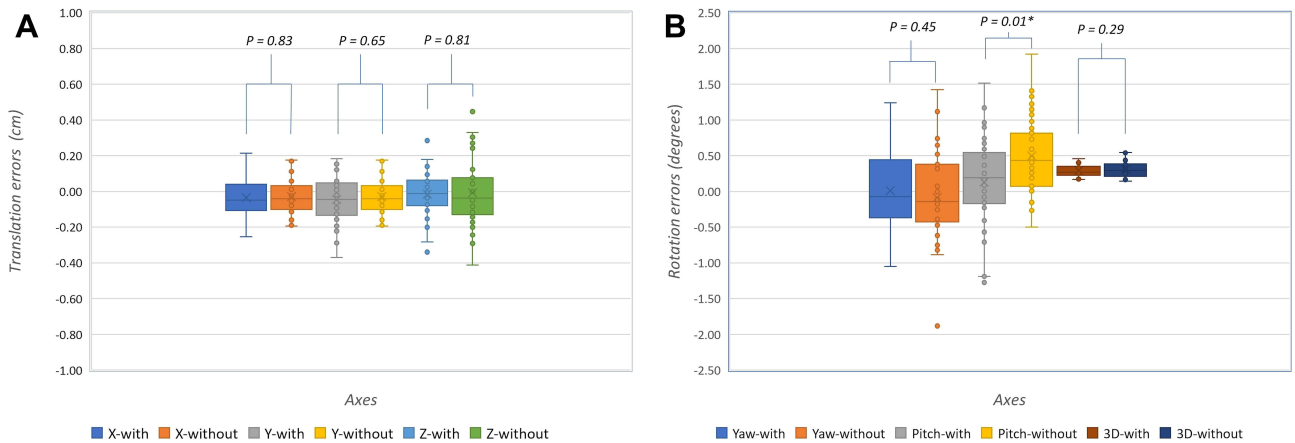

Figure 2 The box plots of the position error for each axis. (**A**) Translational errors in the X, Y, and Z directions (**B**) Rotational errors in the Yaw, Pitch, and 3D vector. **Note**: *p<0.05.

shown in Tables 2 and 3, with the systematic errors, random errors and estimated PTV margins proposed by van Herk et al Table 4 lists the recommended M_{PTV} for the two groups of patients. In the surgical mask group (including HN and

Table 2 Position Errors and Independent *t*-Test Results of 59 Cases of the HN Mask

	HN/type B Headrest			HN/type C Headrest		
	With Mask	**Without Mask**	***p*-value**	**With Mask**	**Without Mask**	***p*-value**
Axes	**Mean ± SD**	**Mean ± SD**		**Mean ± SD**	**Mean ± SD**	
X (cm)	−0.03±0.12	−0.01±0.16	0.41	−0.07±0.17	−0.12±0.08	0.74
Y (cm)	−0.02±0.13	−0.04±0.14	0.77	−0.17±0.02	−0.01±0.10	0.11
Z (cm)	−0.01±0.10	−0.10±0.64	0.93	−0.14±0.06	−0.01±0.36	0.71
3D (vector)	0.28±0.07	0.31±0.11	0.35	0.35±0.09	0.41±0.11	0.59
Yaw(°)	0.18±0.58	0.30±0.11	0.10	−0.63±0.60	−0.11±0.62	0.45
Pitch(°)	0.19±0.70	0.50±0.50	0.09	0.26±0.69	0.44±0.87	0.81

Note: The P value calculated from independent *t*-test.
Abbreviations: SD, standard deviation; X, right-left direction; Y, superior-inferior direction; Z, anterior-posterior direction; 3D, three-dimensional.

Table 3 Position Errors and Independent *t*-Test Results of 22 Cases of the HNS Mask

	HNS/type B Headrest			HNS/type C Headrest		
	With Mask	**Without Mask**	***p*-value**	**With Mask**	**Without Mask**	***p*-value**
Axes	**Mean ± SD**	**Mean ± SD**		**Mean ± SD**	**Mean ± SD**	
X (cm)	−0.02±0.07	0.01±0.09	0.74	−0.05±0.07	−0.11±0.01	0.04*
Y (cm)	−0.06±0.13	0.06±0.02	0.63	−0.05±0.11	−0.11±0.15	0.72
Z (cm)	0.01±0.18	−0.02±0.09	0.76	−0.04±0.14	0.05±0.32	0.77
3D vector	0.32±0.07	0.31±0.09	0.95	0.29±0.14	0.40±0.08	0.22
Yaw(°)	−0.04±0.40	−0.05±0.09	0.96	−0.19±0.39	0.18±0.50	0.51
Pitch(°)	−0.34±0.59	0.17±0.14	0.07	0.34±0.29	0.83±0.08	0.01*

Notes: The P value calculated from independent *t*-test. *p<0.05.
Abbreviations: SD, standard deviation; X, right-left direction; Y, superior-inferior direction; Z, anterior-posterior direction; 3D, three-dimensional.

