Increased in dose to organ at risks did not correlate with the weight loss but did correlate with the lateral neck dimension reduction and volume changes for head and neck patients treated with intensity-modulated radiotherapy.

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Abstract

Introduction
The aim of this study is to investigate the weekly patient geometric and volumetric changes and the resulting dosimetric changes throughout a course of radiotherapy in head and neck cancer patients.

Materials and methods
The study population consists of 5 head and neck cancer patients treated with intensity modulate radiotherapy. Weekly cone-beam computed tomography images were recruited and the impact of the weekly patient geometric and volumetric changes to the organ at risk was studied by comparing accumulated dose from weekly CBCT-based plans with CT-based plans.

Results
Significant increase in spinal cord dose were observed despite of insignificant weight loss. The increased dose was due to the reduction in lateral dimension at the neck. This study shows that if there were no changes in volume, the mean dose for the parotid gland will be lower compared to the planned mean dose. Increase in mean dose to the parotid gland did not correlate with the weight loss but did correlate more with the volume reduction.

Conclusion
This study shows the impact of weight loss largely affected the dose deposited to the critical organs when there is a great change in lateral separation and volume changes. Therefore, it is worthwhile to take additional measure in lateral neck separation as a guide in making re-planning decision.

Introduction
Head and neck IMRT treatment can only be beneficial if it is delivered with accurate patient positioning and under the same geometry. As the course of head and neck IMRT requires about 7 to 8 weeks to complete, setting up the patient exactly the same way every day in agreement with the treatment plan is difficult1.

Although variations of the patient positioning can be minimized with cone beam computed tomography (CBCT) correction, it doesn't correct the anatomical changes in shape and locations, especially spinal cord and parotid glands. All these problems can be solved ideally by generating a modified plan based on the cone beam computed tomography (CBCT) that included the latest information of patient positioning, target location and anatomical change in shape, which is called adaptive radiotherapy treatment planning2,3,4. But, adaptive radiation therapy couldn't be applied clinically yet due to the tremendous workload required which is impossible to implement in busy radiotherapy centres.

A fast and efficient way to adopt the plan is one of the major challenges in adaptive treatment implementation. This paper describes our study on the potential dosimetric impact on the intended treatment plan taking into account the patient’s geometric and volumetric changes over time using cone beam computed tomography for head and neck IMRT plan and to provide a solution to have a better organ at risk dose sparing in a clinically acceptable time frame.

Materials and methods
This work conforms to the values laid down in the Declaration of Helsinki (1964). The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed. All subjects gave full informed consent to participate in this study.

CBCT study on the impact of weight loss on dosimetric end points
Patient CBCT acquisition
To study the dosimetric effect of weight loss for head and neck cases, data for 5 head and neck cancer patients (4 nasopharyngeal and 1 tonsils) treated with IMRT in Pantai Hospital Kuala Lumpur were recruited. Daily patient weights were measured and recorded. Lateral neck dimension was measured at the level of C5 vertebral and recorded weekly based on the CBCT images. Over the treatment courses for H&N IMRT, 7 CBCTs were acquired after the patients were setup under the guidance of wall lasers and patient weight was recorded on a daily basis.

Table: 1 Phantom comparison.

<table>
<thead>
<tr>
<th>Phantom</th>
<th>Chamber 1 (Center)</th>
<th>Chamber 2 (Peripheral)</th>
</tr>
</thead>
<tbody>
<tr>
<td>with 2.5 cm</td>
<td>2.56nC</td>
<td>0.33nC</td>
</tr>
<tr>
<td>with 1.0 cm</td>
<td>2.64nC</td>
<td>0.32nC</td>
</tr>
<tr>
<td>Difference</td>
<td>+ 2.24%</td>
<td>- 2.72%</td>
</tr>
</tbody>
</table>

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Research study

The first CBCT dataset was used as geometric information about the patient’s topography at the start of the treatment. The following CBCT were used to monitor the geometric and volumetric changes by contouring organs at risk (spinal cord, parotid glands, brainstem and optic tracts) at each CBCT scan. The dosimetric endpoints of the critical organs were compared with the first CBCT.

Procedures for dose reconstruction
After each treatment, the acquired CBCT image sets were exported to a focal contouring workstation for fusion and contours registration. The CBCT were registered to the planning CT (pCT) based on the treatment isocenter and the organ contours outlined on the pCT were auto-copied to the CBCT taking into account the organ deformation. These contours were then edited by the same oncologist and physicist who did the initial contouring to study the dosimetric effect of the changes of patient anatomy.

