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Dosimetry

The impact of dental metal artifacts on head and neck IMRT dose distributions

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Abstract

***Background and purposes*: To quantify the cold or hot spot induced in IMRT treatment plans due to the presence of metal artifact in CT image data sets stemming from dental work.**

***Patients and methods*: Metal artifact corrected image data sets of five patients have been analyzed. IMRT plans were generated using five different planning image data sets: (a) uncorrected (UC) (b) homogeneous uncorrected (HUC), (c) sinogram completion corrected (SCC), (d) minimum value corrected (MVC), and (e) image set (d) subsequently corrected with a streak artifacts reduction algorithm (SAR-MVC). The SAR-MVC data set is assumed to be the closest approximation to the absence of metal artifacts and has therefore been taken as the reference image data set. An IMRT plan was generated for each of the image datasets (a)-(e). The resulting IMRT treatment plans for data sets (a)-(d) were then projected onto the reference data set (e) and recalculated. The reference dose distribution (e) was then subtracted from these recalculated dose distributions. Using dose difference analysis, the cold and hot spots in organs at risk (OARs) and the target volumes (TVs) were quantified.**

***Results*: When compared to the reference dose distribution, the UC, HUC, and SCC plans exhibited hot spots showing on average more than 1.0 Gy hot dose in the left and right parotids. For the UC, HUC, and SCC recalculated plans, subvolumes of the clinical target volumes (CTV) were under dosed on average by more than 0.9 Gy. On the other hand, the MVC plan showed less than 0.3 Gy hot dose in both parotids, and the cold dose in the CTVs were reduced by up to 0.8 Gy.**

***Conclusions*: The presence of dental metal artifacts in head and neck planning CT data sets can lead to relative hot spots in OARs and relative cold spots in regions of the TVs when compared to the reference data set that more closely approximates the patient anatomy. This effect can be reduced if a simple minimum value correction (MVC) method for the dental metal artifacts is employed.**

Keywords: Metal artifacts; Treatment planning; Head and neck

The use of IMRT in the treatment of head and neck neoplasms is becoming more common. IMRT allows for improved dose conformality with relatively steep dose gradients among complex primary gross tumor volumes (GTVs), at-risk nodal volumes (clinical target volume [CTV]) [1,5,10,13,19], and normal tissue avoidance structures, which enable the potential for decreasing the spectrum of normal tissue toxicities. One of the main rationales for using IMRT in the treatment of head and neck neoplasms is to preserve salivary gland function [3,4] in addition to reducing the toxicities to the optic and auditory apparatus [16], spinal cord [8], mandible, and other normal structures when compared to treatment with conventional radiation therapy methods. Clinically, IMRT allows one to improve the overall quality of life by reducing the severity of chronic xerostomia—an adverse condition impacting taste, swallowing, dentition, and speech. Cold spots in TVs introduced during inverse treatment planning or caused by daily set-up variations during daily treatment positioning can degrade the efficacy of IMRT [6]. Modeling has shown that a serious loss in tumor control probability (TCP) results if 1% of the TV receives a dose deficit of larger than 20% of the prescription dose even if 80% of the remaining TV receives a 10% boost [14].

Metal artifacts in the form of metal prostheses can distort the dose distribution by inducing cold or hot spots. While methods for improving the precision of IMRT planning, daily set-up verification (cf. [6,12] and references therein), and techniques for metal artifacts reduction have been described in the literature (cf. [17,18] and references

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there in), the effects on the accuracy of head and neck IMRT dose distribution due to metal artifacts in the treatment planning CT images has not been widely studied. CT images of patients with metal implants such as marker pins, dental fillings or hip prostheses suffer from artifacts generally in the form of bright streaks (high electron density), dark voids (low electron density), cupping, and capping. These artifacts are mostly due to quantum noise, scattered radiation, and beam hardening [7]. Mega Voltage CT (MVCT), which is employed in helical Tomotherapy for pretreatment localization, on the other hand does not suffer from these artifacts [9]. However, currently MVCT is only used for pretreatment patient localization and not for treatment planning. The presence of such artifacts in the treatment planning CT can lead to deviations between the dose distribution and actual-delivered dose distribution in both the OARs and TVs.

