Technical Note

Estimation of dose enhancement to soft tissue due to backscatter radiation near metal interfaces during head and neck radiothearpy - A phantom dosimetric study with radiochromic film

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ABSTRACT

The objective of this study was to investigate the dose enhancement to soft tissue due to backscatter radiation near metal interfaces during head and neck radiotherapy. The influence of titanium-mandibular plate with the screws on radiation dose was tested on four real bones from mandible with the metal and screws fixed. Radiochromic films were used for dosimetry. The bone and metal were inserted through the film at the center symmetrically. This was then placed in a small jig (7 cm × 7 cm × 10 cm) to hold the film vertically straight. The polymer granules (tissue-equivalent) were placed around the film for homogeneous scatter medium. The film was irradiated with 6 MV X-rays for 200 monitor units in Trilogy linear accelerator for 10 cm × 10 cm field size with source to axis distance of 100 cm at 5 cm. A single film was also irradiated without any bone and metal interface for reference data. The absolute dose and the vertical dose profile were measured from the film. There was 10% dose enhancement due to the backscatter radiation just adjacent to the metal-bone interface for all the materials. The extent of the backscatter effect was up to 4 mm. There is significant higher dose enhancement in the soft tissue/skin due to the backscatter radiation from the metallic components in the treatment region.

Key words: Backscatter, head and neck radiotherapy, linear accelerator, metallic interface, radiochromic films

Introduction

As many patients receiving metal reconstruction plates have strong indications for postoperative radiotherapy (RT), there is need to focus on the effects of metallic interface on the soft tissue or skin dose near the interface. Titanium implants are increasingly used in oral and maxillofacial surgery for reconstruction purpose. A more detailed knowledge of backscatter-induced effects is therefore desired when head and neck cancers in patients with implants are treated with RT. Interdisciplinary care is required for such patients. Close cooperation between cancer surgeons and prosthodontists, consultation with a radiation oncologists and medical physicists, dosimetrists is needed.

Implanted metals can cause backscatter radiation in RT with a dose enhancement at the bone-metal and tissue-metal interfaces on the beam entrance side. These tissues are then more susceptible to radiation-induced erythema, mucositis, and related salivary gland complications. Various studies have reported that in general, there is an increase in dose due to backscattering just proximal to the metal and a decrease in dose due to shadowing just distal to the metal.[1-5,7,8-12] A study reported the prediction of backscatter by mathematical formula based on atomic number (Z) of the metal or alloy[13] and Monte Carlo calculations.[6,14] A study was reported showing the effect of metal plates on Co-60 dose distributions.[15] They reported a predictive formula

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and clinical implications. The influence of various dental materials on radiation dose was measured with an alanine dosimeter.[16] Dose variation at bone/titanium interfaces was evaluated with the help of thermoluminescent dosimeters (TLDs) for Co-60 and 6 MV X-rays. The level of backscatter radiation from different types of dental implant materials at implant/bone interfaces during simulated RT by high energy 6 and 10 MV X-rays measured with an ionization chamber was reported.

Dose perturbations have been frequently documented, but with considerable variation from one study to another. Use of radiochromic film with spectrometer for such measurements has been reported in 1990. The present study experimentally examines the depth-dose distributions in tissue-simulating phantom material (polymer) adjacent to the metal with the help of Gafchromic film. The objective of this study was to investigate the enhancement of dose to soft tissue due to backscatter radiation near metal interfaces during head and neck RT with 6 MV X-rays. The methodology and the results are discussed.

Materials and Methods

For experimental setup purpose, a cardboard box of 7 cm length, 7 cm width, and 10 cm height was designed. The center of box was marked from outer side at 5 cm depth. Top end of the box was kept open. A Radiochromic EBT3 film (ISP Corp., USA) of 7 cm × 10 cm was used for dosimetry. Four mandibular bones were selected for the study. The bone length was ranging from 3 to 5 cm. The bone diameter was in the range of 1.74-2 cm. The titanium ($Z = 22$) with width (4 mm) and length (5 cm) reconstruction plate with thickness of 1 mm was fixed to each bone with screws. A contour simulating the central shape of the bone and the screws was drawn at the film center. The film was then cut finely and carefully so as to fix the bone with titanium and the screws. With this, the axis of the bone was normal to the film plane as shown in Figure 1. Paraffin wax bolus was used wherever required to get a regular surface for irradiation. This assembly was placed in the center of the box from top side so that the center of the bone was at 5 cm depth from top surface of the box. This box was filled with tissue equivalent polymer granules, so that the box can be considered as homogeneous tissue with a bone at its center.

