Effect of Surgical Mask on Setup Error in Head and Neck Radiotherapy

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Abstract

Purpose: With the widespread prevalence of Corona Virus Disease 2019 (COVID-19), cancer patients are suggested to wear a surgical mask during radiation treatment. In this study, cone beam CT (CBCT) was used to investigate the effect of surgical mask on setup errors in head and neck radiotherapy. **Methods:** A total of 91 patients with head and neck tumors were selected. CBCT was performed to localize target volume after patient set up. The images obtained by CBCT before treatment were automatically registered with CT images and manually fine-tuned. The setup errors of patients in 6 directions of Vrt, Lng, Lat, Pitch, Roll and Rotation were recorded. The patients were divided into groups according to whether they wore the surgical mask, the type of immobilization mask used and the location of the isocenter. The setup errors of patients were calculated. A *t*-test was performed to detect whether it was statistically significant. **Results:** In the 4 groups, the standard deviation in the directions of Lng and Pitch of the with surgical mask group were all higher than that in the without surgical mask group. In the head-neck-shoulder mask group, the mean in the Lng direction of the with surgical mask group was larger than that of the without surgical mask group. In the lateral isocenter group, the mean in the Lng and Pitch directions of the with surgical mask group were larger than that of the without surgical mask group. The *t*-test results showed that there was significant difference in the setup error between the 2 groups ($p = 0.043$ and $p = 0.013$, respectively) only in the Lng and Pitch directions of the head-neck-shoulder mask group. In addition, the setup error of 6 patients with immobilization open masks exhibited no distinguished difference from that of the patients with regular immobilization masks. **Conclusion:** In the head and neck radiotherapy patients, the setup error was affected by wearing surgical mask. It is recommended that the immobilization open mask should be used when the patient cannot finish the whole treatment with a surgical mask.

Introduction

Head and neck cancers account for 9 of the world's 36 most common cancers, with non-Hodgkin lymphoma, nasopharyngeal, lip, oral cavity, brain metastases, and throat cancers predominating et al. About 70% of head and neck tumors are advanced tumors.[1,2] Radiotherapy is an effective treatment for malignant tumors.[3] With the continuous development of radiotherapy technology, the accuracy of radiotherapy continues to improve. However, the recent outbreak of COVID-19 affected the process of radiotherapy for patients. The COVID-19 mainly spreads from person to person through respiratory droplets, and normal people are exposed to infectious droplets when they are in close contact with infected people. Exposure to surfaces in the environment surrounding an infected person may also cause the disease.[4] Van Doremalen et al.[5] described that viral

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aerosols can persist in the air for up to 3 to 4 hours under laboratory conditions. The virus strains had mutated over time and spread in different regions, with one strain becoming more infectious, as described by Tang et al.[6] The surgical mask is divided into 3 layers: water blocking layer, filtering layer and water absorbing layer, with particulate filterability, waterproof and anti-spray properties. The results of the Mata analysis by Chinazzi et al.[7] showed that both N95 respirators and surgical masks can be used to prevent infectious acute respiratory tract infection and prevent the spread of droplets. Wearing masks was also a key factor in the containment of the Wuhan epidemic, and it greatly reduced the spread of disease.[8,9] Also asymptomatic infected people and those in the incubation period still have a certain risk of spreading the disease. Therefore, facial masking is an inevitable choice.[10]

The COVID-19 is generally very contagious, while cancer patients and obese people are more susceptible to infection.[11] Data from Liang et al.[12] show that cancer patients infected with COVID-19 have a higher risk of developing severe disease and worsen more rapidly than non-cancer patients. Cancer patients are physically weak, especially those who are receiving treatment such as chemotherapy and radiation therapy, which may lead to reduced resistance to disease and higher risk of infection. In addition, radiotherapy treatment takes place in a confined space, which increases the risk of contracting the virus.[13] In the early stage of the outbreak of COVID-19, the transmission mechanism of the virus has not yet been studied and there is no conclusion to date. Therefore, cancer patients during radiotherapy should wear a surgical mask to prevent infection between patients and alleviate their fear of the virus. In addition, it is a precaution to protect radiation therapists from droplet transmission.