Table 4 Systematic Errors, Random Errors and Estimated Margins Between the Two Groups

Axes	HN/HNS					
	With Mask			Without Mask		
	Σ	σ	M_{PTV}	Σ	σ	M_{PTV}
X (cm)	0.10	0.15	0.36	0.09	0.15	0.33
Y (cm)	0.13	0.17	0.44	0.14	0.17	0.47
Z (cm)	0.13	0.14	0.42	0.14	0.16	0.46

Abbreviations: X, right-left direction; Y, superior-inferior; Z, anterior-posterior direction; Σ, systematic errors; σ, random errors; M_{PTV}, estimated margins.

HNS), the estimated margins in the X, Y and Z axes were 0.36, 0.44 and 0.42 cm, respectively. In the groups without surgical masks, the estimated margins were 0.33, 0.47 and 0.46 cm, respectively.

Discussion

In our results, in the HNS mask group, only in type C headrest group showed a statistically significant difference. The possible causes are as follows:

1. Patients wearing masks were mainly treated during the epidemic. It was the consensus of the department to take on a reduced number of fractions with a higher dose to reduce the risk of infection. Therefore, patients treated during the pandemic may have less variation in increased displacement errors due to tumor shrinkage and weight loss.

2. The use of HNS masks also mainly consider neck and shoulder displacements, when patients show differences in clearance within the thermoplastic mask, which may also cause displacements due to changes in the neck angle, especially the pitch axis.

From the overall results, it can be seen that although there were significant differences between patients with and without surgical masks in some axial directions, the overall mean position error range was within 2 mm, and the calculated M_{PTV} was also within a reasonable range.[7–12] In the literature, Yu et al[11] suggested the if it is not possible to perform image guidance every day, it is recommended that the M_{PTV} should be at least 5 mm.

Chen et al[7] suggested for patients with head and neck cancer, if IGRT can be performed daily, 3-mm PTV expansion margins seem to be sufficient and do not increase the risk of local treatment failure. In our experience, beyond being easy to implement and comfortable for patients, a good immobilization device should be highly reproducible during the course of treatment and maximally limit patient motion. The mask contains different types of immobilization devices, ie, the thermoplastic mask material, head support and mask wearing position will affect imaging reproducibility. The surgical mask is divided into three layers: a water blocking layer (hydrophobic non-woven layer), a filtering layer (melt-blown layer) and a water-absorbing layer (soft absorbent non-woven), with particulate filterability, waterproof and anti-spray properties. The physical thickness of the mask is about 0.5 mm. Assessing the reproducibility of the mask wearing position was one goal of our research.

During treatment, the position of the thermoplastic mask should also be aligned or adjusted with reference to the markings on the thermoplastic mask. At present, in the other studies have also started to study the feasibility of patients wearing masks to receive different radiotherapy techniques.[13–15]

In the literature, Ding et al.[13] The CBCT was mainly used to measure the difference of patient's position when patient was treated using HN and HNS thermoplastic mask with/without Surgical Mask. Miura et al[14] mainly used ExacTrac positioning combined with IGRT evaluate the fixation of patients undergoing intracranial stereotactic radiosurgery and stereotactic radiotherapy (SRS/SRT) with/without surgical masks. Ohhira et al[15] compared the intrafractional setup error with and without a bite block during fractionated intracranial stereotactic irradiation of patients wearing medical masks.

Unlike the above studies, we used 2D kV image for image guiding because only 15 to 20 seconds were needed for image acquisition in 2D kV image and 2 to 3 minutes were needed for image acquisition in CBCT. Using orthogonal 2D kV to reduce treatment time might have the chance to reduce the virus contamination time or exposure risk in the confined spaces during the epidemic period. Therefore, the imaging data collected in this study are mainly analyzed based on the interfractional error of the patients.

However, since the immobilization devices and setup techniques of each hospital are different, more clinical data needs to be collected for verification in the future.

In clinical practice, interfractional error is usually defined as anatomic structures deviation between pre-treatment position and treatment planning patient's position; intrafractional error is usually defined as the errors caused by organ motion or patient position change during treatment.

Our research has some limitations. First, this was a retrospective study, and there might be some selection bias in the enrolled patients. Secondly, the immobilization mask and treatment may not always be performed by the same group of therapists; IGRT image-matching skills are not necessarily the same for each therapist, although standard operating procedures are used to reduce differences between observers. Third, wearing surgical masks during radiotherapy is only an intervention during epidemics is not routine, so the study did not specifically explore the possibility that patients undergo tumor shrinkage and weight loss during radiotherapy, which may lead to increased displacement errors.

Conclusion

The mean position error of most patients treated with masks was not greater than that of patients without masks. The way in which patients wear masks to receive treatment is a low-cost and easy-to-implement prevention method, which can reduce the risk of virus transmission and therapist contact. At this stage, it is a preventive approach that has more advantages than disadvantages.

Abbreviations

COVID-19, coronavirus disease 2019; IGRT, image-guided radiotherapy; HN, head-neck; HNS, head-neck-shoulder; 3D, three dimensional; VMAT, volume modulated arc therapy; PTV, Planning Target Volume.

Ethics Statement

This study was approved by the Chang Gung Medical Foundation Institutional Review Board (No. 202101085B0).

Disclosure

The authors report no conflicts of interest in this work.

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