For head and neck IMRT, we have investigated the consequences of the presence of metal artifacts on the accuracy of planned dose distributions using these different correction strategies. In particular, we have studied the magnitude of cold and hot spots induced in OARs and the TVs (GTV and CTV) using these correction techniques.

Materials and method

Metal artifacts reduction methods

A total of five patients with advanced H&N cancer receiving high-dose IMRT at the University of Wisconsin were analyzed in the context of this study. The CT dataset of each patient included in the study was corrected for metal artifacts using methods proposed by Olive et al. [11]. Their correction method uses a model derived from the original dataset by a segmentation algorithm (K-means clustering). In this case, four different material classes were used: air, soft tissue, bone, and metal. Pixels belonging to the same class are assigned the same representative Hounsfield unit (HU).

The following five datasets per patient were used in treatment planning of head and neck IMRT:

(a) Original CT image data (uncorrected, UC).
(b) All pixels identified as soft tissue, bone, or metal by the model were set to the electron density of water (homogeneous uncorrected, HUC).
(c) Only 'corrupted' segments identified in the clustering procedure were cut out and replaced by respective model segments, and the corrected sinogram was reconstructed (sinogram completion corrected, SCC).
(d) All pixels identified as soft tissue, bone, or metal were adjusted to the minimum Hounsfield units of water (minimum value corrected, MVC).

The HU of the pixels in the streaks resulting from the presence of metal were replaced as much as possible by the Hounsfield units of the soft tissue class or bone class. The pixels in the corrected image belonging to the soft tissue, bone, or metal classes were adjusted to a minimum HU value equal to water (streak artifacts reduction including minimum value correction, (SAR–MVC).

The SAR–MVC CT dataset for the purpose of this study has been used as the reference data set for dose comparisons since it most closely approximates the absence of metal artifacts in the actual patient anatomy.

Dose calculation

The dose distribution resulting from the treatment plan of each patient was evaluated for each adjusted dataset using the ADAC Pinnacle™ treatment planning system (TPS). The same 0.4 mm^3 dose grid was used in the generation of each set of plans to eliminate any possible interpolation artifacts due to the use of different size dose grids. In the MVC image data sets, the minimum electron density was limited to that of water, which to first order approximates normal head and neck tissue.

The beam arrangement employed consists of seven intensity-modulated fields arranged in an anterior 240° arc, starting at 120° and ending at 240° in the IEC convention, to which a lower neck field, and if clinically indicated lower neck boost field, has been matched. For the purpose of this study, we have only considered the intensity-modulated fields and have excluded the lower neck fields in our analysis. For all patients, the prescription was chosen such that 95–97% of the PTV received the prescription dose of 66–69.3 Gy delivered in 30–33 fractions of 2.1–2.12 Gy. The dose constraints employed during the IMRT planning process are shown in Table 1. Patients were immobilized using custom head molds, half facial thermoplastic masks, and treated using a bite tray attached to the upper maxillary dentition. The bite tray has an optical fiducial array attached to it to allow optically guided localization. The optical array together with position sensors allow real time localization and monitoring of the patient during treatment [15].

Dose comparison

For each of the five patients, an IMRT plan was created on each of the data sets (a) through (e), and the resulting plans from (a) to (d) were projected onto the reference data set (e) and recalculated using the same dose grid. The reference IMRT dose distribution (e) was subtracted from these

Table 1
Optimization parameters for IMRT treatment plans

Structure	Criterion (Gy)	Weight (%)
PTV 50-69.3	Min dose = 50-69.3	30
	Uniform dose = 50-69.3	20
Res parotid	Max dose = 35	5
	Max DVH: 15-50%	5
	Max DVH: 22.5-30%	5
Vocal cord	Max dose = 30	5-1
Spinal cord	Max dose = 35	5
Larynx	Max dose = 30	5
Eyes	Max dose = 2	5
Oral cavity	Max dose = 40	5-1
Mandible	Max dose = 70	2
Normal tissue	Max dose = 31.5-35	1