During the epidemic period of COVID-19, all patients wore masks during radiotherapy. Wuhan was locked down on January 23, 2020, and hospitals in the city urgently invested all their efforts to fight the epidemic. The Hubei Cancer Hospital became the first hospital to resume radiotherapy treatment after the Chinese Spring Festival holiday (Jan 24, 2020-Jan 30, 2020). Patients were required to wear surgical masks for treatment since the resumption of radiotherapy. In this study, CBCT was used to study the effect of wearing surgical masks on patients' setup errors. This study aims to provide suggestions for daily patient positioning and clinical planning target volume (PTV) margin.

Materials and Methods

A total of 91 patients were recruited in this study. The characteristics of all patients are shown in Table 1.

Patients were set up in supine position with appropriate headrest and immobilized with head mask or head-neck-shoulder mask according to the type of disease. CT images were acquired on Brilliance CT BigBore scanner (Philips, Netherlands) with slice thickness of 3 mm, and then sent to the Eclipse treatment planning system (Varian, Eclipse13.6, USA) for target volume delineation and treatment plan design. Patients were set up and verified on the Acuity simulator

Table 1. The Characteristics of 91 Patients.

Age	Median age 52, range 13-79
Sex	Male (48 cases), Female (43 cases)
Tumor type	Brain tumor (59 cases), Nasopharyngeal Carcinoma (17 cases), Lymphoma (7 cases), Parotid Gland Carcinoma (3 cases), Lip Carcinoma (2 cases), Tongue Carcinoma (1 case), Laryngeal Carcinoma (1 case) Maxillary Sinus Carcinoma (1 case)
Staging	stage I (6 cases), stage II (14 cases), stage III (16 cases), stage IV (55 cases)

(Varian, USA) before starting treatment on Varian Edge linear accelerator (Varian, USA). CBCT images were obtained before treatment, and then automatically registered with CT images and then manually adjusted according to bony anatomy. The setup errors of CBCT verification in 6 directions of Vrt, Lng, Lat, Pitch, Roll and Rotation were recorded. All patients underwent CBCT at first 3 treatments, and once a week thereafter.

According to the immobilization mask type, the patients were divided into head mask group and head-neck-shoulder mask group. Patients with isocenter displacement from midline of within 5 mm belonged to the medial isocenter group. And patients with isocenter displacement from midline of 10 mm-60 mm belonged to the lateral isocenter group. Each group was divided into without surgical mask group and with surgical mask group.

The setup error was calculated according to the calculation method described by Stroom.[14] The systematic error is the average of the individual fraction error, and the random error is the variance of the individual fraction error. PTV was defined according to the geometric variation and uncertainty of Clinical Target Volume (CTV). According to Van Herk's formula, the extended boundary (margin of planning target volume, MPTV) $= 2.5\sum + 0.7\sigma$, where $\sum$ represents the standard deviation of individual systematic errors of all patients, and the group random error σ is the standard deviation of individual random errors of all patients.[15,16]

The data were analyzed by SPSS 21.0 software (IBM, USA) to calculate the setup error. Student's *t*-test was performed in 4 groups according to the type of immobilization mask and location of isocenter. Significant difference was defined as $p < 0.05$.