The whole experimental assembly was isocentrically set on the treatment couch of a dual-energy Trilogy linear accelerator (Varian Palo Alto, USA) with the help of lasers. Figure 2 shows the schematic representation of the setup. The film was irradiated with 6 MV X-rays for 200 monitor units for 10 cm × 10 cm field size with source to axis distance as 100 cm and depth of 5 cm and a backscatter of 5 cm. This procedure was repeated for other bones and plates as well. A single film was also irradiated without any bone and metal interface for reference data.

The film was calibrated for range of doses (0.25-7 Gy) for 5 cm × 5 cm field size. The film was scanned with 16-Bit Vidar Dosimetry PRO Advantage Red (IBA, USA) and analyzed with IMRT OmniPro™ (IBA) software. For red channel scanning and constructing calibration response data for Gafchromic EBT2 dosimetry film the performance of VIDAR DosimetryPRO Advantage (Red) scanner is preferred. The films were handled with care to avoid fingerprints and were prepared on a clean surface. The orientation of the film was marked as soon as it was taken out from the box to minimize inaccuracies in measured optical density and thus measured dose due to orientation effects. The EBT2 films were scanned 24 h after irradiation. This is to allow for maximum postirradiation coloration. Scanning orientation was kept consistent for all films. This is because EBT2 film exhibits a different response in portrait orientation compared to the response in landscape orientation of 7-9%. Care was taken to ensure that all films were consistently scanned with the same face towards the light source of the scanner. The films were scanned six times, but only the last three scans were kept for analysis and saved as tagged image file format (.tiff files). Scanner response values were measured in the exposed areas and the calibration data was plotted and fit to a polynomial function. The coefficients of the fitting function were used to convert the corrected flatfield images from scanner value space to dose space. The dose images were smoothed with a 10 × 10 median filter. The vertical dose profile (percentage depth-dose curve) was measured from the film. All the depth-dose profiles were normalized at depth of dose maximum (dmax = 1.5 cm). From this curve, the backscatter dose was noted with mm step-size up to 5 mm. The dose perturbation due to the metal plate was also noted.

Results and Discussion

From the measurements, it was possible to obtain high resolution depth-dose distributions in tissue-simulating phantom. With this we could get the dose response behind and after the metal plate. In the region near a metal interface, differences in secondary-electron production can give rise to a pronounced modification in the dose profile. This is called as "dose-enhancement factor". This factor is defined as the ratio of the maximum dose in water or soft-tissue close to a high atomic number interface material to the dose in water or soft-tissue in the absence of any extraneous material.

Figure 3 illustrates the difference in the depth-dose distributions which occurs on both sides of the material (back- and forward-scatter side) for four different bones with and without metal bone for 6 MV X-rays, respectively. These figures show the dependence of relative measured dose on the depth into the tissue. The left side of curve represents the backscatter, while the right side represents forward

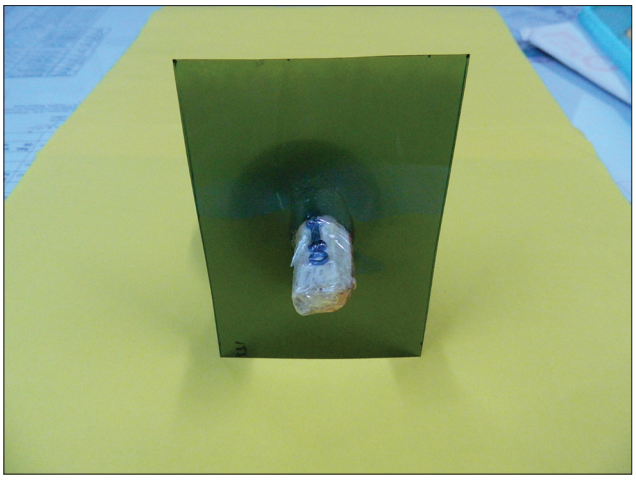

Figure 1: Bone fixed in the film. Bone axis was kept perpendicular to the film plane