After the CBCT image set had been finalized with the corrected contours, it was exported to an XiO treatment planning workstation (CMS, Elekta). The treatment parameters from the original approved plan on simulation were copied and pasted to the CBCT image set, these included gantry angle, number of segments and number of monitor units. The isocenter was placed according to the actual treatment isocenter, which was obtained from the XVI isocenter shift. The dose was then calculated on the CBCT image set. The resultant dosimetric end points for organs at risk were compared with those of the original pCT plans. By comparing the results with the treatment plans, this method of monitoring may be useful to determine if re-planning is necessary.

Phantom study on the impact of weight loss on dose distributions
By using cone beam CT, a method to monitor H&N thickness changes and estimate the dose in response to indicated changes was developed. Tissue equivalent phantom was scanned (14 cm thickness). A dose of 212cGy (dose per fraction for head and neck cancer) was virtually delivered to the phantom with layers of phantom removed simulating weight loss. Chamber doses that represent organ at risk mean doses were recorded. The phantom was then irradiated by removing 1.5cm layers of the phantom. Using the Cone beam CT on an Elekta Synergy linear accelerator and slabs of solid water, this procedure enables us to predict changes in the lateral dimension of the phantom.

Results
From the head and neck patient study, the impact of these geometric changes largely affected the dose deposited to critical organs in the vicinity of the target even if daily setup errors were corrected based on bony landmarks. This might be due to the steep dose gradient that commonly exists between the target and the critical organs in an IMRT plan, and any deviated geometric change, organ deformation or patient weight loss, would result in a considerable change in the dose received by these critical organs.

Estimating the dosimetric effect of weight loss using kV-CBCT images
The relative weight loss over 7 weeks of a treatment course is shown in figure 1. All patients had significant weight loss especially in patient 1 and patient 5 with weight loss of 11% and 13% respectively. Greatest weight lost was...
between weeks 3 to week 7. Figure 2 shows the relative lateral neck separation over the 7 week course of radiotherapy. Patient 3 showed significant reductions as the treatment course continued.

The spinal cord difference between first CBCT dose and accumulated CBCT dose for all patients is shown in. For the spinal cord, the maximum dose increased from 41Gy to 43.2 Gy in patient 3 despite of insignificant weight loss. The increased dose was due to the reduction in lateral dimension at the neck; whereas patient 1, whose lateral neck separation did not have any significant migration (5mm) received a dose close to that initially planned (2% more dose). It is worth noting that increase in maximum dose to the spinal cord did not correlate with the weight loss but did correlate with the lateral neck dimension reduction. This phenomenon is due to the lateral tissue deformation and it tends to place the spinal cord within the high dose regions. Figure 4 shows the cumulative mean dose differences for both parotid glands. Compared with the first CBCT plans, the cumulative parotids mean dose of patient 4 was different from the planned dose by an average of 9.2%.

At treatment completion, the weekly volume planned receiving 26Gy decreased by an average of 52.3%, and generally shifted medially as treatment progressed.

For patient 5, reduced mean dose for both parotid glands were observed. This study shows that if there were no changes in volume, the mean dose for the parotid gland will be lower compared to the plan mean dose even though there is significant weight loss for patient 5. Increase in mean dose to the parotid gland did not correlate with the weight loss but did correlate more with the volume reduction.

There were no significant changes for brainstem and optic tracts maximum dose due to minor changes at the level of cervical vertebra (C2) and at the base of skull.

Phantom study in the effect of patient weight on radiation dose

Similar results were found when the thickness changes were applied to phantoms; the centre chamber (chamber 1) has a higher reading (2.64 nC versus 2.56 nC) and the peripheral chamber (chamber 2) has a lower reading (0.32 nC versus 0.33nC) in response to indicated changes in the lateral dimension as shown in table 1.

Based on the phantom measurement results and CT dose calculation, this study concluded that if the volume of the organ at risks maintain, the mean dose is lower when there is patient weight loss and lateral dimension changes; while the dose to the organ at the centre will be higher.

**Discussion**

This study shows how the impact of weight loss largely affected the dose deposited to the critical organs when there is a great change in lateral separation, especially the spinal cord. Therefore, it is worthwhile to take additional measures in lateral neck separation as a guide in making replanning decision. At the same time, the physicist should try to minimize the spinal cord dose during the IMRT planning to prevent 45Gy isodose line touching the spinal cord when the patient lateral separation becomes smaller. Maintaining patient weight and indirectly maintaining parotid gland volume can help in reducing parotid dose difference, as shown in patient 2.
Conclusion

This study shows that it is feasible to acquire weekly CBCT data sets for dose calculation to analyse changes in anatomy and determine dosimetric consequences of those data sets. By doing comparison, it helps physicist and oncologist to monitor the impact of anatomy changes and to determine if re-planning is necessary.

References