Results

In general, there is no distinguished difference in the mean between the with surgical mask group and the without surgical mask group, but the standard deviation (SD) of the former is larger than that of the latter, especially in 3 angle directions. The setup errors of 48 cases without surgical mask in 6 directions were (0.27 ± 1.27) mm, (-0.04 ± 1.31) mm, (-0.01 ± 1.15) mm, $(-0.04 \pm 0.88)°$, $(0.27 \pm 1.45)°$, $(0.30 \pm 1.24)°$, respectively. The setup errors of 43 patients wearing surgical masks in 6 directions were (0.23 ± 1.49) mm, (0.04 ± 2.07) mm, (0.02 ± 1.57) mm, $(-0.07 \pm 1.69)°$, $(-0.07 \pm 1.60)°$, $(0.42 \pm$
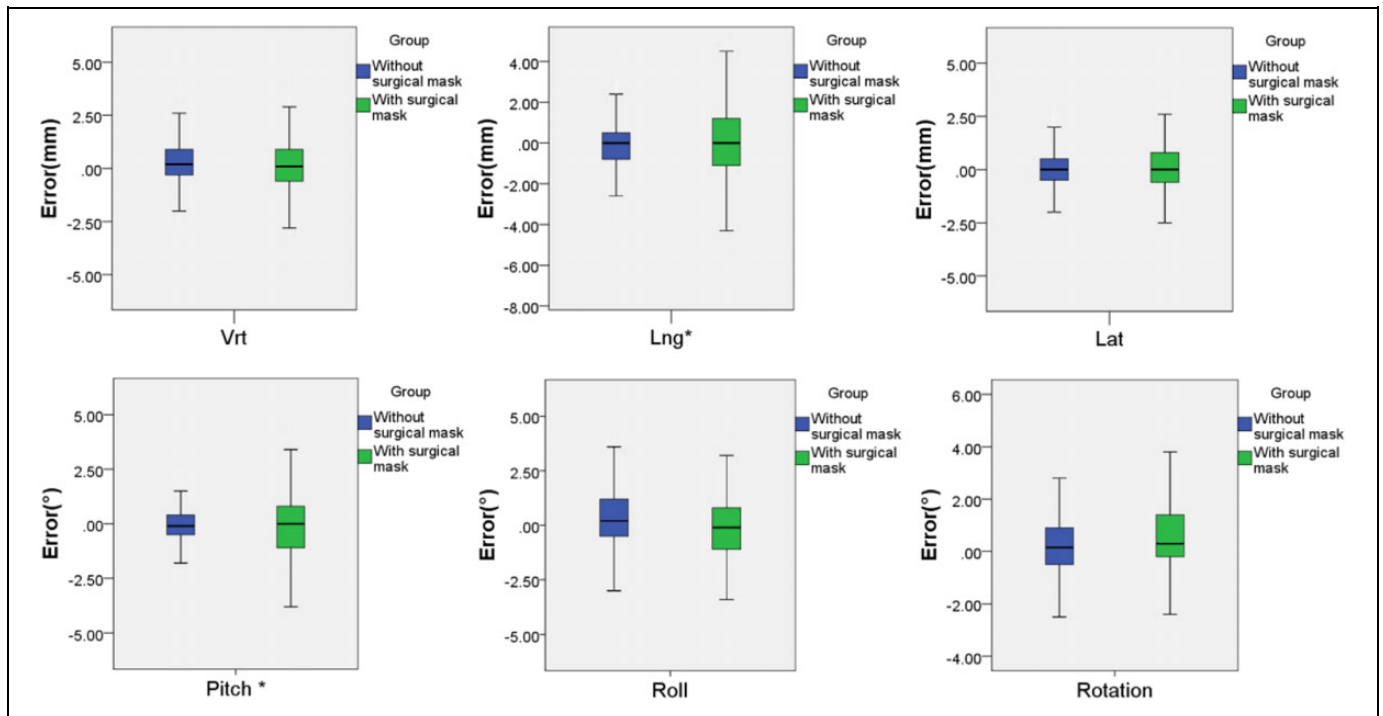
Figure 1. The box plot of setup error of the 48 cases of without surgical mask group and the 43 cases of with surgical mask group in 6 directions. The directions with significant differences were marked with asterisks.

Table 2. Setup Errors and t-Test Results of 59 Cases of the Head Mask Group.

