Assessment of the Offline Setup Correction Protocol and Thermoplastic Mask Use for Head and Neck Cancer Radiotherapy: A Single Institution Experience

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Abstract

This study assessed the efficiency of offline setup correction protocol and the use of a thermoplastic mask for head and neck cancer (HNC) patients treated with three-dimensional conformal radiotherapy at Ocean Road Cancer Institute. A prospective study was conducted from April to August 2021 to verify 62 patients' treatment setup using an offline setup correction protocol while immobilized with a thermoplastic mask. Megavoltage images were matched with digitally reconstructed radiographs obtained during CT simulation to determine the gross set-up deviations. Box plots were used to show the deviations on three consecutive days of the first week and a successive weekly set-up verification in lateral, longitudinal, and vertical directions. The associations between thermoplastic mask types and weekly deviations were analyzed using repeated test ANOVA. A p-value < 0.05 was considered statistically significant. The observed deviations after the use of correction protocol were lower in all three translational directions. There was no statistical significance between types of thermoplastic mask and setup deviations in lateral ($p < 0.65$), longitudinal ($p = 0.19$), and vertical ($p = 0.12$) directions. The offline correction protocol can be used in settings with limited resources and high workloads of patients. Both types of thermoplastic masks are effective in immobilizing HNC patients.

Keywords: Offline setup correction protocol, thermoplastic mask, head and neck cancer, radiotherapy, Ocean Road Cancer Institute.

Introduction

Head and neck cancers (HNC) emerge within mucosal surfaces lining the upper aero-digestive tract of which more than 90% are squamous cell carcinomas (Heroiu et al. 2013, Garfield 2020). According to the GLOBOCAN 2020 estimates, HNC is ranked the seventh most common cancer globally (Sung et al. 2021). It is expected that by 2030, the incidence of HNC will have increased by 30% annually (Gormley et al. 2022).

Management of HNC involves multimodality approaches such as surgery, chemotherapy, and radiotherapy (RT). The modality to use depends on the patient's treatment preference, the disease's primary site, the stage of the disease, and staff expertise (Gilyoma et al. 2015). RT can either be offered alone or with a combination of

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surgery and chemotherapy based on the tumour stage and the patient's condition (Lo Nigro et al. 2017). About 75% of HNC patients require RT for either curative or palliative treatment (Ratko et al. 2014).

RT requires a high degree of precision; hence reproducibility of daily patient treatment setup is recommended due to the vicinity of head and neck anatomical structures (Hong et al. 2005). In this situation, it is not only possible to reduce the spectrum of toxicities to the adjacent normal critical structures but also to maximize the radiation dose to the target (Burnet et al. 2004, Yeh 2010). However, setup deviations defined as a variation of patient setup from the planned position during radiation dose delivery occur for patients undergoing RT (Gupta et al. 2007).

The use of a thermoplastic mask to immobilize patients in treatment positions helps to minimize set-up deviations, thus ensuring reproducibility of patients' treatment positions (Yoram et al. 2023). There are different types of thermoplastic masks that can be used depending on the site of the HNC. These include S-type thermoplastic mask which immobilizes the head, neck, and shoulders and U-type thermoplastic mask which immobilizes the head only. Together with other factors, improper use of these immobilization devices contributes to set-up deviations.

To correct this setup deviation, an online or offline treatment verification protocol is performed. Online verification uses matching of megavoltage (MV) images to digitally reconstructed radiography (DRR) from simulation thus identifying mismatches to be corrected before radiation dose delivery while in the offline verification approach, analysis of setup accuracy is done at some time after radiation dose delivery hence correction is not possible until the next session of dose delivery (The Royal College of Radiologists report 2008). The online correction protocol is effective in managing both systematic and random errors while offline correction has little effect in managing random errors (Middleton et al. 2006). Despite being more precise, online correction protocol is more

expensive as it requires more equipped settings (Prasad et al. 2014). In contrast, using offline verification for centres having high workloads is appropriate for detecting setup deviations (Kasabašić et al. 2007). The choice of whether to use an online or offline correction protocol depends on the institution's workload, resources and equipment availability and education of staff (Leech et al. 2017).

