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SHORT COMMUNICATION

A comparative evaluation of two head and neck immobilization devices using electronic portal imaging

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ABSTRACT. A study was performed to compare the positioning reproducibility and the cost efficiency for two head and neck immobilization devices: the Uvex© (Uvex Safety, Smithfield, USA) plastic mask system and the Finesse Frame with Ultraplast System© (PLANET Medical, Svendborg, Denmark). 20 patients treated with 3D conformal radiation therapy for head and neck cancers were randomly selected (10 for each of the two different immobilization systems) and electronic portal images acquired during their course of treatment were saved and used in this study. The anatomical landmark coordinates and their shifts in the anteroposterior (AP) and craniocaudal (CC) directions with respect to the digitized simulator films for lateral fields were analysed using an in-house developed portal image registration system. Statistically, no evidence was found to indicate that the systematic components of the displacement for the Uvex© system and the Finesse Frame with Ultraplast System© were different from each other or from zero. The random component of displacement was slightly smaller in the AP direction for the Uvex© than the Ultraplast© system (σ=1.9 mm and 2.9 mm, respectively, p=0.007), but larger in the CC direction (σ=3.8 mm and 2.2 mm, respectively, $p<10^{-9}$). Production time and required materials for a radiation therapy department were also quantified to assess costs for each system. The overall costs per patient were estimated at $141.50 (CAD) and $82.10 for the Uvex© and Ultraplast© systems, respectively. The Finesse Frame with Ultraplast System© of immobilization for head and neck cancer treatment provides a field placement reproducibility that is equal to, or greater than, that of the Uvex© plastic mask immobilization system and, while it requires more expensive materials, the workload and consequently overall cost is greatly reduced.

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Radiation treatment to the head and neck region is delivered with accurate and precise placement of prescribed portal fields. Reproducible alignment is increasingly important as we apply high-dose three-dimensional conformal radiation therapy (3D-CRT) techniques and intensity-modulated radiation therapy (IMRT) in conjunction with the need for smaller clinical target volume (CTV) margins. The consequences of field placement errors have been described in various publications; failure to treat the entire planning target volume (PTV) may be responsible for local failure, and irradiation outside of the PTV may result in normal tissue complications to important organs [1–4], such as the spinal cord or the eye, in the case of head and neck cancers. In order to increase the reproducibility of portal field placement, various immobilization devices are used to stabilize the position of the patient's head while treatment is delivered.

Previous publications have compared two or three different systems of immobilization [5–7], and have assessed treatment field position reproducibility with similar results: the standard deviations of field placement errors, σ, were found to be between 1.7 mm and 3.3 mm, for both anteroposterior (AP) and craniocaudal (CC) directions. In this study, an immobilization system involving a Uvex© (Uvex Safety, Smithfield, USA) plastic mask was compared with a low temperature thermoplastic mask system, the Finesse Frame with Ultraplast system© (PLANET Medical, Svendborg, Denmark) using off-line electronic portal imaging. The costs of both systems in terms of production time and materials were also calculated since the clinical introduction of a low temperature thermoplastic mask appears to be less time-consuming, less costly, and more convenient for the patient [7] and, therefore, beneficial in general.

Materials and methods

Clinical setup

This study retrospectively selected 20 consecutive head and neck patients treated at our centre between

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Table 1. A summary of selected demographic data for patients included in both immobilization groups

Demographics	Immobilization device group	
	Uvex	Ultraplast
Age: mean ± SD	65 ± 10	60 ± 11
Sex: Females/Males	2/8	1/9
Diagnosis distribution	Ca tongue – 4	Ca supraglottis – 2
	Ca tonsil –2	Ca floor of mouth – 2
	Ca hypopharynx – 1	Ca tongue –1
	Ca pharynx – 1	Ca oropharynx – 1
	Ca oral cavity – 1	Ca gingiva – 1
	Ca larynx –1	Ca glottis –1
		Unknown primary – 2
Weight change during treatment: Mean ± SD	4.8 ± 3.6	3.4 ± 5.7