Index	Without surgical mask	With surgical mask	p-value	t-value
Vrt (mm)	−0.14 ± 1.18	0.03 ± 1.53	0.342	−0.951
Lng (mm)	−0.02 ± 1.25	0.36 ± 2.11	0.097	−1.671
Lat (mm)	0.02 ± 1.09	−0.01 ± 1.62	0.880	0.151
Pitch (°)	0.13 ± 1.02	−0.20 ± 1.86	0.106	1.626
Roll (°)	0.34 ± 1.63	−0.04 ± 1.78	0.089	1.710
Rotation (°)	0.43 ± 1.48	0.45 ± 1.36	0.907	−0.117

Table 4. Setup Errors and T-Test Results of 61 Cases of the Medial Isocenter Group.

Index	Without surgical mask	With surgical mask	p-value	t-value
Vrt (mm)	0.43 ± 1.15	0.26 ± 1.38	0.293	1.055
Lng (mm)	−0.10 ± 1.42	−0.13 ± 2.08	0.896	0.131
Lat (mm)	0.01 ± 1.06	0.03 ± 1.52	0.919	−0.101
Pitch (°)	−0.01 ± 0.88	0.06 ± 1.70	0.699	−0.388
Roll (°)	0.30 ± 1.45	−0.04 ± 1.66	0.091	1.698
Rotation (°)	0.28 ± 1.25	0.33 ± 1.20	0.757	−0.310

Table 3. Setup Errors and t-Test Results of 32 Cases of the Head-Neck-Shoulder Mask Group.

Index	Without surgical mask	With surgical mask	p-value	t-value
Vrt (mm)	0.80 ± 1.19	0.65 ± 1.33	0.476	0.714
Lng (mm)	−0.06 ± 1.38	−0.65 ± 1.83	0.043	2.052
Lat (mm)	−0.05 ± 1.23	0.09 ± 1.46	0.536	−0.620
Pitch (°)	−0.27 ± 0.59	0.18 ± 1.21	0.013	−2.549
Roll (°)	0.17 ± 1.18	−0.14 ± 1.11	0.131	1.519
Rotation (°)	0.12 ± 0.81	0.34 ± 1.08	0.160	−1.411

Table 5. Setup Errors and t-Test Results of 30 Cases of the Lateral Isocenter Group.

Index	Without surgical mask	With surgical mask	p-value	t-value
Vrt (mm)	−0.01 ± 1.41	0.11 ± 1.68	0.670	−0.427
Lng (mm)	0.07 ± 1.42	0.44 ± 1.95	0.213	−1.255
Lat (mm)	−0.05 ± 1.29	−0.01 ± 1.67	0.865	−0.170
Pitch (°)	−0.09 ± 0.89	−0.41 ± 1.60	0.196	1.298
Roll (°)	0.29 ± 1.30	−0.10 ± 1.48	0.103	1.643
Rotation (°)	0.33 ± 1.24	0.56 ± 1.38	0.313	−1.013

1.28)°, respectively. The error bar chart of the without surgical mask group and the with surgical mask group in 3 linear directions and 3 rotation directions is shown in Figure 1. The setup errors and t-test results of the 4 groups are shown in the following Tables 2–5.

Among the 4 groups, there was no distinguished difference in the mean between the with surgical mask group and the without surgical mask group. The main difference was in the SD. In the head mask group, there was no distinguished

Figure 2. A cranial patient wearing a surgical mask underneath an immobilization open mask in the left, and an immobilization open mask in the right.

difference in the mean between the 2 groups. The SD in the directions of Lng and Pitch of the with surgical mask group were higher than that in the without surgical mask group. The result of a student *t*-test showed that there was no significant difference in all directions ($p > 0.05$). In the head-neck-shoulder mask group, the mean in the Lng direction of the with surgical mask group were larger than that of the without surgical mask group, but there was no distinguished difference in other directions. The SD of the group with surgical mask in Lng and Pitch directions were larger than that of the group without surgical mask. There was significant difference in the Lng and Pitch directions ($p = 0.043$ and $p = 0.013$, respectively), but there was no significant difference in the other directions ($p > 0.05$).