Several offline correction protocols exist including shrinking action level, No Action Level and extended No Action Level protocols as described in the Royal College of Radiologists report (2008). At Ocean Road Cancer Institute (ORCI), an extended No Action Level protocol is used in which verification is done for the first three fractions and once weekly. The efficiency of this protocol for HNC patients immobilized with thermoplastic masks during RT needs to be assessed to improve our practice.

Materials and Methods
Study settings
The prospective study of 62 adult HNC patients who were treated with the three-dimensional conformal radiotherapy (3D CRT) modality was conducted at ORCI in Dar es Salaam from April to August 2021. ORCI is a major public oncology institution in Tanzania. It receives cancer patients from all over the country and abroad. ORCI offers radiotherapy, chemotherapy, brachytherapy, nuclear medicine, and palliative care services. The institute provides external beam radiotherapy services with two cobalt-60 and two Linear accelerator machines. Currently, the institute provides external beam radiotherapy through two-dimensional radiotherapy (2D RT) and three-dimensional conformal radiotherapy (3D CRT) modalities. Most HNC patients are treated with the 3D CRT modality where for curative treatment intent total prescribed dose is 66 Gy (2 Gy per fraction given in 33 fractions). On the other hand, either a total prescribed dose of 30 Gy in 10 fractions or 20 Gy in 5 fractions is given for palliative RT intent. However, this study included HNC patients who were planned to receive a curative treatment.

Data collection method

On their first day of treatment, the patient's set-up and positioning in the treatment room follow markers placed on the thermoplastic mask by using room lasers. In this situation, patients were immobilized in a supine position using a customized thermoplastic mask. Reference points marked on the thermoplastic mask during simulation were defined by laser to reproduce the patient's simulation set-up and positioning. Couch shifts obtained after treatment planning were applied to locate the treatment isocenter. This treatment isocenter was marked at three points representing intersection points for lasers in the anterior and lateral aspects of the patient on the thermoplastic mask. Orthogonal images for verification were taken at 0 and 90 degrees using an electronic portal imaging device (EPID). These images were matched against DRR to determine geometrical set-up deviations. Head and neck bones from MV images and DRR were surrogated during matching. Displacements of the lateral and longitudinal directions were obtained from the anteroposterior field while the displacement of the vertical direction was obtained from the lateral field. Extended no action level protocol was used to obtain electronic portal images (EPIs) for three consecutive days of the first week of treatment and thereafter once per week. The setup deviation recording form was used to record setup deviations in lateral, longitudinal, and vertical directions. The gross errors above the threshold level of 0.5 cm were corrected before treatment delivery.

Data analysis

Microsoft Excel online version 365 was used for statistical computations, which were checked by the SPSS software version 28. Box plots were used to show the deviations on three consecutive days of the first week (1st, 2nd and 3rd days) and a successive weekly verification (2nd, 3rd, 4th, and 5th weeks) in lateral, longitudinal, and vertical directions. The association of thermoplastic mask type on reported weekly deviations was analyzed using repeated test ANOVA. A p-value < 0.05 was statistically significant.

Table 1: Sociodemographic characteristics of participants (n = 62)

Variable		Frequency	Percent
Gender	Male	41	66.1
	Female	21	33.9
Age	≤40	15	24.2
	41–60	26	41.9
	61+	21	33.9
Disease site	Nasopharyngeal cancer	12	19.4
	Hypopharygeal cancer	7	11.3
	Oral cancer	16	25.8
	Larynx	12	19.4
	Paranasal and nasal cavity	5	8.1
	Salivary gland	4	6.5
	Unknown primary	2	3.2
	Tongue	4	6.5
Stage	I	3	4.8
	II	20	32.3
	III	31	50.0
	IV	8	12.9
Histological type	Squamous cell carcinoma	59	95.2
	Non-squamous cell carcinoma	3	4.8
Thermoplastic type	U-shaped (head only)	17	27.4
	S-shaped (head, neck, and shoulder)	45	72.6

Results
Participant's baseline information

Set-up deviations in three translational directions (lateral, longitudinal and vertical) were assessed using an offline set-up correction protocol among sixty-two (n = 62) HNC patients during 3D CRT at ORCI. The median age was 55 years and the range was 18–88 years. The majority (41 or 66.1%) of the study participants were males. Based on the disease site, 16 (25.8%) study participants were having oral cancer followed by nasopharyngeal 12 (19.4%) and laryngeal cancer 12 (19.4%). Most, 59 (95.2%) of the study participants were having squamous cell carcinoma, and 50% of study participants

were stage III. 45 (72.6%) patients were immobilized with S-shaped thermoplastic mask (Table 1).