April 2001 and September 2001. These patients were randomly drawn from two groups representing different immobilization devices used in treatment setup; 10 patients with a Uvex© mask system, and 10 patients with a FinesseFrame with Ultraplast System©. A summary of selected demographic data for both immobilization groups is provided in Table 1. Review of the summary confirms that there was no apparent significant demographical bias between the groups. One patient's results were eliminated from the study due to poor quality imaging. All patients attended the Mevasim simulator (Siemens Medical Solutions, Concord, USA) where lateral portal positioning was marked on the mask for alignment purposes. A planning CT scan using Somatom Plus (Siemens Medical Solutions) was performed at 5 mm intervals for 3D conformal treatment planning on the Helax TMS system (Nucletron B.V., Veenendaal, The Netherlands), and all patients were treated on a Mevatron KD-2 or Primus linear accelerator (Siemens Medical Solutions) with 6 MV beams. The treatment beam arrangement consisted of two parallel opposed lateral fields covering the head and neck target. The nodes in the supraclavicular region were irradiated with an anterior field. Portal images were acquired and stored for daily fractions using Beamview Plus© (Siemens Medical Solutions) video camera based electronic portal imaging. For the purpose of this study, only right lateral portal views were used. An average of 14 (range 9–19) portal images for each patient were acquired for a total retrospective analysis of 272 images.

Immobilization devices

Two different thermoplastic masks and their respective immobilization accessories were evaluated in this study. To form the Uvex© mask, two radiation therapists stabilize the patient's head on a *Timo* head rest and form a plaster impression of the patient's head and neck. One therapist later drapes the negative impression and fills it to form a positive impression. The 1/16″ Uvex© plastic is then heated in a vacuum former and then moulded around the plaster positive. The patient returns approximately 2 days later for the fitting process where the plastic mask is fitted directly onto the patient's head and neck and mounted onto a Perspex© (Lucite International Canada Inc., Mississauga, Canada) acrylic headboard at three fixation points on each side of the head (six fixation points in total, distributed evenly from the lower neck to the top of the head). The treatment field area is cut from the Uvex© mask once a radiation oncologist approves the first-day portal image in order to allow for increased skin sparing.

To form the Ultraplast© mask, the Ultraplast© material is dipped into a hot water bath (≈75℃) while the patient is positioned on a *Silverman* head rest that attaches to a ''Quick Snap and Lock'' carbon fibre headboard by a Finesse Frame system© which is fixed at three points (at the top and on either side of the head). Two therapists then stretch the material and mould the mask directly onto the head of the patient. After approximately 8 min, the mask has hardened. The field area is not cut out from the Ultraplast© masks since they offer better skin sparing than the Uvex© masks [8] and, while reducing the dose in the first few millimetres of skin, field cutouts may affect positioning reproducibility [9].

Image analysis

Right lateral portal images were captured using the Beamview Plus© portal imaging system. These images were then imported into a Portal ViewStation software system developed in-house [10]. Corresponding simulator films were digitized and imported into the Portal ViewStation system. While the field borders of the simulator films were defined manually, the field borders of the portal images were extracted automatically by applying an edge detection algorithm [11]. Adaptive histogram equalization [12] was applied to the portal film in order to enhance contrast. Two experienced radiotherapists delineated bony landmarks (the vertebrae) on both the simulator film and all portal images. The portal images were transformed onto the simulator film coordinate system and, using the chamfer matching registration algorithm [13, 14], the corresponding anatomical landmarks were aligned. Next, the borders of the simulated field were matched with the borders of the portal images by applying a polygon-matching algorithm [15] and the displacement between the simulator film treatment field borders and the portal image borders was recorded and analysed to determine the translational field placement error in the AP and CC directions, as well as the rotational error measured in the plane orthogonal to the lateral beam.

The accuracy of the field placement measurement method was previously assessed to be within 1.5 mm and 1° for translational and rotational displacements, respectively [10].