In the medial isocenter group, there was no distinguished difference in the mean between the with and the without surgical mask groups. The SD in the Lng and Pitch directions of the with surgical mask group were greater than that of the without surgical mask group. There was no significant difference in all directions ($p > 0.05$). In the lateral isocenter group, the mean in the Lng and Pitch directions of the with surgical mask group were larger than that of the without surgical mask group, but there was no distinguished difference in other directions. The SD of the former group in Lng and Pitch directions were larger than that of the latter group. There was no significant difference in all directions ($p > 0.05$).

Some patients had to breathe through mouth when wearing a surgical mask, resulting in them breathing with mouth open. For those patients, open masks with an opening in the mouth region were adopted to facilitate their breathing through nose, as shown in Figure 2. The setup errors of 6 patients with open masks were (-0.25 ± 1.01) mm, (0.02 ± 1.78) mm, (-0.23 ± 0.97) mm, $(0.05 \pm 1.63)°$, $(-0.32 \pm 1.68)°$, $(0.36 \pm 1.51)°$ in 6 directions.

From the PTV expansion formula MPTV $= 2.5 \sum + 0.7\sigma$,[15] it was calculated that in the 59 cases of head mask group, the margin values of 29 cases without surgical mask and 30 cases with surgical mask in the directions of Vrt, Lng and Lat were 2.41 mm, 2.56 mm, 2.16 mm and 2.74 mm, 4.33 mm, 3.32 mm, respectively. In 32 cases of head-neck-shoulder mask group, the margin values of 19 cases without surgical mask and 13 cases with surgical mask in the directions of Vrt, Lng and Lat were 2.02 mm, 3.14 mm, 2.43 mm and 2.97 mm, 4.61 mm, 2.94 mm, respectively.

In 61 cases of medial isocenter group, the margin values of 32 cases without surgical masks and 29 cases with surgical masks in the directions of Vrt, Lng and Lat were calculated to be 2.47 mm, 3.14 mm, 2.13 mm and 2.56 mm, 4.85 mm, 3.01 mm, respectively. In 30 cases with lateral isocenter group, the margin values of 16 cases without surgical masks and 14 cases with surgical masks were 2.91 mm, 2.83 mm, 2.66 mm and 3.35 mm, 3.75 mm, 3.89 mm in the directions of Vrt, Lng and Lat, respectively.

Discussion

The COVID-19 is now in the world pandemic period. The Hubei Cancer Hospital, which was the first in Wuhan to start radiation treatment during the outbreak and the epicenter of the outbreak hospital in Wuhan, has the largest number of radiotherapy patients (the average daily radiotherapy patients exceeded 200 in April). In order to prevent infection, all staff

and patients in our clinic wear masks. In the early stage of the outbreak of COVID-19, in most clinics around the world, the radiotherapy staff were not equipped with full personal protective equipment (PPE) when treating patients. Even until now, not every clinic requires patients to wear surgical masks or has enough resource to fully protect its staff. This paper explores whether the surgical mask worn by patients in the course of radiotherapy has an effect on the setup error, so as to provide reference for other clinics, especially those who treat head and neck patients without daily CBCT. Our study also provides some experiences on general patient masking practice.

The results showed that there is no distinguished difference in the mean between with mask group and without mask group. Generally, the mean of with a surgical mask is larger than that of without a surgical mask. But there was distinguished difference in SD between them.

The surgical masks that patients wore may have different design, and even if the thin wire were pressed to conform to face, there still might be gaps between the mask and face. At the same time, because of the presence of surgical mask, the immobilization mask cannot fit well during the treatment, making it hard to align the chin. Some patients had to breathe through mouth when wearing a surgical mask, which could affect the Pitch and the Lng positioning. However, for the patients with open masks, there is no distinguished different from the error of regular masks. Comparing to regular mask, the intrafraction random and systemic error were less than 1 mm and less than 1° for open masks in head and neck tumors,[17] suggesting that open masks can be used if the patient cannot breathe through nose to the end of treatment.