Assessments of set-up deviations using offline correction protocol

Comparing the set-up deviations before (first three days) and after (weekly) application of the offline correction protocol, the observed deviations after the correction protocol were lower in all three translational directions as shown in Figure 1. Furthermore, no extreme deviations were observed after the application of the correction protocol implying that the protocol did effectively eliminate them.
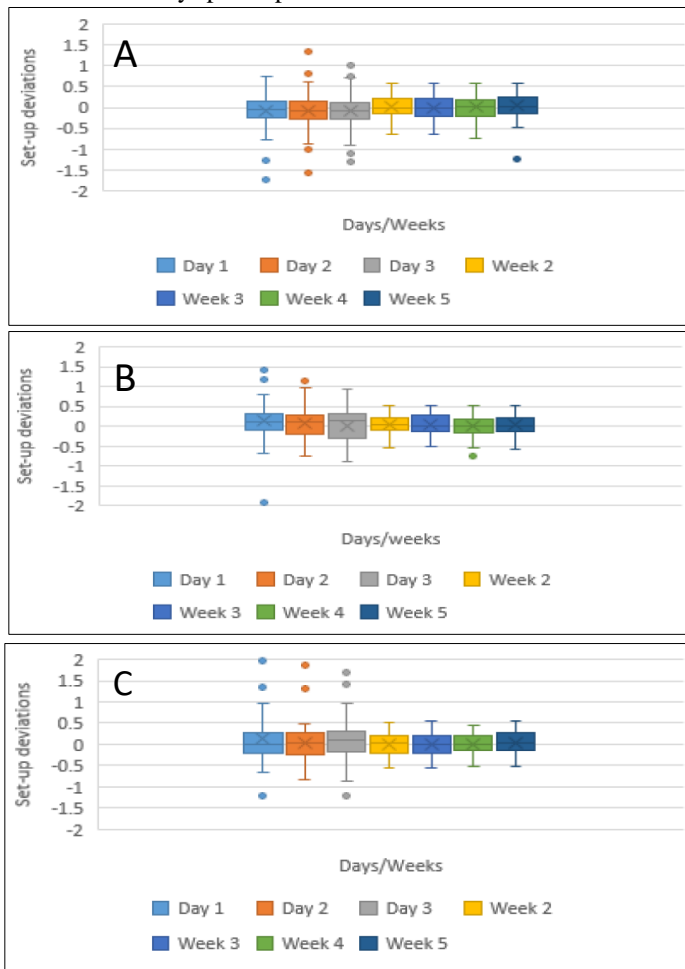

Figure 1: Box plots showing a displacement of the MV-images relative to DRR images before (first three days) and after (2nd to 5th week) application of offline correction protocol in all three orthogonal directions (A: Lateral, B: Longitudinal, and C: Vertical) for 62 HNC patients.