Statistical analysis

The reproducibility of treatment field placement is reflected by a combination of both systematic and random error. The systematic placement error for one patient is that component of the field displacement that was constant throughout the treatment period and can, therefore, quantify the accuracy of patient positioning. This error is defined as the mean of all displacements in either the AP or CC direction. The random error, or the precision with which the patient is positioned daily, is

determined by subtracting the systematic displacement from the total displacement for one fraction. For the Uvex© or Ultraplast© group, the systematic error is quantified by the range and standard deviation of the mean field displacements for all individuals and the random error for the group is the standard deviation of all individual random errors.

Cost calculations

The average time of mask production was determined by taking an average for the production of five masks of each type. The production time included patient education, mask production and, for the Uvex© masks, time spent in plastering the positive mould. The mid-range salary rate for a Radiation Therapist at the Northeastern Ontario Regional Cancer Centre was multiplied by the time of production. In 2004, the salary range for radiation therapists was between $48 750 and $67 500 (CAD) per annum, therefore, the average salary of $58 125 was used in this analysis. Full-time employees working 37.5 h per week, work an average of 1950 h per year, resulting in a cost per minute of $0.50 (CAD).

The total non-reusable materials costs were assessed for masks of each type and the cost of materials for 10 masks was added to the labour cost for 10 masks of that type. An approximate yearly cost was also calculated for both the Uvex© and Ultraplast© immobilization systems.

Results

Patient reproducibility

Whether immobilized with a Uvex© mask system or a Finesse Frame with Ultraplast System©, no difference in the accuracy with which the patients were placed in position for treatment (or systematic error) was detected. A *t*-test applied to the magnitudes of systematic errors measured in both groups yielded $p>0.2$ for translational and rotational errors. For both immobilization systems, using a *Z*-test, the average systematic errors were not statistically different from zero ($p>0.2$ for translations in AP and CC directions, and also for rotations). For the Uvex© mask system, the range of systematic errors was [−2.8, 4.4] mm in the AP direction with a standard deviation of 2.6 mm, [−2.3, 3.2] mm in the CC direction with a standard deviation of 1.6 mm, and [−1.7°, 2.7°] in rotation with a standard deviation of 1.3°. For the Ultraplast© mask system, the range of systematic errors was [−2.5, 2.7] mm in the AP direction with a standard deviation of 1.9 mm, [−3.6, 2.8] mm in the CC direction with a standard deviation of 1.8 mm, and [−3.6°, 2.1°] in rotation with a standard deviation of 1.6° (Table 2).

There was, however, a difference in the random error, or the precision, in field positioning for the two immobilization setup systems: for the Uvex© mask system, the standard deviation of the random error in the AP direction was found to be 1.9 mm compared with 2.3 mm for the Finesse Frame with Ultraplast System© ($p=0.007$) while in the CC direction, the standard deviation of the random error for the Uvex© mask system was 3.8 mm compared with 2.2 mm for the Finesse Frame with Ultraplast System© ($p<10^{-9}$). The standard deviations of the random error in rotation were 1.8° and 2.1° for the Uvex© and Ultraplast System© mask immobilizations, respectively, and the difference was not statistically significant ($p>0.05$).

The frequency of translational field placement errors larger than 5 mm was 11% for Uvex© mask systems and 8% for Finesse Frame with Ultraplast Systems© in the AP direction and was 8% for Uvex© mask systems and 5% for Finesse Frame with Ultraplast Systems© in the CC direction.

Costs

The average time taken by a radiation therapist to produce a Uvex© mask was 134 min. This time measurement included patient contact as well as the production of a plaster positive and vacuum-forming the mask. The average time spent by a second radiation therapist was 47 min for the patient impression and mask fitting. The total time was therefore 181 min, at a cost of $90.50 (CAD) per patient for labour alone.

The average time taken by a radiation therapist to produce an Ultraplast© mask, including room preparation and patient education, was 23.7 min. A second radiation therapist spent an average time of 18.7 min assisting with the production of the mask. The total time was therefore 42.4 min, or a cost of $21.20 (CAD) per patient for labour alone.