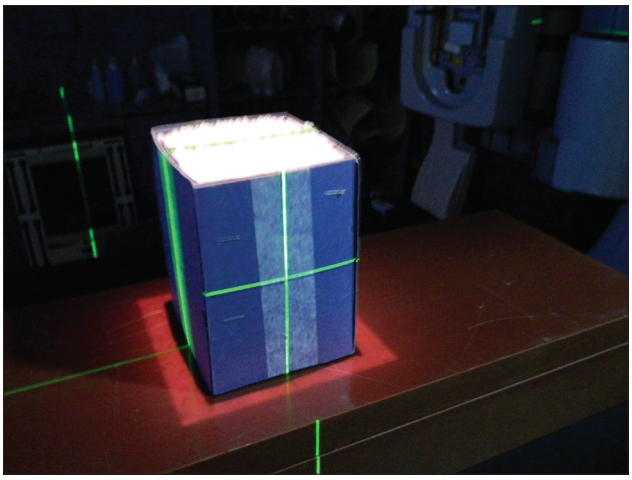

Figure 2: Jig setup on the treatment machine. Lasers are at the center of jig

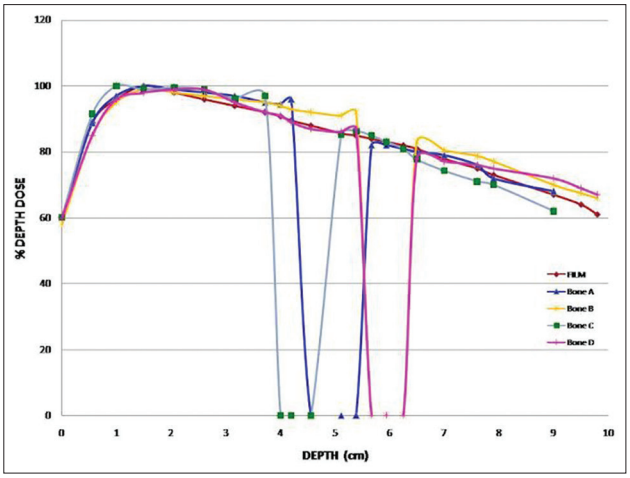

Figure 3: Difference in depth-dose distributions for bone A, B, C, and D, respectively with and without metal for 6MV X-rays with Gafchromic film which occurs on both sides of the material (back- and forward-scatter side)

scatter or the perturbation. A dose enhancement factor on the backscattered side of the interface for this metal with tissue-simulating material was 1.10 from our measurements. The maximum dose enhancement due to the backscatter radiation was 10% just adjacent to the metal-bone interface for all the materials. The extent of the backscatter effect was a maximum of 4 mm. The results indicate the factor of 1.10 in the dose-enhancement in tissue. The maximum dose perturbation due to metal in the forward direction was 5%. In earlier studies, dose variation was reported to occur only in the vicinity of the interface (0-4 mm); consequently, our measurements carried out in this study were more than this range of distances.

It has long been known that metal-tissue interfaces affect planned doses in RT. The effects of metal reconstruction plates on dose have been previously measured using various methods. Various detectors (ion chamber, film, and TLDs) were used. All of these models confirm an increased dose proximal to the plate and a decreased dose distal to the plate but that the effect persists for only 1-2 mm. It was found from our measurements that this effect persists for 4 mm.

Each measurement generated a relative dose curve on the film. Using this, it was possible to measure high-resolution depth-dose distributions in tissue-simulating phantom with metal-bone interface and the differences in dose enhancement close to high-Z interface. We attribute the difference to averaging of the bone thickness and thickness of the metal. We used the actual plates from the same material to be implanted and the real mandibular bone. This helped us to remove all the uncertainties in the correction for the densities for metal and the bone. However, estimated combined uncertainties for these measurements are ± 5% at two standard deviations.

The depth of dose effect is not great (0-5 mm) and although some believe it may not be of clinical significance, this is still substantially greater than the diameter of a tumor or normal tissue cell, 0.015-0.030 mm.[4] Bone is nearly twice as dense as soft tissue and has accordingly a higher electron density. Hence, excessive secondary electron scattering to the soft tissue or low density materials across the interface with high density material would occur primarily due to the compton effect.