Associations between thermoplastic types and weekly setup deviations

The associations between thermoplastic types and weekly set-up deviations were assessed. The findings showed larger weekly set-up deviations among the patients immobilized with U-shaped thermoplastic masks compared to S-shaped thermoplastic masks. However, a two-way ANOVA showed no statistical significance between the two types of thermoplastic masks and setup deviation in lateral ($p < 0.65$), longitudinal ($p = 0.19$) and vertical ($p = 0.12$) directions (Figure 2). This implies that both types of thermoplastic masks are effective in immobilizing HNC patients during RT delivery provided that a thermoplastic mask is well prepared and the patient is well aligned.
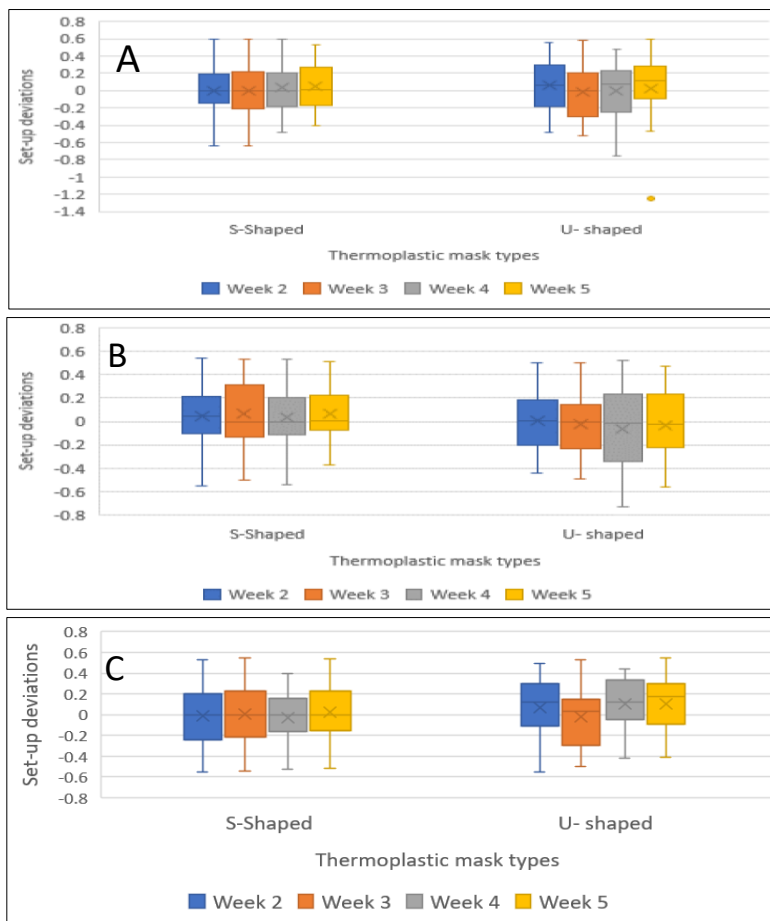

Figure 2: Weekly set-up deviations for U and S-shaped thermoplastic masks in all orthogonal directions. A: lateral direction ($p < 0.65$), longitudinal direction ($p = 0.19$) and vertical direction ($p = 0.12$).

Discussion

This study assessed the set-up deviations of HNC patients undergoing 3D CRT using offline setup correction protocol and immobilized with a thermoplastic mask. In this study, offline correction protocol was used to verify treatment set-ups of HNC patients before radiotherapy delivery. No extreme deviations were observed after the application of the correction protocol implying that the protocol was effective in reducing set-up errors. Many studies

conducted in different treatment sites have reported the effectiveness of offline setup correction in treatment verification (Zeidan et al. 2007, Bayman et al. 2010, Tamponi et al. 2014, Marnouche et al. 2019).

The use of an immobilization device is a way to improve the reproducibility of treatment setups. A study has shown that immobilization devices reduce set-up deviations and improve treatment outcomes (Cheng and Wu 2014). A thermoplastic mask is the mostly used immobilization device for HNC patients since it aids in treatment reproducibility while maintaining the patient's comfort (Tunkr 2014). In this study U-shaped (immobilizing head only) and S-shaped thermoplastic masks (immobilizing head, neck and shoulders) were used to immobilize HNC patients. The study showed no statistical difference between the two thermoplastic mask types and weekly set-up deviations. However, larger weekly set-up deviations were observed among the patients immobilized with U-shaped thermoplastic masks compared to S-shaped thermoplastic masks. The Royal College of Radiologists report (2021) has shown that immobilizing a head, neck and shoulder reduces set-up deviations as compared to immobilizing the head only. The presence of the rim around the thermoplastic mask, over the chin and shoulders, aids in patient positioning (Buzdar et al. 2013). Larger set-up deviations when using three-point or U-shaped thermoplastic masks can be due to position variation of the neck (Ove et al. 2012).

Conclusion

The use of offline treatment verification protocol is effective in detecting patient set-up deviations. It can be used in settings with limited resources and in centres with high workloads. Also, the findings have shown no association between thermoplastic mask types and set-up deviations.

Acknowledgements

Ethical Clearance

This study obtained ethical clearance from the Institutional Review Board of the Muhimbili University of Health and Allied Sciences and obtained permission from Ocean Road Cancer Institute.

Competing interests

The authors declare no competing interest.

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