The cost of mask materials, excluding start-up costs, base plates, or head rests, was $510 CAD for 10 Uvex© masks and $609 CAD for 10 Ultraplast© masks. Therefore, the total materials and labour costs for the 10 Uvex© masks were $1415.00 (CAD) and $821.00 (CAD) for the 10 Ultraplast© masks. At the NEORCC, there are approximately 92 patients requiring immobilization masks per year. At a cost difference per patient of $59.40 (CAD), the total cost difference per year is $5464.80 (CAD) in favour of the Finesse Frame with Ultraplast System©.

Discussion

Setup reproducibility

With the use of IMRT for treatment of head and neck cancers, it is highly desirable to outline smaller margins

Table 2. Systematic and random errors for Uvex© and Ultraplast© immobilization systems

Mask Type	Systematic (S) or Random (R)	Anteroposterior		Craniocaudal		Rotational
		SD (mm)	Positioning error >5 mm	SD (mm)	Positioning error >5 mm	SD (°)
Uvex	S	2.6	16 (11%)	1.6	11 (8%)	1.3
	R	1.9		3.8		1.8
Ultraplast	S	1.9	11 (8%)	1.8	6 (5%)	1.6
	R	2.3		2.2		2.1

that are added to the CTV and, thus, to more effectively avoid normal tissue complications while still increasing the total dose to the PTV in order to gain local control of the tumour. Effective immobilization of the area to be treated is essential for accurate and precise delivery of the treatment plan and dose prescription. While the systematic component of field placement error is primarily due to the transfer of patient setup from treatment planning to delivery, any mispositioning or moving of the patient within the mask may cause the random component of error.

The systematic component of error for both the Uvex© and Ultraplast© mask systems was less than 3 mm (1 SD) for both the AP and CC directions of motion. This value is consistent with previous studies [6, 17, 18] indicating that the patient setup errors are often determined by transfer errors from the simulator to the treatment unit and are not necessarily affected by mask type.

In other publications, the use of thermoplastic masks, as opposed to masks made of other materials such as plastics or polycarbonate, appears to result in a comparable random error [5, 7]. In this study, it was determined that a decrease in random field placement error in the CC direction by using the Finesse Frame with Ultraplast system© could be clinically significant since, according to the formula used by Stroom et al [16], the CTV-PTV margin may be reduced by 1.1 mm in the CC direction. It is not apparent, however, whether this improvement in field placement in the CC direction is due to the rigidity of the thermoplastic mask material or the fixation of the head and neck in the Finesse Frame© which has a fixation point at the vertex of the head. Since the random component of displacement in the AP direction was actually slightly smaller for the Uvex© system, there is no clear evidence that our practice of cutting out the treatment field area from Uvex© masks for better skin sparing, had a significant detrimental influence on the rigidity of immobilization.

There also appear to be fewer field placement errors larger than 5 mm with the use of the Finesse Frame with Ultraplast System©. This may be attributed to a better fit to the patient's anatomy since the Ultraplast© material can be fitted directly onto the patient and there is no intermediary cast necessary. The Finesse Frame with Ultraplast System© provides equal, or perhaps better, immobilization for head and neck cancer radiation treatment.

While the costs of materials for the Finesse Frame with Ultraplast System© are initially higher than those for the Uvex© mask and accessories, the increased time commitment required to produce the Uvex© masks and the corresponding labour costs, in addition to the inconvenience for the patient of having to attend a mould room fitting twice, make the Finesse Frame with Ultraplast System© a preferable option for a radiation therapy department.

Conclusion

The Finesse Frame with Ultraplast system© of immobilization for head and neck cancer treatment provides a field placement reproducibility that is equal to, or greater than, that of the Uvex© plastic mask immobilization system. The Ultraplast© system is also cheaper and more time-efficient, making it a superior product for use in a radiation therapy department.

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