For all patients with open masks, plans of 2 arcs were delivered. Generally surface monitoring system would be utilized for patients with open masks to make sure they hold their positions during treatment. In this case, due to the presence of surgical masks, surface monitoring system could not be used for those patients because it only monitors human skin. Therefore, in order to verity patient position in each fraction, kV orthogonal images were taken between arcs. If the shifts after image registration exceeded threshold (< 1 mm), CBCT must be performed again before the delivery of the second arc.

The bony anatomy-based registration was used in the registration of CT images and CBCT images. The range of Region of Interest (ROI) was selected based on the PTV and the high-dose areas or Organs at Risk (OAR) near the target volume. In the head-neck-shoulder mask group, spine alignment weighed more than that of the head-neck mask group in the registration. This may explain the larger SD in the Lng and Pitch directions of the head-neck-shoulder mask group than that of the head mask group.

In fact, the SD in the directions of Vrt, Lng, Lat and Pitch in the with surgical masks group were larger in the lateral isocenter group. Therefore, it is suggested that the isocenter should be placed as medial as possible. On the other hand, in this group, the majority of patients were brain metastases patients treated with Stereotactic Body Radiation Therapy (SBRT).[18] It is an effective method for the treatment of head

and neck tumors. For those patients, the isocenters were placed at tumor location, most likely not in the medial. However, SBRT patients will be scanned with CBCT before each treatment. Although the error of isocentric eccentricity is relatively large, it can be well corrected by CBCT every time.

It is suggested that in the process of making the immobilization face mask, special attention should be paid to pinching the thin wire on the surgical mask and the fitting condition of the mask on both sides of the nose and chin of the patient for the simulation therapists. In the treatment, the mask should be fit by therapists to fit the patient in the directions of Vrt and Lng.

The margin value from CTV to PTV is affected by positioning accuracy and repeatability.[18,19,20] Therefore, the margin values of PTV of head and neck tumors should be determined according to the setup error. The results of this study show that non-uniform expansion can be adopted. In view of the fact that most of the p values of t-test are greater than 0.05, it is recommended to use the our routine 3 mm for head and neck tumors in margin value of PTV expansion from CTV. In the Lng direction the margin can be extended to 4 mm according to the calculation presented. Because the p values of the head-neck-shoulder mask in the Lng and Pitch directions were less than 0.05 and the SD were large, it is recommended to use open mask for some patients who tend to breath through their mouths.

One limitation of this study is that limited CBCT data set were acquired for each patient, except for SBRT patients. The infrequent image guidance is due to the health insurance policy in China that most of patients pay out-of-pocket for cancer treatment, so most patients could not pay for imaging guidance in all fractions. Therefore, patients generally will only get CBCT scans in the first 3 treatments and once a week in the later treatments. Other possible contribution factors to setup error including respiratory issues and pre-existing comorbidities were not taken into account because patients who have severe respiratory issues or pre-existing comorbidities were not recommended for radiotherapy, therefore not included in this study. Also, the head and neck patients only wear surgical masks under special circumstances, for example, after COVID-19 outbreak. More patients need to be recruited and further study is underway.

Conclusions

In conclusion, wearing a surgical mask during head and neck radiotherapy has an effect on setup error and minimum impact on PTV margins. It provides a practical reference for clinical application. It is suggested that during epidemic prevention and control, special attention should be paid to the fitting of the face mask on the wing of nose, chin and face, as well as the positioning in the Lng direction during setup, in order to ensure the accuracy of positioning repeatability.

Authors' Note

Yi Ding, Pingping Ma, and Wei Li, contributed equally and are joint first authors. This study was approved by Institutional Reviewer Board

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