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Original Report

Dental amalgam artifact: Adverse impact on tumor visualization and proton beam treatment planning in oral and oropharyngeal cancers

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Abstract

Purpose: We evaluated the incidence and impact of dental filling artifacts on the definition of clinical target volume (CTV) for oropharyngeal/oral cavity cancers receiving radiation therapy. We performed phantom proton beam dosimetric analyses using a low-density composite filling to investigate artifact reduction and dose distribution.

Methods and materials: We reviewed oral cavity/oropharynx radiation treatment plans between 2010 and 2012. Plans were evaluated for artifacts and impact on CTV visualization. We constructed a head and neck phantom, obtaining planning computed tomography images at baseline (native tooth) and for each filling (composite and metal amalgam) interchanged into a tooth adjacent to the tumor. We performed uniform scanning proton plans with each filling, evaluating for planning target volume (PTV) coverage and overall dose distribution.

Results: A total of 110 treatment plans were reviewed (71 oropharynx, 39 oral cavity). Artifacts were identified in 81 plans (73.6%), including 53 oropharynx (74.6%) and 28 oral cavity (71.8%). Artifacts obscured the CTV in 77 cases (95%), including 49 of 53 oropharynx cases (92.5%) and all 28 oral cavity cases. On phantom testing, the metal amalgam obscured the tumor while the composite did not. Hounsfield unit (HU) values (range, mean) for the tumor were: baseline (−484.0 to 700.0 HU, 104 HU), composite (−728.5 to 1038.0 HU, 105 HU), metal amalgam (−1023.0 to 807.0 HU, 90.74 HU). The percent of planning target volume receiving 95% of prescription dose of the PTV was baseline (100%), composite (100%), and metal amalgam (92.3%). PTV dose ranges were baseline (98%-106%), composite (98%-107%), and metal amalgam (66%-111%). PTV coverage and dose distributions of the composite and native tooth plans were identical.

Conclusions: A high incidence of artifacts was found on the planning scans of oral/oropharyngeal cancer patients, adversely impacting CTV visualization. In our phantom model, metal amalgam impacted tumor and tissue density. The PTV was underdosed with the metal amalgam compared with the composite

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filling. A potential solution involves exchanging metal fillings with composite before proton treatment planning for improved tumor visualization and dosimetry.

Introduction

Modern head and neck radiation techniques produce highly conformal radiation dose distributions to tumor targets while sparing those critical organs at risk (OARs) from radiation damage. It is therefore of utmost importance to accurately define target volumes and thereby avoid potential marginal misses that could lead to recurrences. Proton beam therapy (PBT) is increasingly being used because its physical radiation dose characteristics often allow greater radiation sparing of OARs, given the rapid radiation dose falloff at the distal beam edge. However, accurate control of this proton beam range and dose falloff requires accurate information on the tissue density along the proton beam path.

Visualization of tumors of the oral cavity and oropharynx on planning computed tomography (CT) scan images may be obscured by artifacts caused by dental filling metal amalgams. Because these amalgams are composed of high-density metals, they lead to streak (increased density) and void (decreased density) changes within the reconstructed x-ray CT images. These artifacts may lead to erroneous alterations in Hounsfield units (HU) of nearby tissues and may obscure tumor and OAR visualization. Accurate calculation of proton stopping power and hence reliable dose calculation depends upon accurate tissue HU assessment of tissue density in the proton beam path because this ultimately defines the computed proton beam range and target coverage. Any obscured geometric boundaries in the CT images of tumors and OARs increases the probability of target misses and reduced sparing of OARs.

Previously published studies have shown increased interobserver variability in contouring head and neck tumor volumes and OAR in the presence of artifacts because of impaired tumor visualization.[1] Dosimetric comparison studies have demonstrated reduced target volume coverage and increased dose heterogeneity because of these artifacts.[2-4] Several solutions have been proposed for artifact reduction, including complicated image processing algorithms, employing different CT imaging techniques, and using physical shielding to cover and reduce x-rays traversing the dental amalgam.[5-12] Many of these solutions are impractical or not readily available and thus are not widely adopted. Current dental practice is to place low-density, composite dental fillings made mostly of ceramic material. The theoretical benefits of the composite fillings are that they have a more natural appearance compared with the native teeth and eliminate exposure to the heavy metals present in the older amalgams. Given the lower density of the composite fillings, less artifact production on CT images is expected, leading to improved tumor visualization and more reliable proton dosimetry compared with metal amalgams. To our knowledge, these expectations have not been systematically studied.

Although there is a perception that many head and neck cancer patients still have metal fillings in place, little is known about the incidence and scope of the problem. As a result, an aspect of this study was to better characterize metal amalgam artifact incidence and determine its adverse impact on visualization of tumors of the oropharynx and oral cavity. Working toward a practical solution to this problem, we present a dosimetric analysis of a newer composite dental filling compared with the metal amalgam and quantify its effect on proton beam dosimetry.

Methods and materials

To determine the incidence of dental artifact, we retrospectively reviewed the treatment plans of patients with oropharyngeal or oral cavity cancer who received either postoperative or definitive radiation therapy at our institution from 2010 to 2012. Treatment planning CT images were evaluated for the presence or absence of dental amalgam artifacts. If present, the treatment plan was reviewed for interference of the artifact (either streak or void component) within the defined high-risk clinical target volume (CTV) obscuring visualization. This review and evaluation component of the project was approved by our institutional review board.

To evaluate the impact of different dental filling materials on PBT dosimetry, we created a custom head and neck cancer phantom. The phantom consisted of an actual human skeletal mandible with dentition intact, surrounded by tissue equivalent material to simulate the soft tissue of the oral cavity and oropharynx. The soft tissue external to the mandible was created with Aquaplast bolus beads (Qfix) placed in water and then molded to the external contour of the mandible. The internal soft tissues were created with Super Stuff bolus material (Radiation Products Design Inc). The model tumor was created with Aquaplast bolus beads mixed with iodinated contrast solution to produce heterogenous tumor contrast enhancement (Fig 1).

The phantom was first simulated with no changes to the natural dentition. Once baseline data were obtained, a professional dentist prepared 1 of the molars for a routine filling. He then "restored" the tooth first with amalgam and then composite. Usual preparation techniques were used, with the exception that both types of fillings were made to be removable and interchangeable so direct comparisons could be made between the natural, unprepared tooth and the same tooth with the different filling materials. Metal dental amalgam when first mixed is composed of 42% liquid mercury and a blend of powdered alloy comprising silver (59%), tin (28%), and copper (13%). As the alloy is