Conclusion

The effect of metal on the dose in backward and forward direction was investigated with the help of Gafchromic film in a specially designed jig and the metal plate was fixed on the real bone. The dose enhancement effect of head and neck reconstruction plates in 6MV X-rays has been confirmed and quantified. The clinical effect of this dose enhancement will be studied systematically. Gafchromic film dosimetry requires a very consistent procedure during

calibration and measurement, film digitization, and film evaluation in order to achieve high precision and accuracy in RT quality assurance and dose verification work. Film measurements are quite unreliable unless done with care.

References

1. Birt D, Gruss JS, Pollock RA. AO/ASIF plate for mandibular reconstruction in tumor surgery: Results in 20 cases. J Otolaryngol 1988;17:274-8.
2. Chow JM, Hill JH. Primary mandibular reconstruction using the AO reconstruction plate. Laryngoscope 1986;96:768-73.
3. Davidson J, Birt BD, Gruss J. A-O mandibular reconstruction: A complication critique. J Otolaryngol 1991;20:104-7.
4. Gullane PJ. Primary mandibular reconstruction: Analysis of 64 cases and evaluation of interface radiation dosimetry on bridging plates. Laryngoscope 1991;101:1-24.
5. Nilsson B, Montelius A, Andreo P. A study of interface effects in Co-60 beams using a thin-walled parallel plate ionization chamber. Med Phys 1992;19:1413-21.
6. Ryu JK, Stern RL, Robinson MG, Bowers MK, Kubo HD, Donald PJ, *et al*. Mandibular Reconstruction using a titanium plate: The impact of radiation therapy on plate preservation. Int J Radiat Oncol Biol Phys 1995;32:627-34.
7. Wenig BL, Keller AJ, Shikowitz MJ, Stern JR, Casino AJ, Pollack JM, *et al*. Anatomic reconstruction and functional rehabilitation of oromandibular defects with rigid internal fixation. Laryngoscope 1988;98:154-9.
8. Castillo MH, Button TM, Doerr R, Homs MI, Pruett CW, Pearce JI. Effects of radiotherapy on mandibular reconstruction plates. Am J Surg 1988;156:261-3.
9. Rosengren B, Wulff L, Carlsson J, Montelius A, Russell K, Grussell E. Back scatter radiation at tissue-titantium interfaces: Analyses of biological effects from 60Co and protons. Acta Oncologica 1991;30:859-66.
10. Scher N, Poe D, Kushner F, Reft C, Weichselbaum R, Panje WR. Radiotherapy of the resected mandible following stainless steel plate fixation. Laryngoscope 1988;98:561-3.
11. Niroomand-Rad A, Razavi R, Thobejane S, Harter KW. Radiation dose perturbation at tissue-titanium dental interfaces in head and neck cancer patients. Int J Radiat Oncol Biol Phys 1996;34:475-80.
12. Das IJ, Kase KR, Meigooni AS, Khan FM, Werner BL. Validity of transition-Zone dosimetry at high atomic number interfaces in megavoltage photon beams. Med Phys 1990;17:10-6.
13. Melian E, Fatyga M, Lam P, Steinberg M, Reddy SP, Petruzzelli GJ, *et al*. Effect of metal reconstruction plates on cobalt-60 dose distribution: A predictive formula and clinical implications. Int J Radiat Oncol Biol Phys 1999;44:725-30.
14. Reitemeier B, Reitemeier G, Schmidt A, Schaal W, Blochberger P, Lehmann D, *et al*. Evaluation of device for attenuation of electron release from dental restorations in a therapeutic radiation field. J Prosthet Dent 2002;87:323-7.
15. Allai AS, Richter M, Russo M, Rouzaud M, Dulguerov P, Kurtz JM, *et al*. Dose variation at bone/titanium interfaces using titanium hollow screw osseointegrating reconstruction plates. Int J Radiat Oncol Biol Phys 1998;40:215-9.
16. Wang R, Pillai K, Jones P. *In vitro* backscattering from implant materials during radiotherapy. J Prosthet Dent 1996;75:626-32.

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